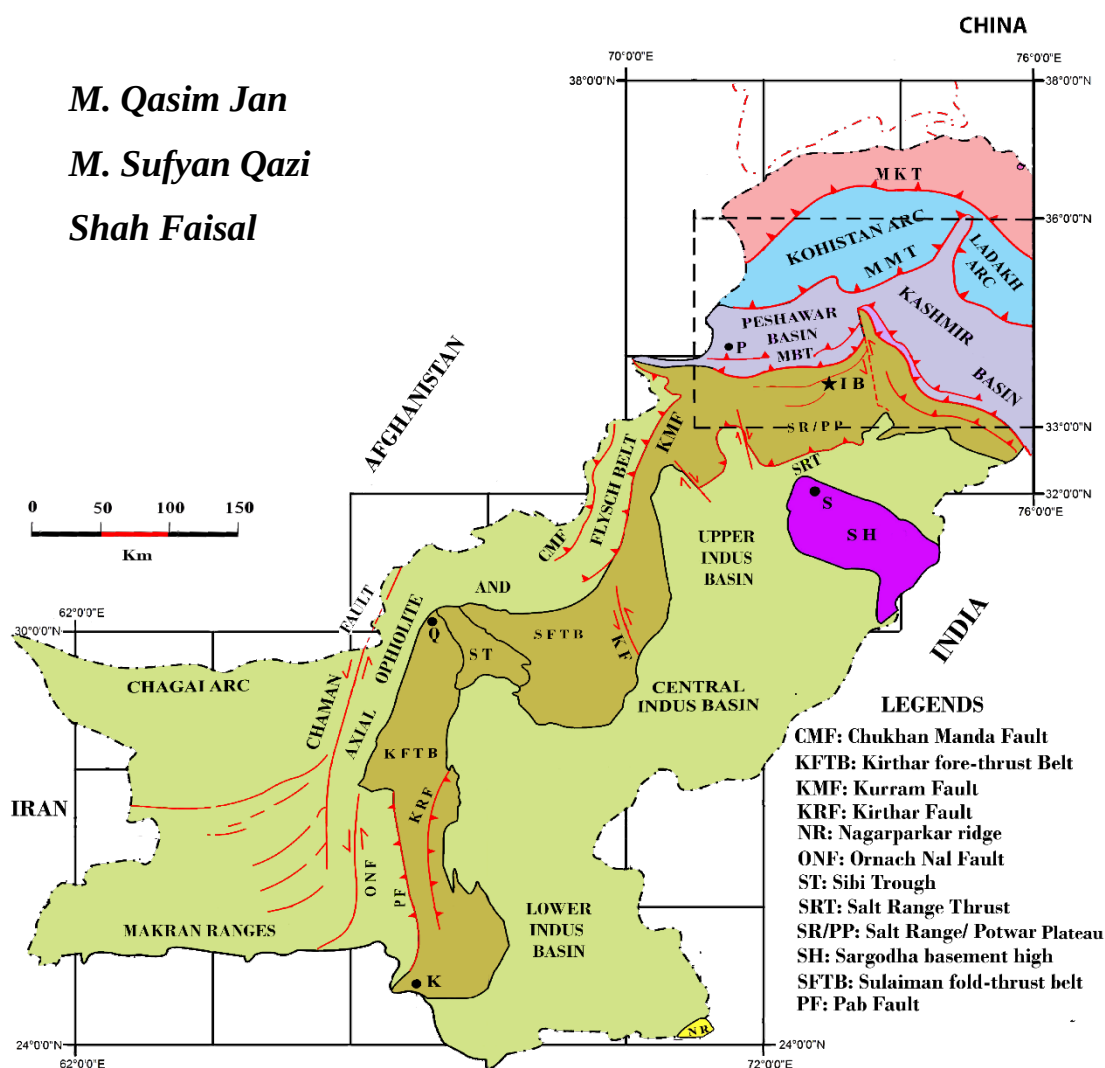


ANNOTATED GEOLOGICAL BIBLIOGRAPHY OF NORTHERN PAKISTAN UP TO AD 2002

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Preface

Way back in 1999, one of us (M. Qasim Jan) submitted a research proposal (titled, Geological Bibliography of northern Pakistan up to AD 2002) to Pakistan Science Foundation (PSF) for funding. The members of Technical Committee, notably Dr. Khalid Mahmood Khan, the then Chairman of PSF, Dr. M. Nawaz Chaudhry, Professor of Geology at Punjab University, Lahore, and Mr. S. Hasan Gauhar, Director General of the Geological Survey of Pakistan (DG, GSP), insisted that the bibliography, instead, should be annotated. The suggestion was reluctantly accepted, without fully realizing the immensity of the task that would take us so many years, and yet be incomplete.

This document covers the Khyber Pakhtunkhwa and its adjacent Tribal territory, Potwar-Islamabad-Murree areas of Punjab, Azad Jammu and Kashmir, and Gilgit-Baltistan. Publications on the foreland basin molasse sediments of the Salt Range have been included for completing references on the Siwaliks of Pakistan. This work incorporates published and publicly available documents related to solid earth sciences and water resources. References to many of the expedition reports and local publications have been given despite our lack of access to them. We would appreciate receiving information on references which have not been annotated or not included.

In this age of fast and efficient communication and availability of so much online information, the need for publication of this manuscript can be debated. However, it can be justified on the ground that it provides ready access to a pool of large number of contributions, including local publications, many of which are not available online. It is hoped that this work would be of substantial use to the earth scientists and those engaged with natural resources, natural hazards, planning and development.

The Pakistan Science Foundation is thanked for having provided seed grant for the execution of this project. We appreciate the continued support of the National Centre of Excellence in Geology, University of Peshawar. Dr. Imran A. Khan, DG GSP and Mr. Asif Nazeer Rana, Director of the Geoscience Laboratory of the GSP, provided a large number of GSP publications, Dr. MonaLisa facilitated access to student theses submitted to Quaid-i-Azam University, Islamabad, and Mr. A. Wahab, Mrs. Malka Saimeen Ozar, Hafiz Shahid Hussain and Mr. Shahid Waheed of our Centre remained helping hands at various stages. We thank them all.

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A/1. Abass, S.F.A., Amin, M. & Siddiqui, F.A., 1967. Talc deposits of Jamrud, Khyber Agency. Pakistan Journal of Scientific and Industrial Research 10, 300-303.

Geology and chemical composition of the talc deposits have been investigated. Two veins, about 3km apart, contained about 40,000 tons of talc. Talc is of fairly good quality, and suitable for use in the cosmetic, pottery, paper, textiles, tile preparation, and soap industry. Improved mining methods are recommended for winning the maximum %age of talc.

Key Words: Talc, Khyber Agency, Jamrud.

A/2. Abbas, A., 1843. Journey of a tour through parts of Punjab and Afghanistan, in the year 1837. Asiatic Society of Bengal Journal 12, 564 - 621.

This is a travelogue of the area stretching from the Salt Range to Waziristan, through Peshawar, Kohat and Kurram Agency. Written in Persian, it was translated into English by Major R. Leech. It contains brief mention of the occurrence of salt at Kalabagh and Karak, antimony in Kurram, and coal and iron in Kanigurum.

Key words: Afghanistan, FATA, Salt Range, Punjab.

A/3. Abbas, S.A., 1996. Mapping of the weathered and sub-weathered layers from seismic refraction rate in Ghaghriot area, Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad.

The seismic refraction data of 'Ghaghriot' village, Islamabad has been reinterpreted with a view to map the weathered and sub weathered layer and establish a relationship between the velocity and lithology of the area. The data was of 25 spreads with reverse shooting scheme. After plotting the travel time curves the velocities and depths were determined and were put in the form of Isovelocity maps of V0, V1 and V2 and Isopach maps of Z0 and Z1. An integrated study of these maps with the tubewell logs and VES columns reveal the following results.

The velocity of weather layer ranges from 333 m/sec to 620 m/sec and the thickness from 2.6m to 5.6 meters. It is composed of clay, silt and sand. The velocity of subweathered layer varies from 1358 m/sec to 1655 m/sec and its thickness varies from 18.9 to 35.1 m. It is composed of boulder and gravel with lesser amount of clay. This thick bed of boulder and gravel is saturated with water and water table varies from a depth of 4m -5m. The velocity of third layer varies from 1974 m/sec to 3096 m/sec showing the presence of interbedded clay within the gravel and boulder layer. It is also saturated with water.

Key words: Seismology, Seismic reflection, Islamabad.

A/4. Abbas, S.G., 1974. Brief report on geology of chromite deposits near Bucha Village, Mohmand Agency, Malakand Division. Geological Survey of Pakistan, Information Release 87, 7p.

Small Chromite bodies were found associated with ultramafic rocks, during a one day reconnaissance traverse near Bucha Village, Mohmand Agency, Malakand Division. The examined area appears to have some economic potential, as Chromite is believed to be of metallic grade and number of boulders indicate the presence of more Chromite bodies which could not be found out during the short time available for investigation. Boulders also show the presence of massive magnetite and haematite probably derived from the adjoining area.

Key words: Chromite, ultramafic rocks, Mohmand Agency.

A/5. Abbas, S.G., 1992. Prospects for metallic minerals in Pakistan. GSP, Information Release 520, 11p.

This report gives brief information on metallic minerals of Pakistan and includes those reported from the northern parts of the country. A generalised summary report describing present status and future prospects of Aluminium, Chromium, Copper, Lead-Zinc, Gold, Silver, Iron, Platinum, Tungsten and Lithium.

Key words: Metallic minerals, economic geology.

A/6. Abbas, S.G., & Rossman, D.L., 1969. Geology and economic potential for Chromite, Dargai Ultramafic Complex, Malakand Agency, Peshawar Division, West Pakistan. GSP and U. S. Geological Survey Project Report, PK Series, PK (IR)–51.

This report presents the geology of the area, along with information on ultramafic rocks including dunites and peridotites. There is some detail on the occurrence and economic potential of the chromite deposits. The report is accompanied by detailed maps (1:25000) and cross-sections.

Key words: Indus Suture, ultramafic rocks, chromite, Malakand Agency

A/7. Abbas, S.H. & Bhuiyan, K., 1967. Geology of Pezu-Sheikh Budin-Paniala (Khisore and Marwat Ranges): Dera Ismail Khan, North West Frontier Province. GSP, Information Release 109, 28p.

Key words: Stratigraphy, Siwalik Molasse, Khisore - Marwat Ranges, DI Khan.

A/8. Abbas, S.Q., Bhatti, M.A., Pasha, M.K. & Din, F., 1992. Structural analysis of Margala-southern Hazara fold belt. Abstracts, First South Asia Geological Congress, Islamabad, p.50.

The structural behavior inferred from the geological mapping of the Margala and southern Hazara Hills depicts that the area is fault propagated folded belt which is characterised by the sub- thrusting and isoclinal folding. On the northern margin of this belt lies the Nathiagali Thrust whereas the southern boundary is marked by the presence of the Main Boundary Thrust (MBT). It is also evident that the folding thus developed within the Jurassic-Miocene sedimentary rock sequence have been truncated as a result of subsequent thrusting and back thrusting. The ramping of the MBT has placed the Jurassic-Pliocene strata to come to abnormally in contact with the Eocene-Miocene rocks.

In the north, this belt has been overrun by the Pre-Cambrian flysch deposits of Hazara Formation while it is riding over the Eocene-Miocene rocks of the Potwar foredeep in the South. An attempt has been made to illustrate the tectonic model of the folded belt by balancing the selected cross-sections across this structural block.

Key words: Structural analyses, Margala, Hazara.

A/9. Abbasi, A.A., 1936. A study of Minapin Glacier. Indus 3(9), 29-34.

Key words: Glaciology, Minapin Glacier, Hunza, Karakoram.

A/10. Abbasi, A.A., 1965. Land sculpture by Karakoram glaciers. Indus 5(12), 28-32.

This is a report of the impact of the major Karakoram glaciers on the landform/ geomorphology of the central Karakoram region. There is an obvious relationship between the two, and glaciers have played a major role in the development of the geomorphic forms.

Key words: Glaciology, geomorphology, Karakoram.

A/11. Abbasi, I.A., 1989. Sedimentology and structure of the southern Kohat, Trans-Indus Ranges, Pakistan. Ph.D. thesis, University of Cambridge.

Key words: Sedimentology, structure, foreland basin, Siwalik molasses, Kohat.

A/12. Abbasi, I.A., 1990. Major patterns of fluvial facies of the Himalayan foreland-basin in the trans-Indus area, Pakistan. Abstract, 2nd Pakistan Geological Congress, University of Peshawar, p.20.

Consult Abbasi, 1992 below for further details.

Key words: Foreland Basin, fluvial facies.

A/13. Abbasi, I.A., 1991. Large scale vertical aggradation of sandstones in the Kamlial Formation of the Kohat basin, Pakistan. Geological Bulletin, University of Peshawar 24, 33-44.

The Kamlial Formation in the Kohat fold-thrust belt is composed dominantly of thick sandstone interbedded with siltstone and intraformational conglomerate. The sandstone bodies are over 100 meter thick in the upper part and, on the average, 30 meter thick in the lower and middle part of the formation. The sandstone bodies are multistoried and their large thicknesses are due to vertical and lateral amalgamation of sand bodies deposited in a slowly subsiding foreland basin. An average thickness of 4-6 meter has been estimated for the individual sand bodies deposited by 6-8 meter deep, intermediate to high sinuosity streams. Tabular sand bodies interbedded with overbank fines were deposited by high sinuosity streams. The drainage system during the deposition of the Kamlial Formation in the Kohat foreland basin was mainly flowing to the east, which is consistent with that of the Potwar Plateau.

Key words: Siwalik Molasse, Kamlial Formation, Kohat.

A/14. Abbasi, I.A., 1992. Major patterns of fluvial facies of the Himalayan foreland-basin in the trans-Indus area, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.1.

Molasse sediments (over 6 km thick) were accumulated in the western Himalayan foreland-basin (Kohat area) and reflect the subsidence of the basin, and approach of the Himalayan orogenic belt. The succession is composed largely of sand and silt in the lower part, and conglomerate in the upper part. The sand-bodies in the sand silt succession are mainly composed of plane bedding, low-angle plane bedding and trough cross bedding. The abundance of plane bedding and low-angle plane bedding suggest deposition from high energy flow conditions commonly associated with low-sinuosity river systems. The sand-bodies are usually 10 to 20 metres thick in the lower part, but up to 100 meters thick and many km in lateral extent in the upper part of the succession. The earliest recorded progradation of proximal conglomeratic facies over the finer grained sediments occurred in the Kohat area of the foreland-basin during Late Miocene. The coarser grained facies probably appeared in response to the northward drift of the depositional area closer to the source area, and the site became the proximal part of a large fluvial system. The thick polymict succession comprised of clast supported massive conglomerate, crudely stratified to horizontally bedded, and planar cross-bedded conglomerate assemblages suggest deposition by proximal braided streams. The early appearance of thick proximal plain facies suggests that the major palaeo-river system entered the foreland-basin through the Kohat area earlier than 10 Ma, approximately along the present day course of the Indus River.

Key words: Molasse sediments, foreland basin, Kohat.

A/15. Abbasi, I.A., 1994a. Subsurface geological and structural studies based on the gravity and magnetic measurement between Mandra-Jhelum and Dina Mirpur. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 51p.

Key words: Geophysics, subsurface geology, structure, Jhelum.

A/16. Abbasi, I.A., 1994b. Clay minerals in the Himalayan foreland basin sediments: Implications for the progress unroofing of an orogenic belt. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia-I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 280-284.

A sequence of over 6km thick detrital sedimentary rocks is exposed in the Kohat area, western Himalayan foreland basin. These rocks are grouped into two coarsening-upward sequences: the basal Rawalpindi Group and upper Siwalik Group. Clay-mineral studies from silt and clay beds through this succession reflect a fairly consistent mineralogy, but relative abundance of different minerals varies across the succession. Chlorite content decreases upsection with a corresponding increase in the smectite content. The proportion of muscovite/illite remains constant. Muscovite/illite crystallinity increases progressively upsection, showing highest crystallinity values in the Shakardarra Formation, which makes up the upper part of the Siwalik Group. The variations in the mineral abundance and inverse trends in the muscovite/illite crystallinity are probably due to progressive unroofing of an orogenic belt in the source area exposing higher grade metamorphic and igneous rocks.

Key words: Clay Minerals, orogeny.

A/17. Abbasi, I.A., 1994c. Fluvial architecture and depositional system of the Miocene molasse sediments, Shakardarra Formation, southeastern Kohat, Pakistan. *Geological Bulletin, University of Peshawar* 27, 81-98.

The Neogene molasse sediments in southeastern Kohat area are divided into two groups, the Rawalpindi, and the Siwalik groups. The Siwalik Group in the study area, around Shakardarra town, is a coarsening upward sequence of silt dominated Chinji Formation, sand dominated Shakardarra Formation, and polymictic conglomerate dominated Indus conglomerate Formation. The Shakardarra Formation is comprised of sandstone-siltstone in the basal part, dominantly sandstone in the middle part and sandstone –conglomerate in the upper part. The major sandstone-bodies, on average, are up to 15m thick and many km in lateral extent in the lower part, whereas, upto 100m thick and tens of kilometers in lateral extent in the middle and upper parts. The sandstone-bodies are multistoried, and are characterised by inchannel lithofacies such as plane bedding, low angle plane –bedding and trough cross-bedding. A number of bar macroforms and channel features of different hierarchical order have been observed in the sandstone-bodies. A high-energy braided river system is suggested for the deposition of the sediments. The paleoriver system was flowing approximately parallel to the present day Indus River and entered the foreland basin through the study area at least since last 10 Ma.

Key Words: Siwalik Molasse, Shakardarra Formation, Kohat.

A/18. Abbasi, I.A., 1997a. Sedimentology and tectonic setting of polymictic conglomerates in a rapidly subsiding Miocene-Pliocene Foreland Basin: Kohat Plateau, Northern Pakistan. *Geological Bulletin, University of Peshawar* 30, 297-309.

More than 6km of Neogene molasse sediments of the Rawalpindi and Siwalik Groups accumulated in the western Himalayan (Kohat) foreland basin, northern Pakistan, in response to active basin subsidence and orogenic uplift. In the Kohat Plateau, the Siwalik Group consists of a coarsening upward sequence of silt in the lower part (Chinji Formation), sand in the middle part (Shakardarra Formation) and conglomerate (Janak Conglomerate Formation) in the upper part. This formation was previously named as the Indus Conglomerate Formation by Abbasi and Friend (1989), but I now propose that it should be called the Janak Conglomerate Formation. This new name is proposed because of the danger that the previous name will be confused with stratigraphic terms used in the Indus Suture Zone of Ladakh, India, where the terms Indus Group, Indus Formation, Indus Molasse and Indus Flysch have all been used in recent years (e.g. Srivastava, et al., 1979; Searle et al., 1990; Searle, 1996). The name of Janak belongs to a village located on the northwestern edge of the outcrop area of the formation, at 71°38'30"E, and 33°14'30" N (Fig. 2). The Janak Conglomerate Formation is exposed over an area of 400km², and is about 1500m thick. The conglomerate/sandstone ratio is 1:1 in the lower part and increases to 4:1 in the middle and upper parts. The formation is laterally variable but consists of three main lithofacies i.e., a) crudely stratified to horizontally bedded conglomerate (Gh), b) massive, clast supported conglomerate (Gm), and c) planar cross-stratified conglomerate (Gp). In lithofacies Gp, some of the cross-sets are up to 7m thick suggesting channels as deep as 14m or more. However, the average thicknesses of the cross-sets are 3-5m, suggesting channels 6-10 m deep. The progradation of the conglomerates over the finer grained formations is probably mainly a response to this depositional site on the Indian plate, to the progressive movement of the plate towards the uplifted Himalaya. But in the Kohat area, the late Miocene progradation of the conglomerates is distinctly earlier than elsewhere in the western Himalayan foreland basin. The conglomerates pass laterally into the finer grained facies of the Nagri and Dhok Pathan formations to the east and south of the Kohat basin, and also pass into finer

grained sediments to the west. This suggests that it was in this area that the largest river system entered the western foreland, about 10 ma, approximately along the course of the present-day Indus river.

Key Words: Sedimentology, tectonics, Siwalik Molasse, Kohat.

A/19. Abbasi, I.A., 1997b. Channel pattern and range front influence on the Indus River, Punjab Plain, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 3.

The Indus River is one of the world's major river systems and is the largest in Pakistan which along with its tributaries drain most part of the Punjab plain. The river pattern is control by bed-rock structures and morphology in the higher mountains and foreland fold-thrust belt, and by its own alluvium in the Punjab plain. Data from Survey of Pakistan topo sheets, satellite images and some old maps were used to interpret the channel pattern and the influence of range fronts i.e., Suleiman Range on the lateral migration of the river system. Wada's reports (Attalla, 1970) and later, are used for water discharge and sediment load.

Average annual sediment load at Methanol (at the confluence of five Punjab Rivers called Punned) was calculated as about 600x1'09 kg (Attalla 1970). New estimates of Millikan and Meade (1983) have shown an annual sediment discharge of about 110x109 kg at the mouth of Indus River due to enormous silting in large reservoirs. The combined waters of Punned River have over 70% of their sediment load in the form of clay and silt in suspension which has a major influence on the channel pattern further downstream. The river system changes its morphology from a strongly braided in the north, to a meandering system in the south due to decrease in gradient (11cm/km) and high suspended load. The river system is multichannel, low sinuosity in the northern reaches with a 'Total Sinuosity' (Rintoul and Richards, 1993) of 3.5 and a strong braiding element. It is transitional between meandering and braided, rather more of an anastomosed type in its middle reaches with a 'Total Sinuosity' of 2.5. South of Mithankot, the river flows as a single, large sinuous system and the 'Total Sinuosity' decreases to 1.5. The Miocene and younger molasse sediments in the Kohat and Trans Indus Ranges and in Indus fan delta suggest that the Indus river occupied its present course at about 8 Ma (Abbasi and Friend, in press). Major thrust loading along the Sulaiman and other western ranges may have controlled the flow direction along their axis since then. The present day river system shows a tendency to migrate laterally towards the range front. A similar range front control is also evident for the Jhelum River due to thrust loading along the Salt Range Thrust.

Key words: Indus river, channel pattern, Punjab plain.

A/20. Abbasi, I.A., 1998. Major patterns of fluvial facies and evolution of the Himalayan foreland basin, southeastern Kohat Plateau, Pakistan. In: Ghaznavi, M.I., Raza, S.M. & Hasan, M.T. (Eds.), Siwaliks of South Asia, 59-96 Geological Survey of Pakistan, Islamabad.

Key words: Siwalik Molasse, sedimentology, Kohat.

A/21. Abbasi, I.A., 2000. Fault geometries in new hydrocarbon prospective zone of Shkardarra area, Kohat Plateau, North Pakistan. Late Abstracts, Third South Asia Geological Congress, Lahore, 2-3.

Key words: Structural geology, petroleum geology, Shakardara, Kohat.

A/22. Abbasi, I.A., 2001. Post Miocene gravel progradation in the western Himalayan foreland basins, Kohat Plateau, northern Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p. 21.

The sedimentary detritus shed by the Himalayan collision belts and accumulated in the foreland basin, allow correlation between the tectonic processes, lithologies involved in deformation and the resulting sediments. Thick coarsening upward molasse sediments deposited by major river systems characterize the Kohat foreland basin along the western fringes of the orogenic belt. Coarse-grained gravel sequences are deposited in the upper part of the

Siwalik Group as proximal alluvial plain facies. Two major polymictic conglomerate sequences are described from the southeastern and western part of the Kohat plateau.

In the southeastern part of the plateau, near Shakardarra town, the conglomerate sequence named as the “Janak Conglomerate”, is considered to be Miocene in age. The conglomerate has a transitional contact with the underlying Shakardarra Formation (Nagri Formation), and is comprised of thick gravel beds interbedded with sandstone. The formation is exposed over an area of 400 km², and is about 1500m thick. The conglomerate/sandstone ratio is 1:1 in the lower part and increases to 4:1 in the middle and upper parts. The clasts are comprised of gneisses, volcanics, schists, granites and quartzites, derived from the igneous and metamorphic belts of the higher and lower Himalayas, and deposited by a trunk river system analogous to the Indus River. In the southwestern part of the plateau, near Zarwam area, an approximately 2500m thick conglomerate sequence is named as the ‘Ahmedzai Conglomerate’. The Ahmedzai Conglomerate is considered as Pliocene-Pleistocene in age and has a transitional contact with the underlying Dhok Pathan Formation.

The conglomerate is comprised of clasts belonging to limestone, quartzite, chert, ultramafics and serpentinites - derived mainly from the western ranges of Waziristan and Parachinar. The conglomerates were deposited by the Kuram River, a major western tributary of the Indus River. The source area for these conglomerates is interpreted as the north Waziristan-Thal collision belt, dominated by the Cretaceous-Palaeocene igneous complex, and Mesozoic and younger carbonate rocks. The conglomerates of the Janak Formation represent deposition by a large trunk river system draining through the higher and lower Himalayan zones and are described as the high mountain fed conglomerates. These middle and lower Siwalik conglomerates provide information about the extent of older incision in the high mountains, and the portion in the basin of the major drainage path. The clasts of the Ahmedzai Conglomerate represent deposition by tributary streams draining the foothills, and are widespread along the mountain fronts. These upper Siwalik conglomerates provide information about relatively young frontal fault activity and growth of local river systems, such as Kuram River.

Key words: Siwalik molasse, sedimentology, Kohat.

A/23. Abbasi, I.A., Abid, I.A. & Khan, M.A., 1983. Statistical study of the Dhok Pathan Formation, Puki Gudikhel, Surghar Range, Karak. Geological Bulletin, University of Peshawar 16, 85-96.

Size analyses of a part of the Dhok Pathan Formation, Surghar Range, was carried out to study the behavior of different size fractions and to interpret the environments of deposition. The measures obtained on phi-scale reveal that the sandstone of the area is medium to fine-grained, moderately sorted, positively skewed and has platykurtic distribution. The C-M pattern for these sediments suggests suspension and tractive current deposits, and is comparable in appearance with the basic pattern IV and V of Passega (1957). There is no systematic horizontal or vertical variation in different statistical measures but present a rather zigzag pattern, which indicates that the material of variable size was brought to the basin between each cycle.

Key words: Siwalik Molasse, Dhok Pathan Formation, Surghar Range, Karak.

A/24. Abbasi, I.A. & Ali, F., 2000. Tectonic significance of Pliocene-Pleistocene polymictic conglomerates exposed along the western margin of Indian plate; Bannu-Waziristan area, North Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.36.

Thick molasse sediments of the Rawalpindi and Siwalik Groups are exposed over a large area around Bannu and North Waziristan, along the western margin of the Indian Plate. The base of the molasse sequence is defined by the Kamli Formation, overlain by the Chinji, Nagri and Dhok Pathan formations. The uppermost part of the sequence is comprised of over 2 km thick conglomerate interbedded with sandstone, known as Ahmedzai Formation. The best exposures of the conglomerate are along the Ahmedzai Syncline, North of Bannu town. The conglomerates of the Ahmedzai Formation are comprised of clasts derived from the Mesozoic and Tertiary carbonate sequences, quartzites, and from mélange zones. The clasts from mélange zones are represented by abundant chert, ultramafics such as serpentinites, and some volcanics. The material is contributed from within the Kunam Mélange Zone, located to the West of the study area. Isolated outcrops of ultramafic lithologies associated with the Paleocene abduction, due to collision along the western margin of the Indian Plate with Afghan block, are exposed in areas such as Kai and North Waziristan. The conglomerates were deposited by a river system analogous to present-day Kurrarn river draining through the western ranges, such as Koh-e-Sufaid and Kurram Mélange zone. Angular to

subangular clasts of ultramafics, particularly the serpentinites, indicate a close by source area and little transportation.

Key words: Siwalik Molasse, tectonics, Bannu, Waziristan, Indian Plate.

A/25. Abbasi, I.A. & Friend, P.F., 1989. Uplift and evolution of the Himalayan orogenic belts, as recorded in the foredeep sediments. In: Derbyshire, E. & Owen, L.A. (Eds.), *The Neogene of the Karakoram and Himalayas*. *Zeitschrift fur Geomorphologies*, Special Publication 76, 75-88.

Key words: Siwalik molasse, Sedimentology, Himalaya.

A/26. Abbasi, I.A. & Friend, P.F., 1993. Fluvial sole structures from the Siwalik Group north Pakistan. *Geological Bulletin, University of Peshawar* 26, 103-112.

The Siwalik Group consists of over 6 km of fluvial clastic sediments, fluvial cycles of thick sandstone (5-20 m) and siltstones (5-50 m) are common particularly in the Chinji Formation. Sole structures are well developed on the base of the sandstone bodies and represent an early phase of erosion of the overbank fines related to channel evulsion before deposition of major sandstone. Examples from the Chinji and Shakardarra formations include gutter casts, crescent marks, and flute marks all due to aqueous scour. Polygonal marks and pedestal structures, meters across, and locally metres in relief, may be subaqueous or sub-aerial in origin.

Key words: Sedimentology, Siwalik molasse, Chinji Formation, Shakardara Formation.

A/27. Abbasi, I.A. & Friend, P.F., 1997. The Neogene of Janak Conglomerate Formation of northern Pakistan: Stratigraphic effects of continental convergence and drainage. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. *Geological Survey of Pakistan, Records* 109, 32-33.

Over 6 km thick Neogene molasse sediments were deposited in the western Himalayan foreland basin in Kohat area in response to active deformation along the orogenic belt and its gradual migration in the foreland basin. In south eastern Kohat area, west of Indus river the sediments are characterised by two coarsening upward sequences of Rawalpindi and Siwalik groups. The Siwalik Group is comprised of an overbank fines rich the Chinji Formation, an inchannel sand rich the Shakardarra Formation and an upper coarse grained polymictic conglomerate rich the Janak Conglomerate Formation. This formation was first named the Indus Conglomerate Formation by Abbasi & Friend (1989), but we now propose that it should be called the Janak Conglomerate Formation. We propose this new name because of the danger that our previous name will be confused with stratigraphic terms used in the Indus Suture Zone of Ladakh, India, where the terms Indus Group, Indus Formation, Indus Molasse and Indus Flysch have all been used in recent years (e.g. Srivastava, Pal and Mathur, 1979; Searle, Pickering and Cooper, 1990). The name of Janak belongs to a village located on the northwestern edge of the outcrop area of the Formation, at 71°38'30"E, and 33°14'30"N.

The study of the Siwalik Group of the Potwar area by Gill (1952), was the first in which it was recognised that the mainly sandstone-dominated successions of the central Potwar are the lateral equivalents of major conglomerates further west, near the Indus River. Outcropping on both Kohat and Potwar sides of the Indus River, these form the Janak Conglomerate. The Janak Conglomerate Formation was deposited by a large (approximately 15 m deep) river draining southwards from the High-Himalayas of northernmost Pakistan. The deposition appears to have started about 8 Ma ago and lasted until Quaternary times. The formation has a thickness of about 1500 metres, and a lateral extent perpendicular to general river flow of about 25 km.

Comparison with other conglomerate occurrences along the Himalayan front shows that a distinction can be made between foothills-fed conglomerates, for which clasts came from local source areas, that were being uplifted along thrusts in the Sub-and Lower Himalayas during Upper Siwalik deposition.

High-mountain-fed conglomerates, for which clasts came from all the Himalayan lithotectonic zones. These conglomerates were formed by large rivers, involving drainage of the whole Himalayan belt, and conglomerates of this type are found in both Middle and Upper Siwalik deposits. The Janak Conglomerate Formation is of this type, and was formed by the paleo-Indus.

Key words: Janak Conglomerate Formation, Siwalik Molasse.

A/28. Abbasi, I.A. & Friend, P.F., 2000. Exotic conglomerates of the Neogene Siwalik succession and their implications for the tectonic topographic evolution of the western Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication, 170, 455-466.

Published information on the Siwalik Group (Neogene) conglomerates in the Sub-Himalayan belt of Himachal Pradesh, India, and the Potwar Plateau, Pakistan, is used as the basis of a model that recognizes two types of conglomerates with different relationships to the linear Himalayan mountain front. The two type are: (1) foothills-fed conglomerates, widespread along the mountain front, that mark the appearance in the basinal succession of sediments derived from within the Sub-Himalayan fold-and-thrust belt or the neighboring Lower Himalaya; these Upper Siwalik conglomerates provide information about relatively young frontal activity and the growth of local river systems that transferred the sediments generated; and (2) high-mountain-fed conglomerate, with restricted lateral extent along the front, that mark the presence of large trunk rivers, draining the Lower and Higher zones of the Himalaya; these Middle and Upper Siwalik conglomerates provide information about the extent of older incision in the high mountains, and the position in the basin of the major drainage paths.

Our work on the Janak (formerly Indus) Conglomerate Formation, outcropping near the present Indus River, shows that it is a high-mountain-fed conglomerate, and was deposited by a large braided system (channels up to 15 m deep) that drained southwards from the High Himalaya of northmost Pakistan. The conglomerate was deposited between 9 and 1 Ma, and is preserved as a formation 1.5 km thick and 25 km wide, perpendicular to flow. This conglomerate marks the position of the Palaeo-Indus in this part of the foreland basin. The syntaxial position of the present Indus in the mountain front, and the remarkable route of the upper Indus, have resulted from drainage evolution during the alter stages of transpressive indentation of the western margin of the Indian block. Our interpretation of the Janak Conglomerate implies that this special role of the Indus must have already started by 9 Ma.

Key words: Siwalik Molasse, Janak Conglomerate Formation, tectonics, Potwar.

A/29. Abbasi, I.A. & Khan, M.A., 1990. Heavy mineral analysis of the molasse sediments, Trans Indus Ranges, Kohat, Pakistan. *Geological Bulletin, University of Peshawar* 23, 215-229.

The molasse sediments in the Kohat plateau comprise two coarsening upward sequences, the Rawalpindi and Siwalik Groups, which are further subdivided on the basis of their lithological characteristics into a number of formations. Correlation of these formations across different areas becomes very difficult due to their time transgressive nature. Heavy minerals area a useful tool for such correlations, as each formation is characterized by a particular heavy mineral suit. The Murree Formation of the Rawalpindi Group contains a simple association of heavy minerals, and epidote constitutes bulk of the heavy mineral suite. The epidote decreases upsection with a corresponding increase in the contents of other minerals and also by the appearance of new minerals. The Kamliyal Formation is characteristically rich in tourmaline and garnet. The Siwalik Group, particularly the Shakardarra Formation of the Miocene age, is marked by the introduction of high-grade metamorphic and igneous minerals such as amphibole, staurolite and kyanite. Amphibole constitutes the bulk of heavy minerals in the Indus Conglomerate Formation (Miocene-Pliocene age) besides pyroxene, kyanite and staurolite.

The mineral chemistry of amphibole and garnet shows that the amphibole was derived mainly from the igneous and metamorphic belts of the Kohistan island arc. The major source of garnet in the molasse sediments is interpreted as the metamorphic belts of the Indian plate exposed along its northern margin. Some garnet in the Indus Conglomerate Formation may have been derived from the Kohistan island arc terrain.

Key words: Siwalik Molasse, Murree Group, heavy minerals, Trans Indus Salt Range, Kohat.

A/30. Abbasi, I.A., Khan, M.A. & Hadi, S., 2000a. Mass movement and landslides in the Murree area, N. Pakistan. Project Report, ICIMOD, Nepal, 55p.

Consult the following for further details.

Key words: Hazards, mass movement, landslides, Murree.

A/31. Abbasi, I.A., Khan, M.A., & Hadi, S., 2000b. Mass movement and landslide hazard, Murree area, North Pakistan. *Earth Science Frontiers* 7, Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, Chengdu, China, P.43.

The summer resort of Murree and adjoining areas is characterized by high degree of erosivity and erodibility due to both natural and man induced factors. This area is part of a young orogenic belt that is experiencing one of the world's most rapid uplift rates, and is located in near vicinity of major thrust faults. Shear zones associated with still active faults, such as Murree Thrust and also the folding generated due to thrusting induce an inherited weakness and natural instability potential in the rocks of the Murree Hills. Ever increasing population pressure, deforestation, large-scale construction works including a new township and a road network have further aggravated the problem.

In order to study the landslides and other mass movement related problems in Murree, an area around the main town is selected for detailed analysis of the problem as it has been focus of major development and road construction work; this study is an attempt to prepare a preliminary hazard/landslide map along major road network, around Murree town to identify the unstable areas. Data collection during the fieldwork and analysis were carried out on Geographic Information System (GIS) based ILWIS format of the ITC, the Netherlands. Detailed study of few selected landslides has also been conducted to understand the mechanism of failure and extent of damage. The landslide distribution map shows that the western slopes of the Murree ridge are worst affected by the land sliding. Major landslides such as Shifang Hotel and MIT, located on the upslopes of the Jhika Gali-Lawrence College Bypass road are caused by an inadequate drainage system from the city center (Murree ridge). Beside the Bypass road section, the MIT Housing Scheme is also adversely affected by the mass movement. In most part of the area around the Murree ridge, creep is a common phenomenon in thick colluvium cover due to obvious loss of vegetation. Most of the landslides initiated at the colluvium-bedrock interface, but once initiated the tension cracks spread into the bedrock and therefore causing the failure in it. Major landslides in the area, such as Kashmir Bazar, Chitta Mor, MIT etc. exhibits a complex array of joint/fracture pattern both parallel and perpendicular to the bedding, and in various ways contribute to the mass movement.

Key words: Hazard, mass movement, landslide, Murree.

A/32. Abbasi, I.A., Khan, M.A., Hadi, S., Ishfaq, M. & Mool, P.K., 2001. Geological controls on slope failure and landslide hazards, Main Boundary Thrust Zone, Murree Hills, North Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.40.

The summer resort of Murree and adjoining areas are characterized by high degree of erosivity and erodibility due to both nature and man induced factors. This area is part of a young orogenic belt that is experiencing one of the world's most rapid uplift rates, and is located in near vicinity of major thrust faults. Shear zones associated with still active faults, such as Murree Thrust and also the folding generated due to thrusting induce an inherited weakness and natural instability potential in the rocks of the Murree Hills. Ever increasing population pressure, deforestation, large-scale construction work including a new township and a road network have further aggravated the problem.

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The landslide distribution map shows that the eastern slopes of the Murree ridge are worst effected by the land sliding. Major landslides such as Shifang Hotel, Midway and MIT, located on the upslopes of the Jhika Gali-Lawrence College Bypass road are caused by an inadequate drainage system from the city centre (Murree ridge). Beside the Bypass road section, the MIT Housing Scheme is also adversely effected by the mass movement. In most part of the area around Murree ridge, creep is a common phenomenon in thick colluvium cover due to obvious loss of vegetation. Most of the landslides initiated at the colluvium-bedrock interface, but once initiated the tension cracks spread into the bedrock and therefore causing the failure in it. Major landslides in the area, such as Kashmiri Bazar, Chitta Mor, MIT etc. exhibit a complex array of joint/fracture pattern both parallel and perpendicular to the bedding, and in various ways contribute to the mass movement.

Key words: Hazards, landslide, MBT, Murree.

A/33. Abbasi, I.A., Khan, M.A., Hadi, S., Ishfaq, M. & Mool, P.K., 2001. Geological controls on slope failure and landslide hazards, Main Boundary Thrust Zone, Murree Hills, North Pakistan. *Journal of Asian Earth Sciences* 19, p.1.

Consult the preceding account for further information.

Key words: Hazards, landslide, MBT, Murree.

A/34. Abbasi, I.A., Khan, M.A., Ishfaq, M. & Mool, P.K. 2002. Slope failure and landslide mechanism, Murree area, north Pakistan. *Geological Bulletin University of Peshawar*, 35, 125-137.

The area around Murree town is inherently vulnerable to mass movement processes, most commonly due to land sliding. It is characterized by high degree of erosivity and erodibility due to both natural and man induced factors. The area is part of a young orogenic belt that is experiencing one of the world's most rapid uplift rates, and is located in the near vicinity of major thrust faults. Shear zones associated with still active faults, such as Murree Thrust and also the folding generated due to thrusting induce an inherited weakness and natural instability in the rocks of the area. This compounded with ever increasing population pressure, deforestation, large-scale construction work in the form of residential and commercial buildings and road network have further aggravated the problem. Lithologically the area is comprised of shale, siltstone and sandstone belonging to the Oligocene-Miocene Murree and Kuldana formations. In order to study the landslides and other mass movement problems in Murree, an area around the main town and along the Murree-Kashmir Highway is selected for detailed analysis of the problem. The eastern slopes of the Murree ridge, and the road section between Jhika Gali and Aliot village are worst affected by the landsliding. Around Murree town, major landslides such as Shijang Hotel, Midway and MIT landslides, located on the upslopes of the Jhika Gali-Lawrence College Bypass road are caused by inadequate drainage system from the city centre (Murree ridge). In most part of the area around Murree ridge, creep is a common phenomenon in thick colluvium cover due to obvious loss of vegetation. The area between Jhika Gali and Aliot village is also affected by landsliding, and some of the largest landslides such as Aliot, Birgran and Kasserri landslides have inflicted great damage to farm and forest land. This area is located in the footwall of the MBT and is deformed by folding and termination splays associated with it. Most of the landslides initiated at the colluvium-bedrock interface, but once initiated the tension cracks spread into the bedrock and therefore causing the failure in it. Major landslides in the area exhibits complex array of joint fracture pattern both parallel and perpendicular to the bedding, and in various ways contribute to the mass movement.

Key words: Slope failure, landslide, MBT, Murree.

A/35. Abbasi, I.A. & McElroy, R., 1991. Thrust kinematics of the Kohat Plateau, Trans Indus Salt Range, Pakistan. *Journal of Structural Geology* 13, 319-327.

The Kohat Plateau consists of a heavily deformed and structurally elevated thrust sheet. Pop-ups, broad synclines and narrow fault- and evaporite-cored anticlines record high-level translation of a large thrust mass along Eocene evaporites. A lower detachment level is also inferred, located at the base of the Mesozoic-Palaeozoic section. This lower detachment is common to both the Kohat and the adjacent Potwar Plateaus whereas the upper level is restricted to the Kohat. Beneath the Kohat, a blind imbricate stack of pre-Tertiary rocks is developed. Above their roof thrust, the foreland basin-fill of Kohat records greater internal deformation compared to that of the adjacent Potwar Plateau. In contrast, the Potwar thrust belt displays a greater amount of overthrusting on its basal surface, this displacement emerging in the Salt Range. Total shortening across the two plateau is comparable, but is accommodated in an areally smaller thrust belt with a higher structural relief in the Kohat as compared to the Potwar structural province. The resultant geographical offset of the thrust front is denoted by the Hukni-Kalabagh lateral ramp. The differences in the thrust kinematics are tentatively suggested to be caused by the mechanical response of the orogenic wedge to different imposed geometries of the wedge laterally within the basin. The Kohat Plateau appears to have a lower basal dip than does the western Potwar, and thus shows greater internal deformation.

Key words: Thrust kinematics, Trans Indus Salt Range, Kohat.

A/36. Abbasi, I.A., Tanoli, S.K., Riaz, M., Iqbal, H. & Rehman, O., 1994. Provenance of the early Eocene Chashmai Formation in south-western Kohat: Indications of an uplifted Island arc. *Pakistan Journal of Hydrocarbon Research*, 6, 53-59.

Key words: Chashmai Formation, sedimentology, uplift, Kohat.

A/37. Abbasi, K.M., 1982-84. Geotechnical Studies of landslides along Karakoram Highway from Shetan Pari to Aliabad. M.Sc. Thesis, Punjab University, Lahore, 122p.

This thesis is mainly composed of the study of about land sliding along Karakoram Highway from Shetan Pari to Aliabad. A brief description of other geological features is also included in the thesis. The geological map shows the different types of rocks present in the project area. Detailed study has been made in the project area to collect the data about discontinuities as joints, which plays the dominant role in case of sliding in hard rocks. This data has been plotted on equal-area stereonet to check the stability of the slopes. In case of sliding in soft material like alluvial fan, samples were collected and tested for detailed analysis. Finally on the basis of this analysis the road is classified into stable, potentially unstable and unstable regions.

Key words: Hazards, landslides, Hunza.

A/38. Abbasi, M.F., 1999. Interpretation of seismic reflection data from E-Salt Range and Potwar Plateau of Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 20p.

Key words: Seismology, Salt Range, Potwar.

A/39. Abbasi, M.H., 1973. General geological mapping of Chalt area and report on feasibility of dam site near Chalt. M.Sc. Thesis, Punjab University, Lahore, 52p.

The Chalt area is located in the south central part of the Hunza valley. The area contains volcanic and low grade metasediments. The Hunza river has a rather narrow span at Chalt, making the locality appropriate for the construction of a hydroelectric dam. Rocks abutting on both banks of the river appear to be hard and compact.

Key words: Mapping, engineering geology, Chalt, Hunza, Karakoram.

A/40. Abbott, J., 1848. Inundation of the Indus, taken from the lips of an eye witness, A.D. 1842. *Journal of the Asiatic Society of Bengal* 17, 230-232.

This is an account of the great flood in the Indus River. It was caused by breaching of a dam generated by a huge landslide near Raikot on the western flank of the Nanga Parbat. The sudden release of water caused a great damage on the river banks all the way to Attock-Khairabad, where a whole regiment of the Sikhs' army was swept away.

Further information is not available to the authors.

Key words: Indus, flood, hazard.

A/41. Abdullah, S.K.M. & Offield, T.W., 1968a. Reconnaissance geology of the Balakot and Mahandri Quadrangles, Hazara district, West Pakistan. U.S. Geological Survey, PK (IR) 34, 41p.

Key words: Reconnaissance geology, Balakot, Hazara.

A/42. Abdullah, S.K.M. & Offield, T.W., 1968b. Reconnaissance geology of the Darband Quadrangle, Hazara district, West Pakistan. U.S. Geological Survey.

Key words: Reconnaissance geology, Darband, Hazara.

A/43. Abdelouahab, M., 1991. Petrologie-geochimie des roches mafiques et ultramafiques grenues de l'arc volcanique obducte du Kohistan (NW Pakistan). Contributions a la genese des arcs volcaniques intra-oceaniques. Ph.D. Thesis, University of Montpellier, France, 189p.

This is an account of mafic and ultramafic rocks of the Kohistan arc, with details of petrography and geochemistry. Petrological and structural conclusions have been drawn on the genesis and development of this intra-oceanic volcanic arc in the neo-Tethys. Many tables of analyses and figures accompany the text

Key words: Kohistan arc, geochemistry, petrology, mafic rocks.

A/44. Abdus-Sattar, 2000. Some geochemical attributes of Higher Himalayan granites from Upper Kaghan valley, NW Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.114.

Higher Himalayan crystalline unit in the Upper Kaghan Valley is comprised of granitoids, pelites, psammites migmatites, turbidites and associated minor marble horizons recognized as basement, covered with thin pelites-psammites and intercalated marbles having amphibolite at the base and a thick sequence of calc-pelites and marbles at the top, intruded by sheet granites. This sequence is bound by the MCT in the south and MMT in the north. The whole block is metamorphosed to upper amphibolite facies. Granitoids of H.H.C in Upper Kaghan valley are mainly concordant with the regional structure and are deformed along with enclosing metasediments and associated amphibolites with minor discordance and interfingering. The geochemical analysis for major and trace elements of twenty three samples of the H.H granites has been carried out with the aim of their geochemical characterization and determining their origin. Colour index ranges from leuco to mesocratic. Analyses are plotted on various diagrams and plots including variation diagram for major/trace elements, major/minor elements, triangular diagrams, discrimination diagrams, trace element spidergrams and indexes & ratios are determined for complete overview of the granites of the Upper Kaghan valley. The analyses confirm that these granites are peraluminous, S-type, and plot in within plate granite and calc-granite field. Fractionation ratios suggest fractional crystallization.

Key words: Geochemistry, granites, Upper Kaghan.

A/45. Abetti, G. & Alessio, A., 1929. Geofisica, Gravita e Magnetismo. In: Spedizione Italiana De Filippi Nell'Himalaya, Caracorum e Turkestan Cinese (1913-1914), ser. I, Vol. II, Geodesia e Geofisica-Zanichelli, Bologna, 1-222.

This is an account of the geophysical surveys (gravity and magnetism) carried out by the de Filippi Italian Expedition to the Himalaya, Karakoram, and Chinese Turkistan in 1913-1914. Further information is not available to the authors.

Key words: Geophysics, Gravity, Magnetism, Karakoram, Himalaya.

A/46. Abetti, G., Alessio, A., Antilli, C., et al., 1929. Astronomia geodetica, geodesia e topografia. In: Spedizione Italiana De Filippi Nell'Himalaya, Caracorum e Turkestan Cinese (1913-1914), 1 (1), Geodesia e Geofisica-Zanichelli, Bologna, 1-418.

This is a report of the De Filippi Italian Expedition to the Himalaya, Karakoram, and Chinese Turkistan in 1913-1914. It concerns geodetic data and topography. Further information is not available to the authors.

Key words: Italian expedition, geodesy, Karakoram, Himalaya.

A/47. Abers, G., Bryan, C., Roecker, S., & McCaffrey, R., 1988. Thrusting of the Hindu Kush over the southeastern Tadjik basin, Afghanistan: Evidence from two large earthquakes. *Tectonics*, 7, 41–52.

We infer from the mechanisms and depths of two large earthquakes that the Hindu Kush is actively thrusting northwest over the Tadjik basin and that the basin is closing rather than being displaced to the west. Teleseismic body waves were used to determine focal mechanisms and depths for the two largest shallow earthquakes on the southern edge of the basin. The two earthquakes, on June 24, 1972 (mb=6.0), and December 16, 1982 (mb=6.2),

have seismic moments of 2×10^{18} N-m and 6×10^{18} N-m, respectively. Focal mechanisms of both events indicate almost pure thrust faulting with nodal planes striking northeast-southwest. The inferred fault planes dip southeast, at 20° for the first event and 50° for the second. The P axes for both events are oblique to the direction of relative motion between India and Asia, suggesting that the Pamir is overthrusting the basin to the west. Depths for both earthquakes are between 20 and 25 km and place them well below the Tadjik basin sediments. The depths and steep fault planes suggest that these earthquakes represent a down dip extension within the basement of shallow folding and thrusting seen in the sediments northwest of the events. Thus convergence in Afghanistan between India and Eurasia is taken up along southeast dipping thrust faults north of the Hindu Kush as well as by northward subduction under the southern part of the range.

Key words: Tectonics, earthquake, Hindukush, Afghanistan.

A/48. Abid, I.A. & Abbasi, I.A., 1983. Stratigraphy, petrography and statistical studies of Siwalik group, Surghar Range, Kohat, N.W.F.P. M.Sc. Thesis, University of Peshawar, 128p.

The late orogenic sediments i.e. Siwalik molasses of post Eocene age, exposed along the western limb of Makarwal Anticline (Surghar Range) are objective of this report. Brief petrographic and statistical studies are carried out to determine characteristics of sandstone to establish a possible provenance. Sandstone comprises of quartz, feldspar mica, calcite, hornblend, rock fragments, and minor amount of epidote, garnet, zircon, apatite chlorite, and ore. Kyanite, staurolite, sphene, orthopyroxene and rutile are the other rare minerals. According to the scheme of Folk (1958) the sandstones are lithic arkose to feldspathic litharenite. From bottom to top feldspar, rock fragments and medium to high grade metamorphic minerals increase while calcite decreases. It may indicate unroofing of granite, granodiorite, and medium to high grade metamorphic belts with the passage of time.

Sieve analyses of 40 samples indicate that dominant clastic fraction is medium to fine (0.25 to 0.125 mm), moderately sorted, positively skewed and steeply peaked. Average values of various statistical measures obtained are

Sorting	skewness	kurtosis	Mean
0.90	0.70	0.86	2.37

All the parameters plotted graphically show that there is a zig-zag pattern rather than a vertical one, which suggests a cyclic repetition of the size factor.

Stratigraphic sections measured at two localities are analysed in term of fluvial stratigraphy. The stratigraphy indicates a fluvial system of laterally migrating stream, leaving behind fining upward cycles of lateral and vertical accretion deposits. The origin of uranium mineralization is not clear. It may be either due to mechanical concentration in old paleochannels (O.W.Chase, 1976) or by percolation of mineralized solution through impervious beds (M.Masoor et. al., 1980)

Key words: Siwaliks, Stratigraphy, Petrography, Kohat.

A/49. Abid, I.A. & Abbasi, I.A., 1984. Preliminary petrography of the Hangu Sandstone, Hangu, Kohat. Geological Bulletin, University of Peshawar 17, 109-112.

The quartzitic sandstone of the Hangu formation is mature both texturally and mineralogically. The detritus is diagenetically cemented by secondary silica giving rise to interlocking texture. The petrography and stratigraphic position of the sandstone suggests shallow marine environments of deposition where feldspar, lithic fragments and other softer material were completely destroyed as a result of repeated winnowing by long shore currents, while quartz and a resistant suite of heavy minerals were retained.

Key words: Petrography, Sand Stone, Hangu, Kohat.

A/50. Abid, I.A., Abbasi, I.A., Khan, M.A. & Shah, M.T., 1983. Petrography and geochemistry of the Siwalik sandstone and its relationship to the Himalayan orogeny. Geological Bulletin, University of Peshawar 16, 65-83.

The Siwalik molasse of post Eocene age, exposed along the western limb of the Makarwal Anticline (Surghar Range), has direct relationship with uplifting episodes of the Himalayan Mountains present to their north. Detailed petrography of the sandstones together with chemical analyses of a few selected samples indicate varied mineral

assemblages and major oxide proportions for Lower, Middle and Upper Siwalik. Thus the Siwalik molasse, which is hitherto classified on the basis of sandstone and shale proportions and the variations in their color, may also be divided into different units on the basis of mineral assemblages and major oxide geochemistry, or at least these aspects can be used for subsurface correlation in limited domains of the Siwalik belt.

Regarding the source rocks, carbonates were major contributor along with other rocks during the deposition of the Lower Siwalik. The presence of igneous and metamorphic rock fragments along with medium to high-grade metamorphic minerals suggest crystalline rocks as the source of the Middle Siwalik. Such a mineral assemblage has also been reported from the Middle Siwalik of India, indicating unroofing of crystallines on a regional scale in the source area. Common occurrence of zircon in the Middle Siwalik seems to have some relationship with recently reported radioactive mineralization. The Upper Siwalik seems to have been derived from the foredeep sediments (Lower and Middle Siwalik), which were involved in the southward prograding orogenic activity by the Pleistocene period.

Key words: Petrography, Geochemistry, Sandstone, Siwalik Molasse.

A/51. Abid, M.S., 1975. Evaluation of geothermal resources in Pakistan. In: World energy crisis and its implications with particular reference to developing countries. World Energy Symposium, Nov. 1975, Karachi, 1-7.

This paper gives an evaluation of geothermal resources of the country, including hot springs of northern Pakistan.

Key words: Energy (geothermal).

A/52. Abid, M.S., & Farid, A., 1995. Cambrian rocks in Pakistan: Distribution and petroleum possibilities. In: Abstract volume, Dissanayake, C. B., Almond, D. C., and Cooray, P.G. (Eds.). Second South Asia Geological Congress, (GEOSAS-II), Colombo, Sri Lanka, p.229.

This is a general account of the occurrence of the Cambrian rocks of Pakistan, including those of the Salt Range and Himalayan fold-and-thrust belt.

Key words: Cambrian, Attock-Cherat, Hazara.

A/53. Abubakr, M., 1965. Geology of parts of Trans-Himalayan region in Gilgit and Baltistan, West Pakistan. Geological Survey of Pakistan records, 11 (3).

Reconnaissance geological mapping at a scale 1 inch to 4 miles was carried out in the Trans-Himalayan region of Gilgit and Baltistan. The region contains three major mountain ranges, namely, the Kailas Range, the Karakoram Range, and the Hinduraj Range. They are arcuate and parallel to each other with convexity northward. The region is underlain by a sequence of metasedimentary and sedimentary rocks, and several types and ages of igneous rocks. Metasedimentary and sedimentary sequence includes slate, quartzite, limestone, and gneiss of Permo-Carboniferous age. They are intruded or intercalated by a group of rocks called Greenstone complex. All these rocks have been intruded by granodiorite and hornblende which are probably of Tertiary age. The salient structural features are the swinging of the strikes of rocks sequence on that of ranges; and isoclinal folding of the Permo-carboniferous rocks, in places, tending to recumbent folds. This swinging nature can be explained as due to the bending of all rock components around the syntaxis of the northwest Himalayas. Metamorphism of the Greenstone complex and carboniferous rocks is widespread.

Key words: Reconnaissance, Mapping, Trans-Himalaya, Gilgit, Baltistan.

A/54. Abubakr, 1986. On a collection of Siwalik Carnivora. Biological Society of Pakistan, Monograph 11, 1-64.

Key words: Paleontology, Siwalik Molasse.

A/55. Achache, J., Courtillot, V. & Besse, J., 1983. Paleomagnetic constraints on the late Cretaceous and Cenozoic tectonics of Southeast Asia. *Earth and Planetary Science letters* 63, 123-136.

Many features of the Cenozoic tectonic history of central and southeastern Asia can be understood as direct consequences of the thrust and penetration of India into Asia. Recent indentation experiments with plasticine (Tapponnier et al.) have extended this idea and have led to the prediction of a pattern of large rotations and displacements of continental blocks that can be tested by paleomagnetism. The available Cretaceous and Cenozoic paleomagnetic data from this part of the world have been reviewed and a new APWP for Eurasia has been constructed for reference. The negligible rotation of South China and large clockwise rotation of Indochina are consistent with the model, i.e., with a history of large-scale left-lateral strike-slip motion along the Altyn Tagh and Red River faults. Data from Malaya and Borneo can be reconciled with the model, although in a less straightforward fashion. The large counter clockwise rotation of South Tibet implies that it rotated in sympathy with India during the collision and suggests that future indentation experiments should include this feature. Finally a middle Cretaceous reconstruction of the south margin of Asia is proposed. One interesting result is the restored continuity of geological features in Tibet and Indochina, with active subduction of oceanic (Indian plate) crust taking place to the south at subtropical latitudes.

Key words: Paleomagnetism, Tectonics, Southeast Asia.

A/56. Afrasiabin, A., 1970. Geological report on Abbottabad and Dunga Gali, Hazara. M.Sc. Thesis, Punjab University, 45p.

This report, as part of the M.Sc. thesis, describes the geology of the Abbottabad-Dunga Gali section. The area is covered by various types of sedimentary rocks ranging from Paleozoic to Tertiary.

Key words: Stratigraphy, Abbottabad, Hazara.

A/57. Afridi, A.G., 1992. Lithogeochemical studies of the Chitral area, Hindukush Range, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 1-2.

Lithogeochemical studies were carried out in the Chitral area, Pakistan to delineate the potential gold mineralization. The Chitral area lies in the central part of the Hindu Kush Mountains, which constitute the northwestern extension of the greater Himalayas. The area is underlain by a wide variety of metamorphic and sedimentary rocks, which are intruded by granites, pegmatites, quartz veins, and basic dikes.

One hundred and twenty samples of a variety of rocks were analyzed for Au, Ag, As, Sb, Cu, Mo, Pb, Zn, K, Rb, and Tl. The concentration of the trace elements is generally low in most of the rocks with the exception of altered carbonates and some quartz veins associated with granites and slates. The altered carbonate rocks have a significantly high concentration of Au, Ag, As, Sb, Cu, Mo, Pb, Zn, Tl. Several samples contain up to 1 ppm Au and more than 1% As. Some of the quartz veins in granitic rocks and in slates contain high contents of Au, Ag, As, Sb, and Tl, but the enrichment of these elements is not high enough to mine them profitably. A high grade vein sample containing boulangerite, however, contains extremely high enough concentrations of Au (30 ppm) and (1350 ppm). Thallium is significantly higher in hydrothermally altered carbonate rocks compared to the unaltered rocks. The enrichment of Tl over K and Rb in hydrothermally altered rocks is demonstrated in Tl-K-Rb ternary diagram. The mineralized rocks fall close to the Tl apex, and the unmineralized rock samples plot near the K apex.

The abundance of Ag, As, Sb, Cu, Mo, Pb, and Zn in altered carbonate rocks is more or less similar to the sediments hosted good deposits of western United States. The enrichment of Au and Tl, however, is not as high as in some of these deposits. The preliminary study suggests that Chitral area probably contains economically important gold deposits. Detailed lithogeochemical and pedogeochemical surveys of certain areas may prove to be useful in locating sediment hosted gold deposits.

Key words: Geochemistry, Hindukush, Chitral.

A/58. Afridi, A.G., Iqbal, S. & Khan, S., 1995. Shangla. US Geological Survey, Geological Map Series 1106, old sheet no. 59 (43 B/9, 1:50000).

Consult the following account for further details.

Key words: Indus Suture, Kohistan Arc, amphibolites, mélange, Shangla, Swat.

A/59. Afridi, A.G., Khan, R.N., Shah, H. & Walliullah, 1995. Charbagh. US Geological Survey, Geological Map Series 1072, old sheet no. 58(43 B/5, 1:50000).

This map and the following show the geology of the Indus Suture zone. The southern part of the area is occupied by the southern Amphibolite belt of the Kohistan Arc. The northern part, Shangla area, is occupied by a tectonic mélange containing ultramafic blocks and blue schists in a sedimentary mélange.

Key words: Indus Suture, Kohistan Arc, Amphibolites, Mélange, Charbagh, Swat.

A/60. Afridi, A.G.K., 1986. Barite deposits of North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 134, 35p.

Key words: Mineral Deposits, barite, NWFP.

A/61. Afridi, A.G.K., Shah, H. & Rahim, S., 1980. Magnetite occurrences in the Kohistan Area, Hazara Division, NWFP, Pakistan. GSP. Information Release 124, 20p.

Minor lenses of magnetite occurs in a complex metamorphic belt in the Kohistan region of the North West Frontier Province, Pakistan. Preliminary field studies carried out by the Geological Survey of Pakistan during 1977-79 have shown that all the known magnetite bodies are of limited extent and show considerable variation in mineralogical content and chemical composition. Reserves of individual lenses do not exceed a few tens of thousand tonnes in each case and the total iron content of an average ore sample is always less than 50 percent. As such these occurrences are not considered to be of economic significance for the foreseeable future.

The small scale mineralization of magnetite in the investigated area owes its origin to partial metasomatic replacement of the erratically distributed marble/ crystalline limestone lenses in the Paleozoic (?) schistose group, in contact with the latter granite.

Key words: Magnetite, Kohistan, Hazara.

A/62. Afridi, A.G.K., Khan, R.N. & Shah, H., 1983. Regional geology of Mingora and Charbagh Quadrangle, NWFP, Pakistan, with the geological map on 1:50,000 Scale. GSP Information Release 132.

This paper, with a nicely produced geological map, covers the rock assemblages on the two sides of the Indus suture. The southern part is represented by metamorphic rocks and granitoids of the Indian plate, and the northern by metabasites of the Kohistan arc. The suture mélange occurs as a sandwich between the two.

Key words: Regional geology, geological map, Mingora, Swat.

A/63. Afridi, A.Z.K., Anwar, J., & Hashmat, S.M., 1976. Fluorite deposits of Chakdara area, District Dir: Internal report of the Pakistan Mineral development Corporation, 57pp.

The fluorite deposits of Chakdara area in Dir District are found near the villages of Chatpat and Tsapparuna. Both the occurrences are about 4 miles apart. Chemical tests of both the deposits have classified them as of metallurgical grade. The Chatpat deposit is of better quality and colour. The fluorite mineralization at Chatpat is occurring in the form of thin multiple veins in granitic gneiss. Major zone of mineralization is 30 to 38 feet thick and 60 to 80 feet long. The fluorite veins which range in thickness from 1/8th of an inch to 4-1/2 feet, and are distributed alternatively with barren granitic gneiss. Some minor dissemination of fluorite is also observed in the intervening gneiss layers. Pinching and swelling is typical character of these lenticular fluorite deposits. Chemical analysis revealed in a xinu content of 51.3% CaO and 33.9% F. The fluorite deposits of Tsapparuna also occur in gneissic rocks which are northeastern extension of the Chatpat outcrops. Three main fluorite veins have been located in Tsapparuna area, which strictly follow the foliation joints. The veins range in thickness from 6 inches to 11 -1/2 inches. The fluorite in

this area is violet to dark violet in colour and is associated with quartz. Chemical analyses indicate 51.2% to 44.9% CaO and 33.7% to 29.2% F. Lead, Vanadium, Titanium, Molybdenum and strontium have also been found in Chatpat deposit. The reserves assessment has revealed that the proved reserves are 3544 tonnes whereas inferred reserves are about 7552 tonnes.

Key words: Mineral deposits, flourite, Chakdara, Dir.

A/64. Afridi, M.I., Badshah, M.S. & Ihsanullah, M., 1991. Copper occurrence in Waziristan. Proceedings First SEGMITE Symposium, Peshawar, Pakistan, March 1991, 70–73.

The geology of the Shinkai area, North Waziristan is described, with a help of a geological map. Copper mineralization exists in the form of stock works, stringers, and cavity/vesical/void fillings, and as dissemination of primary sulphides including pyrite, chalcopyrite and bornite associated with hypogene secondary sulphides and oxides of iron and copper including malachite, azurite, cuprite, tenorite, limonite, jerosite and goethite etc. the copper is of volcanogenic and syngenetic origin. The deposits are genetically similar to Cyprus type. Average copper content is about 0.386 %.

Key words: Copper Mineralization, Waziristan.

A/65. Afzaal, P.A., Din, N., Rashid, C.M. & Majid, A.A., 1995. Influence of basement Tectonic on the structural trends of Himalayas, A case study in Potwar Plateau. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich), Switzerland.

Potwar Plateau (PP) of Pakistan lies in the western Sub-Himalayan tectonic zone and is bounded (a) to the north and south by north dipping Main Boundary Thrust (MBT) and Salt Range Thrust (SRT) respectively (b) to the east and west by Jhelum and Kalabagh wrench faults with associated syntaxial bends respectively (Fig. 1). These bounding structures are different from one another in timing, intensity and causes of deformation, structural styles and their impact on the tectonics of PP.

The present tectonic setting of PP has resulted from the northward underthrusting of Indian Plate under its own sedimentary cover. Major structures of the Sub-Himalayas are the result of reactivation of the preexisting tectonic features of the Indian Shield, in Neogene time, due to flexural bending caused by loading of the basement from southward advancing thrust sheets. The tectonics of the Pre-Cambrian crystalline basement has largely controlled the structural styles of PP in particular and higher Himalayan Ranges in general. The controlling factors are;

- i. Pre-Himalayan tectonic features/directions of the Basement.
- ii. Dip of the Basement.
- iii. Grain of the Basement.
- iv. Segmentation of the Basement resulting from partial docking with Afghan Plate in the north-west.

There are two main tectonic directions, i.e. NW & NE in the Indian Shield rocks exposed at Kirana Hills (surface expression of Sargodha Basement High) and Aravalli Ranges. These directions are reflected in the major tectonic trends of the PP and higher Himalayan Ranges (Fig. 2). In PP, east of 73° - O' Longitude the major structures like Riwat, Adhi-Ghungrilla, Pamal - Domeli, Rohtas and seismically interpreted basement offsets are aligned in a NE-SW direction. West of 73° Longitude the Kallar Kahar fault with its inferred extension, Kalabagh fault, Dhadumbur anticline, Joyamair structure show a NW-SE trend.

Internally PP can be divided into 3 parts on the basis of intensity, type and trend of deformation. These are (i) North Potwar Deformed Zone (NPDZ) (ii) East PP (iii) Southwest PP.

NPDZ represents severest and oldest phase of deformation within PP. It is marked by imbricate stack of thrust faults, tight isoclinal folding, vertical dips and thrust bound ridges. The Eastern PP is characterized by NE-SW trending tight anticlines and intervening broad synclines. In southwest PP there are a series of gentle folds, incipient in nature. A variation in dip of the basement is responsible for the difference in structural style and frequency of structures from east to west of the PP. In the eastern PP dip is <1°, so the structures in eastern PP are viewed as response to a too narrowly tapered wedge in order to increase the taper. In southwestern PP higher dip of the basement i.e. 3.6° allow the thrust sheet to slide without undergoing internal deformation. In NPDZ inspite of higher dip of the basement (3.6°) the area is strongly deformed. This zone is probably an allochthonous block, thrust southwards to its present position.

Seismic data across PP show presence of north facing basement normal faults, some of which have been noted to exist beneath the Chak Beli Khan, Chak Naurang, Qazian and south of Bhaun structures. These faults were pre-

existing weaker zones, reactivated due to loading of the basement, and influenced the deformation of east PP. Fault propagation folds in this area are produced by the movement on these faults. Similarly ramping of eastern Salt Range has been controlled by the basement normal fault south of Bhaun.

Many areas of the PP show evidence of counter clockwise rotation which was more intense in SE PP (maximum 35°) and did not occur simultaneously in all parts of the PP. This indicate the segmented nature of the basement. Taking the example of south PP where data shows differential rotation, both in time and space, of south-east, south-central and south-west PP. These blocks are separated from each other by Domeli -Diljabba and Kallar Kahar faults. The two faults are aligned in NE and NW direction respectively, which are the main tectonic directions of Indian Shield and Himalayas. These faults are interpreted as the surface expressions of deep seated basement fractures which have divided the south PP into three segments each showing differential rotation due to tectonic movement along Jhelum fault, Salt Range Thrust (SRT) and Hazara Kashmir Syntaxis (HKS). East of 730 Longitude, magnitude of SRT appear to diminish near Jalalpur. This is due to the transfer of deformation from SRT to NE-SW trending Domeli - Diljabba thrust which is the resultant of basement fault at Qazian - Bhubar structure. The Domeli-Dabba thrust ultimately merges into Jhelum fault.

The north-south trending left lateral Jhelum fault has been a long lived active feature of the Indian Shield. Synsedimentary movement on this fault may have affected the Siwalik sedimentation and later movement have cause the counter clockwise rotation in east PP. The structures in east PP were originally formed in E-W direction due to movement on the basement normal faults, and rotation have changed their direction to NE-SW. Formation of HKS is due to movement on Jhelum fault and thrusting along MBT and SRT.

Kalabagh right lateral fault is also a basement fault affecting the formation of Kalabagh Syntaxis (KS), which is considered as northwestern spur of Sargodha basement high.

Finally it is concluded that the tectonic features of the Indian shield have been duplicated in the deformation of cover rocks of the Himalayas. The basement normal/reverse faults have been reactivated to cause major thrusting, while the movement on the wrench faults due to segmentation of the Indian Plate, have produced various syntaxial bends.

Key words: Tectonics, structure, Potwar plateau, Himalaya.

A/66. Afzal, M.S., 1983-85. Geology and tectonics of Burawai Area, Upper Kaghan valley, District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 125p.

Nearly 114 sq. km. in the vicinity of Burawai, upper Kaghan valley has been geologically mapped, at the first time. This thesis presents first time accounts of geomorphology, lithostratigraphy, petrography and economic geology of the area. The area constitutes rocks representing old Indo-Pak basement rocks, comprising pelites, calc-pelites and marbles have been metamorphosed to kyanite and sillimanite grades. These are intruded by para-autochthonous sheet granites also metamorphosed.

Major structure comprises an open synform possibly part of a larger structural basin. The western part comprises the nose of a larger antiform.

Marble, biotite mica and kyanite are important mineral deposits which deem further exploration and evaluation. This thesis also includes petrogenesis of the rock units as well as numerous sketch sections and photographs, illustrating the geology of the area.

Key words: Tectonics, geology, geomorphology, Kaghan valley, Mansehra.

A/67. Afzal, S., 1990-92. Geological study for petrography and geology of Atia Qala (District Swat). M.Sc. Thesis, Punjab University, Lahore, 57p.

Rocks of Atia Qala (Distt. Swat) are part of metamorphic hornblend complex. The area lies within the southern portion of Swat. These rocks are probably the extentions of rocks of Dir in the form of a belt running approximately in East-West direction. The area given for field work comprises thirty kilometers in the North-West of Mangora. The area mainly comprises the main rock units are Norite, Diorite, Quartz-O-Feldspar and Pegamatite veins. But at some places patches of Amphibolite are also found but can be considered negligible. As the field evidences, and the laboratory study shows that the Diorite and Norite were formed from basic magma, which have under gone regional metamorphism under the intense orogenic conditions.

Quartz-O-Feldspathic and pegmatite veins are extensively distributed all over the area, indicating the evidence of Diorite magma. Major minerals are Plagioclase, Hornblend, Epidote and Quartz with accessories as Sphene and Magnetite. These are products of regionally metamorphosed igneous rocks.

Key words: Petrography, Geology, Swat.

A/68. Ahmad, A., 1976. The classification of hazard zones in Pakistan. Proceedings, CENTO Symposium on Earth Quake Engineering, 186-196.

Abstract not available to the authors.

Key words: Earthquake, Hazards.

A/69. Ahmad, A., 1961. Olcastephanus Astriecrianus newly recorded from Hazara. Punjab University, Geological Bulletin 1, 65-66.

Key words: Fossils, Hazara.

A/70. Ahmad, A., 1962. Waagen and Wynnes 'Triassic' of the Hazara Mountains. Punjab University Geological Bulletin 2, 52-53.

Assignment of a Triassic age to a section in the Hazara mountains (Pakistan) was based on fossils which could not be found during later field studies. Fossils that were found, however, have been identified by the British Museum as forms ranging from Oxfordian (Jurassic) to upper Cretaceous. A Jurassic age is suggested for the section in question.

Key words: Triassic, Hazara.

A/71. Ahmad, A., 1979-81. Detailed mapping, petrology and structure of Gulpato-Banda Saoni area, Tehsil Kohistan, District Dir, NWFP. M.Sc. Thesis, Punjab University, Lahore, 78p.

Gulpato banda-Saoni area is a part of Hindu Kush range. The total investigated area is about 30 miles². The rocks in the area are composed of metasedimentary complexes with igneous intrusions. The main units in the area are calcareous quartzite, chlorite schist and biotite schist.

It is believed that chlorite schist and biotite schistose are the product of regional metamorphism on argillaceous and calcareous rocks. The contact of calcareous quartzites with schist is gradational. After this the granodiorite magma intruded in the area. In the second phase the intrusion on the magma was siliceous and of granitic composition. It formed small patch schist.

There are extensive quartzo-feldspathic and pegmatitic veins and dykes in granodiorite and schist indicating late residuals of granodiorite magma.

Fossils of larger foraminifera (Assilina, Nummulites, and Alveolina) were collected in calcareous quartzites. They are of lower Eocene age.

Key words: Petrology, maps, Structure, Kohistan, Dir.

A/72. Ahmad, A., 1982-84. Geology and petrotectonic study of Shino-Kaghan-Batal Area, Kaghan valley District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 40p.

Further data for this account was not available to the authors.

Key Words: Petrology, Tectonics, Kaghan, Mansehra.

A/73. Ahmad, A., 2000. Thermal maturity modeling of Kohat-Potwar Basin, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.1.

One - dimensional maturity modeling of three wells, Tolanj-1, Meyal-10 and Pandori-1 was carried out. All available geological, geochemical and geophysical concepts and data were integrated for making this model. Using this model, the timing and amount of hydrocarbons generated from different potential source rocks were evaluated. Vitrinite reflectance measurements of whole of the stratigraphic sequences in Tolanj-1 and Pandori-1 were carried out and used for maturity modeling, while for Meyal-10 only 2 measurements of Jurassic Formations were used. Results of maturity modeling of individual wells and their correlation with other wells indicate that maturity

increases from East and southeast to West and northwest. Salt Range Formation is not mature in eastern Potwar (Khewra gorge) and lies in gas window in central Potwar (Meyal-lo), and is late mature for gas in Kohat (Tolanj-1) area. The time of hydrocarbon generation is also different at different locations e.g., Salt Range Formation was in the peak oil generation phase in middle Eocene time in Tolanj-1 (Kohat area) and it reached at this stage in Late Miocene in Meyal-10 (central Potwar).

Key words: Thermal Modelling, Hydrocarbons, Kohat-Potwar basin.

A/74. Ahmad, A., Jamal, T., Yusaf, S. & Younis, R., 1986. Geology and structure of a part of Kohat Quadrangle, Kohat. M.Sc. Thesis, University of Peshawar, 54p.

The present work describes the stratigraphy and structure of a part of Kohat Quadrangle bounded by lat. 33. 15. 33. 25 N and long 71. 30. 71. 40 E. This part lies in the western corner of Pakistan Survey topographic sheet No. 38-O/11.

The area under investigation is composed of sedimentary rocks ranging in the age from Early Eocene to Pliocene.

The Following formations are exposed in the mapped area.

(8) Dhok Pathan Formation Middle Pliocene.

(7) Nayri Formation Early Pliocene.

(6) Chinji Formation of Siwalik group Late Miocene
. Late Tortonian age.

(5) Kamlial Formation Middle Late Miocene.

(4) Murree Formation of Rawalpindi group Miocene.

(3) Kohat Formation Eocene.

(2) Kuldana Formation..... Early-Early Middle Eocene.

(1) Jatta Gypsum Early Eocene.

The area shows moderate folding and faulting, the folds are mostly open. The faults reveal the significant movement that has taken place on the regional scale. Folds are moderately plunging East or West. The limestone is highly effected by weathering and fracturing. Doubly plunging nature of folds, fracturing and downward slipping of mass of rock or unconsolidated material of any size of limestone are the direct result of the plastic behavior of the gypsum.

Structurally the area under investigation is suitable for Oil and Gas accumulation. It has potential for non-metallic minerals i.e. limestone, common salt and gypsum.

Key words: Stratigraphy, Structure, Kohat.

A/75. Ahmad, A.K., 1884. Account of Dardistan with map of the country surveyed during 1882-83 in connection with Trigonometrical Branch. Survey of India, Dehra Dun.

Key words: Mapping, Dardistan, Baltistan.

A/76. Ahmad, C.R., 1975. Geology and petrology of Battal Baleja and Sathangali area of Mansehra district, Hazara Division. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, Mansehra, Hazara.

A/77. Ahmad, D., 1995. Tectonics analyses of the southern Kohat plateau, NWFP, Pakistan. M.Phil. Thesis, University of Peshawar, 52p.

The studied area constitutes part of the southern Kohat plateau and exposes a suit of sedimentary rocks which includes evaporates, shelf sediments and a thick sequence of mollase sediments. The rocks in the area belong to the Eocene age and consists of Panoba shale, Bahaderkhel salt and Jatta Gypsum, followed by Kuldana and Kohat Formation. These units are overlain by mollase sediments of Miocene to Pleistocene age which comprises Kamlial Formation of Rawalpindi group overlain by the complete stratigraphic sequence of the Siwalik group.

The studies area constitutes the western half of the southern structural boundary of the Kohat Plateau, herein named as "Kohat Plateau Boundary Zone". It is about 120 km long with width ranging from 5-10 km and trends east-west. The studies area is characterized by the large scale east-west trending open, synclinal and tight anticlinal trends.

These compressional structures are superimposed by a Plio-Pleistocene phase of strike-slip deformation. This deformation is displayed on the surface of the formation of two large scale strike-slip faults with apparent dip-slip movements. The Zarwam fault is the northern most structural discontinuity and is believed to be a strike-slip fault with left lateral movement. The bannu-surgad fault lies south of Zarwam fault and is also characterized by strike-slip movement with the sense of movement being right lateral. Both these faults are Rheidal shears which emanates from the Kurram fault.

Key words: Tectonics, Stratigraphy, Kohat Plateau, Siwaliks.

A/78. Ahmad, E., 1960. The Indus - a study in river geography. Geographer 8 (Aligarh).

Further information not available to the authors.

Key words: Geography, Indus.

A/79. Ahmad, F., 1996. Evolution and changes in Indus River system. Programme and Abstracts, 8th All Pakistan Geographic Conference, Peshawar, 7-10 April, p.22.

Key words: Evolution, Geomorphology, Indus River.

A/80. Ahmad, H.A., 1987-89. Geology, petrography and structure of Harno Area District, Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 247p.

Further information not available to the authors.

Key words: Petrography, Structure, Abbottabad.

A/81. Ahmad, H.I., 1971. Geology and petrology of the area on right bank of Tarbela Dam. M.Sc. Thesis, Punjab University, 90p.

Further information is not available to the authors.

Key words: Petrology, Tarbela Dam.

A/82. Ahmad, H.M., Javed, A., Javed, A. & Parvaiz, M., 1976. Mineralogy, petrology and economic geology with emphasis on ore mineral deposits of Lahor Pazzang area, Swat-Kohistan. M.Sc. Thesis, Punjab University, Lahore.

Key words: Mineralogy, petrology, ore minerals, Swat-Kohistan.

A/83. Ahmad, I., 1980. Petrography of Ambela Syenite, Buner Area. M.Sc. Thesis, University of Peshawar, 44p.

This work presents petrographic details of a part of the Ambela Syenite, occupying 12 sq. miles of area in the Bunair. The rocks of the thesis area, occupy north central portion of the Ambela complex, which is considered to be a part of the Peshawar Paline Alkaline Igneous province.

The intrusive rocks of this area comprises dominantly of alkali quartz Syenite with subordinate occurrence of quartz syenite and granite. Texturally the alkali quartz syenites are coarse-grained, hypidiomorphic and sub-inequigranular. Major primary minerals of these rocks are alkali feldspar, quartz and plagioclase, with varying proportions of biotite, sphene, apatite, zircon, muscovite and opaque minerals. Epidote and chlorite are rarely found as secondary minerals.

Key words: Petrography, Ambela complex, Buner.

A/84. Ahmad, I., 1986. Petrochemistry of the Shewa Shahbazgarhi Complex, Mardan. M.Phil. Thesis, University of Peshawar, 130p.

The Shewa-Shahbazgarhi complex is an isolated triangular outcrop, occurring about 12 km north-east of Mardan. The complex consists of acidic rocks, intruded by basic rocks such as metagabbro, metadolerite and local quartz monzonite dykes and sills. The acidic rocks, in order of decreasing relative ages, are microporphyry, porphyritic granite, riebeckite gneiss and aegirine riebeckite porphyry.

The common minerals in basic rocks include hastingsite, clinopyroxene, orthopyroxene (in meta-dolerite), magnetite, biotite, epidote, apatite and leucosene. The acidic rocks contain perthitized orthoclase, orthoclase, perthite, plagioclase, with riebeckite and aegirine as the common ferromagnesian minerals. (Specially in riebeckite porphyry) and the presence of the alkali amphibole and alkali pyroxene is indicative of their alkaline character. Chemical analyses of the amphibole grains obtained with electron probe closely correspond to riebeckite composition. The rocks show considerable degree of deformation and alteration (cataclasis and/or mylonitization). Two types of metamorphism (a) an amphibolite facies metamorphism and (b) retrogressive epidote amphibolite facies metamorphism has been

Noticed. Assessment of the chemical data on conventional two dimension plots and CMAS model, suggest the control of fractional crystallization over the major and trace element distribution in both the rock types. Fractional control of olivine, clinopyroxene and plagioclase is conspicuous in the basic rocks and plagioclase fractionation in the acidic rocks. Major and trace element data suggest that the basic and the acidic rocks are not comagmatic. These are derivative from two different parent liquids. A magma of subalkaline character is proposed for the basic rocks and alkaline to peralkaline for the acidic rocks, both, however, being emplaced in continental rift environments. A rift valley origin is proposed for the complex with the generation of felsic magma, probably as the result of partial melting in the lower crust. The rocks so formed were later intruded by basic dykes of continental flood basalt type.

Key words: Geochemistry, Shewa-Shahbazgarhi, Mardan.

A/85. Ahmad, I., 1987. Geology of Jowar area, Karakar Pass, Swat District, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 144p.

The Jowar area, Karakar pass in the Swat District marks the northern edge of the Indo-Pakistan plate. It is predominantly composed of highly deformed and metamorphosed, Precambrian to Cambrian granitic rocks and Paleozoic metasediments. The granitic rocks are distinguished into augen gneisses and tourmaline granites, each belonging to distinct chemical variety. The metasediments are grouped into Alpurai schist, and Nikanai Ghar marble, which are separated by the "Nikanai Ghar Fault".

Both the granitic rocks and the metasediments have undergone at least two phases of deformation and metamorphism. The first phase of deformation (D1) and the associated metamorphism (M1) produced regional foliation (S1), mineral lineation (L1) and small scale, tight to isoclinal folds (F1), throughout the Lower Swat-Buner region. During M1, the rocks are regionally metamorphosed, and the Hbl+Plag+Grt assemblages in amphibolites suggest an almandine-amphibolite facies metamorphism. The second phase of deformation (D2) is associated with retrograde metamorphism (M2), and folded S1 into mesoscopic to macroscopic scale F2 folds. It also produced crenulation lineation (L2), and locally S2 foliations.

Regional studies in the Lower Swat-Buner region suggest that the Alpurai schist and Granitic rocks formed a large recumbent fold, due to which the stratigraphic sequence in the study area is upside down. The geochemical study suggest that the amphibolite from study area are derivative from a basic igneous parent of continental tholeiitic affinity.

Key words: Geology, Karakar pass, Swat.

A/86. Ahmad, I., 1999. Structure and metamorphism south of the Malakand and adjoining area, North Pakistan. Ph.D. Thesis, University of Peshawar, 151p.

Detailed field, structure and petrographic data show that the stratigraphy in Swat extends into the northern fringe of the Peshawar basin. Two major faults, the Kishora thrust and a back thrust, dominate the structure of the studied area. The Kishora thrust divides the area into two tectonic terranes, the Indus mélanges, and the Indian shelf terrane. Located within the latter, the back thrust brings higher-grade almandine zone rocks in contact with low-grade chlorite zone rocks near Bar Bazdara and Zormandai villages.

Four deformation phases, D1, D2, D3, and D4 are recorded from north to south, each characterized by distinct fabric and folding. In the north Domains 1 and 2, D1 formed S1. The earliest recognizable fabric S1 occurs as relict intrafolial in the S2 fabric, pressure shadows and porphyroblasts. No macroscopic folding event related to S1 has been recognized. This event occurred under greenschist facies metamorphism. During D2, F2, folds (large and small

scale) were formed. F1 and F2 are coaxial and coplanar with isoclinal, recumbent axial surfaces and fold axes, which plunge gently toward the NNW, and are associated with movement on the Kishora thrust. The dominant S2 foliation developed following the interkinematic phase.

The grade of metamorphism varies from greenschist facies in the south to amphibolite facies in the north. Fractures and brittle shearing in the schists and annealing recrystallization in the granite gneiss and marbles dominate the post S2 phase. During D3 crenulation of S2 garnet growth and the formation of the S3 occurred. F3 folds are upright, open and plunge gently, but variably towards north or less commonly the south or southeast. This event occurred under amphibolite facies, and was followed by the retrograde phase (where garnet and biotite altered to chlorite) and development of east-west trending, south vergent F, folds. F, is related to the change of forces from westward to southward in the lower Swat when Kohistan was thrust southward to its present position. The superposition of the E-W trending F, folds on the generally N-S trending F, folds resulted in a dome and basin structure near Mora Kanda. In the south, Domain 3 preserves the last two deformation phases. During D, S, developed. During D, S, was transposed and also involved the growth of the magnetite porphyroblasts. The minerals chlorite, actinolite, biotite and muscovite indicate metamorphism of greenschist facies. F, and F, folds are best preserved. The large-scale F, folds are mainly E-W, but at Rustam and Budal I they are deflected into a broad arc near the Ambela complex. This is related to the back thrust in that the Ambela complex acts as buttress that deflects the later folds towards north. Matrix schist records two periods of metamorphism. During the D, deformation, which produced a transposed foliation, is also involved with the formation of greenschist facies minerals chlorite, plagioclase, and muscovite. During D, the early S, was folded. During D, the S, was folded to produce local - S, space crenulation cleavage. The Dargai ultramafic complex has been emplaced along the Kishora thrust with the ophiolitic mélange. Greenschist facies metamorphism of blocks in the mélange reached its maximum during D, and phased out by the end of D, Low P-T minerals chlorite, albite, and epidote developed during D, and early D, D, related F, folds are not present. The ultramafic blocks show prograde overprinting on greenschist facies assemblage, evident from the formation of fresh olivine in bastite.

Key words: Structure, Metamorphism, Malakand.

A/87. Ahmad, I. & Ahmad, S., 1975-76. The study of pebble features orientation and petrography of Tanaki conglomerate in Hazara N.W.F.P. M.Sc. Thesis, University of Peshawar, 123p.

Tanakki Conglomerate which is exposed at several localities in Hazara district is a heterogeneous mixture of fragments of different shapes, sizes and rock types, embedded in a coarse sandy matrix. It is almost a structureless rock unit with very poorly developed bedding. The thickness varies from a few feet to a maximum of 40 feet in the area of investigation. Tanakki Conglomerate has disconformable contact with underlying Hazara slate formation (Precambrian) or at places with Tanawal formation (early Paleozoic). The upper contact is conformable with Infra Triassic group of Middlemiss (1896).

The age of Tanakki Conglomerate has been regarded by all the workers as Permian on the basis of its so-called close similarity with the Tobra Formation of Salt Range. However, the present study revealed that this correlation cannot be justified. Besides the discovery of some conodont fossils in the Sirban formation has changed the entire ages of Paleozoic rocks in Hazara. The rocks which were regarded as Permian, now fall below in Cambrian and as such Tanakki Conglomerate must belong to Precambrian - Cambrian age.

The external appearance of rock fragments constituting Tanakki Conglomerate has contrasting features. Some rock fragments have entirely smooth surface and lack any surface feature whatsoever. A considerable number of the surfaces are irregular and rough. Grooves, striations, and facets on pebble surfaces pointing towards their glacial origin are also observed.

The dominant size of rock fragments falls in the category of pebbles. Cobbles and occasional boulder size fragments are also present. There is a variety of shapes exhibited by the pebbles but more often they are of irregular shape. The average roundness and sphericity of the pebble is 0.401 and 0.703 respectively.

The bearings of long axes of pebbles show entirely random orientation but the orientation are essentially subhorizontal. Tanakki Conglomerate is composed of sedimentary rocks only. The most dominant lithology is sand stone.

Following are the different rock types met in Tanakki Conglomerate:

- (a) Sandstone
- (b) Slate/Argillite
- (c) Limestone

- (d) Quartzite
- (e) Quartz
- (f) Siltstone

Key words: Petrography, Tanakki Formation, Hazara.

A/88. Ahmad, I. & DiPietro, J.A., 2000. Analysis of folds south of Malakand and adjoining areas, North Pakistan. *Earth Science Frontiers 7 Abstract Volume*, 15th Himalaya-Karakoram-Tibet Workshop, Chengdu, China, 72-73.

North of the study area in Lower Swat, the rocks have been found to have undergone multiple deformations with at least four periods of folding during a single Paleogene metamorphism (DiPietro and Lawrence, 1991). The earliest folds are composite W-SW vergent, syn-metamorphism F1/F2 folds associated with the formation of the regional foliation. Late-metamorphic, N-S trending open upright F3 folds are associated with local foliation development, and E-W trending open F4 folds are associated with retrograde metamorphism. These interfere with each other to produce dome/basin structure.

The northern part of the study area preserves all the four superposed small-scale folds (F1 through F4). F1 and F2 are coaxial and coplanar with isoclinal, recumbent axial surfaces and fold axes that plunge gently toward the NNW. Where they are superposed, the F1 folds, they deform bedding but not foliation, whereas F2 folds deforms a bedding parallel foliation. The similar geometry and orientation suggests that F1 and F2 developed at about the same time during progressive deformation. F3 and F4 are the same as described above. They determine the map pattern of the area. In the south the earlier folds F1 and F2 fold phases are not preserved. Only the large scale F3 and F4 fold phases are well developed. Large-scale F3 folds are closed to tight with variably dipping axial surfaces, whereas large-scale F3 axes plunge gently but variably towards north or, less commonly, the south or southeast.

Large-scale F4 folds are best developed near Thakht-i-Bahai and Mian Khan where they have broadly have broadly folded the Marghazar (Duma), Kashala and the Saidu formations. F4 folds are open and E-W trending. The F4 folds are asymmetric. They have a different vergence in the different domains. In northern and southern part they are south vergent whereas they are north vergent north of Rustam. These large-scale F4 folds trend mainly E-W, but near Rustam they trend NE and near Budal they trend WNW. Thus they appear deflected into a broad arc near the Ambela complex (Fig. 1). North of Rustam, F4 folds gently deflect the northerly trending structures. South of the Rustam, they are the most obvious folds present and become south vergent. The superposition of the east-west trending F4 folds on the generally north-south trending earlier F3 folds has created the dome and basin structure in the Mora area.

The fold sequence implies an early period of E-W compression prior to the development of south verging structures. The small-scale F1 and F2 folds represent a progressive F1/F2 deformation that is associated with a single set of west-southwest vergent large-scale folds (F2). The large-scale F3 folds may have developed in intense localized shear strain related to ophiolite emplacement on the Kishora Thrust. F4 folds are upright and open with east-west axial trends. They may correlate with early doming of the lower Swat sequence and with strike slip displacement in the northern part of the MMT, north of the Swat (DiPietro and Lawrence, 1991).

The reverse vergence of the F4 folds north of Rustam may be better explained by a back thrust. Back thrust is interpreted from the structural profile AA-across Rustam to Mora area. The fault appears on the north edge of the map. This fault is also supported by the abrupt change in the metamorphic grade across the fault. Rocks north of the village of Bar Bazdara and Zormandai are in epidote amphibolite facies whereas those immediately in the south are lower greenschist. In addition, the sheared contact relationship is intrusive, but on the NW margin of the Ambela Complex the base of the Marghazar is strongly sheared. We interpret this to be related to the back thrust. F4 folds are deflected into a north convex arc from Rustam to Budal (Fig. 1). This is probably related to the back thrust in that the Ambela Complex acts as a buttress that deflects the later folds towards north. In effect, the high-grade metamorphics are underthrusting the Ambela Complex.

Key word: Structure, Folds, Malakand.

A/89. Ahmad, I., DiPietro, J.A., & Jan, M.Q., 1999. Structure and metamorphism south of the Malakand and adjoining areas, Northern Pakistan. *Terra Nostra 99. Abstract Volume*, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 1-2.

Four deformation phases (D1, D2, D3, D4), three fabrics (S1, S2, S3), and four folding events (F1, F2, F3, F4) are recorded from north to south (Figure 1). Near Malakand, D1 formed S1. The earliest recognizable fabric S1 is preserved in the S2 fabric as pressure shadows against garnet porphyroblasts and as inclusion trails in garnet and amphibole porphyroblasts within the calc-mica-garnet schist and graphitic schist. Inclusion trails are straight or rotated within garnets and are oblique to the external S2 fabric. No macroscopic folding event related to the S1 fabric has been recognized. This event probably occurred under greenschist facies metamorphism. During D2, F2 folds (large and small scale) were formed. F1 and F2 are coaxial and coplanar with isoclinal, recumbent axial surfaces and fold axes that plunge gently toward the NNW. S2 is defined by calcite, muscovite, plagioclase, quartz, and garnet. The grade of metamorphism varies from greenschist facies in the south to amphibolite facies in the north. During D3 crenulation of S2, garnet growth, and the formation of the S3 occurred. This event occurred under amphibolite facies. This event was followed by a retrograde phase where garnet and biotite were altered to chlorite. In the south, near Rustam and Takht-i-Bahai, the last two deformation phases are preserved. S1 developed during the D3 deformation. During D4, S1 was transposed and also involved with the growth of magnetite porphyroblasts. The minerals, chlorite, actinolite, biotite and muscovite indicate metamorphism of greenschist facies.

Greenschist facies metamorphism of blocks in the mélange and Dargai ultramafics reached its maximum during D2 and was phased out by the end of D3. Low P/T minerals, chlorite, plagioclase, and epidote developed during D2 and early during D3. F2 folds of the D2 deformational phase are not present. The temperature of metamorphism was in the range of 250°C to 350°C and pressures probably up to 3.5 kbar. Evidence of retrograde metamorphism overprinting D2 and D3 minerals is not observed.

Matrix schist within the mélange record two periods of metamorphism. The D2 deformation, which produced a transposed foliation, is also involved with the formation of the greenschist facies minerals, chlorite, plagioclase, and muscovite. During D3, the early S1 was folded and garnets were developed. During D4, the S2 foliation was folded to produce a local S3 spaced crenulation cleavage. This probably occurred during the greenschist facies metamorphism.

Vein mineral assemblages in both blocks and matrix rocks of the mélange provide evidence of P/T uplift paths and conditions, perhaps during emplacement of the Dargai ultramafics and the various blocks in the mélange. Vein minerals common in the talc-carbonate blocks include fuchsite, calcite, quartz and feldspar. The mineral assemblages are indicative of greenschist facies metamorphic conditions. Vein mineral assemblages common in the matrix rocks include calcite and quartz, and are also characteristic of low-grade metamorphism or hydrothermal alteration.

In the north of the study area the earliest superposed small scale folds (F1 and F2), are co-axial and co-planar with isoclinal, recumbent axial surfaces and fold axes that plunge gently toward east. F1 and F2 folds, with localized shear strain, are related to movement on the Kishora thrust. The Kishora thrust is folded by F3 folds. F4 is related to the change of forces from westward to southward in Lower Swat after the Kohistan arc was in its present position. The features described above were noticed during the present study. The Kohora Thrust is folded north of Chakdarra and near Dargai.

Key words: Structure, metamorphism, Malakand

A/90. Ahmad, I., DiPietro, J.A., Lawrence, C.P. & Jehan, N., 2001. Stratigraphy of schistose rocks near Rustam and surrounding area, district, Mardan, North Pakistan. *Journal of Asian Earth Sciences* 19, p.1.

Rustam is located about 24 km northeast of Mardan. The area comprises of low-grade greenschist facies rocks (schists, marbles) of the Indian shelf. The rocks have been grouped from base upward as Jafar Kandao, Duma, Kashala, Saidu and Nikanai Ghar formations (DiPietro et al., 1993, 1999; Pogue et al., 1992), and assigned Late Paleozoic (Carboniferous) to Mesozoic (at least Triassic) ages. Present study reports two more Conodont ages north of Rustam from the lower part of the Kashala formation (348 260 29.400N 728 110 16.300E) and the upper part of the Marghazar formation (348 230 5600N 728 130 5100E). The age of the Kashala is confirmed as Triassic whereas the Marghazar has the upper Famennian age (Late Devonian). Pogue et al. (1992) reported Carboniferous age for the Jafar Kandao formation below the Marghazar. The upper Famennian age for the Marghazar compared to the Conodont age (Carboniferous) from the Jafar Kandao formation equivalent to Marghazar formation (DiPietro et al., 1993) confirm that the stratigraphy near Rustam is inverted. Work is in progress to locate

Permo-Carboniferous boundary. Important aspect of the recent radiometric ages on Mora and Ilam gneisses (Ahmed et al., 1997), and Chakdarra gneiss (DiPietro pers. com.) placed them in Early Permian, and thus provides better control on the stratigraphy. The overlying unconformable relationship of Marghazar formation with Mora and Ilam

gneisses and the intrusive relationship of Chakdara gneiss with Marghazar put it in Late Permian or Early Triassic. The overlying Kashala and stratigraphic equivalent Saidu and Nikanai Ghar may be placed as late Triassic or younger. We interpret the major structure to be north-south trending F4 folds of the Indian plate. The grade of metamorphism increases from south to north. The Karapa greenschist previously considered a single stratigraphic horizon below the Kashala formation (Pogue et al., 1992), Duma formation (DiPietro et al., 1993, 1999) and Jafar Kandao formation (Pogue et al., 1992) are grouped as Marghazar formation (equivalent to higher grade, amphibolites facies in Swat) representing the lower limb of the F4 fold. The core is occupied by the Nikanai Ghar formation (calcic and dolomitic marbles) the youngest unit in the area. The Marghazar formation (psammitic schist, greenschist, graphitic phyllite) is overlain by calcareous schists and marbles of Kashala formation, and followed by stratigraphic equivalent Saidu graphitic phyllite and Nikanai Ghar marbles.

Key words: Stratigraphy, Metamorphism, Rustam, Mardan.

A/91. Ahmad, I., Hamidullah, S. & Jehan, N., 1990a. Petrology and petrochemistry of the Shewa Shahbaz Garhi complex, Mardan, north Pakistan. Abstract, 2nd Pakistan Geological Congress, University of Peshawar, p.46.

The Shewa Shahbaz Garhi Complex occurs as an isolated triangular outcrop about 12 km north-east of Mardan. It consists of a group of acidic rocks intruded by basic rocks, including metagabbro, metadolerite and local quartz monzonite and sills. In order of decreasing relative ages, the acidic rocks are microporphyry, porphyritic granite, riebeckite granite gneiss and aegirine riebeckite porphyry.

The basic rocks are generally composed of hastingsite, clinopyroxene, orthopyroxene (in metadolerite), magnetite, biotite, epidote, apatite and leucocrane. The acidic types contain potash feldspar, plagioclase with riebeckite and aegirine as the common ferromagnesian mineral, indicating alkaline character. The mineralogy of the rocks indicates an amphibolite facies and a retrogressive epidote amphibolite facies metamorphism.

The major and trace element chemistry of both the basic and acidic types are indicative of their primary development as a result of fractional crystallization with olivine, clinopyroxene and plagioclase as the dominant crystallizing phases in basic rocks and plagioclase as the dominant crystallizing phase in acidic rocks.

The chemistry also indicates the derivation of the basic rocks from a sub-alkaline magma and of the acidic rocks from magma with characters in between alkaline and per-alkaline, both types emplaced in continental rift environment followed by the emplacement of basic dykes of continental flood basalt type.

Key words: Petrology, petrochemistry, basic rocks, acidic rocks, alkaline rocks, Mardan.

A/92. Ahmad, I., Hamidullah, S. & Jehan, N., 1990b. Petrology of the Shewa-Shahbazgarhi complex Mardan, north Pakistan. Geological Bulletin, University of Peshawar 23, 135-159.

The Shewa-Shahbazgarhi complex is an isolated triangular outcrop, occurring about 12 km northeast of Mardan. The complex resides 60 km south of Main Mantle Thrust as part of the Indo-Pak plate and consists of basic and acidic rocks including microporphyry, metagabbro, metadolerite and local quartz monzonite, riebeckite gneiss, aegirine riebeckite porphyry and porphyritic microgranite, together with basic and acidic dykes and sills.

The common minerals in basic rocks include hornblende, clinopyroxene, magnetite, biotite, epidote and apatite. The acidic rocks contain orthoclase, perthite and plagioclase together with riebeckite and aegirine, indicating alkaline characters. The mineralogy reflects amphibolite facies metamorphism followed by retrogression down to at least the upper greenschist facies environment in basic as well as in acidic rocks. Following metamorphism a considerable degree of deformation (cataclasis and/or mylonisation) is indicated in the acidic rocks.

Assessment of the chemical data suggest two different parent magmas; a rift-related tholeiitic type for the basic rocks and an alkaline to peralkaline type for the acidic rocks; both being emplaced in continental environments. The chemistry also suggests the control of fractional crystallization on the initial distribution of elements among the minerals of the two groups. A plagioclase-magnetite-clinopyroxene dominant assemblage on the liquidus in basic rocks and a plagioclase-hornblende dominant assemblage on the liquidus in acidic rocks, during fractionation, are suggested. A rift valley origin proposed by previous workers is supported.

Key words: Petrology, alkaline rocks, Shewa-Shahbazgarhi, Mardan.

A/93. Ahmad, I. & Jan, M.Q., 2000. Barium, titanium and manganese-bearing silicate mineral phases from Shewa-Shahbazgarhi complex, Mardan, Northern Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 131-133.

This paper describes unusual Barium titanium and manganese silicates, similar in composition to bafertisite $\text{BaFe}_2\text{TiSi}_2\text{O}_9$, from sodic alkaline rocks. Two microprobe analyses are compared with bafertisite from Mangolia.

Key words: Mineralogy, alkaline rocks, Paleozoic, granites, Mardan

A/94. Ahmad, I., Jan, M.Q. & LeFort, P., 1999. Unusual Ti, Fe, Mn and Ba silicates in alkaline granites from Mardan, Northern Pakistan. Geological Bulletin University of Peshawar 33, 57-62.

The Shewa Shahbazgarhi complex is a late Paleozoic intrusion covering 80² km area. It consists predominantly of silicic rocks (reibikite ± aegirine gneisses, aegirine-reibikite porphyry, porphyritic microgranite and local quartz monzonite) that have been intruded locally by metadolerite. One variety of granitic rocks contains unusual barium-, titanium- and manganese-bearing phases resembling bafertisite from mangolia. The mineral occurs in trace amount as fibre (up to 0.7 mm in length) in feldspar, biotite and rarely groundmass. It is faintly pleochroic from pale yellow to golden yellow. This mineral may be a product of hydrothermal process or autometasomatism related to residual fluids in the granitic magma. Six microprobe analyses are compared with bafertisite from Mangolia.

Key words: Mineralogy, alkaline rocks, granites, Paleozoic, Mardan.

A/95. Ahmad, I. & Lawrence, R.D., 1992. Structure and metamorphism of the Chakdara area, NW of Swat River, Pakistan. Geological Bulletin, University of Peshawar 25, 95-112.

Two major faults, the Kohistan and Kishora thrust, divide the study area into three tectonic terranes, the Indian shelf, Garai mélange, and Kohistan arc. Stratigraphy, deformation, and metamorphism within each of these terranes developed independently until they were juxtaposed during Eocene-Oligocene collision. An important aspect of this study is the documentation of youngest deformation phases related with Himalayan orogen.

Three deformation phases (D_1 , D_2 , D_3) are recorded in the Indian shelf and the mélange matrix, each characterized by distinct fabrics and folding. S_1 occurs as relict intrafolial in the S_2 fabric as well as in the porphyroblasts and pressure shadows, in the Indian shelf rocks. F_1 are locally preserved and are found associated with movement on the Kishora thrust. S_2 is defined by the orientation of platy or elongated minerals and axial planes of F_2 folds. F_2 folds are strongly developed and strike NNE and SSW. These are associated with southeastward movement on the Kishora thrust. S_3 developed as minor crenulation cleavage when S_2 was folded during later deformation D_3 . F_3 strikes NNW and NS. It may probably be associated with the Kohistan thrust during the development of the Indus syntaxis. These deformation phases took place under conditions of amphibolite facies in the Indian shelf and greenschist facies in the mélange matrix.

The mélange blocks and the Kohistan rocks record different deformation events. Apparently they preserve pre-emplacement structures. Two deformation phases are recorded. During D_1 , S_1 and F_1 developed. S_1 occurs as relicts in the S_2 foliation. D_1 occurred independently in the mélange blocks and Kohistan arc. During D_2 , the S_1 foliation was folded. D_2 in the blocks is associated with the Kishora thrust while that in the Kohistan rocks is consistent with the D_2 of the mélange matrix and the Indian Shelf. D_1 and D_2 took place under conditions of greenschist facies in the mélange blocks and of amphibolite facies in the Kohistan arc.

Key words: Structure, stratigraphy, deformation, metamorphism, Malakand.

A/96. Ahmad, I., Lawrence, R.D. & DiPietro, J.A., 1998. Olistostromal blocks in metamorphosed Saidu mélange, Malakand Agency, north Pakistan. Geological Bulletin, University of Peshawar 31. Abstract Volume, 13th Himalaya-Karakoram-Tibet International Workshop. 1-3.

In Swat, the Indus suture zone contains mélanges of diverse origins. [1] distinguished the Shangla blueschist mélange, Charbagh greenschist mélange, and the Mingora ophiolitic mélange. The subduction-related Shangla blueschist mélange contains blocks of blueschist, serpentinite, piemontite schist, greenschist, metadolerite,

metagreywacke and metachert in a sedimentary matrix. The Charbagh greenschist *mélange* is mainly greenschist which is best interpreted as a very large block in the Shangla *mélange*. The obduction-related Mingora ophiolitic *mélange* is composed of tectonized blocks and clasts of serpentinite, emerald-bearing talc-carbonate, greenstone, metapyroclastic, metagabbro, metachert and metasedimentary rock in a talc-carbonate matrix. The structurally underlying Indian shelf rocks are Precambrian Manglaur schist (mostly quartz-mica-garnet schist), Carboniferous to Triassic Alpurai group (calc-mica-garnet schist), and Triassic Saidu formation (graphitic phyllite and marbles). These units along with the *mélange* units were metamorphosed between the latest Cretaceous and late Eocene.

New field work in the area southeast of Malakand Pass (Fig. 1), where the Saidu formation is widely exposed structurally beneath the Dargai ultramafic complex, suggests that this unit contains large olistostromal marble blocks and is in whole or in part a sedimentary matrix *mélange*. Immediately under the Dargai complex ultramafic fragments are sheared into graphitic schists of the Saidu. However to the east near Kharkai village the Saidu is composed of 2 members. The lower member is the graphitic schist previously described as the only unit of the Saidu; the upper member is mainly a quartz-muscovite-talc schist with minor quartz-biotite schists with lensoid inclusions of gray to black marble (Fig. 2). Block dimensions up to 500 m by 50 m are present. The contact between the members is gradational over more than 10 meters. The marble is equigranular, coarse-grained and sugary textured. Much of it is internally brecciated in fragments with the same composition as their matrix. A few fragments contain some mica. These fragments are slightly flattened, but not dramatically strained. Massive, unbrecciated marble layers extend into the marble bodies in various orientations, commonly not parallel to the contact between the marble and the adjacent schists. The quartz-muscovite-talc schists contain small amphibolite layers that may be metavolcanic and a few horizons that look like possible meta-tuffaceous material. This upper member of the Saidu does not resemble any of the units previously mapped in the region.

The Saidu, including the marble lenses, is multiply folded. The several blocks are the noses of tight asymmetric folds overturned toward the SSW. The best documented fold west of Palai has an axis trending S70°E, plunging 30° and an axial plane dipping about 45° to the north. Another lens is made up of 4 boudin shaped fragments. No connection, such as attenuated limbs have been observed between blocks, although several blocks appear to occupy the same horizon in at least one case. Contacts between the marble blocks and the enclosing schists are mostly sheared.

Our best interpretation of this upper member of the Saidu is that it is a slope/rise sedimentary accumulation with olistostromal limestone blocks derived from reefal limestone bodies on the outer edge of the adjacent Gondwana shelf. Much of the internal brecciation may be derived from debris deposits on the reef. Lack of major strain of these features suggests that the folds in which the bodies are found developed under conditions in which the limestone was a competent unit relative to the enclosing clastic materials.

We suggest that the Saidu formation is a metamorphosed olistostromal (sedimentary type) *mélange* analogous to the "Oman Exotics" of Hawasina complex of Oman Mountains. The "Oman Exotics" form isolated masses from boulder size to 1000 m thick Middle to Upper Permian and Upper Triassic fossiliferous limestones that crop out within imbricated thrust slices beneath the Semail ophiolite in the Oman mountains. They are commonly associated with a substrate of alkalic and transitional tholeiitic basalts and are interpreted as a series of reef-associated carbonate buildups deposited in part on oceanic islands or seamounts close to the site of initial rifting of the Oman continental margin. These blocks slid into the deep sea sediments being deposited to the north. Most of these features are present in the Saidu, but obscured by metamorphism.

Key words: Indus Suture, *Mélange*, Malakand, Swat.

A/97. Ahmad, I., Rosenberg, P.S., Lawrence, R.D., Ghauri, A.A.K. & Majid, M., 1987. Lithostratigraphy of the Karakar Pass section, south of the Main Mantle Thrust, Swat, N. W. Pakistan. Geological Bulletin, University of Peshawar 20, 199-208.

The Karakar Pass section marks the northern edge of Indo-Pakistan plate. It is predominantly composed of highly deformed and metamorphosed Cambrian and Tertiary (?) granitic rocks and Paleozoic (?) metasediments. The granitic rocks of the area are divided into augen gneisses and tourmaline granites, each belonging to a different age group. The metasedimentary rocks are grouped into Alpurai schists and Nikanai Ghar Marbles.

The augen gneisses are unconformably overlain by the Alpurai schists and tourmaline granites occur as an intrusive sill-like body into the augen gneisses and the surrounding quartzose metasediments. The Alpurai schists include three members: 1) quartz-mica schist and amphibolites, 2) calc-schists and schistose marbles, and 3) graphitic schist. The whole sequence is terminated in the southeast by the Nikanai Ghar fault, which juxtaposes these units against the Nikanai Ghar Marbles.

Key words: Metamorphic rocks, granites, Precambrian, Cambrian, metasediments, Karakar pass, Swat.

A/98. Ahmad, I., Rosenberg, P.S., Lawrence, R.D., Majid, M. & Ghauri, A.A.K., 1987. Evidence of multiple deformation in the rocks of Karakar pass area, Swat, NW Pakistan. Geological Bulletin, University of Peshawar 20, 189-198.

Lithologically the Karakar Pass area is divided into Swat granitic rocks, Alpuri schists, and Nikanai Ghar Marbles. These rocks units have undergone at least three different phases of deformation (D1, D2, D3).

D1 produced a pervasive regional foliation S1, mineral lineation L1, and tight to isoclinal, NW-SE oriented F1 folds. S1 is generally parallel to original layering (So) and axial-plane to F1 folds. D2 folded S1 into open, upright F2 folds, with north-south axes. It locally caused the development of an S2 crenulation cleavage. D3 resulted into small to large scale, east west oriented, cross folds (F3).

In the Karakar Pass area the Swat granitic rocks and the Alpuri schists from the hinge and the southern limb of the east west oriented large recumbent F3 fold. To the south, the Nikanai Ghar Marbles are interpreted to form a large fault-and-fold nappe, herein named as the Nikanai Ghar Nappe.

Key words: Structure, deformation, Swat.

A/99. Ahmad, J., 1993-95. Electrical Resistivity Survey for groundwater exploration in Zulmkot Area, District Malakand, NWFP, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 82p.

The electrical technique is the most powerful tool to explore groundwater, the buried channels and the bedrock in the subsurface.

This technique was applied to explore the ground water potential in Zulmkot area District Malakand, NWFP Pakistan. Eighteen VES stations were selected for said purpose where Schlumberger and Wenner electrode configurations were used for vertical electrical sounding. The Wenner profiling was also carried out at different locations to detect buried channels of the main stream as well as to observe the lateral variations of the subsurface materials.

In order to have first hand information of material distribution in the subsurface, iso-resistivity maps for different L/2 spacing were prepared by using WINSURF computer program. These maps were used to identify the locations of high and low resistive material in the subsurface.

Later, the field data was processed in order to have the true resistivities and true depths of the subsurface formations by four different methods of interpretation.

Firstly, the field data was processed using quantitative methods such as a complete curve matching and partial curve matching using auxiliary point method. The true depths and true resistivities of the subsurface layers were obtained by using RESIST-87 computer program. The field data was also interpreted by the iterative interpretation technique using A.A.R. ZHODY'S program. Based on the results obtained from these methods of interpretation five different resistivity zones were established such as very high, high, medium, low and very low.

On the basis of true resistivities and true depths of the subsurface layers, geoelectric sections as well as profiles of transverse resistance 'T' and longitudinal conductance 'S' were constructed which helped to interpret the subsurface geology of the Zulmkot area along different lines.

Different aquifer zones have been identified in different geoelectric sections, which were constructed along different lines. There identified aquifer zones generally fall within the medium and high resistive zones, which were further confirmed by the lithologic logs of test wells at different locations. The test well data of project area reveals that the water table, generally, varies from 10 m to 25 m. On the identification of aquifer zones in the project area, different locations have been recommended for test drilling to confirm the results of the survey carried out in the Zulmkot area. In order to get more detailed information of the subsurface geology in Zulmkot area, integrated geophysical survey has also been recommended.

Key words: Geophysics, groundwater, Malakand

A/100. Ahmad, J., Ahmad, I. & Abid, A., 1980. Geology of the area between Manglaur Kishora (Malam Jabba), Swat. M.Sc. Thesis, University of Peshawar, 99p.

This report represents a comprehensive geological study of about 210 square kilometer area which lies 8 kilometer northwest of Mingora (Swat).

The area has been mapped and detailed petrography is presented. The area is occupied mainly by regional metamorphic rocks which represent the extreme northern edge of the lower Swat Buner schistose group and consists of a succession of silicious schist, amphibolite schist, calcareous schist with abundant marbles, phyllite schist and green schist.

The acidic rocks are represented by granitic gneiss and augen gneiss which mainly occupy the area under investigation and towards north have a tectonic contact with the ultramafic rocks of the Shangla Ophiolites.

The structure of the area is complex. The rocks are highly jointed and folded. Plunging folds as well as recumbent folds are commonly seen in the calcareous schist which are produced mainly due to the tectonic relationship of lower Swat Buner Schistose Group (Indian Mass) with the Hornblende Group (Asian Mass). Besides these folds, the rocks are well foliated and lineated. Graphitic schist and phyllitic schist horizons are highly jointed as compared to the other units. The area investigated does not have much economical potentials, however, kyanite, Granite and building stone is of some importance.

Key words: Petrography, granitic rocks, Malam Jabba, Swat.

A/101. Ahmad, J., Khaliq, A. & Khan, T.M., 2001. Uranium potential of graphitic metapelites of Gandghar Range N.W. Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 12-13.

The graphitic metapelite belonging to Manki Formation of Gandghar Range, due to its radioactive nature, was investigated in detail including surface and subsurface exploration through drilling and aditing. The surface and subsurface data revealed that the metapelites are highly anomalous in uranium and contain an average of 40 ppm uranium compared to the uraniferous black shales in the world, which generally contain 5-11 ppm uranium. Chemical analysis of water samples collected from springs and streams located within the graphitic metapelites of Gandghar Range include highly anomalous concentration of uranium at certain localities with evidence of active leaching of uranium. This leaching process is favourable for supergene concentration of uranium within suitable structural traps formed due to intraformational deformation in metapelites and below water table.

The U-Pb isotopes have been successfully used in China to locate blind ore deposits in black shales. The same method was employed and a total of 39 rock samples from metapelites were collected and analysed in China. The results indicated radiogenic lead anomalies at five localities.

The R.O.A.C. survey at selected sites revealed strong anomalous halos at certain places along a linear zone indicating uranium concentration at depth. The chemical composition of rocks of metapelites of Gandghar Range indicate that they are more siliceous and contain high organic carbon content compared to other metapelites in the region. Moreover, these rocks are also enriched in U, Y, Ba, and Pb. The enrichment of some of the elements took place in association with detrital fraction of the rock while the rest of the enriched elements were concentrated from normal seawater in oxygenated transitional environment close to the continent. The graphitic metapelites were probably deposited in a basin fed by various source materials.

Unlike typical black shales deposit uranium does not indicate any correlation with organic carbon. The absence of relationship is primarily caused by dissolution of some elements in ground water circulating freely in otherwise impermeable rocks, made permeable by structure movement in the region. The data collected from metapelites of Gandghar Range show high potential for uranium like other black shale uranium deposits elsewhere in the world.

Key words: Gandghar Range, Uranium mineralization.

A/102. Ahmad, J., Syed, S.A. & Khaliq, A., 2000. Geological appraisal of uranium-thorium occurrences in Ambela granitic complex, NW Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.133.

U-Th anomalies (orthomagmatic, pegmatitic/applectic, hydrothermal) related to granitic rocks have been described. It is proposed that primary Uranium in the complex has been fractionated and remobilized in latter differentiates during cataclastic deformation. The Uranium bearing solution followed the channels so produced.

Key words: Buner, Uranium-Thorium mineralization, Ambela granite.

A/103. Ahmad, K., 1977. Geology and petrology of Mara Granites and its environments. M.Sc. Thesis, Peshawar University, 11p.

Key words: Granites, Petrology, Mara, Swabi.

A/104. Ahmad, K.G., 1967. A petrographic study of the Malakand granite. Pakistan Journal of Scientific and Industrial Research 10, 89-91.

The Malakand albite granite (Pakistan) is described petrographically. Migmatization is common. The enclosing rocks are mica-quartz schist, with abundant garnet near the contact.

Key words: Petrography, Granites, Malakand.

A/105. Ahmad, K.N., 1987. Major peaks, passes and glaciers of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resource Potential of Mountainous Region of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 8-19.

Key words: Glaciers, geography.

A/106. Ahmad, M., 1965. Marbles in Pakistan. GSP 17(1), 12p.

Key words: Marble deposits, economic geology, Swabi, Mullagori.

A/107. Ahmad, M., 1981. Earthquake of 3rd September, 1972 in Gupis–Tangir area. Gilgit Agency, Pakistan. GSP Information Release 154, 15p.

Key words: Earthquake, Gupis, Tangir, Gilgit.

A/108. Ahmad, M., 1981-83. Lithostructural mapping of Mansehra Susal and Matial Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 84p.

Lithostructural mapping with preliminary structural studies have been made of Mansehra, Khaki, Rihar area district Mansehra at a scale of 1:1000. An attempt has been made to delineate the boundaries of igneous and metamorphic rocks precisely. Physiographic/stratigraphic studies and various structural contour diagrams have been drawn to determine axis of minor folds. Orientation has been determined with the help of Rose diagram. Thin section has been studied to determine different phases of deformation. Attempt has been made to analysis the strain with Flinn's and Ramsay's plots.

On the basis of microscopic and mesoscopic analysis it has been tried to interpret the structural and macroscopic scale. On the basis of Kinematics Study, structure of the area is interpreted.

Key words: Structure, Mapping, Mansehra.

A/109. Ahmad, M., 1983-85. Report on geology and structure of Balakot-Kummi Area. M.Sc. Thesis, Punjab University, Lahore, 100p.

The present work constitutes a comprehensive report on the geology of Balakot -Kummi area and is submitted in partial fulfillment of the requirements for the degree of M.Sc. at the University of the Punjab. The report includes a detailed geological map at 1:6,000 of about 65 km. sq. area along with a number of geologic sections and sketches. The various chapters include geomorphology, stratigraphy, structure and tectonics. Stratigraphically, the Balakot-Kummi area includes a number of diverse sedimentary and metamorphic elements ranging in age from Precambrian to Miocene with a fairly large gap in the Mesozoic period. Structurally, the area incorporates part of the core and western limb of the Hazara-Kashmir syntaxis and through it pass the major Murree and Panjal Faults. The Balakot-Muzaffarabad anticline is the major fold overturned and overthrust to the southwest. No major economic mineral

deposit was found within the project area, although a lot of material is available as rock crush, aggregate components and building stones.

Key words: Geology, structure, Balakot.

A/110. Ahmad, M., 1985. Integrated geophysical survey along the Karakoram Highway between Harbon and Gayal. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 99p.

Key words: Geophysics, KKH.

A/111. Ahmad, M., 1985-87. The geology and petrography of volcanic and carbonate rocks of upper Haveli (District Bagh) and Balgiran-Manjhoter, District Muzaffarabad with special emphasis on lead-zinc mineralization. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 110p.

The project area covers about 417 square kilometers located in District Bagh and Muzaffarabad, Azad Kashmir. The work has involved geological mapping of the area on a scale of 1:25,000 and 1:15,000 respectively.

This thesis deals with the geology and petrography of Panjal Volcanics and carbonate rocks of the area. The geological sequence of the area consists of sedimentary, volcanics and metamorphic rocks. Lithologically metamorphic rocks present in the area are Schist, Slates, Phyllites, Quartzite and marble while sedimentary rocks comprise Sand stone, shales, silt stone, lime stone. Volcanic rocks belong to two distinct ages. Dogra trap are of Precambrian age and occur within the Dogra Slates. Panjal volcanics or Panjal trap flows are of Upper Carboniferous age and basaltic to andesitic in composition, while mineralogical studies of Dogra trap shows that they are of basaltic composition. Petrographic analysis of Panjal volcanics, Agglomeratic slates, limestone and marble have been carried out. The mineral assemblage in volcanics is plagioclase + chlorite + epidote + Quartz + Calcite, while of agglomeratic slates is Quartz + epidote + chlorite + Calcite + plagioclase the mineralogical assemblage of lime stone and marble is calcite + quartz + muscovite + magnetite. Pb-Zn mineralization in carbonate rocks of Khetar-Treri areas has been interpreted. The evidences are strongly supporting that Pb-Zn mineralization is the result of hydrothermal solution.

Petrogenesis of Panjal Volcanics has been carried out. The evidences reveal shallow water or submarine origin of the Panjal Volcanics. Tectonically the area is highly disturbed, being involved in Himalayan orogeny.

Key words: Geology, petrography, lead-zinc, Muzaffarabad.

A/112. Ahmad, M., 1985-87. Electrical resistivity survey for groundwater potentials in Masal Talao, Amir Khan Talao, Khachar Talao and Haji Talao, District Peshawar. M.Sc. Thesis, Punjab University, Lahore, 60p.

Electrical resistivity survey in Masal Talao, Amir Khan Talao, Khachar Talao and Haji Talao (District Peshawar) was carried out in collaboration with Hydrogeology Directorate WAPDA Peshawar. The main purpose of the survey was to determine hydrogeological features such as depth to the bed rock, nature and thickness of aquifers, the quality of groundwater, and to select suitable sites for tubewell installation in the project area.

According to resistivity survey and drilling data the entire area is underlain by low resistive clay with occasional gravels. The overlying alluvium is composed of alternating layers of gravels and clays. Ground water appears to be quite fresh in the entire project area. Water table depth varies from 13m to 40m in the area under investigation.

In the project area, twenty seven probes were carried out. After interpreting the data, the V.E.S. No. 95, 93, 51, 40, 15 and 17 have been selected for the test drilling, however other probe sites also indicate the presence of aquifers in the area but of varying thickness.

The entire area appears to be favourable for tubewell installation, however the yield of water depends upon the nature of aquifers, may range from half cusec to one and half cusec project area.

Key words: Resistivity, groundwater, Peshawar.

A/113. Ahmad, M., 1986-88. Electrical resistivity survey for ground water potentials in Khesghi Area (N.W.F.P.). M.Sc. Thesis, Punjab University, Lahore, 70p.

Electrical resistivity survey in the project area includes prominent villages Khashgi Bala, Goddu kili, Mala Kili (N.W.F.P) was carried out in collaboration with Hydrogeology directorate WAPDA, Peshawar. The main purpose of the survey was to determine hydrogeological features such as nature and thickness of aquifers, the quality of groundwater, and to select suitable sites for tubewell installations in the project area.

According to resistivity survey and drilling data the entire area is underlain by low resistive clay, with occasional gravels. The overlying alluvium is composed of alternating layers of clays and sand with gravels. Ground water appears to be quite fresh in the entire project area. Water table depth varies from 11 ft to 75 ft. in the area under investigation. In the project area 32 probes were carried out. After interpreting the data, the V.E.S No. 5 has been selected for the test drilling, however other probe sites also indicate the presence of aquifer in the area but of varying thickness. The area appears to be favourable for tubewell installation; however the yield of water depends upon the nature of aquifer.

Key words: Resistivity, ground water, Khashgi, Nowshera.

A/114. Ahmad, M., 1999. Seismic reflection data interpretation Chak Naurange area. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 45p.

Key words: Seismology, seismic reflection, Potwar.

A/115. Ahmad, M., Ali, K.S.S., Khan, B., Shah, M.A. & Ullah, I., 1969. The geology of the Warsak area, Peshawar, West Pakistan. Geological Bulletin, University of Peshawar 4, 44-78.

The Warsak Area, Peshawar, West Pakistan, has been geologically mapped and the petrography of the rocks described in detail. The area consists of a series of metasediments of the greenschist facies (slates, phyllites, mica schists, garnet schists, hornblende schists, calcareous schists and marbles), which have been divided into a Lower, Middle and Upper Series. On the eastern side the metasediments disappear under the alluvium of the Peshawar plain. They range from Siluro-Devonian to Upper Palaeozoic in age, and are intruded by sills of metagabbro and metadolerite (? Cretaceous), porphyritic microgranite (?Upper Cretaceous to Lower Tertiary) and the Warsak alkaline granite (?Lower Tertiary).

The chemistry and alkaline nature of the granites (which contain aegirine, riebeckite and astrophyllite) is briefly discussed. The structure of the area is shown to be a northwards plunging syncline faulted on the east on the northern side of the Kabul River. The joint patterns and other structural features are described, and the economic geology of the area discussed.

Key words: Geology, Warsak, Peshawar.

A/116. Ahmad, M. & Ali, L., 1979. The geology of the right abutment of Terbella Dam area, reference to porosity and permeability. M.Sc. Thesis, University of Peshawar, 40p.

The Terbella Dam has been constructed on the river Indus in the Terbella quadrangle. The right bank or right abutment from the right side of the Terbella Dam area. It occurs towards the Topi, in Mardan Distt.

The Topi Terbella and Gandaf roads are two accessible routes to this area. The right abutment is originally a sedimentary unit which is later metamorphosed and intruded by some basic igneous rocks. Hence it consists of all the three major types of rock, which are sedimentary, igneous and metamorphic rock. Of the sedimentary rocks limestone is common. Metamorphic rocks dominates the area and the main representatives are quartzites, chlorite schist and phyllites. Basic igneous rocks are found in the form of intrusions. The area is folded and foliated to various extent. The oldest fault occurs beyond the tunnel outlet one trends east-west.

A series of small and compressed folds occur at the power house. The area where these folds occur is occupied by limestone, gypsum and carbonaceous schist.

Key words: Porosity, permeability, Terbella Dam.

A/117. Ahmad, M. & Ibrahim, M., 1991. A study of mineralogy and physico-chemical properties of Swat clay project (Fine slip). Pakistan Journal of Scientific and Industrial Research 34, 12, 500-00.

Mineralogy, chemical and physical investigations of “Fine slip” a by-product of Swat clay reject, have been carried out in order to evaluate and find out the areas of its utilization. The results indicate that it can be utilized in the manufacture of pressed ceramic wares and tiles in particular.

Key words: Physiography, Clay, Swat

A/118. Ahmad, M., & Rehman, A., 2000. Understanding tectonic movements within Pakistan Northern region. Abstracts, Third South Asia Geological Congress, Lahore, 142-143.

The regional movements caused by continuous complex movements along numerous faults need to be understood. This study will lead to the analysis of the processes and sources which cause major earthquakes in this region. The region is characterized by dramatic changes in the azimuth of structural trends involving thrust faults, graben, strike slip faults and folding, and is obviously under continuing severe distortions. In the recent past, magnitude 7 earthquakes have occurred in this region. Larger events (Chatkal 1946, Alai 1974) and magnitude 8 (Kashgar 1902) have been experienced. Cambridge Expedition of 1980, resurveyed the original survey network of triangles and polygons in 1913 by Mason. Armbruster, Seeber & Jacob (1978) estimated activity from micro earthquakes of the order of 37 mm per year of the northward movement of the Indian Plate relative to Eurasian Plate.

Although 1913 survey was not accurate enough as the noise level of survey should be less than 4 cm/year to confirm the movements. The 1980 survey results can be used as datum. The movements are clearly not uniform and then there is the factor of larger earthquakes. Also much of the plate tectonics convergence is definitely being absorbed as sporadic slip on extensive thrust faults and strike slip faults. There will be some locations where strains will be several times the accuracy of survey results can be used as datum. The movements are clearly not uniform and then there is the factor of larger earthquakes. Also much of the plate tectonics convergence is definitely being absorbed as sporadic slip on extensive thrust faults and strike slip faults. There will be some locations where strains will be several times the accuracy of survey observations. With the revolution in survey techniques (GPS), it is now possible not only to have the level of accuracy required but also the observations can be much quicker enough to have repeat observation. Cambridge Expedition recommended that observation be repeated after about 10 years. It will be invaluable to geologists, geophysicists and geodesists to know the deformation pattern and history.

Key words: Tectonics, North Pakistan.

A/119. Ahmad, M., Rehman, S., Khan, M.A. & Naeem, M., 1976. Study of the waterlogged and saline land of Pabbi area. M.Sc. Thesis, University of Peshawar, 72p.

Key words: Water logging, salinity, Pabbi.

A/120. Ahmad, M., Ryan, J. & Paeth, R.C., 1977. Soil development as a function of time in the Punjab river plains of Pakistan. Soil Science Society of America (Madison), 41, 1162-1166.

This is a study that relates the development and composition of soils with time in the Punjab plains. Studies of the soils since the late Pleistocene give an estimate of the time required for the formation of semiarid soils. The authors found secondary accumulations of calcium carbonate in the subsurface of 10,000 to 20,000 year old soils, while 23,000 year old soils had none. The older soils also exhibited clay illuviation and low organic matter.

Key words: Soil, Punjab.

A/121. Ahmad, M., Sahi, M.A. & Qureshi, A.A., 1967. Exploitation of indigenous copper ore: 1. Pakistan Journal of Scientific and Industrial Research 19, 57-60. 69-215.

Key words: Copper, Ore, Economic geology.

A/122. Ahmad, M.A., 1973. Seismic refraction investigations at Tarbela dam site and Pihur area of Hazara and Mardan districts, Peshawar division, NWFP, Pakistan. Geological Survey of Pakistan Records, 21(2), 7.

Seismic refraction survey was carried out during October- November 1970 at Tarbela damsite and Pihur-Topi Gap, Hazara and Mardan districts. The objective of the study was to determine if concealed Indus fault precisely delineated at the damsite maintains its southerly trend along the river course in Pihur-Topi area. Four refraction traverse in Pihur-Topi Gap area and one at the damsite were observed. The subsurface configuration of the bed-rock has been determined and shown in the form of sections.

It is concluded that the main Indus fault extends southwards from the Damsite towards profile AB about 9500 feet down stream from the central axis, under the gravels. Further downstream from profile AB it was not possible to trace the trend of the concealed fault as there was no positive indication on the profile CD, EF & GH which were located west and southward of profile AB in Pihur-Topi Gap.

Key words: Seismicity, Tarbela dam, Swabi, Hazara.

A/123. Ahmad, M.A., Nazirullah, R., Sakhawat, M., & Khadim, I.M., 1988. Geophysical investigations of Degan Paikhel copper prospects in Boya area, North Waziristan Agency, FATA, Pakistan. Geological Survey of Pakistan Information Release 338.

Key words: Geophysics, copper mineralization, North Waziristan.

A/124. Ahmad, M.I., 1962. Radioactivity of the Hunza River alluvium, Gilgit Agency, West Pakistan. GSP, Mineral Information Circular 6, 13p.

Key words: Radioactivity, Alluvium, Hunza river, Gilgit.

A/125. Ahmad, M.K. 1988-90. Petrology and mineralogy of the area (Gokdara-Ghaligai), District Swat. M.Sc. Thesis.

The detailed geological map of the project area has been prepared. The project area has been mapped on a scale 1" = 12500" = 12,500'

This thesis consists of two sections. Section No.1 deals with the general geology of the project area. Introduction, Physiography, Structural Geology & Tectonics and the lithologic units of the project area have been discussed in this part. In Section No.2, Petrography, Chemical analysis, Petrogenesis, Discussion on Petrogenesis, Economic Geology and some thing, new one (Dolomite/Wollastonite Skarn) in the project area is discussed.

The project area is consisting upon the metasedimentary and metamorphic rocks which lie in the Higher Himalaya Crystallines of the MMT Zone. The rock units belong to Lower Swat Buner Schistose Group and are of Lower Palaeozoic age.

Key words: Petrology, petrography, Swat.

A/126. Ahmad, M.N., 1995. Magnetic mineralogy of Khunjerab batholith in Hunza area, northern Pakistan, with special reference to its paleomagnetic reliability. In: Khadim, I.M. & Yoshida, M. (Eds.), Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 13, 23-41.

Rock and mineral magnetic properties are examined for altered granites collected from Khunjerab Batholith, Hunza area, Northern Pakistan. The major magnetic carriers in the granites are determined ilmenite-hematite intergrowth, goethite, maghemite, and trace amount of pyrite on the basis of results of optical microscopy, thermomagnetic analysis, magnetic hysteresis analysis, and IRM measurement. The contents of ferromagnetic minerals are very small but the grain size is rather multidomain state, and the distribution is not homogeneous even in hand sample. All the samples are strongly overprinted by recent local geomagnetic field, but neither thermal nor alternating demagnetization is effective to separate the characteristic component (CgRM) from the NRM because of its magnetic phase transition in heating experiments and high coercivity, respectively. The magnetic phase transition is generally observed at above 350°C in non-oxygen environment, which may be derived from inversion of α -phase maghemite to β -phase magnetite and/or fmm decomposition of pyrite. Therefore, paleomagnetic data of the Khunjerab Batholith, especially the direction of ancient magnetic field during the formation of the granite body can hardly be obtained.

Key words: Magnetism, paleomagnetism, Khunjerab.

A/127. Ahmad, M.N., Fujiwara, Y. & Paudel, L.P., 2000. Paleomagnetic study of igneous rocks of Gupis-Shamran area, Kohistan arc, Pakistan, NW Pakistan. *Earth Science Frontiers* 7, Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, Chengdu China, 120-121.

Kohistan Sequence has been considered as island arc formed during the subduction of oceanic lithosphere at the leading edge of northward moving Indian Continent. Sedimentary sequences indicate that formation of the intra-oceanic Kohistan arc began in early Cretaceous time. The isotopic data demonstrate the involvement of enriched, DUPAL type mantle, suggesting that Kohistan arc was formed at or south of the present equator (Khan et al., 1997). The Intra-oceanic phase of Kohistan lasted until sometime between 102 and 85 Ma, when Kohistan collided with Asia. From this time until collision with India about 50 Ma ago, Kohistan existed as Andean-type margin.

This paleomagnetic study is from the volcanic and plutonic rocks exposed in Gupis-Shamran area (west of Gilgit) in northern part of the Kohistan arc. According to geochronological data these rocks were formed 61~55 Ma ago (Treloar et al., 1989), when Kohistan was existing as Andean-type margin. Seven to nine samples were collected from nine sites of Shamran volcanics (58 ± 1) Ma and from five sites of Pingal, Gupis, and Yasin plutons (Ar-Ar hornblende ages ranges from 61~52 Ma). On the basis of one Rb-Sr age (59 ± 2) Ma from these plutons, the above-mentioned Ar/Ar ages may be regarded as reasonable intrusion ages of these plutons (Searle, 1991).

Magnetic mineralogical study i.e. IRM analysis followed by stepwise thermal demagnetization and microscopic study reveal that magnetite is major magnetic remanent carrier in these rocks. The other opaque minerals observed are ilmenite and pyrite. Opaque minerals occur as both primary magmatic product and secondary product of mafic minerals in all the samples. The primary magnetite is found as irregular grains in interstices of other minerals. Sometimes it is also occurred as inclusions in hornblende and biotite. Secondary magnetite is alteration product of pyroxene, hornblende and biotite. In general in mafic rocks (diorite, andesite, and tuff) secondary opaques are common as compared to felsic rocks (granodiorite and granite). Slight deformation and low-grade metamorphism have affected all rocks. The mafic minerals like pyroxene, hornblende, and biotite have been partially or completely altered to chlorite, epidote, calcite and opaques. The mineralogical evidences show retrograde type metamorphism at relatively higher fluid pressure and low temperature conditions.

In most of cases two magnetic remanent components are revealed from Zijderveld diagrams of progressive thermal demagnetization. First component is a low temperature component having unblocking temperature ranging from 400~500°C, yielding remanent magnetization directions parallel to present earth's magnetic field in geographic coordinates. This remanent direction is interpreted as viscous remanent magnetizations of recent origin, carried by multidomain magnetite grains. In samples of 11 sites (8 from volcanics and 3 from plutonic rocks) characteristic remanent magnetization component with NNW and SSE pointing directions of moderate inclinations of normal and reverse polarity in geographic coordinates is obtained. The unblocking temperature in all of these cases is 570~580°C. This magnetic remanent component may not be of primary origin as mean directions are scattered after the application of the structure correction. This post-folding component may be carried by secondary magnetite, which was formed by the flow of fluids at low temperatures as observed in microscopic study. Hence this secondary remanent magnetization is chemical remanent magnetization (CRM) or thermochemical remanent magnetizations (TCRM). All the plutonic activity in the area is pre-tilting of the volcanics; therefore the secondary magnetite giving post folding remanent magnetizations cannot be produced at the time of intrusion of any pluton. The K-Ar biotite age of Gupis pluton is about 40 Ma. This is giving the evidence that at 40 Ma the area is still hot at about 300°C (closure temperature of biotite). We interpret the formation of this secondary magnetite by hydrothermal processes; due to release of water from water saturated solidus magma, during the uplift of the area. The mean direction for this secondary component along with Fisherian statistics is as follows:

Dec=339.5 Inc=43.6 k=24 Alpha-95=9.5

The calculated mean paleolatitude is about 25°N, which is 10°C south of the present position. Hence the area moved 10°C northward after the acquisition of remanent magnetization. The comparison of calculated paleolatitude of the area with Indian apparent polar wander path (APWP) indicates the acquisition age of these magnetizations is 40~35 Ma. In this comparison 470-km north south shortening south of the Kohistan arc is also taken in account to assign age of magnetizations correctly.

In samples of only three sites pre-tilt characteristic remanent magnetization is obtained. The calculated paleolatitude (6.6°N) for this pre-tilt component is well in agreement with pre-tilt remanent magnetizations of red beds of Kohistan arc. The Ar-Ar hornblende age of the volcanics is about (58 ± 1) Ma. This component may be acquired during the original cooling of the rocks before the tilting of the studied volcanics. Comparing paleolatitude with

present latitude of the area, it can be inferred that area has moved northward about 300-km since the acquisition (about 58 Ma) of remanent magnetization.

Key words: Paleomagnetism, Igneous rocks, Kohistan arc.

A/128. Ahmad, M.N., Fujiwara, Y., & Paudel, L.P. 2001. Remagnetization of igneous rocks in Gupis area of Kohistan arc, northern Pakistan. *Earth Planets Space*, 53, 373–384.

The Kohistan arc was formed due to subduction of neo-Tethyan oceanic crust beneath Asia. The arc is comprised of volcanic, plutonic and sedimentary rocks of Mesozoic to Tertiary age, formed prior and after the suturing of the Indian and Asian continents. Paleomagnetic investigations have been carried out on Paleocene volcanic and plutonic rocks exposed in the northern part of the arc. A total of 110 samples from 16 sites were drilled. According to rock-magnetic studies the main magnetic carrier is magnetite. Optical microscopy study reveals that low-grade metamorphism have effected all rocks. Magnetite is found as both a primary magmatic mineral and secondary alteration product in all samples. Samples of volcanics yield post tilting characteristic remanent magnetizations (ChRM). The in situ mean direction of the ChRMs of the intrusives is similar to the in situ mean direction of volcanics. The presence of secondary magnetite in plutons, the similarity of in situ mean ChRM of plutons with that of post-tilting ChRMs of similar age volcanics and dissimilarity of the mean ChRM of plutons from expected directions at the time of formation of plutons support a secondary origin for the ChRM of plutons. As the ChRM directions of the volcanics and intrusives are the same, it implies that both ChRMs were acquired during the same remagnetization event. Comparing the mean paleolatitude ($25 \pm 6^\circ$ N) from Gupis area with those from Indian APWP and considering the fact that there was prevailing heating event in Lower Tertiary in the area, the acquisition age of this secondary remanent magnetization can be bracketed between 50 and 35 Ma.

Key words: Paleomagnetism, Igneous rocks, Kohistan arc.

A/129. Ahmad, M.N. & Yoshida, M., 1995a. Paleomagnetic studies of Paleogene pyroclastic flow deposits of Utror Volcanic Formation, Kohistan arc, northern Pakistan. In: Khadim, I.M. & Yoshida, M. (Eds.), *Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan*, Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 13, 149-168.

Calc-alkaline volcanic rocks are distributed in the Kohistan arc, the northwestern margin of the Himalayan range. The sequence of Kohistan arc has been interpreted as a mature island arc formed by subduction during Mesozoic time between the Indo-Pakistan Subcontinent and Asian Continent and obducted onto Indian plate in Eocene time. The Utror volcanics Formation is probably the upper most part of the island arc sequence. Total 23 oriented samples (5 sites) from altered plagioclase-rhyolitic pyroclastic flow deposits of this formation to the southwest of Kalam village, upper Swat valley. According to the results of progressive thermal demagnetization (THD), almost all samples possess mainly three components of remnant magnetization; the components 1, 2, and 3. The component 1 is generally unstable remanence and it can be observed in the steps less than THD 300 C. the component 2 is identified in the THD interval between 300 C and 540 C. the component 3 is detected in the final THD steps above 540 C. on the basis of results of optical ore-microscopy, thermomagnetic analysis, and coercivity spectrum analysis, origins of these magnetic components can be interpreted as follows: the component 1 is a recent magnetization of the goethite-magnetite assemblages formed by hydration and low-temperature oxidation processes.

Key words: Paleomagnetism, Utror volcanics, Kohistan arc.

A/130. Ahmad, M.N. & Yoshida, M., 1995b. Paleomagnetic studies of Paleogene pyroclastic flow deposits of Utror Volcanic Formation, Kohistan arc, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geoscience Lab, GSP, Islamabad, 5-8.

Consult the preceding account for further details.

Key words: Paleomagnetism, Volcanics, Utror, Kohistan arc.

A/131. Ahmad, M.N. & Yoshida, M., 1996. Subsurface structures of Northern Suture Zone modeled by geomagnetic and VLF-EM soundings. *Geologica* 2, 195-202.

Key words: Structure, Tectonics, Northern Suture.

A/132. Ahmad, M.N. & Yoshida, M., 1997a. Paleomagnetic of Upper Cretaceous granite and Paleogene volcanics in Kalam area, northern Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (Eds.), *Paleomagnetism of Collision Belts*. Geoscience Laboratory, GSP, Islamabad, 1-11.

Consult the following account for further details.

Key words: Paleomagnetism, Cretaceous, Granites, Volcanics, Kalam, Swat.

A/133. Ahmad, M.N. & Yoshida, M., 1997b. Paleomagnetic study of Upper Cretaceous and Paleogene igneous rocks in Kalam area, Kohistan arc, North Western Himalaya. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 67-68.

The Himalayan mountain belt was formed by a crustal deformation caused by the collision of the Indo-Pakistan subcontinent with the Eurasian continent during the early Tertiary. In the northwestern part of the Himalayan belt, this collision is not simple because Ladakh-Kohistan arc was captured between the two colliding continental blocks. Different types of igneous rocks such as calc-alkaline volcanic rocks and granites are distributed in Kalam area, Pakistan, west centre part of Kohistan arc, northwestern margin of Himalayan Range. Two types of igneous rocks were selected for paleomagnetic study i.e. from altered plagioclase-rhyolitic pyroclastic flow deposits of Utror volcanics and Stage-1 granitic (Sullivan, 1993). Total 23 samples (5 sites) of the Utror volcanics and 10 samples of the granite were selected for the paleomagnetic study. Ar-Ar dates of the Utror volcanics and the granite are 55 Ma and 78 Ma respectively (Zeitler, 1985, and Treloar et al., 1989). Magnetic mineralogical studies such as optical microscopy, thermomagnetic analysis, IRM acquisition analysis reveals that goethite, titanomagnetite, and hematite are the major ferro magnetic carrier of natural remnant magnetization (NRM) in pyroclastic flow deposits of Utror volcanics while in the granite magnetite is the major carrier of NRM. Progressive thermal demagnetization (THD) analysis was carried out in 13-16 steps up to 675°C for the Utror volcanics while for the granite thermal demagnetization analysis was carried out up to 575°C in 14 steps. Zijderveld diagrams for the Utror volcanics are indicating three components of remnant magnetization; the Component-1, -2, -3. The Component-1 is generally unstable remanance and it can be observed up to THD 300°C. The Component-2 is from 300-540°C, and the Component-3 is above 549°C. On the basis of magnetic mineralogical studies, the Component-1 is recent magnetization due to the presence of goethite-maghemite assemblages which might be formed because of low temperature oxidation. The Component-2 is the magnetization of Ti-poor titanomagnetite in anatase-magnetite assemblages produced from a hydrothermal alteration. The Component-3 is remnant magnetization of hematite in ilmenite-hematite intergrowth, which might be developed because of thermal activity. In the granitic samples there is one component in Zijderveld diagrams it is stable up to 300°C then there is drastic decrease in the NRM intensity up to the 575°C. In the case of Utror volcanics negative fold test as well as optical study reveal that the nature of the remnant magnetization (Comp-2 and 3) is secondary and the mean direction are Declination=139°, Inclination=34° and Declination=138°, Inclination=-30 for the Component-2 and -3. The Paleolatitude of the Component-2 and 3 are 19°N and 16°N. The acquisition of these remanences might be due to the obduction of Kohistan arc on to the Indian continent. By comparing with the present day latitude of the study area it is estimated that there is about 2000-km crustal shortening after the collision. The ChRM in the case of granite is considered to be of primary nature and tilted corrected direction are Declination=114° and Inclination=-14°, therefore the formation of the granite was at lower latitudes i.e., 7°N in 75-78 Ma. The comparison of paleolatitudes of the granitic rocks and Utror volcanics shows that there is about 900-km northward movement after the formation of the granite till the Indian-Kohistan collision. The declination data indicate that there is a counter clockwise rotation after the formation of the granite and the collision.

Key words: Palaeomagnetism, Upper Cretaceous, Kalam, Kohistan Arc.

A/134. Ahmad, M.N., Yoshida, M., Ali, M., Khadim, I.M., Kaneda, H., Karim, T. & Aslam, A., 1993. Geomagnetic and VLF-EM survey of some mineralized zones in Chitral District. *Proceedings of Geoscience Colloquium*, Geoscience Lab, GSP, Islamabad, 7, 44-71.

The above interpretation can be concluded in following points:

The magnetic method is useful for the exploration of copper deposits as copper is associated with magnetic minerals. The dimensions of the magnetic body associating copper mineralization can be calculated with the help of magnetic anomaly. In Kaldam Gol site estimated reserves are 3400 tons. Siderite ore deposits in limestone are also detectable by geomagnetic method, but modeling is not possible due to weak susceptibility contrast. Geomagnetic method is useful to explore the suture and faulted zones when some serpentinization develops along them.

In case of VLF-EM data there is a strong anomaly of QUAD and PHASE over siderite deposit. However there is little positive response over other ores either because of shallow depth of penetration of VLF waves because of high frequency (23.4 KHz) or some transmitter problem.

Key words: Paleomagnetism, Northern Suture, sulphide, Hunza.

A/135. Ahmad, M.N., Yoshida, M. & Fujiwara, Y., 1999. Paleomagnetic study of Utror Volcanic Formation and Deosai volcanics of Kohistan-Ladakh arc, Pakistan, North Western Himalaya. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 2-3.

The Kohistan-Ladakh sequence has been considered as an island arc formed during the subduction of oceanic lithosphere at the leading edge of the northward moving Indian plate. The northward movement after collision of Indian plate and the arc led to the formation of the western Himalayan syntaxis.

In order to get information on the tectonic history of the terrane, paleomagnetic study have been carried out on two different volcanic units 1) Paleogene Utror Volcanic Formation (55±2 Ma) along with later stage granitic intrusions (45-48 Ma) west of the Nanga Parbat syntaxis, and 2) Late Cretaceous Deosai Volcanics east of Nanga Parbat syntaxis. 210 samples from 20 sites of Utror Volcanic Formation and 55 samples from 10 sites of Deosai Volcanics were collected.

In case of the Utror Volcanic Formation magnetic mineralogical studies, i.e. Curie temperature analysis, IRM analysis and optical microscopic study indicate the presence of various magnetic minerals such as goethite, maghemite, titanomagnetite/magnetite, and titanohematite/hematite. Three magnetic remanence components are revealed from Zijderveld diagrams if progressive thermal demagnetization. All three remanence directions may not be of primary nature as they show scattering after the application of structural correction. The Comp-1 is of recent field and may be carried by goethite and maghemite. In the Comp-2 (Declination = 275.6, Inclination 18, α -95=13.5) and Comp-3 (Declination = 325.3, Inclination = 28.4, α -95=9.6) the mineralogical situation is rather complicated both have magnetite/titanomagnetite and a hematite/titanohematite as magnetic carriers in different sites. Only in two sites are both components observed otherwise one or the other of these is observed. The nature of these two components is seem to be CRM acquired during some hydrothermal processes as the mean paleomagnetic direction of Comp-2 and ChRM of granitic intrusion are the same. Besides this, in optical studies secondary minerals such as zeolite, which is indicator of hydrothermal alterations, is observed. Hence these rocks may possess magnetic minerals which are the result of alterations varying with micro-environmental conditions and time.

The mean paleomagnetic direction of Comp-2 of the Utror Volcanic Formation and the ChRM of granitic rocks of 48~45 Ma is the same, therefore Comp-2 may have been acquired at the time of granitic intrusion. The paleolatitude of Comp-2 (10° N) is in good agreement with the paleolatitude of Ladakh intrusives of 49~45 Ma (Klootwijk et al., 1979). The Comp-3 may be acquired during some latter stage hydrothermal alteration. The constraint on timing of acquisition of Comp-3 can be provided by zircon fission track age 35.9 Ma of these volcanics. Annealing temperature of zircon is more than 200°C suggesting some thermal or hydrothermal activity at 35.9 Ma. By comparing the paleolatitudes with the present latitude, it is calculated that after the acquisition of Comp-2 and Comp-3 there is about 2500-km and 2000-km crustal shortening respectively. There are 850° and 350° counterclockwise rotations after the acquisition of Comp-2 and Comp-3 respectively.

Magnetic mineralogical study of Deosai volcanics reveals maghemite and titanomagnetite as the major magnetic carriers. The in situ mean direction of ChRM is Declination = 347°, Inclination 24.3° (α -95 10°). The comparison of directions before and after structural correction indicates that they are post deformation magnetizations. By comparing the paleolatitude of Deosai volcanics with that of Comp-2, Comp-3, and the Ladakh intrusive ChRM directions, it can be inferred that these magnetization may be acquired between 40~35Ma. The mean of ChRM directions shows about 13° counterclockwise rotation since the time of acquisition of remanence. This is a

discrepancy, when compared with most of paleomagnetic data from the east of western Himalayan syntaxis having clockwise rotation. The similar counterclockwise rotation is also reported from Tethyan sediments from Zaskar range (Appel et al., 1995). Hence much detail paleomagnetic study is required to know the tectonic rotations related to the formation of the western Himalayan syntaxis.

Key words: Paleomagnetism, Utror Volcanics, Deosai volcanics, Kohistan-Ladakh arc.

A/136. Ahmad, M.N., Yoshida, M. & Fujiwara, Y. 2000. Paleomagnetic study of Utror Volcanic Formation: Remagnetizations and postfolding rotations in Utror area, Kohistan arc, northern Pakistan

The Utror Volcanic Formation forms a NE-SW belt within Kohistan island arc, which lies between the Indian and Eurasian continents in the western Himalayas of northern Pakistan. The Utror Volcanic Formation formed during Late Paleocene, when Kohistan existed as an Andean-type arc on the southern margin of Eurasia. Five to ten block samples were collected from 17 sites of the formation for paleomagnetic studies. Magnetic minerals that serve as remanent carriers are maghemite, magnetite, hematite and titanohematite. Magnetite, hematite, and titanohematite carry the characteristic remanent magnetization (ChRM). The declination values of ChRM are highly discordant before and after structural correction. While inclination values show uniformity in geographic coordinates. The ChRM carried by magnetite yields downward inclinations, whereas the ChRM carried by hematite or titanohematite have upward inclinations in geographic coordinates. The correlation between polarity state and magnetic mineralogy suggests that the acquisition of magnetization occurred during two distinct time intervals. An inclination only fold test of ChRM of these two mineral assemblages indicates that they are post-folding magnetizations. The calculated paleolatitudes for ChRM carried by magnetite and hematite or titanohematite are $9 \pm 4^\circ$ N and $13 \pm 4^\circ$ N respectively. A comparison of these paleolatitudes with the Indian apparent polar wander path (APWP) shows that the remagnetization likely happened between 55 to 45 Ma. Discordant declinations indicate that these volcanics suffered local rotations after remagnetization event.

Key words: Paleomagnetism, Utror Volcanics, Kohistan.

A/137. Ahmad, M.N., Yoshida, M., Khadim, I.M. & Ali, M., 1993. Preliminary report of paleomagnetic study of Kalam (Utror) volcanics, Kalam area, upper Swat valley, N.W.F.P. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 6, 42-59.

Paleomagnetic studies have been performed on the Utror volcanics in order to get information on the tectonic history of the Kohistan island arc. It has been concluded that the Kohistan arc drifted about 10 degree (ca. 1000 km) northward and made 40 degree counterclockwise rotation.

Key words: Paleomagnetism, Utror Volcanics, Swat.

A/138. Ahmad, M.N., Yoshida, M., Khadim, I.M., & Ali, M., 1996a. Magnetic susceptibility observation across Himalaya–Karakoram Range, northern Pakistan with special reference to magnetic modeling of Kohistan Island Arc Crust. In: Khadim, I.M. & Yoshida, M. (Eds.) Rock Magnetism and palaeomagnetism – recent progress in Pakistan. Proceedings Geoscience Colloquium, Geoscience Lab. Geological Survey of Pakistan, Islamabad. 13, 5-21.

Consult the following for further details.

Key words: Geophysics, magnetic susceptibility, Kohistan arc, Himalaya, Karakoram.

A/139. Ahmad, M.N., Yoshida, M., Khadim, I.M., & Ali, M., 1996b. Magnetic susceptibility observation across Himalaya–Karakoram Range, northern Pakistan with special reference to magnetic modeling of Kohistan Island Arc Crust. Trans. American Geophysics Union, EOS, 77 (22), Western Pacific Geophysics Meeting. Suppl., W28.

Bulk magnetic susceptibility observation was performed for rocks exposed along the Karakoram Highway, northern Pakistan, traversing from Hasan Abdal town, the north-western margin of Indo-Pakistan subcontinent, to the

Ghujerab River, southern part of the Karakoram block which is a part of the Eurasian continent. The variation of magnetic susceptibility corresponds well to the rock type, and in general the Kohistan island arc occupying between the subcontinent and the Eurasian continent appears as a relative higher susceptibility zone. This anomalous contrast in magnetic susceptibility is derived from lithologic contrast, i.e. the Kohistan island arc sequence mainly consisting of igneous rocks which are often rich in iron bearing minerals as compared to the surrounding terranes. The magnetic susceptibility is high over Main Mantle Thrust (MMT) and Main Karakoram Thrust (MKT) because of the presence of serpentinite bodies. On the basis of the susceptibility variation data of Kohistan island arc, a five layer model of magnetic structures of island arc crust is proposed. K₀ ratio of the rocks is less than 1.0 except that of mafic igneous rocks, gabbro and, norite of Chilas complex. Most of granitic rocks in the area are correlated with ilmenite-series showing low magnetic susceptibility while the granitoid body in the northern part of the Kohistan batholith arc solely belongs to magnetite-series, which is probably the indication of deep angle subduction.

Key words: Magnetism, Kohistan Island Arc, Himalaya, Karakoram.

A/140. Ahmad, M.N., Yoshida, M., Khadim, I.M., Ali, M. & Kausar, A.B., 1994. Geomagnetic and VLF-EM survey over northern Suture Zone and Nomal sulphid mineralized zone, Hunza, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 8, 57-70.

On the basis of the discussions, the following points can be inferred.

1. The magnetic anomalies over the Northern Suture zone look to be strongly, effected by the lithologies. Geomagnetic field shows anomaly in the suture zone, hence geomagnetic method is useful to recognize the suture zone because of their typical magnetic character and subsurface structure modeling of the suture zone is also possible.
- 2 In- Phase parameter of VLF-EM sounding shows anomaly over mélangé in the suture zone due to the conductivity contrast. Therefore the VLF-EM survey is useful to survey in the suture zone.
- 3 There is no magnetic anomaly over the sulphide zone, hence it can be said that geomagnetic method cannot be used for the evaluation of Nomal sulphide

Key words: Paleomagnetism, Northern Suture, sulphide, Hunza.

A/141. Ahmad, M.U., 1981. Jadeed sciency Nazriat ki bunyad per Pakistan main madaniyat ke talash. (Urdu report). GSP Information Release 153.

Key Words: Mineralization, economic geology.

A/142. Ahmad, M.U., 1992a. Porphyry copper in Pakistan. GSP, Mineral Information Release 9.

Key words: Mineralization, copper.

A/143. Ahmad, M.U., 1992b. Industrial minerals of Pakistan (A Resume). GSP, Mineral Information Release 12.

Key words: Industrial Minerals.

A/144. Ahmad, M.U., & Calkins, J.A., 1969. Geology of the Terbela dams site area, Peshawar division, West Pakistan. GSP and U.S. Geological Survey Project Report PK (IR)–47.

Key words: Tarbela, Damsite.

A/145. Ahmad, M.U., Khan, A.L., & Abbas, S.G., 1992. Industrial mineral potential of Pakistan. GSP Information Release 534, 8p.

Key words: Industrial minerals, economic geology.

A/146. Ahmad, N., 1960. Soil erosion by the Indus and its tributaries. Pakistan Geographical Review 15, 5-17.

Key words: Soil, Erosion, Indus.

A/147. Ahmad, N., 1972. Geological report on Khanpur Hazara Dam area. M.Sc. Thesis, Punjab University, 110p.

Key words: Khanpur dam, Hazara.

A/148. Ahmad, N., 1983-85. Geology and Petrology of Burawai Area, Upper Kaghan Valley, District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 119p.

Nearly 114 km² area in the vicinity of Burawai, upper Kaghan Valley has been geologically mapped, at 1:18,000 for the first time. This thesis presents first time accounts of geomorphology, lithostratigraphy, petrography and economic geology of the area. The area constitutes rocks representing old Indo-Pak basement rocks, comprising pelites, calc-pelites and marbles, have been metamorphosed to kyanite and sillimanite grades. These are intruded by para-autochthonous sheet granites also metamorphosed. Major structure comprises an open synform possibly part of a larger structural basin. The western part comprises the nose of a larger antiform.

Marble, biotite mica and kyanite are important mineral deposits, which deem further exploration and evaluation. This thesis also includes petrogenesis of the rock units as well as numerous sketch and photographs, illustrating the geology of the area.

Key words: Petrology, Kaghan, Mansehra.

A/149. Ahmad, N., 1985-87. Geology and petrography of Luat-Thod Area, Neelum valley (Azad Kashmir) with special emphasis on metamorphites. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 111p.

The project area is a part of Middle Himalayas and covers about 350 sq. km. located between Doarian and Thod in Neelum Valley (Azad Kashmir) at the scale 1: 25,000 of topographic sheet No. 43 F/13, 43 F/14 and 43 J/2 of survey of Pakistan. The studied area comprises of broader lithology of Salkhala formation containing predominantly metapelites, psammites and calcareous material. Various granitic and basic bodies are also outcropping the area. Basic bodies are present as dykes and sills. The metasediments of Salkhala formation have witnessed metamorphism and deformation. The metamorphism undergone by metasediments is of regional reverted character involved from green schist to Almandine- Amphibolite facies. The area is rich in economic rocks and mineral deposits are discussed briefly.

Key words: Petrography, Metamorphism, Neelum, Azad Kashmir.

A/150. Ahmad, N., 1986-88. Petrofabrics, facies analysis and basin studies of Samana Suk Formation in Hazara and Margalla Hills of Pakistan, along a tentative study of its source? Reservoir potential. M.Sc. Thesis, Punjab University, Lahore, 95p.

Key words: Basin analyses, Samana Suk, Margalla, Mansehra.

A/151. Ahmad, N. 1990. Rock phosphate of Kakul area of Hazara District. Abstract, 2nd Pakistan Geological Congress, University of Peshawar, p.10.

Phosphorite deposits are present at Kakul area in Hazara District. The chemical analysis and various techniques employed show that P₂O₅ contents are in the range of 25-30%; other impurities are well within the permissible limits except at some horizons, where carbonate and iron contents are on the high side. Moreover, acid volume, concentration and temperature effect have also been studied, and for the maximum recovery of P₂O₅ contents,

suitable volume, concentration and temperature have been determined. The techniques used are Gravimetric, Volumetric, Spectrophotometric and atomic absorption spectroscopy. A comparison of all the four methods has been made and advantages of each method have been pointed out.

Key words: Geochemistry, Phospahte, Hazara

A/152. Ahmad, N. & Ali, D., 1961. Sediments characteristics of Indus with reference to erosion of the catchment. Pakistan Journal of Forestry 11.

Key words: Sediments, Erosion, Indus.

A/153. Ahmad, N. & Ali, D., 1962. Sediments of the Indus. Journal, West Pakistan Water and Power Development Authority.

Key words: Sedimentology, Indus.

A/154. Ahmad, N. & Ali, D., 1968. Sediment production, transport and an estimate of soil erosion for West Pakistan. Proceedings, First West Pakistan Watershed Management Conference, Peshawar, 151-174.

Key words: Sediments, erosion, West Pakistan.

A/155. Ahmad, N. & Chaudhry, M.N., 1999. A study of oil shales of Kohat Basin, Pakistan. Pakistan Journal of Geology 10 & 11, 1-8.

Key words: Oil shale, Kohat.

A/156. Ahmad, N. & Chisti, H.M., 2000a. Thermogravimetric analysis of selected samples of Pakistani oil shales in dynamic air atmosphere. Abstracts, Third South Asia Geological Congress, Lahore, p.148.

Thermogravimetry is a rapid and widely used technique for the characterization of oil shale and other rocks with organic content of any extent. The thermal behavior of such rocks in a-dynamic air environment may show characteristic of both the organic and inorganic (mineral) content of the sample. This study presents oxidative profiles of five samples of the Cambrian and the Early Eocene oil shales of Pakistan. These profiles showed extra peaks in comparison to the profiles in an inert atmosphere, which believed to due to loss of inter-layer water from clay minerals, and oxidation of organic matter in the samples.

Some samples of the Early Eocene oil shale showed a major carbonate decomposition 'peak' ($> 600^{\circ}\text{C}$), some samples indicated minor carbonate decomposition in the same region, while the sample from the Cambrian oil shale was completely devoid of any carbonate peak. Thermogravimetric analysis of these oil shales in an inert atmosphere showed that the major DTG pyrolysis peak for all the samples was singular in nature, with an average T_{max} of 475°C for the Cambrian oil shale. However, the oxidative characteristics of the organic components of these oil shales in the $230^{\circ}\text{C} - 520^{\circ}\text{C}$ region are multi-step in nature, with two major oxidative events at about $350^{\circ}\text{C} - 450^{\circ}\text{C}$ and 480°C . The rate of weight loss of the first oxidative events was greater than the second event for all samples. Also, a shouldering effect was observed at about 346°C in the Cambrian oil shale.

Key words: Thermogravimetry, Oil shale.

A/157. Ahmad, N. & Chisti, H.M., 2000b. Geochemistry of oil shale deposits of Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.149.

The Eocene and Cambrian oil shales are found in the Kohat Basin and the Sat Range Formation of Pakistan. Little has been done to characterize these deposits or to estimate their economic potential and their upgrading as a viable

energy source. These oil shales were deposited in a hydrologically restricted, shallow marine, land locked sea, representing a hypersaline environment. The Jutta gypsum unit in the Kohat Basin contained an oil shale horizon occurring at about 27-30 m below the top of this unit, the gypsiferous shales of the Salt Range Formation contained 3-5 m thick layer of oil shale. The mineralogical composition varies significantly between two deposits; the Eocene oil shales consist of clays-mainly an illite/smectite mixed layer, and quartz with a subordinate amount of dolomite and pyrite, whereas the Cambrian oil shale mainly contains quartz and gypsum with a minor content of chlorite and pyrite. Major and trace element contents of both deposits also differ significantly, in particular the exceptionally higher concentrations of vanadium and chromium in the Cambrian oil shales. The oil shales were retorted in a fixed bed pyrolysis unit to determine the yield of oil. The spent shale, oil and retort water were also analyzed for trace metal content to determine the partitioning of the trace metals between the product streams. These deposits were characterized by high concentrations of alginate rich organic matter. The carbon and hydrogen content of both oil shales were similar, but the Eocene oil shale, on average, gave higher yields of oil during the retorting of the oil. The Eocene oil shale had an average oil yield of 13% with a maximum value of 20%, whereas the Cambrian oil shale exhibited an average yield of 11% with a maximum value of 14%.

Key words: Geochemistry, Oil shale.

A/158. Ahmad, N. & Pervez, S.D., 1960. Soil erosion in northern region of West Pakistan. *Indus* 1(7).

Key words: Soil, erosion, West Pakistan.

A/159. Ahmad, N. & Pervez, S.D., 1963. Soil erosion in northern regions of West Pakistan. *Pakistan Journal of Forestry* 13, 291-195.

Key words: Soil, Erosion, West Pakistan.

A/160. Ahmad, N., Qaiser, M.A. & Amin, M., 1990. Comparative evaluation of laterite deposits of Pakistan. *Pakistan Journal of Scientific and Industrial Research* 33, 7, 265-00.

Studies on various samples of laterites from Cherat, Attock, Abbottabad, Sargodha and Ziarat areas of Pakistan were carried out by chemical, X-ray powder diffraction and thermal analysis for comparative evaluation. The minerals identified in these laterites are vermiculite, goethite, calcite, limonite, hematite, quartz, kaolinite, diaspore, boehmite and illite.

Key words: Laterite deposits.

A/161. Ahmad, N. & Williams, P.T., 1998. Influence of particle grain size on the yield and composition of products from the pyrolysis of oil shales. *Journal of Analytical and Applied Pyrolysis* 46, 31-49.

Oil shales from two regions of Pakistan have been pyrolysed in a fixed bed reactor in relation to particle grain size. Five size ranges were investigated, <0.5, 0.5–1.0, 1.0–1.7, 1.7–2.8 and 6.0–10 mm. The pyrolysis system consisted of a 200 cm³ stainless steel fixed bed reactor externally electrically heated. The samples were heated to 520°C at 10 K min⁻¹ and the oil shale sample was continuously purged with nitrogen to remove the pyrolysis products from the reactor and to minimise secondary reactions. The gases were analysed for their content of CO, CO₂, H₂, CH₄ and other hydrocarbons up to C₄. The derived pyrolysis oil was condensed in a series of cold traps and the total oil yield determined. In addition, experiments were carried out on a thermogravimetric analyser using the three smallest particle grain sizes under identical heating conditions to the fixed bed reactor. It was found that increasing the particle size up to the largest size used of 10 mm resulted in an increase in oil yield. The total gaseous yield was decreased, reflecting a decrease in concentration for H₂, CO, CO₂ and the majority of the hydrocarbon gases. The raw oil shale samples of various particle size ranges were analysed to determine the elemental composition and surface area to determine their influence on the compositional changes in oil and gaseous yield with particle size range.

Keywords: Oil shale, Pyrolysis, TGA.

A/162. Ahmad, R., 1957. Radioactive minerals in parts of Hazara District. Abstract, 9th All Pakistan Science Conference, Peshawar, p.118.

Key words: Radioactivity, Hazara.

A/163. Ahmad, R., 1963. A Cassidulid Achnoid from the so-called "Triassic Limestone" of Hazara District. Geological Bulletin, Punjab University 3, p.35.

During the 1963 summer field season the writer worked in the Thandiani locality and collected some echinoid remains from the upper beds of the so-called "Triassic Limestone" of the Hazara District. Complete specimens were not obtainable, but the evidence furnished by the fragments shows that they belong to the genus *Pygurus* of the family of the cassidulidae of the irregular echinoids (Zittel, 1900). A drawing of one of the pieces is shown in Fig. 1. The range of this genus is from upper Jurassic to Cretaceous. Its presence in the Nerinea Horizon confirms the view that at least, the upper part, of the limestone is of Jurassic age, as was indicated by the forms of *Nerinea* reported on by Aftab Ahmad (1962). This is the first time that cassidulids have been recorded in this formation.

Key words: Palaeontology, limestone, Hazara.

A/164. Ahmad, R., 1981-83. Geological mapping with special studies of discontinuities in rocks and their effect on the rockmass strength at Kalabagh Damsite. M.Sc. Thesis, Punjab University, Lahore, 124p.

The Department of Geology was upgraded to an Institute in 1979. According to the new rules and regulations three year B.Sc. Applied Geology Courses were introduced. In accordance, with these rules 1 1/2 year courses in studies were established leading to M.Sc. Applied Geology Degree. This comprehensive research report about a particular geological project has been submitted as a part of the M.Sc. Examination.

Our group comprising four students was allotted a Geo-Engineering problem, with special emphasis on the study of discontinuities at the proposed Kalabagh Dam site. Kalabagh dam site is 10 miles upstream of Kalabagh Town, situated just below the confluence of Soan and the Indus River. According to initial investigation height of the dam is proposed 945 feet above mean sea level, with reservoir level 925 feet above mean sea level. This dam is going to be constructed for hydro-electric, irrigation and flood control purposes.

We spent about one and a half month at the site in July and August, 1984. Again we made a short visit in the middle of December, 1984, to review our previous work. Extensive studies relating to our problem were made under the guidance of Mr. M.H. Malik, Assistant professor, Institute of Geology.

In this Research Report conventional topics like History, Physiography Stratigraphy, Damsite Geology, and Structural Setting of the area and Hydrology have been discussed in detail. These topics are spread in six chapters i.e. from Chapter No.2 to 7.

Key words: Mapping, damsites, Kalabagh.

A/165. Ahmad, R. & Ahmad, F., 1962. Geology of Rupper area south-west Hazara. M.Sc. Thesis, Punjab University, Lahore, 30p.

Key words: Geology, Hazara.

A/166. Ahmad, R., & Ali, S.T., 1977. Occurrence of Phosphate in Loe-Shilman Carbonatite, Khyber Agency, NWFP, Pakistan. GSP Information Release 101, 19p.

Key words: Phosphate, carbonatite, Khyber Agency.

A/167. Ahmad, S., 1972. Geochemistry and physical properties of chromites from Pakistan. Ph.D. Thesis, Punjab University, Lahore, 212p.

Seventy two chromite specimens have been studied from Hindubagh, Harichand and Fort Sandeman areas of Pakistan. Out of these sixty seven samples were selected from Hindubagh area comprising Nisai, Saplai torghar, Jung troghar and North Hindubagh. Three samples from Harichand and two from Fort Sandeman were studied for purposes of comparison.

Chromites with different structures such as orbicular, nodular, banded, disseminated and chain, have been observed and are described briefly. Colour of chromites in thin section varies from brownish yellow to deep cherry red. Brownish yellow chromites have been found to have low Cr/Fe ratio as compared to deep cherry red chromites.

Some chromites showed alteration with opaque alteration products along cracks or along the grain boundaries. Such chromites showed the presence of abnormally high amount of Fe_2O_3 as compared to other chromites which are without such alteration. Such chromites gave a number of sizable chromite separation on an isodynamic separator. The variation in chemistry of fractions of a chromite specimen from mine 155 is described. The main inference is that chromite fractions obtained at 0.1 Amp has Fe_2O_3 16.28% as compared to the fraction separated at (0.4 Amp.) which has Fe_2O_3 10.35%.

An improved scheme for chromite analysis is presented, the accuracy of which has been checked on synthetic standard. A gradual change in chemical composition of chromites was observed from Nisai (Cr/Fe ratio 2.24-2.99) to Jungtorghar (Cr/Fe 2.52-3.75). A variation in chemistry has been found with in a mine e.g. in mine 7ML Cr/Fe ratio varies. Certain physical properties such as, specific gravity and micro-indentation hardness, have been determined on all the specimens, whereas cell edge dimensions and Refractive indices were determined on some selected specimens. These physical properties were compared with chemistry and a relationship was found to be present, between specific gravity and chemistry of chromites from Hindubagh in the form of a mathematical expression. This can be used to estimate weight percentage of Cr_2O_3 , Al_2O_3 and MgO in Hindubagh chromites from known values of weight percentages of FeO , Fe_2O_3 and specific gravity. The results obtained showed the error to be within 5% of the contained oxides.

A relationship was also found to exist between cell edge dimension and weights percentages of Cr_2O_3 . This relationship helped to derive a method by means of which weight percentages of Cr_2O_3 , FeO and MgO of Hindubagh chromites can be determined within about 5% of the contained oxides. The other two physical properties, Micro-indentation hardness and refractive indices showed no definite relationship which could be used to determine the weight percentages of the constituents oxides. However a rough conclusion that can be drawn is that chromites with a higher Al_2O_3 weight percentages have higher values of Vickers hardness number and refractive index

Key words: Geochemistry, chromite.

A/168. Ahmad, S., 1976. Geochemistry of chromites from Harichand, Malakand Agency, Pakistan. Geological Bulletin, University of Punjab 12, 91-96.

Chemical analyses of three purified chromite samples from Harichand area Malakand agency are presented and compared with chromites from Muslimbagh. A number of diagrams have been drawn to present the chemical data. The analysed Harichand chromites are aluminian chromite with tendency towards chromian spinel due to high alumina. Microhardness and specific gravities of all the specimens are presented whereas cell edge dimension and refractive indices of two samples are given.

Key words: Geochemistry, Chromite, Malakand.

A/169. Ahmad, S., 1980. A study of opaque minerals in rocks of Thak Valley igneous complex, North West Frontier Province, Pakistan. Pakistan Journal of Science 32, No. 3-4, 199-200.

Key words: Opaque minerals, Thak valley, Chilas complex, Kohistan arc.

A/170. Ahmad, S., 1981a. Preliminary account of the occurrence of Ni sulphides in serpentinites of Souch area, Kaghan Valley, District Mansehra, North West Frontier Province, Pakistan. Geological Bulletin, Punjab University 16, 172-174.

Souch area lies between longitude 73 40' -73 45 E and latitude 34 55'-34 59' 30" N. Qadir (1979) has described in detail the Petrology of the area and classified the area into three groups.

1. Metamorphic rocks consisting of garnet mica schist, graphitic schist, marble, amphibolites.
2. Quartzofeldspathic rocks consisting of granite gneiss, pegmatites, aplites.
3. Ultramafics, consisting of dunites, Serpentinites, Pyroxenites, Talc and Carbonates.

The first outcrop of the ultrabasic is at 19 km. above Lidi a small village on right bank side of river Kunhar. Chemical analysis of two serpentinite rock samples showed Ni--0.28 to 0.32%. The rock under study was weathered to greenish black and fine to medium grain size. The major minerals are antigorite, chrysotile, olivine forsterite, with small amounts of magnesite, magnetite heazlewoodite and pentlandite. The presence of heazlewoodite and pentlandite, was identified by the Ore-microscopic techniques, such as, reflectivity, microhardness and etch tests described by Cameron (1961) and Ramdohr (1969).

These two minerals occur as small disseminated among and molded about silicate minerals, and appears to be a primary accessory of the ultrabasics. The texture of mineral assemblages and their association favours the Phenomenon of Sulphide-silicate immiscibility and consequent magmatic differentiations in situ. Such sulfide disseminated in ultramafic rocks have been reported by many workers, such as Souch, Podolsky et al (1969), from Sudbury deposits Canada and Woodal and Travis (1969) from kambalden deposits in Western Australia. In these, sulfides grade from minor disseminations in ultramafic rocks to massive ores. The disseminated ores appear to represent an early stage of the process that formed massive ores. A detail work on the other ultramafic rocks of the area is in progress and will be published soon. The author is highly thankful to Mr. Qadir for providing samples.

Key words: Mineralogy, Ni sulphides, serpentinite, Kaghan, Mansehra.

A/171. Ahmad, S., 1981b. Physico-chemical method for determination of chemical composition of chromite. Geological Bulletin, Punjab University 16, 43-65.

Key words: Chromite, geochemistry.

A/172. Ahmad, S., 1983-85. Geotechnical studies of land slides with special emphasis on slope stability along Karakorum highway between Thakot and Besham, District Swat. M.Sc. Thesis, Punjab University, Lahore, 117p.

Engineering geological investigations were carried out about the land slides and slop stability problem along the Karakoram Highway between Thakot and Besham. The project area mainly comprises of Thakot metasediments, Lahor granite, Shang granite gneiss and mineralized scree (near Besham). These are mainly controlling the rugged topography and other geomorphological features of the project area. The general trend of stresses is SE-NW.

So far the stability of the region is concerned, the detailed analysis for critical slopes is performed. Among different modes of failure encountered, the plane failure is proved to be unstable particularly near Maira and at Kandaurgai. Other than this a large variation in discontinuities is observed that controls sliding in hard rocks and highly weathered rocks which are responsible for mass wasting and rock fall. Road alignments were studied keeping in view landslide problems and slop stability, for potentially unstable regions remedial measures are also given, for potentially unstable regions remedial measures are also given. 1h; 2v cut slopes and benches are proposed. Benches may be provided at each 8 meters interval.

Key words: Geotechnical study, land slides, Besham, Swat

A/173. Ahmad, S., 1984. Necessity for geochemical prospecting in Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, 45-55.

The validity of geochemical methods in the exploration of new mineral resources and development of already known deposits is well established all over the world. An application of these methods in a number of areas from Pakistan such as Kirana Hills, Kaghan Valley, Malakand, Nomal-Chalt and Swat showed encouraging results. Regular geochemical survey of the country is recommended.

Key words: Geochemical prospecting, exploration.

A/174. Ahmad, S., 1988. Total magnetic survey of the central Potwar and adjoining area. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 42p.

Key words: Magnetism, Potwar.

A/175. Ahmad, S., 1989. Groundwater investigation in Rawalpindi. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 44p.

Key words: Ground water, Rawalpindi.

A/176. Ahmad, S., 1990. Geology of southern Tanawal area, north of Haripur, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 51p.

The southern Tanawal region exposes a suite of metasedimentary rocks comprising of conglomerate, argillite, quartzite and dolomite. The basal sequence –unfossiliferous quartzite of Precambrian age belongs to Tanawal Formation and is unconformably overlain by thick succession of argillite, quartzite and dolomite of Cambrian age. This assemblage of younger metasediments is named as Sherwan formation.

The southern tanawal area lies on the hanging wall side of the Panjal fault and is largely influenced by the deformational pattern associated with this fault.

Key words: Geology, stratigraphy, Tanawal, Hazara.

A/177. Ahmad, S., 1991. Distribution of major and trace elements in soils and adjoining rocks of Yasin valley. Culture Area Karakorum Newsletter (Tubingen) 1, p.11.

Key words: Geochemistry, trace elements, Yasin Valley.

A/178. Ahmad, S., 1992a. Distribution of major and trace elements in soils and adjoining rocks of Gilgit, Northern Areas. Culture Area Karakorum Newsletter (Tubingen) 2, p.20.

Key words: Geochemistry, soil, Gilgit.

A/179. Ahmad, S., 1992b. Distribution of major and trace elements in soils and adjoining rocks of Gilgit, Northern Areas. Mountnews (Lahore) 5, 30-31.

Key words: Geochemistry, soil, Gilgit.

A/180. Ahmad, S. & Farooq, U., 2000. The distribution behavior of trace elements during combustion of Surghar Range coal and their environmental effects. Abstracts, Third South Asia Geological Congress, Lahore, p.162.

The Surghar Range coal fields comprise of Makarwal, Gula Khel and Kurd coal fields, constituting the northernmost part of the Trans-Indus mountains. The distribution behavior of hazardous trace elements, As, Be, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Sb, Se, V and Zn present in the Sughar Range coal deposits, indicate that these are concentrated within clay and sulphides minerals. During combustion of coal, these elements segregate between flyash and coal ash. Although contents of trace elements in coal are only in parts per million, the amount of coal used for burning purposes is so great that quantity of elements released to the environment may become higher than the permissible among limits. As the human race is highly dependent on complex interrelations among the biosphere, atmosphere, hydrosphere and lithosphere, the dispersed particulate matter and the gaseous pollutants in general, present in the flyash could be injurious to health during mining in particular and to the environment.

Key words: Trace elements, coal, Surghar range.

A/181. Ahmad, S. & Ahmad, D., 1995. Tectonic Analysis of the Kohat plateau boundary zone, NW Himalayas, NWFP, Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The southern most structural boundary of the Kohat Plateau is herein named as Kohat Plateau Boundary Zone. It is about 120 Km long with width ranging from 510 kms and trends East-West. Towards the west it is bounded by the Kurram fault whereas towards the East it joins the Kalabagh fault.

The Kohat Plateau Boundary Zone is characterized by strike slip, deformation in addition to the thrust slip deformation having transtensional and transpressional bends. Towards the west, the Boundary zone exhibits transtensional deformation with large-scale normal faults and form negative flower structure. Towards the east, north of Karak it exhibits transpressional deformation forming positive flower structure and is characterized by large-scale reverse faults.

All the kinematic indicators and ages of rocks involved in the deformation shows that the Kohat Plateau Boundary Zone has experienced a Plio-Pleistocene phase of strike slip deformation with sense of motion being right lateral.

Key words: Tectonics, structure, Kohat Plateau.

A/182. Ahmad, S., Ahmad, I. & Ghauri, A.A.K., 1990. The geology of southern Tanawal area, north of Haripur, Hazara, NWFP, Pakistan. Abstract, 2nd Pakistan Geological Congress, University of Peshawar, p.38.

The southern Tanawal area exposes a suite of metasedimentary rocks comprising quartzite, dolomite, argillite and conglomerate. These rock units are grouped into two stratigraphic units: (a) Lower Tanawal Formation and (b) Upper Sherwan Formation.

The Precambrian Tanawal Formation consists of unfossiliferous quartzite with thin intercalations of argillite; whereas the unconformably overlying Sherwan Formation comprises younger quartzite, dolomite, argillite and dolomite of Cambrian age. These rock units represent the hanging wall of the Panjal fault and constitute a series of north-east trending overturned folds and north dipping thrust/reverse faults. The overturned folds invariably verge; southward and the orientation of both the faults and folds vergence indicates a southward directed tectonic transport which is typical of the foreland fold-and-thrust belt of the Hazara Himalaya. The Panjal fault which runs south of the study area exhibits ramp and flat geometry beneath the southern Tanawal area and it is inferred that the structure of this region took shape during the development of Panjal fault.

Key words: Metasediments, Tanawal, Haripur, Hazara.

A/183. Ahmad, S., Ahmad, I., Ghauri, A.A.K. & Riaz, M., 1992. Revised stratigraphy of the southern Tanawal area, North of Haripur, NWFP, Pakistan. Kashmir Journal of Geology 10, 153-160.

The southern Tanawal area exposes a suite of metasedimentary rocks comprising quartzite, dolomite, argillite and conglomerate. The oldest rocks belong to the Tanawal Formation of Precambrian age. The Tanawal Formation is unconformably overlain by a thick sequence of quartzite, dolomite, argillite and conglomerate, previously named as Abbottabad Formation. Baig and Lawrence (1987) renamed this sequence as Sherwan Formation and considered it to be of Cambrian age. The stratigraphy of the area is revised in order to differentiate between the dolomite-quartzite sequence exposed north and south of the Panjal fault in the southern Hazara region.

Key words: Stratigraphy, Tanawal, Haripur, Hazara.

A/184. Ahmad, S. & Ahmed, Z., 1974. Petrochemistry of the Ambela granites, southern Swat District, Pakistan. Pakistan Journal of Scientific and industrial Research 26, 63-69.

This paper presents a petrographic and chemical study of the granites together with five chemical analyses. The rocks are discussed with reference to the Peshawar plain alkaline igneous province. The granites are considered to be comagmatic with the Warsak and Shewa-Sheh Baz Ghari microgranites and the Warsak alkaline granites.

Key words: Geochemistry, petrology, Ambela granites, Swat.

A/185. Ahmad, S., Ali, F., Ahmad, I. & Hamidullah, S., 2001. Geological map of Kohat Plateau North-West Himalayas, NWFP, Pakistan. Geological Bulletin, University of Peshawar 34.

This is a colored geological map at a scale of 1:133000. Structural elements are shown together with Main Boundary Thrust in the north of the map. The rocks range from Jurassic to Pleistocene (overlain by Quaternary alluvium), with a hiatus of Oligocene.

Key words: Geological Map, Kohat Plateau, Himalaya,

A/186. Ahmad, S., Ali, F., Ahmad, I. & Hamidullah, S., 2001. Structural geometry of the Himalayan frontal thrust zone: Surghar Range, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.32.

Surghar Range of the outer Himalayas in Pakistan represents the active deformational front of Kohat fold-thrust belt, which is migrating southward in response to the underthrusting of Indian craton underneath its sedimentary cover. The surface expression of the range in the vicinity of Chichali pass is characterized by south facing Surghar anticline at the level of Jurassic. Its southern limb is dissected by Surghar thrust, which moderately dips towards north and is detached within or at the base of Triassic sequence. Several out of sequence thrust faults are mapped south of the major ramp structure representing migration and structural disruption from the main locus of crustal shortening in the range interior towards Punjab foreland. Variations in the structural geometries along the range front suggest that it is a strongly emergent thrust in the west (north of Kutki village) and translates into a tip-stick thrust front in the east (north of Chapri and Toila Mangli village). The restored cross-section along Kutki section reveals that 5.6 Km overall shortening has taken place along the Surghar Thrust. The available constraints on the timing of deformation suggest that the uplift along the range front started 2.3 Ma ago.

Key Words: Structural Geometry, frontal thrust zone, Surghar Range.

A/187. Ahmad, S., Ali, F., Ghauri, A.A.K. & Danishwar, S., 1994. Imprints of transpressional deformation on the southern Kohat plateau, NW Himalayas, NWFP Pakistan. Journal of Nepal Geological Society 10, Abstract Volume 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, 5.

We present evidence for Plio-Pleistocene transpressional deformation in the Kohat Plateau, which is part of the NW Himalayan foreland Fold and thrust belt of N. Pakistan. The Karak structure in the SW Kohat Plateau is interpreted as an E-W trending positive flower structure, which is exposed for 20-km along strike and is about 5-km wide. It is bounded by the N-dipping Karak thrust in the south and the S-dipping Nari Panos backthrust in the north and internally subdivided by the south dipping Banda Kunghara backthrust. All these faults trend E-W and have moderate surface dips. A right lateral component of deformation along the Karak structure is indicated by ENE directed trends of the Daggar syncline in the footwall of the Nari Panos backthrust and of small scale thrusts in the core of this syncline. A strong lateral component of deformation along the Karak structure is also in accordance with seismic data (906-NSK-47) which indicate rapid steepening of the Karak and Nari Panos thrusts to near vertical with depth.

Right lateral transpression along the Karak structure is also supported by ENE trending en-echelon folds south of Banda Charpara. This work emphasizes the importance of transpression within the NW-Himalaya on a regional scale. Recent work by Beck et al. (in prep.) has suggested transpressive deformation along the Main Boundary Zone (MBZ) to the west of the Kohat Plateau.

Key words: Structure, deformation, Kohat Plateau.

A/188. Ahmad, S., Ali, F., Rehman, N. & Gul, J., 2000. Lithostratigraphy of the Kurram Group rocks along Mirali-Miran Shah road, North Waziristan Agency, NWFP, Pakistan. Geological Bulletin, University of Peshawar 33, 79-86.

This study focuses on the identification and description of a thick Mesozoic sequence exposed along Mirali-Miran Shah road in North Waziristan Agency, previously named Kurram Group. The detailed field investigation have resulted in establishing six distinct lithostratigraphic units, ranging in age from Late Triassic to Late Cretaceous with Dominant lithologies being limestone, sandstone, shale, and siltstone. The oldest rocks i.e. Triassic of the area is named as Spalga Formation. The contact between the Triassic and the base of Jurassic is marked by a thrust fault in the entire mapped area. The Jurassic rocks are represented by a thick sequence of limestone and shale, which are divisible into two formations named as Sarobi Formation and Isha Formation. These rocks are disconformably overlain by the Cretaceous sequence, which includes Chashmai Kharsai Formation, Marsi Formation and Zerghar Formation. Except the Triassic, all the rocks assemblages have yielded fossils of their respective age. The fauna and lithology of the area is broadly correlative with Mesozoic rocks of Samana- Kohat area towards north and Baluchistan Province in the south.

Key words: Lithostratigraphy, Kurram group, Miran shah, North Waziristan.

A/189. Ahmad, S., Ali, F., Sayab, M., Ahmad, I. & Hamidullah, S., 1999. Structural geometry of the Himalayan Frontal Thrust Zone: Surghar Range, Pakistan. Geological Bulletin, University of Peshawar 32, 13-23.

Surghar Range of the outer Himalayas in Pakistan represents the active deformational front of Kohat fold and thrust belt. The range is migrating southwards in response to the underthrusting of Indian craton underneath its sedimentary cover. The structural geometry of the range, in the vicinity of Chichali pass area is characterized by a south facing anticline i.e. Surghar anticline at the level of Jurassic. It is interpreted to be a fault bend fold above a major ramp detached within or at the base of Triassic rocks. The range front is thrust southwards over Punjab foreland along Surghar fault, which is interpreted as south verging fore thrust. The thrust sheet above Surghar fault displays contrasting structural geometries along strike. The Surghar fault is believed to be a strongly emergent thrust in the west (north of Kutki village) having shallowly folded thrust sheet. Eastwards, the Surghar fault translates into a tipstick thrust front (north of Chapri and Tola Mangli village) with its thrust sheet being tightly folded and disrupted by several out of sequence thrust faults. The restored cross section along Kutki section reveals that 5.6 km shortening has taken place along Surghar Fault. The constraints upon the timing of deformation suggest that uplift along range front started about 2.3 Ma ago.

Key words: Structure, Surghar Range, Himalaya.

A/190. Ahmad, S. & Humayun, Q.M., 1980. Detail Geology of phosphorite bearing rocks of southern Lagarban area, Abbottabad. M.Sc. Thesis, Peshawar University, 65p.

This report gives details of the area south west of Garhi Habibullah. The thesis area is a synclinalorium. The rocks deposited are folded. Some details of the stratigraphy and structure is given.

Key words: Structure, Phosphorite, Abbottabad.

A/191. Ahmad, S. & Mirza, K., 1999. Palynostratigraphy of the Lower Jurassic Datta Formation from the Salt Range, a major tectonic unit of Pakistan Himalaya. Terra Nostra 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 3-4.

The Salt Range, the most well studied area of the Upper Indus Basin, is one of the major tectonic units of the Pakistan Himalayas. It is regarded as a key region for understanding the stratigraphy of Pakistan. It is known as the "Field Museum of Geology" because of its almost complete stratigraphic sequence with excellent exposures from the pre-Cambrian through the Pleistocene. The Salt Range is situated between the Sargodha High and the Jhelum plain in the south and the Potwar Plateau in the north, respectively. The Salt Range and its Trans-Indus extensions are the result of tectonic forces imposed during the collision of the Indian and Eurasian plates. The exposed stratigraphic units are mainly unmetamorphosed sediments. The Lower Jurassic rocks belonging to the Datta Formation in this area are represented by thick sequence of variable lithological characters including shale, siltstone, sandstone, and mudstone of red, maroon, grey and white colors deposited in continental environments.

The present state of knowledge concerning stratigraphy and palynology of the Datta Formation of the Salt Range and Hazara of north Pakistan is reviewed. Detailed studies of the Datta Formation have revealed abundant and

varied palynomorphs assemblages. This unit is well developed in the western Salt Range, Trans-Indus Range, Surghar Range and a few exposures in the Hazara area are also found. Fifty samples have been collected from Gorge, Makerwal and Hazara areas. These are regarded as classical localities for palynostratigraphical investigations. In general, the preservation of the species recorded is good. Miospores from the Hazara are in an inferior state of preservation when compared with the Salt Range. It is of interest to note that saccate pollen grains have rarely been encountered. Ubiquitous forms of trilete and monolete miospores have frequently been observed. However, some endemic elements have also been recorded during the present investigations. The Datta Formation is characterized by the presence of pollen grains, i.e. *Classopollis*, together with a trilete miospore genus. These forms have been recorded in the Lower part of Datta Formation. The absence of phytoplankton (acritarchs and algae) in this unit is in harmony with respect to the continental facies. Some of the index taxa that are regarded as indicator of the Lower Jurassic of Pakistan includes: *Gleicheniidites*, *Divisporites*, *Densoisporites*, *Lycospora* and *Matonisporites*. Long ranging genera of Laevigate forms such as *Punctatisporites* and *Leiotriletes* are also profusely represented. Another miospore genus *Convolutispora* belonging to the infragenera *Muornati* has also been found occurring in the Lower Jurassic of Pakistan. These miospore forms have also been reported from the Upper Devonian of many parts of the world including North America, North Africa, Europe, Asia and Australia.

Key words: Stratigraphy, Lower Jurassic, Datta formation, Salt Range.

A/192. Ahmad, S., Sheikh, R.A., Haque, I. & Naeem, M., 1992. Lead-zinc-copper mineralization in Treri-Manjhotar area, District Muzaffarabad (Azad Kashmir), Pakistan. *Acta Mineralogica Pakistanica* 6, 164-166.

Key words: Lead-zinc-copper, Muzaffarabad.

A/193. Ahmad, S.A., 1999. Catalogue of GSP Publication. GSP. Special Issue, 34p.

Lists all Memoirs, Records, Information Releases, Miscellaneous Publications (USGS Professional papers, Mineral Information Series, Special Issues), and Geological Map Series produced until the middle of 1999 by the GSP.

Key words: Bibliography, GSP.

A/194. Ahmad, S.A., Hafeez, M.A. & Ahmed, R. 1991. Publications of GSP. GSP Information Release 518, 29p.

Lists all Memoirs, Records, Information Releases, Miscellaneous Publications (USGS Professional papers, Mineral Information Series, Special Issues), and Geological Map Series produced until 1991 by the GSP.

Key words: Bibliography, GSP.

A/195. Ahmad, S.A., Hafeez, M.A. & Khan, S.H., 1994. Status of geological mapping on 1:50,000 in Pakistan. GSP, Information Release 552.

One of the principal activities of the Geological Survey of Pakistan (GSP) has been mapping of the Pakistan territory. Much of the country was poorly mapped, and some of the mountainous areas had been studied only along stream courses. Over the 37 years period, the GSP has been engaged actively in preparation of the geological maps on various scales. This is an account of the areas which have been mapped at 1:50,000 scale.

Key words: Mapping.

A/196. Ahmad, S.A., Mahmood, A. & Khan, A.R., 1985. Geology and petrology of Gulpatobanda-Saoni area, Dir District, Pakistan. *Acta Mineralogica Pakistanica* 1, 90-94.

Geological map covering about 30-km² area near Gulpatobanda-Saoni in Dir District is presented. The area is composed of metasedimentary complexes with igneous intrusions. The main units in the area calcareous quartzite, calcareous mica schist and siliceous mica schist. Detailed petrography of the major units is described.

Key words: Petrology, metasediments, Dir.

A/197. Ahmad, W., 1990-92. Geological study for petrography and geology of Atia Qala, District Swat. M.Sc. Thesis, Punjab University, Lahore, 57p.

Rocks of Atia Qala (Distt. Swat) are part of metamorphic hornblende complex. The area lies within the southern portion of Swat. These rocks are probably the extensions of rocks of Dir in the form of a belt running approximately in East-West direction. The area given for fieldwork comprises thirty kilometers in the Northwest of Mangora. The area mainly comprises the main rock units are Norite, Diorite, Quartz, Feldspar and Pegmatite veins. But at some places patches of Amphibolite are also found but can be considered negligible. As the field evidences and laboratory study shows that the Diorite and Norite were formed from basic magma, which have under gone regional metamorphism under the intense orogenic conditions. Quartz-O-Feldspathic and Pegmatite veins are extensively distributed all over the area, indicating the evidence of Diorite magma. Major minerals are Plagioclase, Hornblende, Epidote and Quartz with accessories as Sphene and Magnetite. These are products of regionally metamorphosed igneous rocks.

Key words: Petrography, Swat.

A/198. Ahmad, W., 1990. Sedimentologic and magnetostratigraphic studies of upper Siwalik group Sulaiman Range, Pakistan. M.Sc. Thesis, University of Peshawar, 88p.

Key words: Sedimentology, Magnetostratigraphy, Sulaiman Range, Siwaliks.

A/199. Ahmad, W. & Hamidullah, S., 1987. Island arc signatures from the Waziristan igneous complex, NWFP, Pakistan. Geological Bulletin, University of Peshawar 20, 161-180.

The Waziristan igneous complex consists of peridotite, gabbro, diorite, diabase and a variety of volcanic rocks. Petrographic studies and mineral chemistry of the rocks contradict their oceanic crust origin and evince an island arc parentage. The high Mg# (89-95) of the olivine and pyroxenes, and absence of plagioclase in the cumulus peridotite suggest crystallization at high pressures – not typical of oceanic crust. The calcic-plagioclase (An_{90-97}) and clinopyroxene (Wo_{44-46} En_{44-50} Fs_{5-12}) association in the gabbroic rocks of the Waziristan igneous complex is akin to other island arc-related gabbros. A variety of diagrams used for discrimination of clinopyroxenes from different tectonic environments, also indicate the island arc affinity of this complex.

Key words: Petrography, Geochemistry, Waziristan.

A/200. Ahmad, W. & Khan, M.J., 1990. Sedimentologic and magnetostratigraphic studies of the upper Siwalik Group, Sulaiman Range, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 33-34.

The Siwalik Group exposed in the eastern foothills of the Suleiman Range includes Vihowa, Litra and Chaudhwan Formations. The Vihowa Formation consists of grey and brown sandstones and red to brownish-red siltstone. The overlying Litra Formation comprises light-grey sandstone with subordinate brown to reddish- brown siltstone. Chaudhwan Formation overlies Litra Formation and predominantly consists of conglomerates with ancillary interbedded pale-grey sandstone. Present studies are confined to the upper Litra and Chaudhwan Formations. Sandstone of the Litra Formation is characterized by the abundance of almandine garnet and blue-green hornblende, indicating substantial contribution from the northern provenance (i.e., Kohistan island arc). Whereas the petromict orthoconglomerates of Chaudhwan Formation indicate a western provenance (i.e., Fort Monroe anticline).

Paleomagnetic studies of the overbank deposits from the upper Siwalik sequence show that NRM of most samples is composite of (a) a secondary component of magnetization, and (b) a stable, hopefully primary, component of remnant magnetization. Secondary magnetization was successfully removed by Partial Thermal Demagnetization at 400°C, and thus the stable component of magnetization was isolated. Thereafter, all samples were subjected to a single step thermal demagnetization at 550°C (one sample at 660°C).

Considering the rates of sediment accumulation of the upper Siwaliks in general, and the faunal contents of the upper Siwaliks from a nearby locality, the observed normal magnetic- polarity is tentatively correlated with the Jaramillo subchron of the Matuyama Chron. This correlation suggests that the upper Litra Formation was deposited

during 1.5 Ma. to 7 Ma. whereas the Chaudhwan Formation was deposited between .7 Ma. and 50,000 yr. BP., in consequence of the synchronous acute tectonic uplift along Fort Monro anticline.

The alluvial fan deposits, overlying the Chaudhwan Formation, are also tilted due to the formation of Zinda Pir and Sakhi Sarwar anticlines. This manifests active forelandward (eastward) migration of the deformation front of the Sulaiman Range.

Key words: Sedimentology, Magnetism, Siwaliks, Sulaiman Range.

A/201. Ahmad, W. & Khan, M.J., 1991. Petrography of the upper Litra and Chaudhwan Formations, Upper Siwalik Group, Zinda Pir anticline, northern Sulaiman Range. Geological Bulletin, University of Peshawar 24, 191-202.

The Zinda Pir anticline of northern Sulaiman fold belt exposes, along its periphery, the Siwalik Group which comprises Vihowa, Litra and Chaudhwan Formations (in younging order). Petrographic studies of the upper Litra and Chaudhwan Formations indicate that the sandstones of these formations are texturally similar. Moderate angularity and sorting, along with high content of feldspar, indicate textural immaturity of these sandstones. The Litra Formation is characterized by the abundance of almandine garnet and blue-green hornblende, indicating substantial contribution from the northern provenance (i.e., Kohistan island arc). Whereas petromict orthoconglomerates of the Chaudhwan Formation indicate a predominant western provenance (i.e. Fort Monro anticline).

Key words: Petrography, Siwaliks, Zinda Pir, Sulaiman Range.

A/202. Ahmad, Z., 1969. Directory of mineral deposits of Pakistan. GSP Records, 15(3), 220p.

The directory is an alphabetical listing of the known mineral deposits and showings in Pakistan. It also includes a brief description of the mineral deposits of chromite, asbestos and magnesite in ophiolitic rocks.

Key words: Mineral deposits.

A/203. Ahmad, Z., 1978a. Petrology of Taghma area, Swat district, NWFP. Pakistan. GSP Information Release 15, 31p.

Key words: Petrology, Taghma, Swat.

A/204. Ahmad, Z., 1978b. Bibliography and Index of the GSP Reports. GSP. Records, 42, 39p.

This is a compilation of GSP reports. It contains an index of all the reports collected in this bibliography.

Key words: Bibliography.

A/205. Ahmad, Z., 1981. Geological sketch and mineral deposits of Azad Kashmir. GSP, Record 57, 28p.

This report summarizes information on the geology and mineral deposits of Azad Kashmir. It contains brief descriptions of those mineral deposits that have some economic or geological significance. These include Boxite, bentonite, coal, fireclay, gemstones, graphite, gypsum, limestone and dolomite, mica, phosphatic rocks, pyrite, quartzite, radioactive minerals, slate and soapstone. There are two tables and an index map.

For further information, see Ali, S.T., 1984.

Key words: Mineral deposits, Azad Kashmir.

A/206. Ahmad, Z., 1987-89. Geotechnical study of proposed Ghazi-Gariala hydropower project and material testing of District Hazara and Attock. M.Sc. Thesis, Punjab University, Lahore, 142p.

Key words: Geotechnical, Material Testing, Hydel power, Hazara, Attock.

A/207. Ahmad, Z., 1992. Clays. GSP Mineral Information Series 11, 56p.

This is a general information on clay minerals, their uses, geology and origin along with distribution in Pakistan. Included are bentonitic clays of Azad Kashmir (Bhimber, Chander, Chitta Dheri) and some parts of NWFP (Chashma Valley, Karak).

Key words: Clay minerals, Azad Kashmir, NWFP.

A/208. Ahmad, Z., 1995. Base metal deposits of Azad Kashmir, Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 26-27.

Base metal sulphide mineralization in Azad Kashmir is described from two main mineable deposits: one at Treri (lat. 34° 26' 48"N; long. 73° 43' 10"E) and the other at Lamnian (lat. 34° 14' 19"N; long. 73° 46' 52"E). Both occur in the Panjal Sequence which is developed along the eastern syntaxial limb of the Azad Kashmir Himalayas.

Various descriptive and genetic attributes of the lead-zinc sulphide ore deposits of Treri area correspond to those of the Mississippi Valley type (MVT) deposits. The deposit formed as a stratabound Pb-Zn ore deposit in the shallow-water deposited platform carbonates of Triassic age by epigenetic crystallization from solutions evolved in the sedimentary basin. The process involved filling of preexisting open spaces as well as replacement of lithified carbonates. Upper part of the deposit also involved ponding beneath an impermeable shale cap. The solutions were not derived from high heat-producing igneous bodies, but from the dewatering of associated shale especially the black carbonaceous shale. The incursion of saline warm brines carrying Pb-Zn-Cu-Fe from deeper shale basin to its margins and further into the fracture system in dolomite may have occurred by gravitational flow, or by stratafugic dewatering by compaction or by episodic excess pore pressure. The sulphides precipitated by reduction of sulphate in the formation fluids with concomitant recrystallization of coarse calcite observed in the deposit. Unlike most MVT deposits, the Treri deposit is not associated with barite or fluorite mineralization.

Key words: Base metal, Azad Kashmir.

A/209. Ahmad, Z., Alam, G.S., Khan, R.N., Hussain, A., Khattak, A. K., Saleemi, B. A., Khan, R., Ahmad, S. & Qureshi, S.A., 1976. Investigation of placer mineral deposits in the Indus, Gilgit, Hunza and Chitral Rivers, Pakistan GSP Records 35, 25p.

The placer mineral deposits of parts of the Indus, Gilgit, Hunza and Chitral rivers of Pakistan were collected by spot sampling and analyzed. A few high terrace gravel deposits were also sampled. A measured volume of sand and gravel was washed and whatever gold was recovered from any sampling site was calculated as oz/l. ton for that site. The gold contents of the alluvium deposits, as determined during the reconnaissance survey, are low. In the upper Indus Valley, between Thore and Sasi in Gilgit Agency range between the lowest of 0.0004 Oz/l. ton to the highest of 0.011 oz/l. ton. On the high side, there is only one exception; one sample from a high terrace in the Bunji-Jaglot area was found to contain 0.05 Oz/l. ton of gold. Among the lower Indus Valley deposits, the lowest and highest gold contents range between 0.002 Oz/l. ton and 0.014 Oz/l. ton, and in the Chitral and Mastuj Valleys, the same are 0.0003 and 0.0108 oz/l. ton, respectively. A few deposits are being recommended for detailed study to see if any portion of them contain values higher than the ones recorded during this survey.

Key words: Placer Minerals, Indus, Gilgit, Hunza, Chitral.

A/210. Ahmad, Z. & Bilgrami, S.A., 1987. Chromite deposits and ophiolites of Pakistan. In: Stowe, C.W. (Ed.), Evolution of Chromium Ore Deposits. Von Nostrand Reinhold Co., New York, 238-264.

Key words: Mineral Deposits (chromite), Ophiolites.

A/211. Ahmad, Z., Hussain, F., Iqbal, M.W.A., & Saleem, M., 1980. Bibliography of the geology of the Northern Pakistan. GSP Records, 48, 37p.

This is a geological bibliography of northern Pakistan. The references in this document were included in the Geological Bibliography of Pakistan by Khan and Khan, 2002.

Key words: Bibliography, North Pakistan.

A/212. Ahmad, Z. & Khan, M.Y., 1980. Geology of Barwa quadrangle, N.W.F.P., Pakistan. GSP, Record 41, 16p.

Key words: Barwa, NWFP.

A/213. Ahmad, Z., Rehman, H. & Sheikh, M.A., 1991. Limestone and dolomite. GSP, Mineral Information Release 8.

Key words: Limestone, dolomite.

A/214. Ahmad, Z. & Siddiqi, R.A. (Eds.), 1991. Minerals and Rocks for Industry. GSP, Quetta, Volume 1.

This (and the following two accounts) are a series of three volumes, published in successive years. These accounts give a detail of the minerals and rocks used in the industries.

Key words: Industrial minerals and rocks.

A/215. Ahmad, Z. & Siddiqi, R.A. (Eds.), 1992. Minerals and Rocks for Industry. GSP, Quetta, Volume II, 325p. GSP Special Publication, 326–609.

Key words: Industrial minerals and rocks.

A/216. Ahmad, Z. & Siddiqi, R.A. (Eds.), 1993. Minerals and Rocks for Industry. GSP, Quetta, Volume III. GSP Special Publications, 610–802.

Key words: Industrial minerals and rocks.

A/217. Ahmad, Z.H. 1987-89. Geology, petrography and structure of Harno area District Abbottabad. M.Sc. Thesis. University of Azas Jammu & Kashmir.

A comprehensive geological study of Harno area (70 sq km), a northeastern section of the Attock Hazara Belt, including geological mapping 1:9434 is presented. In early Jurassic to Early Eocene shelf sedimentary sequences overlie metamorphosed Hazara slates. Possible depositional environments of various stratigraphic units interpreted on the basis of petrographic study. The area has suffered a 4 phase deformation. The first phase related to metamorphism of Hazara slates, the next two to the NE-SW trending structures and the fourth and final phase related to gentle NW-SE cross folds produced during formation of Hazara Kashmir syntaxis. Asymmetric to overturned tight to isoclinal folds and high angle dip slip strike faults of both normal and reverse type are related to the second and third phase of deformation. A chapter on the economic geologic potential of the area is also included.

Key words: Petrography, Structure, Abbottabad.

A/218. Ahmed, A., 1959. Salt Range, Potwar, Hazara and Swat. M.Sc. Thesis, Punjab University, Lahore.

Key words: Salt Range, Potwar, Hazara, Swat.

A/219. Ahmed, A., 1986. Geochemical characterization of the upper crust from southern Malakand Agency, Pakistan. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, p.3.

Whole rock major and trace element contents of extensive Proterozoic crystalline schists of the southern Malakand Agency and adjacent regions have been determined. The chemistry and mineralogy of samples, consistent with a sedimentary origin, display protolith variations. Chondrite normalized rare earth element 'petterns' of all the samples show very steep LREE enriched gradients with LaN /YbN ranging from 11.311 to 119.536. All analyzed samples exhibit negative Eu anomalies which may be due to mixing of various source lithologies during sedimentation. The patterns are comparable to that of average post-Archean upper crust except the higher PEE contents of some samples.

Key words: Geochemistry, Malakand Agency.

A/220. Ahmed, A. 1989. Shallow seismic reflection investigation for determination of seismic velocities on exposed rock units S/W Margala Pass and Thatta Khalil area, District Rawalpindi. M.Sc. Thesis Quaid-i-Azam University, Islamabad.

The seismic velocities are determined on the exposed rock units in the area lying between Margalla Pass and Thatta Khalil, near Taxila in Rawalpindi District. These lithologies are limestone, sandstone and conglomerate. The experiment was carried out on sixteen points by laying spreads of varying length of 65 meters and 55 meters by using OYO, McSeis-1500 system. A 10 lbs hammer was used as energy source. The data was processed by computer package "Simple refraction" H.P. model 216. The results show that the seismic velocity on limestone of weathered layer ranges from 590 m/s to 1250 m/s and corresponding (average) thickness varies from 1.5m to 2m, sub-weathered layer ranges from 1900 m/s to 2910m/s and its thickness varies between 4.1m to 8m and the 3rd-layer velocities are 3200 m/s to 4400 m/s. The seismic velocity on sandstone, of surface layer ranges from 850 m/s to 1580 m/s and the (average) thickness varies from 4.4m to 7.2m. The velocity of 2nd-layer ranging from 2340m/s to 2900 m/s, could be of sandstone of Murree Formation in the area, and the seismic velocity of surface layer on conglomerate.

Key words: Seismicity, Margala pass, Rawalpindi.

A/221. Ahmed, A., Mateen, A., Rogers, G., Chaudhry, M.N. & Butt, K.A., 1997. Rb-Sr geochronology of the Lower Swat granite gneiss, NW Himalaya, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.6.

The regionally metamorphosed granites forming several plutons and loop-shaped bodies within the Pacha Formation and designated as "the Lower Swat Granite Gneiss", have been exposed in the Northern Buner district, Mingora and Manglaur areas. The augen gneisses were previously correlated to the Mansehra granites of Hazara (Jan et al 1981, Shams 1983) and were believed to represent the granitoid magmatism related to the crustal evolution in the region during the Late Precambrian to Cambrian periods (Le Fort et al 1980). Some authors assigned Lower Cambrian age and have argued that these granite gneisses (e.g. Hum Granite Gneiss) occurred in different tectonostratigraphic framework, being emplaced in the Swat Higher Himalayan tectonic block between MMT and MCT as part of crystalline basement (Chaudhry et al 1992). Rival models concerning the geology of the Lower Swat area predict that the granite gneisses are either Precambrian or Paleozoic in age. In order to test these rival hypotheses a Rb-Sr whole-rock geochronological study of two sets of granite gneiss bodies has been undertaken. On the basis of existing major and trace element data, samples were selected which covered the compositional range in order to obtain a wide variation in Rb/Sr ratio. Five samples from Karaker area (Hum Granite Gneiss) gave an isochron age of 260 ± 52 with an initial $87\text{Sr}/86\text{Sr}$ ratio of 0.709 ± 10 . While the second set of representative samples from Mura Kandao, Prona (Saidu) and Manglaur yielded age of 285 ± 8 Ma with initial $87\text{Sr}/86\text{Sr}$ ratio of 0.7093 ± 7 . The results obtained indicate that none of the studied granites are Precambrian or Cambrian in age, thus negating the views of Le Fort et al (1980). The Mura -Prona -Manglaur granite gneisses gave the best fit age of 285 ± 8 Ma is Lower Permian. The age estimates of Hum granite gneiss could be the same as it shows considerable scatter of the data. The geochronological history of the Swat Granite Gneiss is discussed in context with the petrogenetic evolution of Permo-Carboniferous alkaline rocks from Buner Swat (e.g. 300 Ma Koga alkaline-carbonatite

complex). The granites are suggested to be related to the bimodal magmas of Eastern Australia and Europe emplaced in the India -Australia rift zone along the Tethyan margin.

Key words: Geochronology, granite gneisses, Buner, Swat.

A/222. Ahmed, B., 1988. Reservoir seismicity of Tarbela Dam. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 64p.

Tarbela reservoir located in a seismically active region of previously reported basement faults like IKSZ and HLSZ, and surficial faults like Punjal-Tarnawal fault and Hazara thrust system. The present study reveals that the presence of reservoir has caused induced seismicity to pad up the tectonic seismicity of the region. Initial period (1975-1979) energy release or seismic activity gradually decreases in middle of the period (1980-82) is increased and reached a maximum position. The energy release patterns over 8 years (1975-1982) period are largely uncorrelated with the cyclic fluctuation of reservoir. Whereas in the second cycle (1981- 1986) the pattern of reservoir fluctuation and energy release are not so widely uncorrelated. But energy release related with the immediate region of 10 km distance discloses a mild correlation between the patterns of energy release and lake fluctuations during 1981 to 1984 after which the energy release (1984- to 1986) is increased prominently without maintaining relationship with the reservoir fluctuation. As a result the reservoir fluctuation apparently has negative relations with energy release. However, within an immediate region of 10 Km distance or less positive relations may exist. The analysis of the region lying in 10 km radius in short-term changes reveals that a subtle relationship exists. Therefore, using an expanded area and the located earthquake epicentres occurring in a half cycle (below and above average water level of reservoir) in a specific time give very important results, i.e. seismicity related with water fluctuation is increasing (when water below average level) with the passage of time.

Key words: Seismicity, dams, Tarbela.

A/223. Ahmed, C.I., 1998-99. Geological mapping of Rawalpindi-Sihala (Islamabad) area with special emphasis on engineering geological impacts on quality of ground and surface water (Soan River Basin) Rawalpindi-Islamabad, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 91p.

About 105 sq. km of Rawalpindi-Sihala area has been mapped on survey of Pakistan toposheet No. 43-J/2 on a scale of 1:12500. The investigated area lies in the Soan basin. There are two main available sources of water, wells and river water. The physio-chemical parameters have been investigated for ground and surface water (Soan River Basin). The quality of water is going on increasing and it is going on for beyond the limits established for standards by AEPA, WHO etc. Physiochemically the area is high risky. Chemically the quality of water is risky. The water quality is chemically beyond the safe limits in the upstream areas like upper Sihala area where as its quality is highly risky at Soan Bridge area and Morgah Town area. The test results show that the quality of the investigated ground and surface water is of sodium bicarbonate type.

Key words: Engineering geology, ground water, Soan River, Rawalpindi.

A/224. Ahmed, Ch.I., 1996. Combined geophysical and hydrogeological studies to delineate the water bearing aquifers in Q.A.U. Housing Scheme. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 85p.

Key words: Geophysics, Hydrogeology, Ground water, Islamabad.

A/225. Ahmed, F., 1997-98. Structure, stratigraphy, micropaleontology and petrography of Jabri-Bodla areas District Haripur & Abbottabad Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 78p.

The Jabri-Bodla area lies in the Attock-Hazara fold-and-thrust belt of the northwestern Himalaya of Pakistan. Precambrian to Cenozoic sedimentary rocks are folded and imbricated during the Tertiary-Himalayan collision.

The oldest exposed stratigraphic unit is the Precambrian Hazara Formation. The formation is composed of slates, shales and phyllites. The presence of ripple marks and graded bedding shows that the Formation is deposited in shallow water turbidity environments. The Middle Jurassic Samana Suk Formation, Late Jurassic to Early Cretaceous Chichali Formation and Early Cretaceous Lumshiwal Formation were deposited in shallow marine conditions. The late Cretaceous Kawagarh Formation was deposited in deep to shallow water shelf environment.

The late Cretaceous to Early Paleocene uplift in the area caused the regression of the Tethyan Sea. The Tethyan regression initiated the deposition of ferruginous sandstone of the Hangu Formation.

The lower Tertiary sequence of Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margala Hill Limestone and Early to Middle Eocene Chorgali formation mark the complete cycle of transgression and regression of the Tethyan Ocean. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockharia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show the tropical sub-tropical open sea upper slope to outer shelf environments.

The Paleocene-Eocene boundary cannot be marked on the basis of microfossils in the area because the Patala Formation lacks microfossils. However, the tentative Paleocene-Eocene boundary between the Patala Formation and the Margala Hill Limestone can be marked at the base of Margala Hill Limestone on the basis of first appearance of Early Eocene microfossils.

Key words: Structure, Stratigraphy, Micropaleontology, Petrography, Abbottabad, Hazara.

A/226. Ahmed, G., 1992-94. Lithostructural mapping and geology of the Sirgah and microfacies study of the Cretaceous Kawagarh Formation of Jabri Area, Hazara, Northwest Himalaya. M.Sc. Thesis, Punjab University, Lahore, 153p.

A comprehensive study of Geology and structure of the area around Dhamtaur and Sirgah is presented. There is also a special section on the sedimentology of Kawagarh Formation of Jabri area, some distance to the south of Dhamtaur area. Geological mapping at the scale (1:10,000) is presented. The lithostratigraphic units range from Precambrian Hazara Slate basement to the Paleocene Patala Formation. Structurally the area comprises NE-SW trending double plunging/cylindrical folds with a general vergence to the Southeast. The folded sequence has been disturbed by a series of reverse faults. A small number of normal faults also exist. Faulting is dip slip to oblique slip and in general involves a maximum displacement of few hundred meters. Apart from the regular fault, decoupling is frequently noted at the formational boundaries leading to the slip and discontinuity of thin marker horizons.

The Kawagarh Formation of Jabri is divided into three internal units and twenty-one microfacies for the first time. It is basically a transgressive unit deposited during Cretaceous global transgression. The maximum depth of the sea at that time was about 250 meters. On the basis of planktonic fossils the age of the unit ranges from upper Coniacian to lower Campanian.

Key words: Structure, Cretaceous, Kawagarh formation, Hazara.

A/227. Ahmed, I., 1986-88. The geology and petrology of Chilas ultramafics complex in the vicinity of Chilas (District Diamar) with special emphasis on geology of the area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 113p.

The project area covers about 368 sq. Km. located in the vicinity of Chilas, District Diamar. The work has involved geological mapping of the area on a scale of 1:50,000. This thesis deals with the geology, petrography and petrogenesis of the Chilas complex and adjacent southern rock units. The possible relation of Chilas complex with the southern Jijal complex has also been discussed.

The geological sequence of the area consists of metadiorite rocks of the Chilas complex and granodiorite. The rocks of the Chilas complex are divided into two main associations, the ultramafic-anorthosite association and the main norite/gabbro-norite association. Both the associations represent lower and upper cumulates respectively and are in a complicated contact possibly due to syndepositional folding-and faulting. Diorite is the most evolved unit of the Chilas complex.

Field evidences suggest that Chilas complex was intruded into an old pluton, the metadiorite which was included in Kamila amphibolite by Coward (1982). The relationship of Jijal with Kamila amphibolite also shows that the Jijal complex was accommodated in the rocks represented by Kamila amphibolites, suggesting an older age of Kamila rocks than Chilas and Jijal complexes.

The Chilas complex is unmetamorphosed and is present in an anticlinal position with ultramafics chiefly restricted to the core of the anticline. The ultramafics are overlain by more evolved rocks i.e. gabbro-norite association and diorite capped on both limbs by metadiorite roof rock. On the southern limb, the metadiorite roof rock unit is intruded by a granodiorite pluton which seems to be younger in age than the Chilas complex.

Key words: Petrology, Ultramafics, Chilas Complex, Diamir.

A/228. Ahmed, I., 1991. Shallow seismic refraction survey to establish velocity-lithology relationship and to trace the nature of the refractor near Kuri village District Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 38p.

Key words: Geophysics, lithology, Islamabad.

A/229. Ahmed, I., 2000. Fault plane solution studies of N-W Himalayan fold and thrust belt for the period 1992-1998. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 27p.

Key words: Structural geology, Himalayan fold and thrust belt.

A/230. Ahmed, M., 1959-61. Geology of the Murree and Abbottabad Areas. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Murree, Abbottabad.

A/231. Ahmed, M., 1965. Marble in Pakistan. GSP Records 17(1), 12p.

Key words: Marble.

A/232. Ahmed, M., 1979. Petrology and Economic Geology of Shangla Par Alpurai area. (Toposheet No, 43B/9; Scale 1:50,000), with special emphasis on ultrabasics. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, ultrabasics, Shangla, Alpurai, Swat.

A/233. Ahmed, M., 1989. Seismicity of Tarbela region. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 91p.

Nine year (1977-86) computerized earthquake data of magnitude range 3 to 5 on Richter scale when plotted on two maps with respective hypocentral depths less than 10 km and more than 10 km, gave very interesting results.

The map (fig. 5.1) showing seismic events (with hypocentral depth exceeding 10 km) shows that besides IKSZ and HLSZ, there could be a third basement structure parallel to them.

The other map (fig. 5.2) having seismic events of hypocentral depth range less than 10 km shows that the shallow seismicity is more scattered and can also be associated with the surface structures such as Darband fault, Punjal fault and Main Mantle Thrust. In this case it indicates that Darband/Thakot fault and Punjal fault are active in the north at a considerable distance from Tarbela Dam. In Tarbela region their activity is minor one, however, it may increase in future if southwards migration is believed to be in progress.

Key words: Seismicity, Tarbela.

A/234. Ahmed, M., Ali, K.S.S., Khan, B., Shah, M.A. & Ullah, I., 1969. The Geology of the Warsak area, Peshawar, West Pakistan. Geological Bulletin, University of Peshawar 4, 44-78.

The Warsak Area, Peshawar, West Pakistan, has been geologically mapped and the petrography of the area described in detail. The area consists of a series of metasediments of the greenschist facies (slates, phyllites, mica schists, garnet schists, hornblende schists, calcareous schists and marbles), which have been divided into a lower,

Middle and Upper Series. On the eastern side the metasediments disappear under the alluvium of the Peshawar plain. They range from Siluro-Devonian of Upper Paleozoic in age, and are intruded by sills of metagabbro and metadolerite (? Cretaceous), porphyritic microgranites (?Upper Cretaceous to Lower Tertiary) and the Warsak alkaline granite (? Lower Tertiary). The chemistry of alkaline nature of the granites (which contain aegirine, riebeckite and astrophyllite) is briefly discussed. The structure of the area is shown to be a northwards plunging syncline, faulted on the east on the northern side of the Kabul River. The joint patterns and other structural features are described, and the economic geology of the area discussed.

Key words: Warsak, Peshawar.

A/235. Ahmed, M. & Javed, M., 1992. Seismic risk evaluation for northern Pakistan using probabilistic approach. Abstracts, First South Asia Geological Congress, Islamabad, p.2.

The instrumental seismic data for Northern Pakistan recorded by world-wide seismological network during the current century was used to evaluate the seismic hazard through the probabilistic approach of seismic risk evaluation. For this purpose, seismic data was collected from various International and local agencies and a composite list of earthquakes was made. From this list, frequency-magnitude relationship for the area was developed and 'a' and 'b' parameter determined. A statistical analysis was performed using the recurrence relationship developed above and the popular attenuation law of Joyner & Boore (1981), horizontal ground acceleration for various probabilities of exceedance during the life time of a project were calculated and the results presented in the paper.

Key words: Seismicity, Northern Pakistan.

A/236. Ahmed, M.K., 1989-90. Petrology and Mineralogy of the Area (Gokdarra-Ghaligai) District Swat. M.Sc. Thesis, Punjab University, Lahore, 83p.

The detailed geological map of the project area has been prepared. The project area has been mapped on a scale 1"=12,500". This thesis consists of two sections. Section No.1 deals with the general geology of the project area. Introduction, Physiography, Structural Geology and Tectonics and the lithologic units of the project area have been discussed in this part. In Section No.2, Petrography, Chemical analysis, Petrogenesis, Discussion on Petrogenesis, Economic Geology and some thing new one (Dolomite/Wollastonite Skarn) in the project area is discussed. The project area is consisting upon the metasedimentary and metamorphic rocks, which lie in the Higher Himalaya Crystalline of the MMT Zone.

Key words: Petrology, petrography, Swat

A/237. Ahmed, M.N., 1992. Gravity modeling of bed rock in Ghagriot area, Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 33p.

Key words: Gravity modelling, Islamabad.

A/238. Ahmed, M.U., 1981. Earthquake of 3rd September, 1972 in Gupis-Tangir area, Gilgit Agency, Pakistan. GSP, Information Release 154.

Key words: Earthquake, Gupis, Gilgit.

A/239. Ahmed, N., 1989. Electrical resistivity survey for groundwater investigations in an area between Kot Hathial and Malpur. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 97p.

Key words: Resistivity, Groundwater.

A/240. Ahmed, N., 1990. Shallow seismic refraction survey to map the low velocity zone around the Minsa Kaswal (District Rawalpindi). M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 47p.

Key words: Seismology, Rawalpindi.

A/241. Ahmed, N., 1996. Shallow seismic refraction survey in Behrain area to delineate faulting in the bedrock. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 23p.

Key words: Seismology, faults, Behrain.

A/242. Ahmed, N., Qaiser, M.A., Alauddin, M. & Amin, M., 1987. Physico-chemical properties of some indigenous clays. Pakistan Journal of Scientific and Industrial Research, 30, 731–734.

Keywords: Clays.

A/243. Ahmed, N., Zareen, A., & Faridullah, 1980. Geology of the Marghazar area, Swat. M.Sc. Thesis. Peshawar University, 98p.

Keywords: Marghazar, Swat.

A/244. Ahmed, S., 1986. Magnetic studies in the Margala and Hazara Ranges. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 85p.

Keywords: Magnetism, Margala, Hazara.

A/245. Ahmed, S., 1989. Shallow seismic reflection investigation for determination of seismic velocities on exposed rock units between Margalla Pass and Thatta Khalil area District Rawalpindi. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 47p.

Keywords: Seismology, Margalla, Rawalpindi.

A/246. Ahmed, S.A., & Jan, A.R. (undated). Detailed mapping, petrology and structure of Gulpato Banda Saoni area (Tehsil Kohistan), District Dir, NWFP, with special emphasis on calcareous quartzites and Chlorite Schist. M.Sc. Thesis. Punjab Univ. Lahore.

Keywords: Mapping, petrology, structure, Kohistan, Dir.

A/247. Ahmed, S.A., Mazhar, F., Sayab, M. & Abbasi, I.A., 2001. Lithofacies, sedimentary cycles and depositional environments of the Miocene-Pliocene, Dhok Pathan Formation, Bannu Basin, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.22.

The molasse sediments of the Miocene-Pliocene Dhok Pathan Formation in the Qubul Khel and Mochimar areas, Bannu basin are studied to work out their origin and depositional setting. The formation has variable thickness in different parts of the basin and is comprised of interbedded siltstone, sandstone and conglomerate in variable proportions. The coarse to fine ratio is 1:3 in the lower part, which changes to 1:5 in the middle and upper part of the formation. Four main lithofacies are recognized in the formation, comprising; a) massive, clast supported conglomerate (Gm), b) trough cross bedded coarse sandstone with hard bands (St), c) parallel bedded fine sandstone (Sh) and d) laminated siltstone/shale (F).

The lithofacies Gm is interpreted to have been deposited in the core of major longitudinal basin associated with wide and shallow braided river system. Lithofacies St and Sh were deposited in the sand flats/bars and channels of a sand rich river system, whereas, the lithofacies F resulted due to vertical accretion in the flood plain. Abundant clast supported exotic conglomerates; pebbly sandstone and common scouring at the base of the sandstone bodies reflect deposition under high-energy conditions usually associated with a trunk braided river system. High ratio of flood

plain sediments in the middle and upper part of the formation is due to gradual shifting of the trunk river from this area and deposition of fines in the flood plain.

Key words: Lithofacies, Miocene, Pliocene, Bannu basin.

A/248. Ahmed, S.M., 1975. Research report on a gravity survey of Gilgit valley. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 109p.

Key words: Gravity, Gilgit.

A/249. Ahmed, S.N., McGann, G.J. & Aizad, T., 1992. Dhurnal oil field, Potwar basin. Abstracts, First South Asia Geological Congress, Islamabad, p.3.

The Dhurnal Oilfield is located 74 kilometers southwest of Islamabad in the Potwar Basin, and was discovered in March, 1984. The total recoverable reserves are estimated at about 50 MMBO.

The field was developed with four producing wells and three water injection wells. Three main reservoirs are present, of Eocene, Paleocene and Permian age. All of the reservoirs are limestone.

The Limestones are extremely tectonically fractured and all production is derived from fractures. The average thickness of these carbonates are 430, 540 and 325 feet respectively. The overlying thick claystones and shale of Murree Formation (Miocene) provided a vertical and lateral seal to the Paleogene and Permian limestones.

The surface expression of the Dhurnal structure is an eastwest trending sinuous syncline. At Eocene level, the field is a WSW- ENE trending anticline with well define axial plunge. The northern and southern flank are bounded by major thrusts. The tectonic history of the Dhurnal structure is complex and resub from a combination of thrust faulting and flexing, modified by later salt flowage. The field has a maximum areal closure of 3325 acres at Eocene level. There are different original oil-water contacts in the Eocene, Paleocene and Permian reservoirs. The field began production in May 1984, reaching a mulmum rate of 19370 BOPD In November. 1989. The present average production is about 13,200 BOPD (3840 dog API) plus 31 MMSCFDP of gas. The cumulative production as of May 31, 1991 was 36.151 MMBO plus 87,658 MMSCF of gas. Cumulative water injection was 44,617 MMBW. Water injection for pressure maintenance was initiated in 1987, about three years after field was brought on stream. The current Injection rate is 30,000 BWPD.

Key words: Oilfields, Dhurnal, Potwar basin.

A/250. Ahmed, W., 1962a. Copper showings near Barwa-Kambat, Dir State. GSP, Mineral Information Circular 7, 11p.

Key words: Copper, Dir.

A/251. Ahmed, W., 1962b. Copper showings in the Usheri region, Dir State. GSP, Mineral Information Circular 8, 14p.

Key words: Copper, Dir.

A/252. Ahmed, W., 1962c. Mica deposit, blue beryl and radioactive rocks of Talash region, Dir State. GSP, Mineral Information 9, 14p.

Key words: Mica, Beryl, Radioactive, Dir.

A/253. Ahmed, W., 1962d. Lal Qila-Manial pyritiferous quartz-sericite-sedierite veins, Dir State. GSP, Mineral Information Circular 10, 9p.

Key words: Pyrite, quartz, Dir.

A/254. Ahmed, W., 1963. Celestite deposits of Pakistan. CENTO Symposium on Industrial Rocks and Mineral, Lahore, Proceedings, 440-445.

Key words: Celestite.

A/255. Ahmed, W. 1965. Preliminary Bibliography and Index of the Geology of Pakistan. GSP Records 12(2).

Key words: Bibliography, Geology.

A/256. Ahmed, W., 1972. Tectonic and environmental study for exploration of mineral resources in Pakistan. GSP, Geonews 11, No.2, 77-82.

Key words: Mineral Resources.

A/257. Ahmed, W. 1981. Metallogenic Framework and Mineral Resources of Pakistan. Geological Survey of Japan, Chika Shigen Chosajo Hokkaido, Sapporo. 261, 47-76.

Key words: Mineral Resources.

A/258. Ahmed, W., Ahmed, K.O., Khan, M.A., Qureshi, Z.I. & Ali, F., 1989. Seismic refraction survey of Tarbela. M. Sc. Thesis, Punjab University, Lahore.

Key words: Seismicity, Tarbela.

A/259. Ahmed, W., & Alam, S., 1992. Geochemistry of saturated hydrocarbon biomarkers in crude oils of Potwar basins, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.3.

The Potwar basin is a productive oil province with reservoir oil present at a number of stratigraphic levels from Cambrian to Miocene. Distribution of sterane and triterpanes was determined to classify and correlate these oils. The samples were analysed at Federal Institute of Geosciences and Natural Resources (BGR), using 30 m fused silica capillary column coated with SE 54 and connected to mass spectrometer operated in the selected ion Monitoring mode. The mass ion fragments /mz 191 and 217 were recorded. Hopane, gammacerane, tricyclic diterpane and three steranes with 27, 28 and 29 carbon atoms are dominant biomarkers. The mass fragmentograms of these biomarkers appears to be similar. There are little variations, which are probably caused by different maturity level and analytical variance. The results indicate that the oil produced from Potwar basin is similar and appears to be genetically related to one family.

Key words: Geochemistry, hydrocarbons, Potwar.

A/260. Ahmed, W., & Alam, S., 2000. Organic geochemistry and source rock characteristics of Salt Range Formation, Potwar Basin. Abstracts, Third South Asia Geological Congress, Lahore, 111-112.

Salt Range Formation which is widely distributed in Salt Range contain, low grade oil shales. These shales are developed in the middle part of the formation and are laterally quite persistent. In some localities, the top of the formation contain high grade shales, which are lenticular in nature and are highly localized.

To assess source rock potential of the formation, 64 outcrops and well samples were collected and analysed for TOC, extraction, pyrolysis vitrinite reflectance, and low temperature carbonization analysis (Fischer Assay).

The results indicated that the formation has best oil source rock potentials. The formation exposed in the eastern Salt Range is extremely rich in organic carbon, TOC up to 30% and has excellent geochemical source rock parameters.

(HI upto 879 and EOM/TOC upto 255). Also the low grade oil shale encountered in west-central and western Salt Range are excellent potential Oil source rocks having TOC 2.5%, HI up to 746 and EOM/TOC up to 204. The organic matter consists predominantly of pre-bitumen and solid bitumen and partly contains major proportions of liptinite. The oil yield of high grade oil shale varied from 15 to 20% of rock weight.

Key words: Geochemistry, hydrocarbons, Potwar.

A/261. Ahmed, W. & Gauhar, S.H., 1986. Plate tectonics, crustal evolution and metallogeny of Pakistan. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 8-9.

A study of the metallogenic zonation of different regions of Pakistan shows a close genetic and temporal relationship with various aspects of crustal dynamics and plate boundary features such as subduction, continental collision, rifting, and emplacement of ophiolites. In the perspective of delineating their exploration potential and priorities, these zones have been further classified into different 'metallotect' belts by combining the plate tectonic environments of each separately discernible geological region with its characteristic metallogenic imprints. Thus besides serving the general purpose of a review article of the state of art on the accumulated knowledge about the evolution of crust in this part of the world, the present paper also attempts to give a brief yet unified synthesis on the mineral potential of Pakistan as interpreted in terms of the current concepts of metallogenesis and plate tectonics.

Based on mineral prognosis and plate tectonic interpretations, a number of new target areas have been identified for initiating scientific exploration. Some of the more important of these include; copper and other base metals in shield protrusions and shield derived sediments in the Punjab and Sind; rifting-related hot spot and brine solutions in the Salt Range and the Punjab Plains for sucking and concentrating metals in early Paleozoic sediments; barite-fluorite associated lead-zinc-silver deposits in shelf sediment~ in parts of Baluchistan and NWFP; porphyry copper and massive sulphides in Chagai and Kohistan regions; epithermal gold in clay altered volcanic rocks in Chagai; Lithium in pegmatites in Chitral and adjoining areas; chromite in northern ophiolites; and tin, tungsten and base metals in porphyries of Chagai and in the magmatic granitoids and their contact Paleozoic carbonate rocks in NWFP and Northern Areas.

Key words: Tectonics, metallogeny.

A/262. Ahmed, W., Gauhar, S.H., & Siddiqui, R.A., 1986. Coal resources of Pakistan. GSP Records, 73, 55p.

Key words: Coal.

A/263. Ahmed, Z., 1977. Electron probe composition of the spinel phases from a lherzolite near Bar Bandai, Swat District, Pakistan. Geological Bulletin, University of Punjab 14, 45-50.

In the light of electron probe scanning photomicrographs, the textural and compositional features of the spinel phases and their surrounding silicates from an alpine type lherzolite body outcropping near Bar Bandai, Swat District, Pakistan, are discussed.

Key words: Mineralogy, spinel, Swat.

A/264. Ahmed, Z., 1978a. Petrology of Taghma area, Swat District, North West Frontier Province, Pakistan. Geological Bulletin, Punjab University 15, 25-31.

Key words: Petrology, Swat.

A/265. Ahmed, Z., 1978b. Geological Investigations of the Chromite Ore Deposits of Malakand Agency Pakistan. Pakistan Science Foundation Project Report, PU/Earth (17) 38p, Lahore.

Key words: Chromite, Malakand.

A/266. Ahmed, Z., 1978c. Chromite from Sakhakot-Qila area, Malakand Agency, Pakistan. *Mineralogical Magazine* 42, 155-157.

Unlike most podiform deposits, the chromite layers in the area show considerable lateral persistence. Chromite grains have always rounded outlines. Cataclastic shattering, healed by serpentine, is frequent. Octahedral cleavage is well developed in most samples. Chemical assay of seven cleaned chromite samples show that they contain 39.06% to 50.66% Cr₂O₃; the MFe ratio varies from 2.06 to 2.53. Plots of the chromites on "Stevens triangular diagram" show that six belong to the "alumina chromite" field and one to the "chromian spinel" field

Key words: Ophiolites, chromite, Sakhakot-Qila, Malakand.

A/267. Ahmed, Z., 1983. Geology and Chromite Deposits of the Sakhakot-Qila, Ultramafic Complex, Pakistan. *Abstracts Ofioliti*, 8 (2), 261–262.

Key words: Chromite, Ultramafics, Malakand.

A/268. Ahmed, Z., 1995. Ore occurrences in the Panjal Sequence in the Chham-Balgiran sector of the Lesser Himalaya, Azad Kashmir, Pakistan. In: Abstract volume, Dissanayake, C.B., Almond, D.C., and Cooray, P.G. (Eds.), Second South Asia Geological Congress, (GEOSAS-II), Colombo, Sri Lanka, p.7.

Consult the following account for further details.

Key words: Mineralization, Panjal, Lesser Himalaya, Azad Kashmir.

A/269. Ahmed, Z., 1997. Ore occurrences in the Panjal Sequence in the Balgiran-Chham transect of the Lesser Himalaya, Azad Kashmir, Pakistan. In: Wijayananda, M.P., Corray, P.G. and Mosley, P. (Eds.), *Geology in South Asia-II. Geological survey & Mines bureau, Sri Lanka*, Professional paper 7, 281-299.

The Panjal Sequence along the eastern syntaxial limb of the Azad Kashmir Himalayas contains base metal deposits at Treri, Lamnian and certain other localities. The Treri deposits are of the Mississippi Valley type. Epithermal galena-rich sulphide ore of the Lamnian area occurs in epigenetic quartz veins in the carbonaceous phyllite. Some of the veins contain albite. Accessory tourmaline occurs extensively in rocks of the Panjal Sequence. The Precambrian augen-gneiss at Reshian resembles a para-gneiss and lacks the skarn mineralization reported by previous workers. The granitic orthogneiss occurs in the Chham area. Whereas at Nauseri the granitic gneiss is migmatitic. The pyrite- and pyrrhotite-rich silicified bodies of the Reshian area seem to be associated with a fault zone, which is traceable towards NW by similar bodies occurring at diverse stratigraphic levels in the Nera, Tara, Nauseri and Bagnad areas, respectively. On the Nera-Kafir Khan hillslope of the Harijala area, such bodies occur in Triassic metasediments above the limestone horizon. South of Tara, in the Panjkot area, such bodies occur at the upper contact of metavolcanics with the Triassic limestone. In the Nauseri area, they occur in the Panjal Thrust contact zone. At Bagnad, the silicified bodies occur within the Precambrian Nauseri gneiss. Another fault is revealed by the different stratigraphic levels of the zone of black, carbonaceous and pyritous with limonitic, gypsiferous and sulphurous weathering patches, and by slicing effects and displacements of strata in the Reshian, Klietar, Treri, Nauseri, Harijala, Tararan and Jabre Saiyidan areas.

Key words: Mineralization, Panjal, Lesser Himalaya, Azad Kashmir.

A/270. Ahmed, Z., 1982. Porphyritic-nodular, nodular and orbicular chrome ores from the Sakhakot-Qila complex, Pakistan, and their chemical variation. *Mineralogical Magazine* 45, 167-178.

A new kind of chromitite texture—a porphyritic nodular texture, found in an alpine-type complex in Pakistan, is described. The chromite from phenocrystic nodules and that from their disseminated chromitite groundmass show comparable trivalent elements and postcumulus to subsolidus Mg-Fe²⁺ variations, which are also recorded from

'normal' nodular ore samples. The nodular ores differ from all other textural types of chromitite from this complex in an unusual, though slight, increase in $\text{Cr}/(\text{Cr}+\text{Al})$ with $\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$ between stratigraphically different deposits, which is caused by magmatic differences. The implications of major element variations in chromites and olivines of nodular chromitites are discussed and a cumulus origin is supported. Temperatures of final chromite-olivine equilibration ranged from 750 to 900 °C the individual nominal values being higher for chromitite with coarser chromite crystals and, or, higher chromite/silicate ratio.

Key words: Chromite, ophiolites, Sakhakot-Qila, Malakand.

A/271. Ahmed, Z., 1983. Geology of chromite deposits of the Sakhakot-Qila Ophiolite, Pakistan. *Ophiolite* 8, 261-262.

Key words: Geology, Ophiolites, Sakhakot-Qila, Malakand.

A/272. Ahmed, Z., 1984. Stratigraphic and textural variations in the chromite composition of the ophiolitic Sakhakot-Qila complex, Pakistan. *Economic Geology* 79, 1334-1359.

The deposits and their host rocks compare well with podiform ores hosted by alpine-type peridotites of ophiolites. Unlike most alpine-type complexes, predominant stratigraphic variations in the chemical composition of chromite exist. The chromite deposits fall in two major zones, the first consisting of three subzones. Regular compositional correlations between the accessory chromites of the host rocks and the associated segregated chromites are drawn, indicating relatively later crystallization of the former. Relict cumulate chromitite textures cover the podiform range and are examined in the light of compositional data. The inequigranular textural varieties probably developed by crystallization of successive crops from magmatic fractionation, with their coarser grained, massive chromite components always being slightly higher in $\text{Mg}/(\text{Mg} + \text{Fe}^{+2})$ than the associated finer grained chromite components. The $\text{Mg}-\text{Fe}^{+2}$ exchange between chromite and silicates seems to start during the cumulus stage and continues during the postcumulus stage, but is reduced to a very small intensity during the subsolidus stage until it ends at about 700 degrees C.

Key words: stratigraphy, chromite, ophiolites, Sakhakot, Malakand.

A/273. Ahmed, Z., 1985a. Ore-mineral composition from galena mines of Thelichi valley, Gilgit Agency, Pakistan. *Acta Mineralogica Pakistanica* 1, 10-16.

Microanalytical work on ore sample from small scale mine developed for galena at Thelichi Valley shows the presence of lead, silver, antimony, and, zinc. Mineralogical aspects are discussed. Mineralization probably occurred from low temperature hydrothermal solutions by fissure filling.

Key words: Ore, Galena, Thelichi, Gilgit.

A/274. Ahmed, Z., 1985b. A new occurrence of uranium-bearing thorium monazite, northern Pakistan. *Acta Mineralogica Pakistanica* 1, 27-33.

A new type of occurrence of uranium- and thorium-bearing monazite is described from a chloritic rock from near Musa Mena in Malakand Agency. The locality is being reported for the first time and may prove an economically viable mining area for uranium, thorium, and rare earth elements such as lanthanum, cerium, and neodymium, in addition to titanium-mineral rutile. Monazite forms euhedral porphyroblasts, which appear zoned and occur along with euhedral rutile in schist of low metamorphic grade. Microprobe analyses of rutile, monazite, apatite and chlorite are presented. The chlorites of monazite-bearing and adjacent monazite-lacking schists are chemically different. Zoned monazite crystals display increased Th and Ca and decreased Ce, Nd, Sm, Gd and Dy towards the rims. This is different from the usual trends.

Key words: Radioactive, Malakand.

A/275. Ahmed, Z., 1985c. Mineral chemistry of small intrusives from Mullabagh area, Kohi Safaid, Kurram Agency, Pakistan. *Acta Mineralogica Pakistanica* 1, 49-63.

Key words: Mineralogy, geochemistry, Kohi Safaid, Kurram Agency.

A/276. Ahmed, Z., 1985d. Petrology of the Niat Gah part of the Thak valley igneous complex, Gilgit Agency, Pakistan. *Acta Mineralogica Pakistanica* 1, 116-117.

Key words: Petrology, Niat Gah, Thak gah, Chilas Complex.

A/277. Ahmed, Z., 1985e. Basic pegmatite from near Chilas Diamir District, Pakistan. *Acta Mineralogica Pakistanica* 1, 118.

Key words: Pegmatite, Chilas.

A/278. Ahmed, Z., 1985f. Mineral microanalytical data on the doleritic dykes from Mansehra-Amb State area, Hazara Division, Pakistan. *Acta Mineralogica Pakistanica* 1, 98-115.

The mineral phases present in a suite of doleritic sills and dykes cutting across the granitic-pelitic metamorphic rocks of Mansehra-Amb State area, have been analyzed by electron microprobe. Doleritic rocks represent a variety of rocks produced by magmatic differentiation, subsequent metamorphism of varying intensity and rock alteration. Plagioclase and biopyroxene compositions exhibit strong variations in different doleritic samples. Sphene, epidote and hydrogrossular, found in small amounts in some samples, may indicate some auto-metasomatism. Magnetic and ilmenite are abundant among opaques and oxidized titanomagnetite is also present. A large part of magnetite formed from pyrite and chalcopyrite.

Key words: Mineralogy, dolerite, Mansehra.

A/279. Ahmed, Z., 1986a. Mineralogy of Proterozoic metamorphites of southern Malakand Agency, Pakistan. *Acta Mineralogica Pakistanica* 2, 24-46.

Mineral assemblages of a variety of lithological samples of the greenschist facies metamorphic rocks that occur widespread in southern Malakand Agency and adjacent areas, have been investigated and chemically analyzed by microprobe. Mineral chemical data is presented in respect of chloritoid, chlorite, muscovite, fuchsite, talc, biotite, spessartine, Mn-bearing garnet, apatite, sphene, ilmenite, monazite and rutile. Data on fuchsite is supplemented by its lattice parameters. Chlorite zone is extensively developed with regional metamorphic chloritoid found in a portion. The chloritoid has low Mg, Mn and inferred Fe^{3+} . It equilibrated with chlorite at a temperature higher than that of the comparable rocks from Turkey. The celadonite and Ti contents in muscovite show progressive increase with metamorphic grade. From under the base of an ophiolite an even higher-grade spessartine-bearing rock is found affected more by higher pressure than by higher temperature. Its chlorite has relatively high MnO and CaO contents. At or near the contact of ophiolitic rocks, evidence of metasomatic and hydrothermal activity is noticed.

Key words: Mineralogy, metamorphism, Malakand.

A/280. Ahmed, Z., 1986b. Ophiolites and chromites deposits of Pakistan. In: *Chromites. UNESCO's IGCP-197 Project, Metallogeny of Ophiolites*. Theophrastus Publications S.A., Ethens, 241-262.

Key words: Chromite, ophiolite.

A/281. Ahmed, Z., 1986c. Ophiolite related mineral resources of Pakistan. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 2-3.

A review of various metallic and non-metallic mineral resources genetically linked to the ophiolitic rocks of Pakistan is presented. Geotectonic and geological features of all the known ophiolitic rocks of Pakistan are summarized. Distribution and characteristics of certain mineral commodities have been outlined and described. Many Pakistani ophiolites lack the upper portions of the ophiolite sequence; others exhibit intimate association of non-ophiolitic and ophiolitic volcanic rocks. Metallic grade chromite is the most widespread of the minerals and forms rich concentrations. Precious gem quality emerald deposits show ophiolitic derivation, probably not observed elsewhere.

Key words: Mineral Resources, ophiolites.

A/282. Ahmed, Z., 1987a. Mineral chemistry of the Sakhakot-Qila ophiolite, Pakistan: Part 1, Monosilicates. *Acta Mineralogica Pakistanica* 3, 26-41.

This paper is the first of a 4-part serial characterization of the mineral chemistry of the Sakhakot-Qila Ophiolite. Monosilicates from this ophiolite include olivine, sphene and garnets. Olivine with a Fe content of 73% to 97% shows variations in Mg and Fe contents related to the primary rock-types, and to the textural components within rock samples. Olivines with the highest Mg and lowest Fe from inclusions in chromite crystals. Olivine grains embaying into the boundaries of chromite crystals are intermediate between such inclusions and discrete grains. Olivines with the highest Fe and lowest Mg are those from the Fe-websterite dyke. Sphene is a late-stage crystallization product found only in metadolerites and plagiogranite differentiates. Its chemical variation is insignificant. Garnets are all metasomatic and present in various type of rodingitic veins and dykes. Grossular is the most common garnet and often coexists with hydrogrossular, or rarely, andraditic grossular. At interfaces of rodingites with the chromitite wall rocks, uvarovite or Cr-rich titanian grossular may develop. The garnet compositions are commensurate with the mother fluids having a seawater source.

Key words: Mineralogy, Ophiolite, Malakand.

A/283. Ahmed, Z., 1987b. Mineral Chemistry of the Sakhakot-Qila complex, Pakistan: Part 2, polysilicates. *Acta Mineralogica Pakistanica* 3, 140-158.

Polysilicates contained in the SQO include enstatite, bronzite, diopside, endiopside, salite, augite, magnesio-anthophyllite and a variety of calcic amphiboles. Their compositions vary mainly with the primary rock types, and too much less extent, with the effects of secondary metasomatic activity. Orthopyroxenes exhibit a relatively restricted range in Fe variation, except for more magnesian inclusions in chromite crystals and more Fe-rich crystals in websterite dykes. Primary Mg-Fe variations in clinopyroxenes are superimposed by the metasomatic Ca-enrichment. The primary amphiboles exhibit a less marked Fe-enrichment, Si-depletion trend with increasing SiO₂ in the rock. This is overshadowed by the secondary tremolite-actinolite formation by the interaction of fracture-controlled SiO₂ rich solutions. Minor element variations in polysilicates are not significant.

Key words: Mineralogy, ophiolite, Malakand.

A/284. Ahmed, Z., 1988a. Bulk-rock chemistry and petrography of the Sakhakot-Qila ophiolite, Pakistan. *Acta Mineralogica Pakistanica* 4, 4-29.

Petrographic observations on the Sakhakot-Qila ophiolitic rocks are supplemented by their characterization in terms of bulk-rock contents of major, trace and rare-earth elements. The thick, mantle-rock sequence exhibits Mg-rich compositions with very small variations. Strong magmatic differentiation is shown by non-cumulate dyke rocks. REE abundance levels progressively increase during the magmatic evolution, maintaining LREE-depleted pattern. The criteria used by Ishiwatari (1985) indicates derivation of this ophiolite after a moderate degree of partial melting of an Iherzolitic mantle.

Key words: petrography, geochemistry, ophiolite, Malakand.

A/285. Ahmed, Z., 1988b. Mineral chemistry of the Sakhakot-Qila ophiolite, Pakistan: Part 3, phyllosilicates. *Acta Mineralogica Pakistanica* 4, 45-64.

Phyllosilicates of the Sakhakot-Qila ophiolite are products of secondary processes and include rock-forming and vein-serpentine, chlorite and clintonite. Serpentine of rock-forming and vein types appear chemically indistinct, and are rich in Mg. Structure of the asbestos chrysotile is 2Mc1. rarely, within samples, earlier serpentines may contain higher SiO₂, MgO and lower FeO, Al₂O₃, NiO, MnO than the later ones. Chlorite shows diversity in mode of occurrence and composition. Rodingites and chromitites often contain “IIb-even” structure type chlorite with b cell dimension varying from 9.18 to 9.24 Å. Chlorite has variable Al, Fe and Mg; and a trend of Fe-enrichment and Mg-depletion is depicted from earlier towards later magmatic differentiates. Clintonite forms in rodingites by localized Al-metasomatism.

Key words: Mineralogy, Ophiolite, Malakand.

A/286. Ahmed, Z., 1988c. Mineral chemistry of the Sakhakot-Qila ophiolite, Pakistan: Part 4, disilicates, tectosilicates and non-silicates. *Acta Mineralogica Pakistanica* 4, 65-80.

The rocks of Sakhakot-Qila ophiolite contain disilicate: clinozoisite and vesuvianite; tectosilicate: quartz and albite; and non-silicates: chromian spine, ilmenite, corundum, perovskite, apatite, nantokite, native Cu and a nickeliferous opaque mineral assemblage comprised of awaruite, pentlandite, heazlewoodite, PGE-rich awaruite, and troilite. In clinozoisite, theoretical pistacite content increases from the lower level towards the higher-level within the metagabbros. The accessory chromite in ultramafic rocks is more ferruginous and less magnesian than the associated ore forming chromite. Both types conform to compositions known from ophiolitic rocks, except the Liguria-type ophiolites. Rodingitizing fluids cause increased Al-activity that is reflected by the presence of corundum: the elevated Cu and Cl concentrations in the fluid are reflected in native Cu, nantokite and chlorapatite; and reaction of rodingitizing fluids with chromite may result in some local perovskite. Serpentinizing fluids form a variety of nickeliferous opaque minerals whose composition depends upon host-rock chemistry.

Key words: Mineralogy, ophiolite, Malakand.

A/287. Ahmed, Z., 1990a. An overview of Pakistani ophiolites. *Science Technology and Development* 9, 31-48.

Key words: Ophiolite.

A/288. Ahmed, Z., 1990b. Geochemical characterization of Proterozoic upper crustal metamorphic terrain of southern Malakand Agency, Pakistan. *Precambrian Research* 46, 189-194.

Proterozoic crystalline schists that have extensive outcrops in the southern Malakand Agency and adjacent regions were sampled from localities west of Dargai town to include lithologically different samples. Their major and trace element chemistry and mineralogy indicate a sedimentary origin, protolith variations, and a passive continental margin tectonic setting. The REE contents indicate considerable mixing of various source lithologies during sedimentation. The samples have high TREE and LREE/HREE compared with the post-Archaeon upper crustal values. The chemical data indicate their derivation from a typical granodioritic upper crust with a large component of K-rich granitic rocks.

Key words: Geochemistry, metamorphism, Malakand.

A/289. Ahmed, Z., 1991. Comparison of the chemistry of ophiolitic pyroxenites with a strongly fractionated dyke of pyroxenite from the Sakhakot-Qila ophiolite, Pakistan. *Chemical Geology* 91, 335-355.

Exceptionally strong fractionation has been found amongst the pyroxenite dykes crosscutting the ultramafic rocks of the Sakhakot-Qila ophiolite, Pakistan. One such dyke, an “Fe-websterite”, is particularly fractionated and anomalously Fe-enriched and Mg-depleted. This is supported by the data from whole rock analyses of major, trace and rare earth elements, as well as by the mineral chemistry of the constituent chromian spinel, olivine, clinopyroxene, orthopyroxene and magmatic amphibole. Secondary sulphides of the “Fe-websterite” include troilite-

pentlandite instead of the awaruite-hazlewoodite-pentlandite assemblage typical of all the other ultramafic rocks of the host ophiolite. The non-cumulate parent liquid of the magnesian pyroxenites crystallized in an initial episode when the surrounding cumulates were still hot. In a belated second episode, the Fe-websterite may have crystallized in isolated pockets after its differentiation to an extent much greater than that known from most pyroxenite dykes in ophiolites.

Key words: Geochemistry, ophiolite, pyroxene, Malakand.

A/290. Ahmed, Z. & Ahmad, S., 1974. Mineralogy and petrology of spinel lherzolite from Bandai, Swat District, Pakistan. Geological Bulletin, Punjab University 11, 7-14.

Minor ultramafic bodies occur sporadically within the so-called Upper Swat Hornblendic Group (? Precambrian) of northern Pakistan. A spinel lherzolite outcropping near Bandai, Swat, District, Pakistan, has been investigated. It's field relations, textural features and petrography is described. Modal analyses of twelve samples and chemical analysis of one of them are included. Contemporaneous with the crystallization of silicate minerals, a spinel solid solution exsolved into two phases, a non-titaniferous magnetite and a chromehercynite. Ore microscopic features of the spinel phases and their alteration products are described.

Key words: Mineralogy, petrology, spinels, Swat.

A/291. Ahmed, Z. & Ahmad, S., 1975. Garnets from the upper Swat hornblendic group, Swat District, Pakistan. Part 1: Garnets from gneisses and pegmatites. Mineralogical Magazine 40, 53-58.

Chemical analyses and refractive indexes are reported for eleven garnets. They are dominantly consisting of almandine component.

Key words: Garnets, Swat.

A/292. Ahmed, Z. & Bevan, J.C., 1981. Awaruite, iridianawaruite and a new Ru-Os-Ir-Ni-Fe alloy from the Sakhakot-Qila Complex, Malakand Agency, Pakistan. Mineralogical Magazine 44, 225-230.

The authors report the first occurrence of awaruite in Pakistan, in the Sakhakot-Qila ultramafites. Electron-microprobe analysis reveals a considerable variation in the compositions of awaruites from different parts of the complex. The presence of copper in awaruite, in amounts up to 5 atomic percent, is also reported for the first time. In one chromitite body, an iridian awaruite with up to 27 wt% of iridium occurs in association with 'normal' awaruite and a new Ru-Os-Ir-Ni-Fe alloy. The awaruites are discussed in relation to those from other localities.

Key words: New minerals, ultramafics, Malakand.

A/293. Ahmed, Z. & Chaudhry, M.N., 1976. Geology of Babusar area, Diamir District, Gilgit, Pakistan. Geological Bulletin, University of Punjab 12, 67-78.

A geological map of 67.4-km² area near Babusar, Gilgit Agency, Pakistan, has been prepared on a scale of 1:63,360. Detailed petrography of various rock units with 20 selected modal analyses is given. Ten chemical analyses are reported. Regional metamorphites of both ortho- and para- type occur in the Babusar area in addition to a small peridotite body. Pelitic, carbonaceous and calcareous schists of upto almandine grade belonging to the Precambrian Salkhala Series lie in the south. Between these and the Thak Valley Igneous Complex to the north are concordantly present meta-igneous rocks of chlorite to almandine grade and a higher grade banded amphibolite. Minor dykes and sills intruding these metasedimentary and meta-igneous rocks, were subjected to amphibolite facies regional metamorphism. A Tertiary alpine peridotite was intruded into the banded amphibolite as a curved L – shaped lensoid body.

Key words: Geology, Babusar, Gilgit.

A/294. Ahmed, Z. & Hall, A., 1981. Alteration of chromite from Sakhakot-Qila ultramafics complex, Malakand Agency, Pakistan. *Chemie der Erde* 40, 209-239.

Key words: Chromite, Ultramafics, Malakand.

A/295. Ahmed, Z. & Hall, A., 1982. Nickeliferous opaque minerals associated with chromite alterations in the Sakhakot-Qila complex, Pakistan and their compositional variation. *Lithos* 15, 39-47.

Chemical compositions of the awaruite-heazlewoodite-pentlandite assemblage from the Sakhakot-Qila ultramafic complex, Pakistan, indicate its genesis in highly reducing conditions with f_{O_2} and f_{S_2} much below those yielding nickel sulphide ores. The compositions from various parts of the complex exhibit larger variations than those reported so far from a single complex, and include unusually high Ni contents. Awaruite compositions extend beyond the previously known limit of Ni content, and are unique in containing Cu and not Co as the third constituent after Ni and Fe; with sympathetic relation between Cu and Ni. Previous reports indicate genesis of such minerals by serpentinization only, but the present example links them to chloritization and the formation of 'ferritchromit' as well. Their petrographic distribution is related to that of chromite grains and segregations and not to that of serpentine.

Key words: Chromite, Ultramafics, Malakand.

A/296. Ahmed, Z. & Hall, A., 1984. Petrology and mineralization of the Sakhakot-Qila ophiolite Pakistan. In: Gass, I.G., Lippard, S.J. & Shelton, A.W. (Eds.), *Ophiolites and Oceanic Lithosphere*. Geological Society of London, Special Publication 13, 241-252.

The Sakhakot-Qila complex is an incomplete, dominantly ultramafic ophiolite. The geology, rock and mineral compositions, and occurrences of chromite ore deposits are described. The predominant ultramafic rock types are harzburgite, wehrnite and dunite, and dykes of pyroxenite. The mafic components of the complex are a metamorphosed gabbro and dykes of metadolerite. Postmagmatic alteration is common, and several kinds of rodingite are abundant. They formed by addition of Ca, Al, Cl and Cu and removal of Si, Mg, Fe and Ni from pre-existing rocks, and contain corundum, clintonite and Al-depleted ferritchromite in addition to the more usual minerals such as grossular and vesuvianite. The rodingites appear to have developed independently of serpentinization, probably with the participation of seawater. There are numerous small chromite deposits, varying widely in texture and composition. There is a strong reciprocal Cr-Al variation and lesser Mg-Fe²⁺ variation, partly related to the stratigraphic position of the chromite. Nickeliferous opaque mineral assemblages are well developed.

Key words: Chromite, Petrology, Ultramafics, Malakand.

A/297. Ahmed, Z., Hussain, S. & Awan, A., 1977. Petrology of Thelichi area, Gilgit Agency. *Geological Bulletin, University of Punjab* 14, 27-38.

Near Thelichi, Gilgit Agency, 181 square Kilometer area lying along the newly constructed Karakorum Highway, has been geologically mapped and studied in detail. Detailed petrography including 49 modal analyses of various rocks is presented. Field and microscopic evidences show that there are two major dioritic plutons of Cretaceous-Eocene age, separated by regionally metamorphosed epi- and meso- zonal rocks and a sill of porphyritic diorite. The metamorphics including amphibolites were derived from original sedimentary rocks of different composition. The dioritic rocks lack pyroxenic basic rocks or ultrabasics. They show systematic mineralogical variations due to magmatic differentiation and assimilation. Residual agmatic fractions crystallized the widespread pegmatites and hydrothermal quartz veins. A brief survey of the economic mineral potential of the area is included.

Key words: Petrology, Thalichi, Gilgit.

A/298. Ahmed, Z., Khan, R. & Rauf, A., 1978. Petrology of the Taghma area, Swat District, NWFP, Pakistan. *Geological Bulletin University of Punjab* 15, 25-31.

A detailed geological map of Taghma area, Swat District, N.W.F.P., Pakistan, based on petrographic rock types, is being presented. The field relations and petrography of various rock units is given. Certain genetic features of various rock types and the china clay deposits are discussed briefly.

Key words: Petrology, Swat.

A/299. Ahmed, Z., Navid, M.A., Siddiqui, M.A., & Mirza, K.J., 1983. Field Report on the Geology of Kitiari Shamoza Area, District Swat, North West Frontier Province, with special emphasis on Mineralogy and petrology of Marble, Garnet–Mica–Schist, Graphitic and Green Schist, Carbonates and Amphibolites. M.Sc. Thesis. Punjab University, Lahore.

Key words: Petrology, Marble, Graphite, schists, Swat.

A/300. Ahsan, N., Ahmad, N., Chaudhry, M.N. & Hameed, A., 1999. Petrology and environment of deposition of Lumshiwal Formation, Jhamiri Village, Haripur-Jabrian Road, Hazara Basin, Pakistan. Pakistan Journal of Geology 10 & 11, 9-19.

Key words: Petrology, Deposition, Lumshiwal Formation, Haripur, Hazara.

A/301. Ahsan, N., Ahmad, N., Chaudhry, M.N., Mahmood, T. & Masood, K.R., 1999. Microfacies analysis and environment of deposition of Hangu Formation at Chahla Bandi, Azad Kashmir, NW Lesser Himalayas. Pakistan Journal of Geology 10 & 11, 34-40.

Key words: Microfacies, Deposition, Hangu Formation, Lesser Himalaya, Azad Kashmir.

A/302. Ahsan, N., Ahmad, N., Nadeem, M. & Chaudhry, M.N., 1998. Sedimentological studies of Chorgali Formation at Chahla Bandi on the western limb of Hazara Kashmir Syntaxial Region in Azad Jammu and Kashmir. Pakistan Journal of Geology 8 & 9, 18-28.

Key words: Sedimentology, Chorgali Formation, Hazara-Kashmir-syntaxis, Azad Jammu and Kashmir.

A/303. Ahsan, N., Ahmad, N., Rehman, Z., Chaudhry, M.N., Ghazanfar, M. & Masood, K.R., 1998. Lithofacies studies of Margalla Hill Limestone at Khaira Gali, Murree-Ayubia Road, Hazara Basin, Pakistan. Pakistan Journal of Geology 8 & 9, 7-17.

Key words: Lithofacies, Limestone, Margalla Hills, Hazara.

A/304. Ahsan, N., Baloch, I.H., Chaudhry, M.N., Chaudry, M.M. & Gondal, M.M.I., 2001. Petrography and geotectonic study of Allai River bed aggregate near Banna, NWFP, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 55-56.

The Allai River is an important tributary of the River Indus. The Allai River conflues the Indus near Besham at Kund Syyadian. A number of dams with a total hydroelectric potential of about 1000 MW are likely to be built on the Allai River and its tributaries. Therefore tens of thousands of cubic metre of fine and coarse aggregate will be required for the dam and related civil structures. The gravel and associated sand deposit occurs on the bed of the Allai River and its tributaries near Banna. These deposits were studied petrographically as well as from engineering point of view. The Allai River derives its sediments both from the Indian plate edge as well as from the Indus suture zone and Kohistan island arc. The Indian plate edge in the area is composed of high grade pelites, psammite, S-type Mansehra granite, Susil Gali granite and metasediments belonging to Hazara Group as well as Tethyan sediments which are composed of thick sequence of dolomite, dolomitic limestone, limestone and slates. The suture zone and Kohistan island arc is composed of ultramafics, norites, diorites and amphibolites. Since the Allai River flows near

the boundary of the Indian plate and the Kohistan island arc, therefore the composition of the sand and gravel along the river varies widely. However, we have chosen Banna because of the large quantity of available sand and gravel. All fractions of the coarse aggregate have been studied petrographically. The range in composition of all the sieves is composed of amphibolites (1.3 to 15.6%), diorite (0-33.8%), granite (8.2% to 19.5%), S-type granite gneiss (0-10.7%), granite mylonite (0-7.1%), marble (12.7% to 25.5%), mylonite (0 to 6.8%), pegmatite (0-2.5%), schist (0-20.5%), vein quartz (0-3.7%), norite (0-12.2%) and dunite (0-28.4%). The fine aggregate is composed of granite/granodiorite (1.1% to 24.6%), diorite/tonalite/ amphibolite (0 to 32.8%), quartzite (8.1% to 21.8%), phyllite/slate* (7.2% to 20.4%), greywacke group* (0-0.4%), chert* (0-0.8%), quartz mica schist/gneiss (4.6% to 8.5%), quartzpolygrain quartz (21.1% to 53.6%), feldspar (4.4% to 8.3%), biotite (1.3% to 2%), muscovite (1.4% to 2.4%), amphibole (0.9% to 3.7%), epidote (1.5% to 1.8%), magnetite (1.0% to 3.0%), garnet (1.1% to 1.2%), tourmaline (0-0.1%) and zircon (0-0.3%). The physical properties of the coarse and fine aggregate fulfil the parameters set by BS812: 1965 and ASTM part 4.

Key words: Petrography, tectonics, Allai River, Banna, NWFP.

A/305. Ahsan, N., Baloch, I.H., Chaudhry, M.N. & Majid, C.M., 2000. Strength evaluation of mortars of Lawrencepur, Chenab and Ravi sands and concrete using Lockhart and Margala Hill limestones. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 213-239.

Key words: Concrete, limestone, Lawrencepur, Chenab, Ravi, Margalla.

A/306. Ahsan, N. & Chaudhry, M.N., 1998. Facies and microfacies analysis of Kawagarh Formation of Hazara basin, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 5-6.

The Upper Cretaceous in the Hazara Basin is marked by a transgression which deposited Kawagarh Formation (Latif, 1970, Shah, 1977). At the type locality (lat. 33° 45' 30" N; long. 70° 28' 30" E) the Kawagarh Formation is composed of dark marl, cleaved calcareous shale and nodular argillaceous limestone. The section of the Kawagarh Formation at the type locality is incomplete due to folding and faulting. A study of four sections of Kawagarh Formation of Hazara Basin at Jabri, Changla Gali, Giah and Borian is presented and discussed in the following.

The Kawagarh Formation near Jabri (lat. 33° 55' N; long. 73° 15" E) is composed of light brown to chocolate, whitish grey to light grey and pinkish grey limestones. The basal portion contains thinly laminated dirty to earthy grey and rusty grey marls interlayered with arenaceous limestone (Ahsan et al., 1993). The formation here is divided into eight facies which are composed of glauconitic arenaceous mudstone facies, mixed arenaceous limestone/marl facies, mud to wackestone facies, mixed grainstone to mudstone facies, wackestone to mudstone facies, mixed grainstone to mudstone facies, mudstone facies and mixed dolomitic limestone facies.

The Kawagarh Formation at Changla Gali (lat. 33° 55'30" N; long. 73° 22'30" E) consists of medium to dark grey limestone which we attiers to offwhitish grey, yellowish grey and light grey shades. Earthy grey, rusty to yellowish grey and splintery mart (20.52m thick) is present at the top. However, eight marly horizons intercalated within the limestone also occur. The formation is composed of four facies which are dolomitic arenaceous mudstone facies, packstone-, dolomitic packstone-dolospar and mad facies, mixed wackestone packstone-marl facies and marl facies (Ahsan et al. 1994). The Kawagarh Formation at Giah (lat.34° 6' 30"; long.73° 21'26") is white to light grey, bluish grey and dark grey limestone (Chaudhry et al., 1992). It is composed of four facies which contain mixed dolomitic limestone-dolospar facies, biomicrite facies, sandy biomicrite facies, sandy dolomitic limestone facies, sandy dolospar facies. Towards top it contains coarse grained detrital quartz. The Kawagarh Formation at Boriati (lat. 34° 9' 15" N; long. 73° 17' 15" E) is composed of light to dark grey, light yellowish grey, whitish maroon, reddish maroon to maroonish grey limestone (Ahsan et al. 1993), The formation consists of four facies which contain mixed wackestone-packstone-dolomite facies, mixed mudstone to wackestone facies, mixed mudstone-wackestone facies and mixed mudstone-wackestone-intraclast bearing wackestone-dolostone facies. The sections of the Kawagarh Formation at Jabri 3rd Changla Gali which are located southwards of the Nathiagali Fault contains fair amount of marls and arenaceous limestone. Arenaceous limestone and mars constitute 23.13m of lower part of the Jabh section. The Changla Gali section is composed of alternations of marl and limestone horizons. The sections situated/the north of the Nathia Gali Fault do not contain mads or limestones of significant clastic matter. The sections south of the Nathia Gali Fault which contains fair amount of the marl were deposited at relatively shallower depths of around

80 to 100 m since they lack benthic fauna and contain pelagic foraminifera. However, the sections to north of the Nathia Gali fault which lack marl were deposited towards the very shelf edge at about 200 to 250 m as indicated by presence of *Oligostegina*. Carbon oxygen isotope studies of selected samples show that it was deposited in warm water conditions. It has been established that Indian Plate established its first contact with Kohistan Arc at about 67 ± 2 Ma (Bard et al., 1979). It resulted in uplift of shelf and lateritization of the Kawagarh Formation in Maastrichtian (Chaudhry et al., 1994). The burial of Kawagarh Formation started with deposition of shelf carbonates and shales in Thanetian and continued upto deposition of Murree Formation, The total thickness of sediments is about 3800m. The deposition of Siwaliks is not certain in the studied area. The maximum temperature was about 125°C and pressure reached about 0.9 kb. Non ferroan microcrystalline calcite is penecontemporaneous to the bioclasts. The Mg^{++} bearing solutions from Chichali Formation deposited authigenic dolomite during burial. The ferroan recalcification of dolomite, groundmass and some bioclasts is associated with final uplift and is due to influx of reducing waters. Microstylolites were developed at pressure of about 0.9 kb.

Key words: Facies, Microfacies, Kawagarh Formation, Hazara Basin.

A/307. Ahsan, N. & Chaudhry, M.N., 1999. Sedimentology of Lumshiwal Formation, Attock Hazara fold and thrust belt, NW Lesser Himalayas, Pakistan. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 4-5.

The Middle Cretaceous Lumshiwal Formation (Shah, 1977; Chaudhry et al., 1994, 1997) is a time transgressive unit of the Attock Hazara Fold and Thrust Belt, "AHFTB" (Ghazanfar and Chaudhry, 1990) and Salt - Surghar Ranges of North Western, Pakistan. This unit is composed predominantly of marine glauconitic sandstone in the AHFTB and parts of Salt Range. This unit overlies the Lower Cretaceous marine black shales, which were deposited in an anoxic basin with poor circulation. The deposition of Lumshiwal Formation marks the onset of relatively open marine conditions with better circulation. In the Attock Hazara Fold and Thrust Belt of North Western Pakistan, five sections of this formation were measured and studied in detail for facies, microfacies, provenance, environment of deposition and diagenesis in the north western part of the oil and gas producing Indus Basin. The Lumshiwal Formation is producing gas in the northern part of Punjab Platform.

Facies: It is composed predominantly of glauconitic arenite and quartz wackes. Arenaceous limestones, arenaceous dolomites and oolitic limestones are subordinate to arenites. Shales and sandy shales are rare. They are well to very well sorted, subangular to rounded, compositionally mature and texturally submature to mature. Diastems at places are marked by sub-marine hard grounds. These horizons are cemented with iron oxides and may occasionally contain collophanite or dahalite.

Cement Stratigraphy: Based on detailed textural studies in various sections of the following general cement stratigraphy has been worked out. Glauconite and calcite is present as very early cements. The formation of glauconite itself suggests slow rates of sedimentation (0.96 mm/1000 years, Chaudhry, et al., 1998) and mildly reducing conditions. Other events in younging order includes i) Flint cement, ii) Kaolinite cement, iii) Early calcite cement, iv) Dolomite cement, v) Ferroan calcite cement, vi) Deep burial quartz cement, vii) Late diagenetic kaolinitic cement and viii) Iron oxide cement.

Provenance: Plagioclase, microcline, schorl, indicolite, zircon, epidote and sphene are the accessory minerals. These minerals indicate sialic basement with minor basic component as the ultimate source. The granitoid component was S-type. Thermal aureoles contributed indicolite. The restricted suit of heavy minerals, compositional maturity and shape of grains strongly suggest significant recycling. Lack of high grade metamorphic minerals suggest absence of high grade schists and gneisses. Their fine grain size and palaeocurrent indicators suggests derivation from low relief area on the Indian Shield to the south.

Environment of Deposition: The Lumshiwal Formation of the Attock Hazara Fold and Thrust Belt contains marine fossils like pelecypodes, brachiopods and belemnites. They indicate better circulation conditions during the Tithonian with a depth of less than 80 meters within photoic zone. Slightly reducing conditions, at least below the water sediment interface, are indicated by the ubiquitous presence of organic matter, glauconite and pyrite. Towards the end of Lumshiwal deposition, the shallower subtidal shelf rapidly deepened during the worldwide Cretaceous transgression to receive the Upper Cretaceous pelagic Kawagarh Formation (Ahsan et al., 1993; Ahsan and Chaudhry, 1998) which contains pelagic fauna.

Diagenesis: The textural evidence suggests that glauconite formed from clays during the early stages of burial. The clays were present within the pores of quartz arenites. During these stages, calcite formed which was then replaced by dolomites due to rising of Mg^{++} rich solutions from the underlying clay rich Chichali Formation. Suturing of quartz grains occurred during deep burial and provided silica for cementation. The other silica contributing sources

are clays and siliceous Skeletons of organisms. Iron oxides and some manganese oxides appear to have precipitated due to halmyrolysis. Iron oxides also formed during late diagenetic processes involving circulation of oxygenated meteoric waters through Fe-rich glauconitic sandstones during uplift replace all other minerals.

Key words: Sedimentology, Lumshiwal Formation, Attock Hazara, Lesser Himalaya.

A/308. Ahsan, N. & Chaudhry, M.N., 2000. Characterization of Pakistani oil shales. *Pakistan Journal of Geology* 12 & 13, 13-25.

Key words: Oil shale.

A/309. Ahsan, N., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1993. A preliminary interpretation of microfacies, deposition and diagenesis of Kawagarh Formation at Barian Abbottabad-Nathiagali Road, Hazara, Pakistan. *Geological Bulletin, Punjab University* 28, 30-40.

Key words: Microfacies, deposition, Diagenesis, Kawagarh Formation, Hazara.

A/310. Ahsan, N., Chaudhry, M.N. & Hameed, A., 2001. Petrology and environments of deposition of Lumshiwal Formation, Jhamiri village, Haripur-Jabrian Road, Hazara basin, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 53-54.

The section of Lumshiwal Formation (Shah, 1977) exposed at Jhamiri (Fatmi, 1972) on Haripur-Jabrian Road, Hazara Basin (Chaudhry et al., 1998; Ahsan and Chaudhry 1999) is 21.60m thick. The formation is mainly composed of very fine to coarse-grained sandstone, which is blackish brown, dark greenish grey and mustard brown to reddish grey on surface. At places, fresh surface shows greenish tinge that becomes darker green on wetting. The basal part is coarse grained with large quartz grains. A few maroonish, rusty to brownish thin layers of splintery shale are present.

The formation at Jhameri village contains twelve microfacies. These include: 1) Coarse to medium grained iron oxides and glauconite cemented quartz arenites, 2) Medium grained carbonate and glauconite cemented quartz arenites, 3) Medium grained iron oxides cemented quartz arenites, 4) Fine grained clay and iron oxides cemented quartz arenites, 5) Fine grained glauconite and clay cemented quartz arenites, 6) Fine to medium grained clay and iron oxides cemented quartz arenites, 7) Fine grained clay cemented quartz arenites, 8) Fine to medium grained glauconite cemented quartz arenites, 9) Fine to medium grained glauconite and iron oxides cemented quartz arenites, 10) Fine-grained glauconite and carbonate cemented quartz arenites and, 12) Fine to medium grained glauconite cemented quartz arenite.

Textural parameters show that the arenites of the formation are generally supper mature and are angular to subrounded. The accessory minerals include tourmaline, zircon, rutile, sphene, epidote, muscovite, microcline, albite, quartz, chert, flint, chlorite and biotite. The suite of heavy minerals indicates derivation of sediments from the south from S-type granitic or gneissic source. The formation was deposited in marine middle subtidal zone (Flugel, 1982). The lower contact with Chichali Formation (Chaudhry et al., 1998) and upper contact with Kawagarh Formation (Ahsan and Chaudhry, 1998) is transitional.

Key words: Petrology, Deposition, Lumshiwal Formation, Hazara Basin.

A/311. Ahsan, N., Chaudhry, M.N., Mahmood, T. & Masood, K.R., 2001a. Facies analysis and environment of deposition of Lockhart limestone, Chahla Bandi, Azad Kashmir, northwest Himalayas. Abstracts, 4th Pakistan Geological Congress, Islamabad, 22-23.

The Lockhart Limestone near Chahla Bandi Azad Kashmir (Ghazanfar et al., 1987) is 72.80m thick. It is dark grey on fresh surface and weathers to light grey, pale grey, bluish grey to blackish grey. Lithologically the limestone is divided into nodular limestone and massive to thick-bedded limestone. The limestone contains abundant corals, mollusks, echinoids and rare algae. Prominent benthic foraminifera include *Ranikothalia sindensis*, *Miscellanea miscella*, *Lockhartia haimei*, *Discocyclusa ranikotensis* and *Lockhartia conditi*. The Lockhart limestone at Chahla Bandi is divided into five facies from bottom to top. Mudstone facies (I) contains splintery, very thin bedded, and

clayey limestone with pyrite nodules at the base. In the middle part this facies is composed of argillaceous nodular limestone. Mudstone to wackestone facies (II) composed of thin bedded, nodular (3cm x 3cm) limestone. Wackestone to packstone facies (III) is composed of very well bedded nodular limestone. Most of the nodules (4 cm X 5 cm) are of equal size. It is thin bedded. Mudstone to wackestone facies (IV) contains nodular (20 cm X 10cm) limestone. It is medium bedded. Wackestone to packstone facies (V) is massive and contains rare nodules. The nodules where present are 30 cm x 20 cm in size and there is no clayey/shale partings interbedded in this facies. The upper contact with Patala Formation is transitional, whereas the lower contact with Hangu Formation is unconformable (Shah, 1977; Chaudhry and Ahsan, 1998).

The groundmass of the microfacies is nonferroan calcite. Neomorphism to ferroan calcite is a common phenomenon. Evidences of physical and chemical compaction are present. Dolomite is rare and where present has been recalcified. This lithostratigraphic unit was deposited in subtidal environment probably on a carbonate shelf. The lower most facies is a shallow shelf deposit with some reworked allochems (echinoids). The rest of the formation is a middle subtidal deposit. There is an overall dominance of Acritarchs and Algal spores, with sporadic occurrence of Pteridophytic spores and Angiosperm pollen. Gymnosperm pollens are absent. Mycorrhizal and Fungal spores also exist in all samples.

Key words: Facies, deposition, Lockhart Limestone, Azad Kashmir.

A/312. Ahsan, N., Chaudhry, M.N., Mahmood, T. & Masood, K.R., 2001b. Microfacies and environment of deposition of Hangu Formation at Chahla Bandi, Azad Kashmir, NW Lesser Himalayas. Abstracts, 4th Pakistan Geological Congress, Islamabad, 52-53.

The Hangu Formation at Chahla Bandi, Azad Kashmir, overlies unconformably the Abbottabad Formation, while in the Hazara Basin (Chaudhry et al., 1988; Ahsan and Chaudhry, 1998) it overlies the Kawagarh Formation of Cretaceous age (Shah, 1977; Latif, 1970; Butt, 1989).

The Hangu Formation at Chahla Bandi contains eleven microfacies. These include: 1) Black shale with occasional quartz grains of 1-2mm in size. It weathers to orange to rusty grey. Some streaks of siltstone also occur; 2). Clay/sericite cemented coarse-grained quartz arenite that weathers to rusty brown colour, 3). Clay/sericite, iron oxide cemented medium grained quartz arenite that weathers to rusty brown to light grey. 4). Clay/sericite cemented coarse to medium grained quartz arenite that weathers to off-white, grey and orange, 5). Clay/sericite, iron oxide cemented coarse-grained gritty quartz arenite. Its fresh colour is off-white and it weathers to rusty brown; 6). Clay/sericite cemented coarse-grained quartz arenite that weathers to brownish grey, 7) Clay/sericite cemented medium grained quartz arenite that weathers to orange to black; 8). Clay/sericite and carbonaceous cemented quartz arenite that weathers to maroon colour; 9) Coal with medium grained quartz weathers to dull black; 10) Coal with fine-grained quartz that weathers to dull black; and 11) Bauxitic clay that weathers to rusty orange.

The basal microfacies, black shale/marks the on set of a transgression after a gap of about 505 million years that deposited 227 cm thick black shale (microfacies 1). The microfacies 2 to 7 represent deposition at upper shore face to lower shore face. The microfacies 8 to 10 are coal bearing and represent supratidal marshy depositional regime. The microfacies 11 is residual deposits (70 cm thick) of continental origin that is composed of pisolitic bauxite. It marks an episode of regression at the end of Danian.

Hangu Formation contained poorly preserved palynoflora presenting a case of marginal palynology. Microfossils were fragile, impregnated with high amount of fixed carbon, posing special problems in correct identification. Pollen and spores were equally represented with sporadic occurrence of Dinoflagellates and Acritarchs at certain horizons. Pollen Were of stephanocolpate and polycolpate type whereas spores were predominantly trilete and psilate.

Key words: Facies, Deposition, Hangu Formation, Azad Kashmir.

A/313. Ahsan, N., Chaudhry, M.N. & Majid, C.M., 2000. Mineralogy, engineering properties and alkali aggregate reaction potential of Mira sand, Thakot, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 150-152.

The Kawagarh Formation of Jabri area is divided into eight internal units and thirty- six microfacies for the first time. It is basically a transgressive unit deposited during Cretaceous global transgression. The maximum depth of the sea at that time was about 250m. On the basis of planktonic fossils the age of the unit ranges from Upper Coniacian to Lower Campanian.

Key words: Engineering properties, alkali aggregate, sand, Thakot.

A/314. Ahsan, N., Chaudhry, M.N. & Rehman, Z., 2000. Lithofacies and microfacies studies of Margala Hill Limestone at Khaira Gali, Murree-Ayubia road, Hazara, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.150.

A preliminary sedimentological account of Margala Hill Limestone exposed at Khaira Gali is presented for the first time. This formation is divided into 12 lithofacies units and 63 microfacies. The 2 lithofacies units are separated by 11 marly horizons. These horizons formed as a result of influx of clay into the basin of deposition due to fluvial channel shifting. The entire formation is free of oolites and pellets. Sedimentary structures like ripple marks, cross bedding etc. are deposited in open marine conditions on a carbonate ramp under subtidal conditions. The unit is marked by a number of minor changes in sea level resulting in deposition from upper subtidal to lower subtidal environs. The organic content on the average is about 2%. However, some horizons contain as much as 5% organic content. The porosity (other than fracture porosity) is around 2% but varies from traces to 5%. Fracture porosity on the out crop scale is dominant. Both mechanical and chemical compaction have played an important role in volume reduction.

Key words: Facies, microfacies, Margala Hill, limestone, Khaira Gali, Hazara.

A/315. Ahsan, N., Chaudhry, M.N., Sameeni, S.J. & Ghazanfar, M., 1993. Reconnaissance microfacies studies of Kawagarh Formation, Jabri area, Hazara, Pakistan. Pakistan Journal of Geology 1 & 2, 32-49.

Key words: Microfacies, Kawagarh Formation, Hazara.

A/316. Ahsan, N., Iqbal, M.A. & Chaudhry, M.N., 1994. Deposition and diagenesis of Kawagarh Formation, Changla Gali, Murree - Ayubia road, Hazara, Pakistan. Pakistan Journal of Geology 2, 17-23.

A field and petrographic study of Kawagarh Formation from Changla Gali was carried out in order to work out microfacies, environment of deposition and diagenesis. The formation has been divided into 30 microfacies. They include dolomitic arenaceous mudstone, packstone, dolomitic packstone, dolospar and wackestone with occasional intercalated marls. These microfacies are grouped into four units from bottom to top. CU-1 was laid down on top of Lumshiwal Formation in upper subtidal zone probably at a depth of about 50 to 80m. CU-II marks a rapid transgression and was deposited under pelagic shelf conditions below upper subtidal zone. This was followed by a CU-III, sequence of wackestone to packstone with marly intercalations deposited in lower subtidal zone CU-IV marks on-set of regression culminating into subareal exposure. Post depositional changes such as cementation, neomorphism, compaction, dolomitization and dedolomitization are discussed.

Key words: Deposition, diagenesis, Kawagarh Formation, Murree, Ayubia, Hazara.

A/317. Ahsan, N., Majid, C.M. & Chaudhry, M.N., 1997. Strength evaluation of blends of Lawrencepur, Chenab and Ravi sands with Lockhart and Margalla Limestones for use in concrete. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Concrete is a composite material consisting of inert coarse and fine aggregates bound by a binding medium. The cement water and air combine to form a paste that binds the aggregates together. Pakistan is gifted with enormous quantities of coarse and fine aggregates. The coarse aggregates from the Lockhart Limestone and Margalla Hill Limestone were used with fine aggregates from Lawrencepur, Chenab and Ravi to evaluate their strength properties with ordinary Port land cement. The Lockhart Limestone and Margalla Hill Limestone showed excellent physical and mechanical properties: bulk densities 84 lbs/cft and 86 lbs/cft water absorption 0.8% and 0.6%. Los Angeles abrasion values 24% and 26% impact value 13% and 16% crushing value 25% and 27% and soundness by Na_2SO_4 1.71% and 1.60% respectively. The Lawrencepur, Chenab and Ravi sands were tested and found that the Lawrencepur sand is the best which generally meets the requirement given in BS 882/1965. However the Chenab

sand showed the desired results when mixed with Lawrencepur sand in the proportion of 25-30: 75-70 while the Ravi sand is not good for use in concrete as it is fine and does not come up to the required standards. The coarse and fine aggregates were blended with ordinary Portland cement keeping in view the desired water-cement ratio for acquiring desired strength. The Lockhart Limestone and Margalla Hill Limestone were found excellent coarse aggregates with pure Lawrencepur sand and a blend of Chenab and Lawrencepur sand. They gave high compressive strength (upto 8000 psi). The Ravi sand with its very fine size was not found satisfactory as an individual fine aggregate. It is not an economic deposit when blended with the Lawrencepur sand. The Chenab sand is however economical when blended with Lawrencepur sand.

Key words: Sand, concrete, limestone, Lawrencepur, Chenab, Ravi, Margala.

A/318. Ahsan, A., Naveed, N., Khawaja, A.A. & Chaudhry, M.N., 2001. A preliminary account of facies and determination of Ca, Mg, Sr, Mn, Fe and Na in Kawagarh Formation, Kala Pani, Abbottabad-Thandiani Road, Hazara, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 54-55.

Kawagarh Formation (Shah, 1977; Chaudhry, et al., 1998. Ahsan and Chaudhry, 1998) at Kala Pani is composed of light grey to grey limestone. The formation is generally medium to thick bedded but nodular at the base. The lower contact of the formation is transitional with Lumshiwal Formation (Ahsan and Chaudhry, 1998) and upper contact is unconformable with Hangu Formation. Petrographically it is established that faunal constituents of the formation are composed of planktons and oligosteginids. On the basis of the proportion of these allochems, the formation is divided into planktonic facies, planktonic-oligosteginid facies and oligosteginid-planktonic facies. The planktonic facies constitutes 23.34% of the formation and is composed of 34.48% plank-mudstones, 41.37% plank-wackestones and 24.14% plank-packstones. The planktonic-oligosteginid facies constitutes 60.49% of the formation and contains 17.33% plank-oligo- mudstone, 73.33% plank-oligo- wackestones and 9.34% plank-oligo- packstones. The oligosteginid-planktonic facies is 16.17% of the formation and is composed of 10% oligo-plan -mudstone, 70% oligo-plank-wackestones and 10% oligo-plank-packstones. 20 whole rock samples of the formation were analyzed to determine major (Ca, Mg) and minor (Fe, Sr, Mn and Na) trace elements by atomic absorption spectroscopy using air-acetylene flame. The Ca varies from 19.23% to 39.11% with an average of 33.92%, Mg varies from 0.132% to 1.854% with an average of 0.335%, Mn ranges from 0.319 ppm to 1.723 ppm with an average of 0.929 ppm, Sr varies from 0.715 ppm to 4.213 ppm with an average of 2.975 ppm, Na ranges from 4.7 ppm to 8.5 ppm with an average of 5.969 ppm and Fe varies from 6.11 ppm to 36.11 ppm with an average of 17.244 ppm. Moreover a comparison was made in the estimation of Ca and Na by using flame photometer and atomic absorption spectrophotometer. The values obtained by the two methods, were almost the same.

Key words: Facies, Kawagarh Formation, Abbottabad, Hazara.

A/319. Ahsan, Z., 1981-83. Lithostructural mapping and biostratigraphic study of Burikhel Bandakha Area (Western Salt Range) District Mianwali. M.Sc. Thesis, Punjab University, Lahore, 93p.

Detailed Lithostructural Mapping and Biostratigraphic study of Barikhel- Bandakha Area (Western Salt Range) District Mianwali, has been done at 1:10,000. Area is exclusively a sedimentary terrain. Stratigraphy along with micropaleontology of certain formations is described. In addition to this macrofauna have been described. Lateral extension of limnic permean coal is noted. Tectonic style of the area is described with the help of structural details i.e. study of folds, faults and joints etc.

Key words: Lithostructure, biostratigraphy, Salt Range, Mianwali.

A/320. Ajmal, M., 1987. A research report on groundwater investigations with special emphasis on hydrochemical study of National Park, Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 19p.

Key words: Groundwater, hydrochemistry, national Park, Islamabad.

A/321. Akash, B., 1975. Focal mechanism earthquake of December 28th 1974, North Pakistan. *Journal of Earth and Space Physics* 4, 15-19.

Key words: Earthquakes.

A/322. Akbar, J., 1977-79. Mineralogy Petrology of Udigram Area, District Swat. M.Sc. Thesis, Punjab University, Lahore.

The project area lies in northwestern extension of Himalayas in Pakistan. It is part of edge of the Indian plate at its subduction zone. The project area is partly meta-sedimentary and meta-igneous. It consists of the Lower Swat-Buner Schistose group.

The four major rock units have the following sequence from top to bottom.

Green Schist; Phyllitic Schist; Schistose marble; Amphibolite;

The meta-sedimentary sequence has the following grade chlorite, biotite, garnet, kyanite. The green schist formation at the extreme of the project area and extends northward 35-km to the Shangla area where blueschists are developed proving the fossil trench position. The meta-sedimentary sequence is of Paleozoic age and therefore older than the plate movements which took place during the Cretaceous period of blueschists. Therefore the original metamorphism was older than subduction episode but retrograde metamorphism had occurred during plate subduction.

The green schist belongs to the edge of subduction zone, as it is well known that subduction zone rocks are composed normally of igneous detritus, oceanic floor basalts and basic intrusions mixed with sediments. Therefore, green schist evolved out of such a mixed lithology, predominantly from the basic igneous rocks. The zonation of pressure/temperature is so placed that towards Shangla high temperature-low pressure lithologies were formed, while towards project low temperature-low pressure rocks were formed such as green schist. Under the same action, meta-sedimentary sequence suffered retrograde metamorphism of low temperature and low-pressure type.

Key words: Petrography, petrology, Udigram, Swat

A/323. Akbar, M., 1980-82. Geology and Petrology of Hasis-Gahkoch-Gupis (Gilgit Agency). M.Sc. Thesis, Punjab University, Lahore, 90p.

The project area (HESIS-GUPIS) lies in the Punial-Gupis Valley, District Gilgit, Latitude 30° 4' 32' - 36° 24' 35' and Longitude 73° 25' 0' - 73° 47' 0' has been mapped tectonically. The area is located in the Centre of Karakoram Mountains and represents a part of a cross section through this mighty range. Area is intensely disturbed tectonically being involved in Himalayan Orogeny, which is evident from the strained, crushed and deformed lamellae of the mineral in the rock

Structure found in area is orthotectonic. Following features are present in the project area, which is characteristics of an orthotectonic region. Cleavage is well developed in the project area i.e. slaty cleavage, schistosity, fracture cleavage and crenulation cleavage. Igneous activity is present and it shows a magmatic phase on the origin. Folding of isoclinal nature because of the prevalence of severe stresses. The basin, in which deposition has been taking place, is completely destroyed so it is too difficult to reconstruct the geological history of the area. This is a typical characteristic of an orthotectonic region. The project area is composed mainly of igneous and metasedimentary rocks. Metasedimentary rocks are originally deposited in eugeosynclinal conditions as argillaceous sediments and afterwards.

Key words: Petrology, Gupis, Gilgit.

A/324. Akbar, M., 1981-83. Geological mapping and site investigations of dam site and reservoir area of Basha Dam (Chilas Diamer). M.Sc. Thesis, Punjab University, Lahore, 101p.

The electric power demand of Pakistan is very high and the present generation capabilities of the country are insufficient to cope with the increasing load created by industry, agriculture and domestic consumers. In order to tide over the situation water and power development of Pakistan initially identify thirteen sites on the Indus River upstream of Tarbela upto Skardu, because the drop along Indus plains show attractive locations for hydro power development. To study the potential/plan the development of 13 identified sites and feasibility of one best site first

Canadian Technical Assistant has been arranged. Basha damsite is the site selected by the Canadian Consultant for the feasibility purposes which is located on the Indus river near the village Basha about 45 km downstream of Chilas in Gilgit Agency.

Key words: Mapping, reservoir, Basha, Chilas.

A/325. Akbar, S., 1962. Geology of Upper Batrasi area Mansehra, Hazara. M.Sc. Thesis, Peshawar University, 30p.

Key words: Geology, Batrasi, Mansehra, Hazara.

A/326. Akhtar, A. & Khan, F.G., 1998. Stratigraphy and structure of Reshun area (Chitral) north Pakistan: Implications for construction of small hydel power project. M.Sc. Thesis, University of Peshawar, 70p.

Key words: Stratigraphy, structure, hydel power, Reshun, Chitral.

A/327. Akhtar, J., 1987. Vertical magnetic survey of the lead-zinc deposit in Lahor-Serai area, Besham, N.W.F.P., Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 31p.

Vertical magnetic investigations were carried out (as a part of integrated geophysical survey) to demarcate the lateral subsurface extent of Pb-Zn ore in Lahor-Serai area of Besham. This study shows that strong magnetic anomalies are solely generated by magnetite concentration in carbonate rock units; whereas the magnetic signal over Pb-Zn ore is very weak.

Analyses of magnetic anomalies yielded that, magnetic patterns of low amplitude (i.e. in the range of -500 to +150.0 gammas) can guide ore exploration within a depth range of 10-20 metres at places located along structurally weak zones.

Key words: Magnetism, Lead-Zinc, Lahor, Besham.

A/328. Akhtar, J., & Iqbal, Z., 1979. Geology and petrology of the Udigram Area, District Swat. M.Sc. Thesis. Punjab University. Lahore.

Key words: Geology, Petrology, Udigram, Swat.

A/329. Akhtar, J., & Sakhawat, M., 1991. Magnetic survey around Khabbal area, near Oghi, District Mansehra, NWFP. GSP Information Release 499.

Key words: Magnetism, Khabbal, Oghi, Mansehra.

A/330. Akhtar, M., 1983. Stratigraphy of the Surghar Range. Geological Bulletin, University of Punjab 18, 32-45.

Sedimentary rocks of marine and non-marine origin ranging in age from Permian to Pliocene constitute most of the stratigraphic sequence in the Surghar Range. The sequence comprises 10 lithostratigraphic units with a cumulative thickness of more than 5000 meters. The lithologies consist predominantly of limestone, shale and sandstone with subordinate marl, dolomite and minor interformational conglomerate. Permian-Triassic boundary is marked by a slight lithological break indicating a paraconformity. Cretaceous-Paleocene and Eocene-Miocene sequences are also intervened by unconformities.

Key words: Stratigraphy, Surghar.

A/331. Akhtar, M. 1984-86. The geology and mapping of Muzaffarabad area from Chehla Bandi to Chhattar Kalas with special emphasis on landslide problems along roads. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 64p.

Nature does not supply all the things to man, but merely offers opportunity to secure all things, and a condition where man controls the elements is inestimably superior to a condition where the elements control man.

This field report comprises a complete geological study based on mapping of nearly 100 sq. kms of Muzaffarabad – Chhattar Kalas area. Special emphasis has been put on describing the stratigraphy and landslide problems in the project area. The stratigraphic succession has been established. The rock units present in this area Hazara Formation (Cambrian), Abbottabad Formation (Cambrian), Patala Formation (Paleocene) Margala Hill Limestone (Eocene), Kuldana Formation (Eocene) and Murree Formation (Miocene). The major tectonic features in the proximity are Jhelum fault, Muzaffarabad anticline.

The Muzaffarabad-Kohlala road is the main way of transportation and communication between the Pakistan and Azad Kashmir. A number of huge slides occur on this road which blocks it for hours and sometimes for days. Due to the vital importance of the road it is unbearable. So this field report is prepared with the aim to study the area in detail and to explore the reasons of sliding on this road.

The samples are taken for laboratory tests. The purpose of laboratory test is to evaluate the strength parameters which are responsible for driving and resisting the moment. In this report an attempt is made to explore the reasons of failures in the area as well as economical and adequate remedial measures were suggested.

Key Words: Geology, mapping, landslides, Muzaffarabad.

A/332. Akhtar, M., 1988a. Preliminary bibliography of lower Tertiary rocks of Pakistan. Geological Survey of Pakistan, Information Release 347.

Key Words: Bibliography, Lower Tertiary.

A/333. Akhtar, M., 1988b. Lithological description of type and reference section of Triassic-Cretaceous rocks of Surghar Range. Geological survey of Pakistan, Information Release 346.

Key words: Type Section, stratigraphy, Triassic-Cretaceous, Surghar Range, Trans-Indus Salt Range

A/334. Akhtar, M., & Butt, A.A., 1999a. Microfacies and foraminiferal assemblages from the Early Tertiary rocks of the Kala Chitta Range (Northern Pakistan). *Geologie Mediterranee* 26, 185-201.

Key Words: Microfacies, foraminifera, Tertiary, Kala chitta.

A/335. Akhtar, M., & Butt, A.A., 1999b. Lower Tertiary biostratigraphy of the Kala Chitta Range, northern Pakistan, *Revue de Paleobiologie*, 18(1), 123-146.

Key Words: Biostratigraphy, Tertiary, Kala chitta.

A/336. Akhtar, M., & Masood, T., 1988. Guidebook to the geology of Surghar Range. Geological Survey of Pakistan, Information Release, 341.

The Sur ghar Range is a part of the Trans-Indus Salt Range. This guide book is a useful accompaniment with the paper by Alam (1983) on the range.

Key words: Surghar Range, Trans-Indus Salt Range

A/337. Akhtar, M., & Sarwar, M., 1987. A giant Tetraconodont species from Middle Siwaliks of Dudial, Azad Kashmir, Pakistan. *Kashmir Journal of Geology* 5, 101-104.

A very large-sized tetraconodont maxilla bearing last two molars, roots of the first molar and root impression of the last premolar has been described from the Middle Siwalik beds exposed along the River Puch near Dudial, Azad Kashmir, Pakistan. Its comparison with the known species of the genus has proved it to be a new species. Regarding size, it happened to be the largest of the known tetraconodont. The name, *Tetraconodont dudialensis*, has been proposed for this new species.

Key Words: Conodont, Siwaliks, Dudial, Azad Kashmir.

A/338. Akhtar, M.G., 1984. Integrated geophysical survey along Karakoram Highway between Taglat and Gunar farm. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 123p.

Key Words: Geophysics, Karakoram Highway, Gunar farm.

A/339. Akhtar, M.K., 1968. A report on the geology of Nawansher Giah area, Hazara. M.Sc. Thesis, Punjab University, 86p.

Key words: Geology, Nawansher, Hazara.

A/340. Akhtar, M.K. & Abbas, S.Q., 1988. Investigation for clay deposit in Dandot area, Chakwal District, Punjab. GSP, Information Release 332.

Key words: Clay, Dandot, Chakwal.

A/341. Akhtar, M.K., Abbas, S.Q. & Khan, A.A., 2001. Geological map of Murree (43 G/5, 1206). Geological Survey of Pakistan.

Key words: Geological map, Murree

A/342. Akhtar, M.K. & Cheema, M.R., 1988/89. Distribution and evaluation of fireclay and bauxite deposits of Chhoi-chak Jabbi area, Attock district, Punjab. Geological Survey of Pakistan, Information Release 331.

Key words: Fireclay, bauxite, Attock, Punjab.

A/343. Akhtar, S., 1982-84. Report on geology and structure of Balakot-Kummi Area. M.Sc. Thesis, Punjab University, Lahore, 101p.

The present work constitutes a comprehensive report on the geology of Balakot -Kummi area and is submitted in partial fulfillment of the requirements for the degree of M.Sc. at the University of the Punjab. The report includes a detailed geological map at 1:6,000 of about 65 km. sq. area along with a number of geologic sections and sketches. The various chapters include geomorphology, stratigraphy, structure and tectonics. Stratigraphically, the Balakot-Kummi area includes a number of diverse sedimentary and metamorphic elements ranging in age from Precambrian to Miocene with a fairly large gap in the Mesozoic period. Structurally, the area incorporates part of the core and western limb of the Hazara-Kashmir syntaxis and through it pass the major Murree and Panjal Faults. The Balakot-Muzaffarabad anticline is the major fold overturned and overthrust to the southwest. No major economic mineral deposit was found within the project area, although a lot of material is available as rock crush, aggregate components and building stones.

Key words: Mapping, structure, Balakot.

A/344. Akhtar, S., 2001. 2-D seismic reflection data interpretation of Chak-Naurang area line No. 855-CW-03. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 67p.

Key words: Seismicity, Chak Naurang.

A/345. Akhtar, S.M., 1974. Akora Khattak clays of Nowshera Tehsil. Pakistan Journal of Scientific and Industrial Research 17(4 & 5), 160-162.

Key words: Clay, Nowshera.

A/346. Akhtar, S.M., Alauddin, M. & Khan, A.H., 1972. A note on Sirvik Gol pegmatites, Pakistan. Science and Industry 9(1 & 2).

Key words: Pegmatites.

A/347. Akhtar, S.M., Khan, Z.A., & Khan, A.H., 1970. Dolomite of Ghundai Tarako (34° 13'N, 72° 25' 15"E), Peshawar Division. Pakistan Journal of Scientific and Industrial Research 12, 488-492.

The small hill of Gundai Tarako at Mardan Swat State boarder is mainly composed of marble. High dolomite content was observed in four localities. Composite sample analyses from localities two and four contain 68-95% dolomite, 0.37-11.47% silica and 0.85-0.88% R_2O_3 . Sulphur and phosphorus are either absent or present only in traces. The dolomite from these two localities are of chemical grade and can be used in metallurgical and glass industries.

Key words: Dolomites, Mardan, Swat.

A/348. Akhtar, S.M., & Siddiqi, F.A., 1965. Mineralogy of the alluvial sand of Kabul River near Charsadda. Pakistan Journal of Scientific and Industrial Research 8(4), 245-248.

Key words: Mineralogy, Alluvial Sand, Kabul river, Charsadda.

A/349. Akram, H., 1994. Groundwater contamination study of the Sihala Industrial Triangel area, Kahuta Road with reference to hydrochemical, biochemical and physiochemical analysis. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 56p.

Key words: Groundwater, contamination, Hydrochemical, Biochemical, Sihala, Islamabad.

A/350. Akram, H., Ahmad, M.N. & Yoshida, M., 1996a. Magnetic susceptibility and hysteresis loop properties of Late Quaternary loess-paleosole deposits of Haro River area, Attock, Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 90-93.

Key words: Magnetism, Paleomagnetism, Quaternary Deposits, Haro River, Attock.

A/351. Akram, H., Ahmad, M.N. & Yoshida, M., 1996b. Rock magnetic studies of late Quaternary Loess-paleosol deposits of Haro river area, Attock district, Pakistan. Proceedings of geoscience colloquium, Geoscience labs, GSP, Islamabad, 14, 93-105.

Rock magnetic properties of the loess deposits for 24 samples collected from two different sites of Haro river in the Pakistan area were studied. Magnetic methods such as isothermal remanent magnetisation acquisition experiment and the magnetic analysis indicated the presence of magnetite, accompanied by trace amount of maghemite and goethite. Hysteresis loop parameters show that most of the magnetic grains are of multi domain nature and some of them are of pseudo single domain. The hysteresis loop parameters such as coercive force and ratio of remnant magnetisation to saturation magnetisation increase with the increase of finer $W_{60} < 0.3\mu m$ of the clay percentage, which proves that magnetic methods can be used for grain size differentiation in these loess deposits. Magnetic susceptibility is not high in the case of paleosols as compared to the other loess beds, which shows a very different behavior from weal loess-paleosol sequences in the Chinese Loess Plateau.

Key words: Magnetism, Paleomagnetism, Quaternary Deposits, Haro River, Attock.

A/352. Akram, H. & Yoshida, M., 1997. Ultra-fine magnetite/maghemite and their magnetic granulometry in the Late Pleistocene loess-paleosol deposits, Haro River area, Attock Basin, Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (Eds.), *Paleomagnetism of Collision Belts*. Geoscience Laboratory, GSP, Islamabad, 153-169.

Variation of magnetostratigraphic properties in late Pleistocene (18-130 ka) loess-paleosol sequence of Haro River area, Attock basin, Pakistan were studied. Isothermal remanent magnetization (IRM) acquisition experiment and thermomagnetic analysis indicate that magnetite and maghemite are the major ferromagnetic (ferromagnetic) minerals present in these samples. Hysteresis loop parameters such as coercivity (H_c), remanence coercivity (H_{cr}), coercivity ratio (H_{cr}/M_c), and remanence ratio (M_r/M_s) show that the magnetite/maghemite grains are mostly of pseudo-single domain (PSD) size, while less amount of multi domain (MD) and superparamagnetic (SPM) grains are also present. Anhyseretic remanent magnetization (ARM) and its normalized parameter discloses the relative enrichment of (SD to SPM size) magnetite/maghemite grains in the paleosols as compared to loess deposits, which are considered to be of pedogenic origin. Bilogarithmic plot of saturation isothermal remanent magnetization (SIRM) and volume magnetic susceptibility also shows relative concentration of ultra-fine ferrimagnetic minerals in the paleosols. This magnetostratigraphic data was correlated with the mechanical sedimentological analysis data. The magnetic granulometry is informative to understand the particle-size distribution of natural sediments like in the case of loess-paleosol deposits, particularly for the SPM.

Key words: Magnetism, Pleistocene, Haro River, Attock.

A/353. Akram, M., 1986-88. Geology and structure of Balakot-Garhi Habibullah-Dalola area Kaghan valley District Mansehra, NWFP, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 116p.

This report comprises a complete geological study of nearly 320 sq. km; located between and around Balakot-Garhi Habibullah. In the project area micaceous quartzites, quartz mica schists, garnet mica schists, dolomite, limestone, Sandstones and slates are encountered. A stratigraphic sequence has been worked out. The rocks extend in age from Precambrian to Miocene.

Structurally, the rock, are folded into a number of major structures. The area comprises of major structures like Balakot Anticline, Garhi Habibullah syncline, Muzaffarabad fault and Murree Fault. Micro structures of the project area has also been discussed in detail. Hazara Kashmir syntaxis has a great influence on the stratigraphy, structure, and tectonics of the investigated area. In the field of economic geology a number of deposits including clays, graphite, limestone, feldspar, granites and sandstone have been discussed. This report also includes a petrographic description of the rock units as well as numerous sketch section and photographs, illustrating the geology of the area.

Key words: Geology, structure, Kaghan, Mansehra.

A/354. Akram, M., 1988. Crustal studies along a single total intensity magnetic profile between Jhelum and Nowshera. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 46p.

Key words: Magnetic profile, Jhelum, Nowshera.

A/355. Alam, G.S. & Cheema, M.R., 1974. Hunza spinel (ruby spinel) deposits, Hunza state, Gilgit Agency, Pakistan. Geological Survey of Pakistan. Information Release 77.

Key words: Spinel, ruby, Hunza.

A/356. Alam, G.S., Hussain, A. & Asrarullah, 1976. The mapping of Warcha and Kalabagh salt mines and potash investigations, Punjab, Pakistan. Geological Survey of Pakistan, Records 40, 14p.

Key words: Mapping, Salt Mines, Potash, Warcha, Kalabagh, Punjab.

A/357. Alam, G.S., Jaleel, A. & Masood, T., 1989. Report on evaluation of limestone and clay deposits at Wah, Punjab, Pakistan. Geological Survey of Pakistan, Information Release 403.

Key words: Economic geology, limestone, clay, Attock

A/358. Alam, G.S., Kausar, A.B. & Jawed, S., 1986. Heavy mineral analyses and petrography of Chinji and Nagri formation of Salt Range-Potwar areas, Punjab, Pakistan. *Acta Mineralogica Pakistanica* 2, 83-92.

The paper describes the lithology and mineral contents of Chinji and Nagri Formations of late Tertiary age, from sections located in the Salt Range and Potwar. Minerals in the heavier than bromoform fractions of sandstone include amphibole, chlorite, tourmaline, garnet, epidote, magnetite and pyrite. The sandstone samples are also chemically analyzed for major and certain trace element contents.

Key words: Mineralogy, petrography, heavy minerals, Chinji Formation, Nagri Formation, Salt Range.

A/359. Alam, I., 2000. Structure and stratigraphy of the area south of Kohat, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 74p.

Key words: Stratigraphy, structure, Kohat.

A/360. Alam, I., Ghauri, A.A.K. & Ahmad, S., 2001. Structural and tectonic setup of the area south west of Kohat NWFP, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.32.

The study describes the stratigraphy and structural setting of the 250-km² areas constituting a part of Kohat foreland basin and located southwest of Kohat city. No rocks older than Eocene are exposed. The outcropping rocks consist of Panoba shale, Sheikhan Formation, Kuldana Formation and Kohat Formation of Eocene age, unconformably overlain by the Murree and Kamlial Formations of the Rawalpindi Group. The imprints of the ongoing Himalayan tectonics are well recorded in the outcropping rocks and represented by a series of south verging anticlines and synclines with a common east-west axial trend. In addition to these folds, several east-west trending and north and south verging thrust faults are also present. The part of the Kohat Plateau has undergone three distinct phases of deformation. The earliest phase D1, was responsible for development of the large overthrust sheet. This thrust sheet was later on folded in second phase of deformation D2. During D2 the entire package of rocks and structures (including autochthonous rocks and overlying allochthonous thrust sheet) was folded. The third phase of deformation D3, represents the collapse of structurally elevated rocks due to gravity.

Key words: Structure, stratigraphy, tectonics, Kohat.

A/361. Alam, K., 1986. Geophysical investigations for groundwater in Qandhari Safi Plain, Mohmand Agency, N.W.F.P. Geological Survey of Pakistan, Information Release 265.

Key words: Geophysics, groundwater, Mohmand

A/362. Alam, K. & Nazirullah, R., 1998. Reconnaissance gravity-magnetic profiles for iron ore exploration in Nizampur area, NWFP, Pakistan. GSP, Information Release 681.

Key words: Gravity, Magnetism, Ore, Nizampur.

A/363. Alam, K. & Salam, A., 2001. Electrical resistivity survey for groundwater exploration in Shakar Dara area, Kohat District, N.W.F.P. Geological Survey of Pakistan, Information Release 736.

Key words: Geophysics, electric resistivity, groundwater, Shakar dara, Kohat

A/364. Alam, M.M., 1964. Geology of Tanawal, Hazara. M.Sc. Thesis, Punjab University, 40p.

Key words: Geology, Tanawal, Hazara.

A/365. Alam, M.Z., 1987. Composite fault plane solution study of the events occurring in the vicinity of Tarbela Dam, Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 63p.

Key words: Faults, Tarbela dam.

A/366. Alam, S., 1995-96. Structure, stratigraphy, micropaleontology and petrography of Shahdara and Pirsohawa areas, Margala Hills, Islamabad, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 107p.

The Shahdara pirsohawa area lies in the Attock-Hazara fold and thrust belt of the northwest Himalaya of Pakistan. The Mesozoic to Cenozoic rocks in the area are entirely sedimentary in nature. The rocks are strongly folded and imbricated during Tertiary Himalayan collision. The study deals with the structure, stratigraphy, micropaleontology and petrography of the area.

The early Paleocene Hangu Formation unconformably overlies the late Cretaceous Kawagarh Formation. The late Cretaceous subduction of the Indian plate below the Kohistan Island arc caused the deepening of the Tethyan shelf in the subduction zone and initiated the deep marine deposition of the Kawagarh Formation. The abrupt change from Late Cretaceous deep marine environment of the Kawagarh Formation to terrestrial deposition of Hangu Formation indicates the initial Early Paleocene collision of the Indian plate and Kohistan island arc. The Lower Tertiary sequence of Early to late Paleocene Lockhart Limestone, Late Paleocene Patala Formation, Early Eocene Margalla Hill Limestone and Late Eocene Kuldana Formation mark the complete cycle of transgression and regression of the Tethyan Ocean. The presence of Early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globigerina, lockhartia, assilina, nummulites and fasciolites in the limestone and shales of the Lower Tertiary sequence show the tropical to sub-tropical open sea upper slope to outer shelf environments. The Kuldana Formation includes marine limestone, continental clays and shales and evaporitic gypsiferous beds. The rock assemblage shows transgression of Tethyan Ocean and initiation of continental deposition of the Kuldana Formation due to Himalayan uplift.

The Paleocene- Eocene boundary can not be marked on the basis of microfossils in the area because the Patala Formation lacks microfossils. However, the tentative Paleocene-Eocene boundary between Patala Formation and Margalla Hill Limestone can be marked at the base of Margalla Hill Limestone on the basis of first appearance of Early Eocene microfossils.

The two phases of D1 and D2 deformations related to Himalayan collision are recorded in the Mesozoic to Cenozoic shelf and platform sediments of the Attock-Hazara fold-and-thrust belt of Shahdara-Pirsohawa area. D_{1a} is the main phase of southeast-directed thrusting and the southeast vergent F1 folding. D_{1b} is related with the folding of MBT due to backsteepening. The backsteepening is documented by southeast dipping thrust faults and at places northwest

vergent Makhnia and Pirsohawa synclines. The D2 deformation phase is related with the folding of earlier northeast-southwest trending D1 structures along northwest plunging F2 fold axes. The F2 cross folds are mainly antiforms and synforms. The F2 cross folds are related with the development of Hazara-Kashmir syntaxes.

Key words: Structure, stratigraphy, micropaleontology, petrography, Margala, Islamabad.

A/367. Alauddin, A., Khan, A., Masood, H., Begum, F., Khattak, M.A. & Khan, M.A., 1994. Studies of potash bearing evaporate basins of Kohat Karak Salt Range, NWFP, Pakistan. Pakistan Journal of Scientific and Industrial Research 37(11), 491-00.

Potash-bearing minerals occur in nature with common salt and usually deposited in the evaporite basin on evaporation of brine water. In view of the huge deposits of common salt in Pakistan, particularly in Kohat-Karak evaporite basin, NWFP; investigations to locate the potash deposits in the common salt of the area were undertaken. The geology of the potash bearing deposits reveal their occurrence in the form of lenticular beds associated with rock salts. The present study has successfully brought into focus areas of potash concentration in the above area, which after refining may be exploited to meet the requirement of potash for fertilizer.

Key words: Potash, Evaporate, Kohat, Karak, Salt Range.

A/368. Alauddin, M., 1969. Preliminary petrography of Sarok Gal pegmatite, Chitral. Geological Abstracts, 11th Annual Conference, Scientific Society of Pakistan, Multan, p.18 (In Urdu).

This report is in Urdu and gives the mineral composition of this granitic pegmatite in Chitral area.

Key Words: Pegmatite, Chitral.

A/369. Alauddin, M., Hussain, V. & Jan, N., 1992. Characteristics of glass making sands of Munda Kuchha, District Mansehra and their beneficiation and utilization for the production of colorless container glass. Pakistan Journal of Scientific and Industrial Research 35(4), 151-00.

Large deposits of silica sand occur at a distance of 50-km to the northeast from Mansehra town, near Munda-Kuchha village along the Siran river. Estimated reserves up to a workable depth of 300 feet are 57 million tons. Twelve representative samples were collected from the area for studying their suitability for glass industry. The chemical composition and grain size distribution of these samples were determined. Beneficiation studies by physical and chemical methods were undertaken to remove color-imparting impurities, which are a factor for producing the glass of inferior quality. The objective of this study was to upgrade the quality of silica sand to the acceptable limits for the production of colorless container glass. Using physical methods a maximum of 41.66% of the iron, the most undesirable impurity, was removed; by chemical treatment seven of the twelve samples can be brought into the specification for colorless container glass, five can be brought into, or very near, the specification for optical glass.

Key Words: Silica sand, glass, beneficiation, Munda Kuchha, Mansehra,

A/370. Aleem, S., 1989-91. Geology and Geochemistry of Battal Village and its surrounding area with special emphasis on the Geochemistry of altered products near Ahl Village, and water & Soil chemistry along the Karakoram High way (KKH), District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 113p.

The present study has been basically focused on the geology and geochemistry of a part of the lesser Himalayas. The study has been divided into four parts. The first part deals with the geological mapping and tectonic setup of the area which reveals that the studied area lies between the syntaxial loop and Oghi shear zone of the lesser Himalayas, comprising of mainly metamorphic rocks, granitic rocks and granite gneiss of Precambrian, Cretaceous/Tertiary and Cambrian age respectively. Tectonically, the area represents a sandwich between the two major thrusts, i.e., Main Central Thrust (MCT) in the north and Main Boundary Thrust (MBT) in the south, also, there runs a NS Oghi shear zone in the west and syntaxial loop of NW Himalayas in the east. The second part deals with the detailed geochemical and mineralogical investigation of the area. Three types of rocks are characterized in the studied area; a) metamorphic rocks of garnet mica schist grade comprising mainly of quartz, garnet, muscovite, biotite and chlorite. b) granite gneiss mainly composed of quartz, K-feldspar, plagioclase feldspar, muscovite, biotite and

sphene; c) minor basic intrusions as amphibolites; mainly consist of amphiboles (hornblende) along with quartz, sphene and muscovite. The third part deals with the geochemistry of the altered products near Ahl Village. The variation of major oxides in the altered products as: $\text{SiO}_2 > \text{Al}_2\text{O}_3 > \text{Na}_2\text{O} > \text{K}_2\text{O}$, with FeO, and CaO & MgO as minor constituents. It suggested that this aluminum-silicate rich material could be used for ceramic purpose. The fourth part deals with the water and soil chemistry of the studied area to explore the weathering style and water and soil characteristic in the area. The chemistry of water samples show that they are rich in Ca^{+2} and HCO_3 indicating the decomposition of plagioclase feldspar; the X-ray diffraction patterns of the soil samples show the presence of quartz, albite, muscovite and anorthite which are the unaltered constituents of the same parent rocks while the presence of illite and phlogopite in all the soil samples, and saponite and sepiolite in some samples represents the intensity of the weathering in term of bauxitization. The water quality of the studied area is well within the permissible limits of drinking standards. The soil samples of the studied area classify into the category of normal soils with pH ranges from 6.4 to 7.7 and other parameters like EC, ESP & RSC are also within the permissible limits for cultivation purpose. The cultivation of tea at various localities where pH of the soil is relatively lower is recommended for the uplift of socioeconomic condition of the area.

Key words: Geochemistry, mapping, Himalaya, Hazara.

A/371. Alessadri & Ginori, V., 1931. Meteorologia, geofisca, aerologia e pirelometria. In: Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan Cinese (1913-1914), 3. Zainchelli, Bologna, 570p.

Key words: Meteorology, geophysics, Karakoram, Chinese Turkestan.

A/372. Ali, A., 1976-78. Geology of Jogabunj-Sadiqa Banda Area Dir District. M.Sc. Thesis, Punjab University, Lahore, 115p.

The project area lies in central Punial area, adjoining to Yasin Valley, Gilgit Agency. The area is located in Karakoram Mountains. Area is intensely disturbed tectonically being involved in Himalayan Orogeny. Evidence is provided by crushing and strained effect on minerals. Project area is composed mainly of igneous rocks and metasedimentary rocks.

These different rock units are shown on map, which was previously prepared by enlargement of toposheet. The major units in the project area are granite, diorite, amphibolite and paragneiss. Special emphasis was given to the mineralogy description and petrographic analysis of the rock units and is reported in detail. The petrogenesis of these rocks units has been discussed as well.

Granite is considered to be a part of Karakoram axial granite, which is emplaced as a partially fused and mobile mass rich in alkali feldspar during synthetic phase of orogeny. Diorite is probably tholeiitic basaltic magma injection. Granodiorite produced during differentiation with decrease of calcic contents.

Key words: Geology, granites, Dir.

A/373. Ali, A., 1992. Shallow seismic velocities of rock units in Islamabad and Rawalpindi. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 31p.

Key words: Seismicity, Islamabad, Rawalpindi.

A/374. Ali, A., 1997-98. Geological mapping and hydrogeological studies of Rawlakot area (District Poonch) A.K. with special emphasis on pollution studies and waste disposal. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 52p.

The spring water and stream water has been investigated from Rawlakot Azad Kashmir to the quality of water for drinking and other uses. The area lies under the influence of lesser Himalayas. The total of 74 samples were collected from spring and stream waters in two phases. 40 samples were collected in wet season and 34 samples were collected in dry season. Chemical constituents such as Ca, Mg, Si, carbonate and bicarbonate were determined. Physical properties colour, taste, odour and temperature were noted in the field. Turbidity, TDS and conductivity were determined in the laboratory.

The effects of solid and liquid wastes and sewage water effected the quality of ground and surface water. The concentration of Pb, Zn, Cu and Ni increases due to waste disposed off into streams and nala water. The waste water from households seepage of water through sewage system, waste water from CMH and the suspended load of finer particles from Murree formation are main pollutants. The waste disposed by shopkeepers and municipal wastes also pollutes the surface and ground water. The experimental data show that the waste dispose sites should be selected by Municipal Corporation and the treatment plant is essential for supplying good quality drinking water in Rawlakot area. The water available from Hussain Kot springs can be developed and supplied to the inhabitants of Rawlakot. Pure water can also be developed by drilling tube wells in Rawlakot valley. Kanapara, Baikh, Chotagala, Khaigala, CMH Rawlakot, Rawlakot city, Tirar, Banjosa and Dhamni localities. It is concluded that the ground and surface water resources are available and need development on scientific grounds.

Key words: Mapping, hydrogeology, pollution, Rawlakot, Azad Kashmir,

A/375. Ali, A., 1997. Structure and Stratigraphy of a part of Kohat basin between Lachi and Banda Daud Shah, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 58p.

The detailed mapping of the study area have resulted in establishing nine lithostratigraphic units which range in age from Eocene to Pliocene. These units fall within three groups which are from bottom to top as Chharat, Rawalpindi and Siwalik Groups. The Chharat group is represented by five formations in the area including Panoba shale at the base, overlain by Jatta Gypsum along with its lateral equivalent Sheikhan Limestone, Kuldana and Kohat Formations. The Chharat group is unconformably overlain by the Murree and Kamlial Formations of the Rawalpindi group. The representative units of the Siwalik group in the area are Chinji and Nagri Formations. The structural geometry of the area comprise large scale, east-west trending folds and thrust faults. The fold structures include narrow anticlines and anticlinoria mostly cored by thrust faults. The synclinal folds are open, with both their limbs overturned and reflect fan-geometry. The faults include fore and back thrusts. The back thrusts are mostly overturned at their surface exposures and have changed their vergence from north to south.

The proposed structural model based on surface and subsurface seismic data shows a series of large scale hinterland dipping listric thrust faults emerging from the basal decollement. All these faults are steeply dipping at surface and becomes gentle with depth. Other prominent features are associated pop-ups and triangle zones which are the result of north verging splays from the listric thrust faults. The presence of triangle zones bounded by thrust faults of opposing vergence have resulted in the tectonic overprinting and delamination of different horizons at various levels. All the above mentioned features are characteristic of the foreland fold and thrust belts in different parts of the world. The basal detachment is located at the base of salt range formation at a depth of around 8 km and 8.4 km in the southern and northern parts of the study area respectively. The restored version of the deformed state cross-section shows about 19.5 km shortening for the mapped area with maximum structural relief of about 4000 meters above the regional level.

Key words: Structure, stratigraphy, Kohat basin.

A/376. Ali, A., 1998-99. Engineering geological mapping from Naushera to Barsala (District Muzaffarabad) with special emphasis on joint orientation of the Miocene rocks of Kohala Hydro Electric Project Area (A.K.), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 135p.

Key words: Structure, engineering geology, Miocene, Azad Kashmir,

A/377. Ali, A.M. & Afridi, M.K., 1999. Seismic reflection interpretation of Chak-Naurange area, Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 47p.

Key words: Seismicity, Chak Naurang.

A/378. Ali, C.M., 1962. The stratigraphy of the southwestern Tanol area. Hazara, West Pakistan. Geological Bulletin, University of Punjab 2, 31-38.

The stratigraphy of the pre-quaternary rocks of the southwest Tanol Area, Hazara, based on preliminary mapping is described. The rocks are compared with those found in the Abbottabad and Swabi areas, previously referred to as the Infra-Trias, in the former, and now redesignated the Abbottabad Formation. Three major rock units could be distinguished – the Hazara Slate Formation, the Tanol Formation, and the Abbottabad Formation.

Key words: Stratigraphy, Hazara Slate, Abbottabad Formation, Tanol Formation, Hazara.

A/379. Ali, F., 1992-93. Geological mapping and sedimentology of the Dhok Pathan Formation, Siwalik Group in Surghar Range-Shinghar Range, Bannu Basin, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 198p.

Key words: Sedimentology, Dhok Pathan Formation, Siwaliks, Bannu basin.

A/380. Ali, F., 1994. Structure and tectonic set-up of area north and north-west of Karak, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 83p.

The Karak area which constitute southern edge of Kohat plateau exposes a suite of evaporite deposits, shelf sediments and a thick molasses sequence of Cenozoic age. The oldest rocks in the area are of Eocene age and constitute Bahaderkhel Salt and Jatta Gypsum followed by shelf sediments which comprise Kuldana and Kohat Formations. These units are overlain by molasse sediments of Miocene to Pliocene age which include rocks of Rawalpindi Group (Kamlial Formation) and Siwalik Group (Chinji Formation, Nagri Formation, Dhok Pathan Formation and Soan Formation).

Structurally the area is interpreted as an east-west trending positive flower structure which is exposed for 20 Km along strike and is about 5 Km wide. It is bounded by the north dipping Karak Fault in the south and the south dipping Nari Panos Fault in the north and internally subdivided by the south dipping Banda Kunghara Fault. All these faults trend eastwest and have moderate surface dips.

A right lateral component of deformation along the Karak structure is indicated by (a) the east-north-east directed trends of the Daggar syncline in the foot wall of the Nari Panos backthrust, (b) by small scale thrusts in the core of this syncline and (c) by east-north-east trending enechelon folds south and south east of Banda Charpara. The idea is supported by interpretation of seismic data (906-NSK-47) which indicates rapid steepening of the Karak, Nan Panos and Banda Kunghara Faults to near vertical with depth and east-west trending slickenlines present on different fault surfaces of the area. This work emphasizes the importance of transpression within the NW Himalaya on a regional scale. Recent work by Beck et al. (in prep.) has suggested transpressive deformation along the Main Boundary Zone (MHZ) to the west of the Kohat Plateau.

Key words: Structure, Tectonics, Karak.

A/381. Ali, F., Ahmad, S. & Abbasi, I.A., 2000. Imprints of transpressional deformation on the southern Kohat Plateau, Karak area, NW Himalayas, NWFP, Pakistan. Late Abstracts, Third South Asia Geological Congress, Lahore, p.1.

Consult the following account for further information.

Key words: Deformation, Kohat Plateau, Karak, Himalaya.

A/382. Ali, F., Ahmad, S., Ahmad, I. & Hamidullah, S., 2000. Imprints of transpressional deformation on the southern Kohat Plateau, Karak area, NW Himalayas, NWFP, Pakistan. Geological Bulletin, University of Peshawar 33, 87-95.

A suite of evaporite deposits, shelf sediments and molasse sequence of Early Cenozoic age from Karak area marks a part of southern Ghat Plateau. Structurally the area is interpreted as east-west trending positive flower structure, which is exposed for about 20 km along strike with widths varying from 3-5 km laterally. It is bounded by the north dipping Karak Fault in the south and south dipping Nan Panos Fault in the north and internally subdivided by the south dipping Banda Kunghara Fault. All these faults trend east-west and have moderate surface dips. A right lateral component of deformation along the Karak-Nari Panos structure is indicated by: 1) the north-east directed trend of

the Daggar Syncline in the footwall of the Nari Panos Fault, 2) the local scale thrusts in the core of this syncline and 3) east-north east trending right stepping folds located south-east of Banda Charpara in the footwall of Banda Kunghara Fault. The idea of transpressional deformation is also supported by the seismic data, which shows that all the major fault structures become steep, converging at deeper level and the presence of horizontal to sub-horizontal slicks on different fault surfaces. The region has experienced an early phase of compressional deformation overprinted by later phase of transpressional deformation of Plio-Pleistocene age.

Key words: Deformation, Kohat Plateau, Karak, Himalaya

A/383. Ali, F., Khan, I. & Ahmad, D., 1996. Significance of mesoscopic shear zones in the Precambrian limestone belt around Gandghar and Attock-Cherat Ranges, NW Himalayas, Pakistan. Abstract volume, 11th Himalaya- Karakoram- Tibet Workshop, Flagstaff, Arizona (USA), p.17.

The south and southeastern boundary of the Pakistan basin exposes a belt of Precambrian limestone (Shekhai, Utch Khattak and Shahkot formations). This limestone belt has well preserved mesoscopic scale, brittle-ductile shear zones, which are related to the movements along the Panjal Fault in the Gandghar Range and Khairabad Fault in the Attock-Cherat Ranges.

The detailed geometric analysis of these steeply dipping conjugate shear zones in the Gandghar Range shows that sinistral shear zones strike NNW and dextral shear zones strike WNW. The conjugate shear zones mapped in the Attock-Cherat Range are moderately dipping with sinistral shear zones, striking NE and dextral shear zones striking NW. The slip linear and the acute bisectors of these conjugate shear zones indicate that the Gandghar Range has developed in response to NW oriented compressional stresses and the Panjal Fault which lies south of it, is an oblique ramp with left lateral strike-slip adjustments in addition to major thrust-slip movements.

The Attock-Cherat Range has experienced NS directed compressional stresses and the Khairabad Fault which is the northern most tectonic boundary of the Attock-Cherat Range is south verging frontal ramp.

Key words: Shear zone, Limestone, Gandghar, Attock-Cherat, Precambrian.

A/384. Ali, Ch.M., 1962. The stratigraphy of the southwestern Tanol area, Hazara, West Pakistan. Geological Bulletin, Punjab University 2, 31-38.

The stratigraphy of the pre-Quaternary rocks of the southwest Tanol area, Hazara, based on preliminary mapping, is described. The rocks are compared with those found in the Abbottabad and Swabi areas, previously referred to as the infra-Trias, in the former, and now redesignated the Abbottabad formation. Three major rock units could be distinguished--the Hazara slate formation, the Tanol formation, and the Abbottabad formation.

Key words: Stratigraphy, Tanol, Hazara.

A/385. Ali, I., Shah, M.T. & Jan, M.R., 1992. Geochemical techniques for the analyses of rocks and their application to the rocks of granitic composition from Kala Dhaka area, Mansehra. 1st National Symposium on Analytical and Environmental Chemistry, Baragali.

Key words: Geochemistry, Granitic, Kala Dhaka, Mansehra.

A/386. Ali I., Shah, M.T. & Jan, M.R., 1994. Geochemical analysis of granitic rocks of Kala Dhaka area, Hazara Division. 2nd National Symposium on Analytical and Environmental Chemistry, University of Sindh.

Key words: Geochemistry, Granitic, Kala Dhaka, Mansehra.

A/387. Ali, I., Shah, M.T., Jan, M.R., & Khan, S., 1998. Trace elements determination by Atomic Absorption Spectrophotometer in the Rocks of Kala Dhakka area, Mansehra. GSP Information Release 671, 16p.

Key words: Trace Elements, Atomic Absorption, Kala Dhaka, Mansehra.

A/388. Ali, K., 1992. Geology and Tectonic setup of a part of Dara Adam Khel Kotal Pass Transect (Kohat Hill Range), Kohat Division, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 61p.

This study describes the geology and structural set-up of a 168 km² area along the Darra Adam Khel-Kotal pass transect in the Kohat Hill Range. The area comprises, from bottom to top, the Jurassic Samana suk, the Cretaceous Chichali, the Lumshiwal, the Kawagarh, the Palaeocene Lockhart and Patala, (Palaeocene), the Eocene Kohat and the Miocene Murree Formations. The area is deformed into complex structures. The principal structure is a "pop-up". It comprises a south verging thrust (Main Boundary Thrust) at the southern flank against the Kohat plateau and a pair of north verging back thrusts at the northern flank against the Peshawar plain. Between these divergent thrusts, there are large scale fold structures (some with half-wave length > 7 kms) which have a fan shaped geometry, conforming to the pop-up style of deformation exhibited by the thrusts.

Overall four phases of deformation are recognized in the studied part of the Kohat Hill Range. D1 phase of deformation resulted in local duplex structure, just to the south of the Kotal pass. At least two horses have been recognized each with a stratigraphic range between the Samana suk and Kawagarh Formations, stacked below a roof thrust in the Kawagarh Formation. D2 is the principal phase of deformation related with the development of Main Boundary Thrust (MBT), the back thrusts and fan-shaped folding and pop-up shape of the Hill range thrust sheet. D3 is post folding and is represented by out-of-the-syncline thrusts in the southern limb of the wahabian valley syncline, D4 is marked by low angle normal faults, which represent gravity collapse of the abnormally uplifted Hill range in the latest stages of deformation. The deformation in the Kohat Hill Range started after the deposition of the Miocene Murree Formation and probably continued until recently.

Key words: Tectonics, Kotal Pass, Kohat.

A/389. Ali, K., Abdullah, A.M. & Ahmad, A., 1987. Geology and structure of area south and southeast of the village Pir, Abbottabad. M.Sc. Thesis, University of Peshawar, 44p.

Key words: Geology, structure, Abbottabad.

A/390. Ali, K.A. & Anwar, J., 1969a. Stratigraphic studies of Nowshera Reef Complex, Nowshera Tehsil, N.W.F.P., M.Sc. Thesis, University of Peshawar, 48p.

Consult the following account for further information.

Key words: Stratigraphy, Reef Complex, Nowshera.

A/391. Ali, K.A. & Anwar, J., 1969b. Stratigraphic studies of the, Nowshera Tehsil, West Pakistan. Geological Bulletin, Peshawar University 4, 33-43.

A belt of Siluro-Devonian limestone and quartzite, pink or yellowish-pink in colour, is exposed on either side of the Nowshera-Risalpur road. This belt was identified as a 'Reef Complex' in 1965, and is the first of its kind to be discovered in the Indo-Pak sub-continent. Prior to this discovery, the limestone belt had been erroneously assigned a Precambrian age and regarded as part of the Attock Slates.

The entire belt unconformably overlies the Kandar Phyllite and is divisible into four definite units: 1. Carbonate Rocks, 2. Reef Core, 3. Reef Breccia, and 4. the Misri Banda Quartzite. The first three collectively are known as the Nowshera Formation. With the exception of the last, these units represent the characteristic structural layers of a reef.

The age of the reef complex on the basis of its fossil assemblage ranges between Upper Silurian and Devonian. However, there is no fossil present which may pinpoint an exact age. The uncertainty about the precise age of the reefs largely due to the destruction of many organisms by the process of dolomitization.

In the opinion of the writers, the Nowshera Formation and the Misri Banda Quartzite were deposited in the southernmost extremities of the basin in which the Muth Quartzite, of Siluro-Devonian age, was formed.

In their opinion, the Nowshera Formation and the Misri Banda Quartzite can be correlated with the middle and upper parts of the Muth Quartzite. .

Key words: Stratigraphy, Reef Complex, Nowshera.

A/392. Ali, K.S.S., Ahmad, M. & Khan, B., 1969. Geology of the northern part of Warsak area. M.Sc. Thesis, University of Peshawar, 62p.

The northern part of the previously unmapped Warsak area, bounded by 34° 10' and 34° 14' North Latitudes, 71° 20' and 71° 26' east longitude has been mapped on a 1 inch to 0.314 mile scale and the petrography and structure of the rocks is described in detail.

The rocks of the thesis area are typical of the Paleozoic metasediments of the Mohmand Agency that have been intruded by ultramafic (near Tangi etc) basic and acidic rocks, including pegmatites and quartz veins.

The oldest rocks of the area are metasediments represented by quartz-biotite schists, hornblende schists, phyllitic schists, garnet-chlorite schists and calcareous schists. These were intruded by a series of basic intrusions represented by metagabbros and metadolerites, and acid intrusions represented by porphyritic microgranites and alkali granites. The alkali granites possibly represents a differentiated fraction of the porphyritic granite. The intrusions are probably late Mesozoic to early Tertiary, and many are concordant. Quartz veins are commonly associated with all of these rocks. During recent times, the eastern low hills of the area were covered by alluvium.

The structure in the investigated area is simple, most of the rocks strike north-west and dip north-east. However, the rocks to the south-west (in Khyber agency) are folded and faulted, and the relationship of the rocks of the area with those of Khyber Agency are not well understood. Economic minerals were looked for but the results were not encouraging. However, marbles, granites and some other rocks can be exploited profitably for building and decorative purposes.

Key words: Metasediments, Warsak.

A/393. Ali, L.M. & Nadar, H., 1984. Geology of portion of Kohat quadrangle, Darra Adam Khel, Kohat, North West Frontier Province, Pakistan. M.Sc. Thesis, Peshawar University, 97p.

Key words: Darra Adam Khel, Kohat, NWFP.

A/394. Ali, M., 1995-96. Structure, stratigraphy, micropaleontology and petrography of Darthian, Narota & Karwali areas District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 95p.

The Darthian, Narota and Karwali area are part of Attock-Hazara fold-and-thrust belt of the northwest Himalaya of Pakistan. The lithographic units exposed in the area are mainly sedimentary in nature and range in age from Mesozoic to Cenozoic. The area is deformed by folding and faulting during the Tertiary-Himalayan collision.

The Early Cretaceous Lumshiwal Formation has disconformable contact with the overlying Late Cretaceous Kawagarh Formation. The presence of glauconite in the Lumshiwal Formation reveals that the formation was deposited in marine condition during regressive as well as transgressive phases. The Late Cretaceous subduction of the Indian plate below the Kohistan Island arc caused the deepening of the Tethyan shelf in the subduction zone and initiated the deep marine deposition of the Kawagarh Formation. The contact between Kawagarh Formation and Early Paleocene Hangu Formation is marked by break in deposition which is evidenced by the presence of laterite/haematite and sandstone. The abrupt change in facies from deep water marine environment of Kawagarh Formation to terrestrial deposition of Hangu Formation indicates the initial Early Paleocene collision of the Indian Plate and Kohistan Island arc.

The Lower Tertiary sequence exposed in the area is Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margala Hill Limestone, Early Eocene Chorgali Formation and Early to Middle Eocene Kuldana Formation. The Lower Tertiary sequence marks the complete cycle of transgression and regression of the Tethyan Sea. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockharia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show

the tropical sub-tropical open sea upper slope to outer shelf environments. The Kuldana Formation is composed of marine limestone, continental variegated clay, shales and evaporitic gypsiferous bands.

Key words: Structure, stratigraphy, paleontology, petrography, Haripur, Hazara.

A/395. Ali, M. & Ahmed, S., 1978. Interpretation of Bouguer anomalies over Gilgit valley, northern area, Pakistan. Geological Bulletin, University of Punjab 15, 40-51.

The Bouguer anomalies and up to third degree trend surface gravity analyses of the Gilgit valley, reveal that under the alluvial cover, the metasediments of Permo-Carboniferous age extend towards East and steeply dip under the thick basic igneous complex in the southeast. These basic rocks in the northeastern segment are overlain by intrusions of granodioritic rocks of Cretaceous to Eocene age, which continue up to the eastern boundary. The Permo-Carboniferous rocks in the West, contain a dyke intrusion of a granitic complex of Oligocene to Miocene age.

Key words: Geophysics, Bouguer anomaly, Gilgit.

A/396. Ali, M. & Das, A., 1997. Gravity modeling across Peshawar Basin. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.8.

Peshawar basin studied extensively by several workers is manifested by high angle vertical faulting in association with magnetic activity. Our gravity interpretation from Peshawar to Dargai suggests that the basin is a rifted-graben structure which is bounded by east-west trending Charsadda basement fault in the south and the Vale rift zone in the north. Charsadda fault is a consequence of the gravity modelling of steep gravity gradient in that zone. Large to small scale dykes appear intruding in rifting and Malakand granite is the major intrusion in weaker zone. Gravity traverse across the eastern section of Dargai complex supports the idea that it is a smaller ultramafic body that migrated from Dir ultramafic complex.

Key words: Gravity, Magnetism, Peshawar.

A/397. Ali, M., Khawaja, A.A., Ahmad, Z., Akhtar, J., Mazharulhaq, Kh. & Fraz, E., 1987. Geophysical study of Lead-Zinc deposit of Besham area. Acta mineralogical Pakistanica, 3, p.65.

Key words: Geophysics, lead-zinc, Besham.

A/398. Ali, M., Latif, Y. & Nazeer, M., 1997. Bed rock studies in Behrain with the use of seismic refraction. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.9.

The application of seismic methods in civil engineering and construction work has increased rapidly because of the recognition of the importance of shallow geological structures in all phases of site selection and foundation studies. Seismic refraction experiment conducted in igneous/metamorphic terrain of Behrain for the delineation of bedrock configuration indicates that the bedrock represented by seismic velocity more than 3000 m/sec is faulted/fractured on places and lies under overburden that varies in thickness from 10 to 40 meters.

Key words: Seismology, geotechnical.

A/399. Ali, M. & Mujtaba, G., 1992. Gravity and magnetic studies in the region of Main Boundary Thrust, west of Himalayan syntaxis. Geological Bulletin, University of Peshawar 25, 51-58.

Interpretation of gravity measurements in the west of Hazara Kashmir syntaxis, particularly around Main Boundary Thrust region suggests that the crustal thickness in the region is around 47 km, and the Moho dips at an angle around 1.0 degree towards northeast against the calculated dip of about 4.0 degrees just south of Margala ranges. The residual gravity, which corresponds reasonably to a generalized litho-structural model of the area, predicts also some anomalous situation which get support from magnetic results. The density modeling along Islamabad-Haripur

sections gives the possibility of existence of basement or ultra-basic slices near Islamabad at a depth of 5 km. Further, the MBT and langrial faults to be changing dips downwards to 25° or more.

Key words: Gravity, Magnetism, MBT, Himalayan Syntaxis.

A/400. Ali, M., Yoshida, M., Khadim, I.M. & Ahmad, M.N., 1994. Total gamma-ray observation along the Karakoram Highway, northern Pakistan: An attempt of geological interpretation by radioactivity of rocks. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 8, 81-93.

The purpose of this survey was to see the possibilities of lithogeological application of radioactivity of rocks and radiometric pollution of air and soil across major rock units exposed along the KKH between Hassanabdal and Khunjerab river. The following conclusions were arrived at:

- (1) The change of total intensity of the natural gamma-ray radiation along the KKH is closely related to surface geology as well as lithology. It means total gamma- ray survey is applicable for geologic mapping, especially for regional reconnaissance survey.
- (2) Most anomalies in total gamma-ray radiation are probably derived from potassium (K^{40}) in rocks. Granitic rocks and micaceous metasediments shows relatively high intensities of total gamma-ray radiation.
- (3) The hot-spring area around the Nanga Perbat gneiss body shows the highest value of radiation in the surveyed route. It may due to radioactive radon-gas associated with the hot-spring water. It also suggested that the hot-spring is supplied from subsurface fracture-type reservoirs in the country rocks.
- (4) Further spectral gamma ray-survey is recommended for detailed geological and mineralogical interpretations.

Key words: Geophysics, KKH.

A/401. Ali, M., Yoshida, M., Khadim, I.M., Ahmad, M.N. & Fujiwara, Y., 1993. An isotropy of magnetic susceptibility measurement of some igneous-metamorphics rocks in northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 6, 66-81.

An isotropy of magnetic susceptibility (AMS) of the Jijal and Chilas complexes and Mansehra granite were performed for the purpose of structural analyses. It is tentatively concluded that the directions of AMS of the Chilas and Jijal complexes closely correspond to their internal structure, such as foliation. The paper also emphasizes that AMS measurement is not only useful in solving the micro-structural problems, but informative on magnetomineralogical viewpoints such as SD grain ratio.

Key words: Palaeomagnetism, igneous, metamorphic.

A/402. Ali, M.A., Ahmad, M.A. & Khan, A., 1986. Ground water conditions Nikpikhel area, Mingora, Swat, N.W.F.P., Pakistan. M.Sc. Thesis, University of Peshawar, 42p.

Key words: Groundwater, Mingora, Swat.

A/403. Ali, M.M., 2000. Application of geoelectrical and hydrological parameter for roundwater investigation studies in the area of G-14/4 Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 67p.

Key words: Groundwater, Islamabad.

A/404. Ali, R., Ahsan, N., Chaudhry, M.N. & Masood, K.R., 2000. Lithofacis, microfacies, diagenesis, environment of deposition and palynology of Lumshiwal Formation at Kundla, Hazara basin, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.155.

The Lumshiwal Formation from Kundla is divided into XII Lithofacies on the basis of field observations. These include lower grey sandstone facies, fossiliferous limestone facies, phosphatic glauconitic, lower grey sandstone

facies, silty sandstone facies, green sandstone facies, light grey sandstone facies, carbonaceous sandstone facies, hard ground facies; upper grey sandstone facies, and grey arenaceous carbonates facies. These facies contain 19 microfacies that repeat at random. The formation was deposited in intertidal to subtidal environment but not below 80 m. Diagenetically, glauconite was the first cement to deposit in the sands from the alteration of mixed layer clays, then quartz, carbonates, flint and iron oxides were precipitated. The sandstone are compositionally mature. Texturally these are submature to super-mature. They are very fine grained to coarse grained. Tourmaline, zircon, epidote and sphene indicate derivation from sialic metamorphic-igneous basement. However some basic sources also contributed during the deposition of the formation. Palynomorphs were represented by Dinoflagellates (*Baltisphaeridium* sp. And *Michrystribium* sp. Pollen and spores (*Densoisporites*, *Leptolepidites*, *Punctatisporites* and *Acropolis*) and some *Acritarchs*.

Key words: Lithofacies, Microfacies, Deposition, Palynology, Lamshiwal Formation, Hazara.

A/405. Ali, R. & Halim, A., 1962. Geology of the lower Batrasi area, Hazara. M.Sc. Thesis, Punjab University, 30p.

Key words: Geology, Batrasi, Hazara.

A/406. Ali, S., 1991-93. Slope stability problem along Murree Kohala Road. M.Sc. Thesis, Punjab University, Lahore, 123p.

Key words: Natural Hazards, Slope Stability, Murree.

A/407. Ali, S., 1996. Seismic refraction studies to map bed-rock in Sai area (Gilgit) for Sai Hydel Power Project. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 55p.

Key words: Seismology, Hydel Power, Gilgit.

A/408. Ali, S., 1997-98. Geological mapping of Rawlakot area with special emphasis on engineering characteristics of geo-material as aggregates. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 43p.

Geological mapping of Raw and has been conducted at the scale 1:50,000 and the total area of research is about 100 sq. km. The aggregates available in the area are Murree Sand stones. These natural sandstone aggregates from Rawlakot are being used for manufacture of concrete for building construction and other Civil engineering projects. The durability of the aggregate has not yet been evaluated by any organization or through any research work. Theses work summarizes the main characteristics for consideration of aggregated to be used as concrete which is still little understood, specially those leading to cracking and deterioration. It considers the specifications of aggregates through experiments and local experience and emphasis the need of testing to be used more specifically in different climatic and geological settings, the strong influence on aggregates performance is mineralogical composition and the changing environmental conditions. Presently work related to mineralogical composition, Losangles, Abrasion Value, Crushing Value, Impact Value, Specific Gravity, Water Absorption, Flakiness Index & Elongation Index are performed and related to mineralogical composition according to ASTM standards. The percent value of chert, clays, silt, plagioclase chlorite, muscovite and hematite effect the aggregates when in contact with water. Reserves of minerals sandstone estimated from Dharamsal and Dhamni are 10.2×10^5 million tons and Damsite and Dhoke Kohian are 5.8×10^6 million tons.

Key words: Mapping, engineering, Muzaffarabad.

A/409. Ali, S., Din, A. & Faruqi, F.A., 1983. Geology, exploration and evaluation of the commercially feasible glass sand deposits of Surghar Range (Trans Indus Salt Range), District Mianwali. Second National Seminar on Development of Mineral Resources, Peshawar, 1, 17p.

Key words: Exploration, Glass, Surghar Range, Mianwali.

A/410. Ali, S.T., 1959. Mineral deposits and showings in the northern part of West Pakistan GSP, Information Release 2, 36p.

Please refer to Ahmad, Z. 1969.

Key words: Mineral deposits, West Pakistan.

A/411. Ali, S.T., 1962. Bentonites. Natural Resources 1(4 & 5), 13-18.

Key words: Bentonite.

A/412. Ali, S.T., 1967. Iron ore resources of Pakistan. In CENTO Symposium on Iron Ore, Isphahan, Turkey, 55-60.

Key words: Iron Ore.

A/413. Ali, S.T., 1978a. Mineral resources of Pakistan. GSP, Information Release 105, 33p.

Key words: Mineral Resources.

A/414. Ali, S.T., 1978b. Mineral deposits of Pakistan. National Seminar on Development of Mineral Resources, Lahore March 6-9, 1978, 32-35.

Key words: Mineral Deposits.

A/415. Ali, S.T., 1984. Mineral deposits of Azad Jammu and Kashmir. Abstracts, First Pakistan Geological Congress, Lahore, p.70.

Areas comprising the territory of Azad Jammu and Kashmir are occupied by a suite of igneous, metamorphic and sedimentary rocks ranging in age from Pleistocene to Precambrian. These rock units have been briefly discussed in this paper. The mineral deposits found in various environments are described, their commercial viability or otherwise, has been elaborated.

Key words: Minerals Deposits, Azad Jammu and Kashmir.

A/416. Ali, S.T., Abdullah, S.K.M., & Rashid, M.A., 1965. Bentonite deposits of Azad Kashmir: Geological Survey of Pakistan. Information Release 31, 20pp. 2 maps.

The bentonite deposits of Bhimber and Mirpur areas are found in 3 to 8 inches thick beds associated with volcanic ash extending for about 40 miles, laterally. Bentonite is of white, bluish grey, black and brownish varieties, is mostly a calcium bentonite and is categorised as a non-swelling type. The reserve estimates indicate that about 4800 tonnes, per foot of depth of white and bluish grey varieties of bentonite. Very large reserves of brownish-black variety of bentonite are available in both the areas.

Key words: Minerals Deposits, Bentonite, Azad Jammu and Kashmir.

A/417. Ali, S.T., Ahmad, M. & Siddiqui, R.A., 1978. Mineral Map of Pakistan. GSP, Geological Map Series, Scale 1:2,000,000.

This map shows locations of minerals of economic interest in Pakistan together with other brief information.

Key words: Mineral deposits, maps.

A/418. Ali, S.T., Ashraf, M. & Malik, R.H., 1983. Mineral deposits of Azad Jammu Kashmir-a review. *Kashmir Journal of Geology* 1, 119p.

The territory of Azad Jammu and Kashmir lies between Pakistan (on its west) and Indian occupied main land mass of the disputed State of Jammu and Kashmir (on its east). The total area of Azad Jammu and Kashmir is about 12,000 km². It has a fairly rugged mountainous topography.

Geology is simple and well exposed. Almost all the rock units are of sedimentary origin, ranging in age from Precambrian to Recent. Acidic and occasional small basic intrusive bodies are present in the Neelum Valley. Large scale regional metamorphism is encountered in the northern half of the State. The major tectonics are controlled by the collision of the Indo-Pak Plate with the Eurasian Plate north of the Nanga Parbat, the fourth highest mountain peak in the world. One of the most important tectonic features in this area is the Syntaxial bend of the Himalayas as just around Muzaffarabad, the capital town of the States of Azad Jammu and Kashmir.

Major metallic mineralization has not been met with up till now, however, workable deposits of bauxite, bentonite, coal, dolomite, fireclay, graphite, gypsum, limestone, marble, mica, quartzite, silica sand, slates, soapstone, and volcanic ashes are well established as a result of numerous exploratory surveys carried out by various concerned agencies. Reported occurrences and showings include phosphate, gemstones, feldspar, iron ores, lead, oil, gas. Pozzulana materials, gold barite and rare earths. The possibilities of discovering minerals like scheelite, ilmenite, monazite and zircon exist.

Key words: Minerals Deposits, Azad Jammu and Kashmir.

A/419. Ali, S.T., Calkins, J.A. & Offield, T.W., 1964. Mineral deposits of the southern part of the Hazara District, West Pakistan. *Geological Survey of Pakistan, Record* 13(1), 38p.

Key words: Mineral Deposits, Hazara.

A/420. Ali, S.T., Offield, T.W., & Calkins, J.A., 1967. Soapstone deposits of the Sherwan area, Hazara district, West Pakistan. *GSP and U.S.G.S. Project Report, PK (IR)* 25, 13p.

Key words: Soapstone, Hazara.

A/421. Ali, S.T., Offield, T.W., & Calkins, J.A., 1968. Reconnaissance geology of the Tarbela quadrangle, Hazara district, West Pakistan. *GSP and U.S.G.S. PK (IR)* 37, 37p.

Key words: Reconnaissance, Tarbela, Hazara.

A/422. Ali, S.T., Calkins, J.A., & Offield, T.W., 1969. Geology and mineral resources of the southern Hazara district, West Pakistan and part of Western Kashmir. *GSP and U.S.G.S. Project Report, PK (IR)* 43.

Key words: Mineral resources, Hazara.

A/423. Ali, S.I., 1964. What geology says of Kohat. *Geological Bulletin, Peshawar University* 1, 26-28.

This report gives an account of the area between Kohat and Hangu. The details are based on the field trips conducted by the students. This is a very preliminary study and gives some information about the topography and stratigraphy of the area.

Key words: Topography, stratigraphy, Kohat.

A/424. Ali, S.M., 1975a. A concise review on marbles, pegmatites, graphitic schists and garnetiferous rocks exposed along roadside between Chakdara and Dargai areas of Dir and Swat, North West Frontier Province. Pakistan Mineral Development Corporation, Report, 30p.

Key words: Marbles, pegmatite, graphite, Dir, Swat, NWFP.

A/425. Ali, S.M., 1975b. A brief note on geology and proposals for future drilling and adding operation on Chakdara fluorite deposits, District Dir, North West Frontier Province. Pakistan Mineral Development Corporation, Report, 25p.

Key words: Fluorite, drilling, Dir, NWFP.

A/426. Ali, S.M. & Amin, M., 1963. Chemical composition of chromite from Peshawar region. Pakistan Journal of Scientific and Industrial Research 6, 227-232.

Seventeen (complete and partial) analyses suggest that most chromites are aluminian, some are ferrian. The deposits containing $\text{Cr/Fe} > 3$ are of metallurgical grade. The number of divalent (Fe^{+2} , Mg) and trivalent (Cr^{+3} , Al, Fe^{+3}) cations per unit cell are calculated and discussed in relation to the unit cell structure.

Key words: Geochemistry, chromite, Peshawar.

A/427. Ali, S.M. & Amin, M., 1968. Beneficiation of low-grade laterites for the production of alumina. Pakistan Journal of Scientific and Industrial Research 11(1), 31-34.

Key words: Beneficiation, laterite.

A/428. Ali, S.S., 1992. Shallow seismic refraction study in Darbokach (Kohat). M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 50p.

Seismic data of a line is obtained for interpretation collected in DARBOKACH area near KOHAT. The survey was done by OGDC and the objective was to establish velocity lithology relationship and to detect any subsurface structures present in the area. The seismic line is shot at 100 meters interval. Splitspread shooting scheme with 96 channels recording system was used. The offset distance on either side of the shot is 75 meters and the intergeophone spacing is 25 meters. The reverse profiles were prepared at 50 meters interval using the splitspread data.

Parameters such as depth Z_0 and velocities V_0 and V_1 are determined and their distribution along the seismic line is established. Depth under each geophone for reversed profiles using delay time and Plus Minus methods is determined. From the obtained results it is concluded that weathering layer thickness ranges from 18.5 m to 25.5 m with refractor being almost horizontal. Weathered layer velocity ranges from 1320 m/sec to 1820 m/sec and consists of sandstone with interbeds of shale. The refracting surface is faulted towards southeast end with downthrown side towards northwest. The average displacement in the bed is 42.6 m.

Key words: Seismicity, Kohat.

A/429. Ali, T.A. & Akbar, S., 1962. Geology of upper Batrasi area, Hazara. M.Sc. Thesis, Punjab University, 23p.

Key words: Mineral deposits, Hazara.

A/430. Ali, U., 1997. Geomorphological hazards and their impact in Swat valley, northern Pakistan. Abstracts, 9th All Pakistan Geographic Conference, Peshawar, 8-9.

Key words: Geomorphology, Hazard, Swat.

A/431. Ali, Z., 1991-93. Geology of Dubran Area District Haripur with microfacies study of Langrial Algal limestone. M.Sc. Thesis, Punjab University, Lahore, 127p.

Geological mapping of some 64-km² area around Dubran in District Haripur has been carried out at the scale 1:12500. The geomorphology, soils, stratigraphy and structure have been described. Stratigraphically a Mesozoic-Tertiary sedimentary cover is overlying a Precambrian to Eo-Cambrian basement of Hazara Group now metamorphosed in the lower greenschist facies. Numerous faults, high angle north dipping Nathiagali Thrust is the main fault that passes through the area and has thrust the Precambrian Hazara Slates over the younger sedimentary sequence. Dubran syncline lying on top of a major anticlinorium makes an interesting structure.

Key words: Sedimentology, Microfacies, Limestone, Haripur.

A/432. Ali, Z. & Raza, S., 1999. Engineering geology of Ghazi Barrage Site (Ghazi Barotha Hydropower Project, Terbela), Pakistan. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Engineering geology, Hydel power, Ghazi Barotha, Tarbela dam.

A/433. Alizai, S.A.K. & Ali, J., 1988. Comparison of Landsat and SIR-A data for geological applications in Pakistan: Current status and future programme. International Journal of Remote Sensing, 7, 1147-1151.

Key words: Remote sensing.

A/434. Alizai, S.A.K. & Khan, G.M., 1990. Remote sensing applications to geologic/mineral studies. In: Siddiqi, F., Husain, V., Kaifi, Z. & Ghani, A. (Eds.), Proceedings, First SEGMITE Conference on Industrial Minerals, March 1990, Peshawar, 68-73.

The application and interpretation of RS is described with respect to geological work. With the help of Landsat images, brief comments are made on the structure of five selected ranges of Pakistan: the Balochistan arc, Western Salt Range and Khisor Range, Eastern Salt Range and Potwar Plateau, Southern Sulaiman Range, and Coastal Makran Range. The author lays emphasis on combining field studies with RS. The western Salt Range and Khisor Range have complex structure, with considerable impact of salt tectonics. The Siwaliks of the Himalayan foreland are viewed as vertical sequence of individual stream channels overlain by related flood plain facies (shales and certain sandstones).

Key words: Remote sensing, salt range, Potwar, Sulaiman Range, Makran Range

A/435. Alizai, S.A.K. & Mirza, M.I., 1986. Remote sensing applications in Pakistan. International Journal of Remote Sensing, 9, 85-94.

Key words: Remote sensing.

A/436. Allauddin, M., 1969. Preliminary Petrography of Sirvik Gol Pegmatite, Chitral. Abstracts, 11th Annual Conference Science Society, Pakistan, p.18.

Key words: Petrography, Pegmatite, Chitral.

A/437. Allen, C.R., 1974. Preliminary report on visit to Tarbela dam and vicinity. Prepared for TAMS, Tarbela Dam Report, 23p.

Key words: Dams, Tarbela.

A/438. Allen, J.E., 1964. Quaternary stratigraphic sequences in the Potwar Basin and adjacent Northwest Pakistan. Geological Bulletin, Peshawar University 1, 2-5.

Prof. Ahmad Hassan Dani and Farzand Ali Durrani of the Department of Archaeology; Univ. of Peshawar kindly permitted the writer to accompany them upon a number of their trips to the remarkable Archaeology "digs" near Charsadda, Senghao and Thana which were under investigation during 1963-64.

The problem faced by them in the dating of the formations within which artifacts occur at once aroused the writer's interest since they are in large parts geological problems in Quaternary stratigraphy. Nothing has been published on this aspect of the area, the nearest work has been in Kashmir (De Terra. 1939) many miles to the north-west, and in Gujrat (Zeuner 1950-63) over farther to the south. Both are indifferent drainage systems, which might not correlate with Potwar System.

After a number of trips to various parts of the region, a pattern emerged in March of 1964, and tentative correlations appeared possible between similar sequences of unit found near the Swat River a mile south-east of Thana, along the Sher Garh nullah 17 miles north of Mardan and north of Katlang near Sanghao, Because of the absence of the previous publications, it seemed worthwhile to present the available data and some conclusions reached as a guide to further investigation, inspite their highly tentative and incomplete nature.

Key words: Quaternary, stratigraphy, Potwar Basin.

A/439. Allen, T. & Chamberlain, C.P., 1989a. Thermal consequences of mantle gneiss dome emplacement. Earth and Science Planetary Letters 93, 392-404.

Key words: Mantle gneiss dome.

A/440. Allen, T. & Chamberlain, C.P, 1989b. Petrologic constraints on the tectonic history of the northern Shyok suture and the main Karakorum Thrust, Baltistan, Northern Pakistan. Geological Society of America Abstracts with Programs, 21(6), p.A181.

The Northern-Shyok Suture and the Main Karakorum Thrust (MKT) separate rocks in the Asian plate from rocks in the Kohistan-Ladakh Island Arc. We determined the P-T history of the metamorphic rocks both north and south of this suture in effort to place constraints on the suturing process. The terranes north and south of the MKT have different, unrelated metamorphic histories. Our data is consistent with a tectonic model that involves metamorphism of the Kohistan-Ladakh Arc due to plutonic activity and metamorphism of the Karakorum Metamorphic Complex as a result of subduction related processes. After metamorphism the two terranes were juxtaposed by the late south directed MKT, which obscures the original Northern-Shyok Suture.

Key words: Petrology, tectonics, Shyok Suture, MKT, Baltistan.

A/441. Allen, T. & Chamberlain, C.P., 1991. Metamorphic evidence for an inverted crustal section, with constraints on the Main Karakorum Thrust, Baltistan, northern Pakistan. Journal of Metamorphic Geology 9, 403-418.

The Shyok Suture Zone separates rocks in the Asian plate from rocks in the Kohistan-Ladakh island arc. In Baltistan, this suture has been reactivated by the late 'break-back' Main Karakorum Thrust (MKT). The P-T histories of metamorphic rocks both north and south of the MKT have been determined in an effort to place constraints on the tectonic history of this zone. The terranes north and south of the MKT have different, unrelated metamorphic histories. Rocks from the Kohistan-Ladakh island arc south of the MKT have undergone a static low-P (2-4 kbar, c. 500° C) thermal metamorphism. The P-T paths and metamorphic textures of these rocks are consistent with metamorphism due to emplacement of plutonic rocks into the island arc. This metamorphism pre-dates folding and deformation of these rocks. Rocks in the Karakorum Metamorphic Complex, north of the MKT, have experienced a complex deformational and metamorphic history. Prograde metamorphic isograds have been deformed by subsequent south-verging folding and by gneiss dome emplacement. However, decompression metamorphic reactions occurred during nappe emplacement. Higher pressure rocks are associated with higher level nappes,

creating an inverted pressure metamorphic sequence (8–9-kbar rocks over 5–6-kbar rocks). There is little variation in temperature with structural level (550–625° C). These two different terranes have been juxtaposed after metamorphism by the late south-directed MKT.

Key words: Petrology, Tectonics, Shyok Suture, MKT, Baltistan.

A/442. Al-Nawab, L.M.A., 1983. Geology of a portion of Kohat quadrangle Darra Adam Khel, Kohat, North West Frontier Province, Pakistan. M.Sc. Thesis, Peshawar University, 97p.

Key words: Darra Adam Khel, Kohat

A/443. Aloisi, P., 1933. Le rocce. Relazioni scientifiche della Spedizione Italiana “De Filippi” nell’ Himalaya, Caracorum e Turchestan Cinese (1913-14). Series 2^a, Risultati Geologici e Geografici 7; Le Rocce. Zanichelli, Bologna.

This is a compilation of the scientific work of the Italian expedition to the Himalaya, Karakoram and Chinese Turkestan, now referred to as Sinkiang. This covers the work done during the period 1913 – 14 and concerns the lithology and rocks of the region studied.

Key words: Lithology, Italian Expedition, Himalaya, Karakoram, Chinese Turkestan.

A/444. Aloisi, P. & Dainelli, G., 1934. (Exact title not known). Series 2^a, Risultati Geologici e Geografici 7; Le Rocce. Zanichelli, Bologna.

The authors distinguish in the Karakoram and the neighbouring regions three types of granites of different ages on stratigraphic ages: 1. Precambrian, 2. Biotite granites and two mica granites, the most frequent and pre-cretaceous in age (Himalayan granite), 3. Mica-amphibole granites with associated diorites and basic rocks of Senonian age (trans-Himalayan granite).

Key words: Granites, Karakoram, Himalaya.

A/445. Alvi, D.H., 1985-87. The mineralogical/geochemical studies of rocks, soils and water from Khanaspur Dewal Area. M.Sc. Thesis, Punjab University, Lahore, 102p.

This report gives an account of Mineralogical and geochemical studies carried out in Khanspur and Dewal area. The prescribed area lies to the north of Murree, in extreme east of Abbottabad and southwest of Muzaffarabad. Except an area of about 6 sq. km. which belongs to District Rawalpindi, the area lies in Abbottabad District, N.W.F.P. It is a mountainous region with fairly high relief.

Geological mapping of approximately 56 sq. km. on lithostratigraphic basis, at the scale 1:10,000 was carried out. The stratigraphic succession ranges from Datta Formation (Jurassic) to Murree Formation (Miocene). The lithology is mainly limestone, shales and sandstone. Extensive sampling of rocks, soils and water was carried out and these samples were studied in laboratory and data regarding these studies are given in this report.

A brief systematic description of various rock units in hand specimen and thin section is included. A brief description of chemical staining techniques applied to the limestones and that of performed limestone analysis is also given. A chapter regarding the detailed geochemical studies of soils of the project area is also included. This chapter gives an account of all the parameters necessary for soil study and according to these parameters, the soils of the area are categorized as non-sodic, non-saline.

Geochemistry of two main streams of the area has also been studied in detail and the data regarding the chemical analysis of the water are reported and interpreted by various graphical techniques. According to these data, the mineral components and other parameters lie within the safe limits, established for water to be used for domestic and agriculture purposes. Chemical characteristics of waters of various springs of the area, originated in different rock units have also been studied and interpreted in detail. Spring waters are also fit for irrigation and drinking purposes. Finally, there is a general discussion about the waters of the area and the effect of various encountered rock units on the chemistry of water passing through them.

Key words: Mineralogy, geochemistry, hydrogeochemistry, soil, water, Abbottabad.

A/446. Ambraseys, N., Lensen, G. & Moinfar, A., 1975. The Pattan earthquake of 28th Dec. 1974. UNESCO, Paris (RP 1975–76/2, 222, 3), (Serial No. FMR/SC/GEO/134), 41p.

Consult the following account.

Key words: Earthquake, Pattan.

A/447. Ambraseys, N., Lesen, G., Moinfar, A. & Pennington, W., 1981. The Pattan (Pakistan) Earthquake of 28 December, 1974: Field Observations. In: *Quarterly Journal of Engineering Geology* 14, 1-16, Edinburgh.

In the early evening of 28 December 1974, a magnitude 6.0 (*mb* USGS) earthquake occurred in a remote and mountainous region of northern Pakistan, resulting in loss of life and damage to property. The Pakistani Army Engineers involved in construction and maintenance of the Karakorum Highway, a one-to two-lane gravel road along the Indus River valley, quickly established an efficient relief operation. Since the highway was damaged and unusable during most of the relief operation, helicopters were used to carry supplies from Besham, at the end of the usable highway, to Pattan, where a hospital camp was set up.

Two seismic reconnaissance teams visited the affected area: the first arrived from Tarbela Dam on 1 January 1975, and included one of the authors (Pennington); the second team, with the other three authors (Ambraseys, Lensen and Moinfar) arrived later in January. The following report is based largely on their field studies (Ambraseys *et al.* 1975; Pennington 1975).

The earliest known earthquakes of the Northwest Frontier Provinces (NWFP)

As early as the 4th century BC, the region north of the Jhelum was reputed for its destructive earthquakes. Historians who accompanied Alexander the Great on his expedition in Swat allude to such events; they briefly state that as a result of earthquakes in this track of country even the beds of rivers are changed. Alexander must have reached Aornos (modern Pir-sar about 20 km from Besham) late in 327 BC (Stein 1927, 1929;

Key words: Earthquake 1974, Pattan.

A/448. Amerise, C., Quintavalle, M. & Tropepi, R., 1998. Palynological dating (Arenig) of the sedimentary rocks overlying the North Karakoram crystalline basement near Vidiakot, Chitral, Pakistan. CIMP Symposium and Workshop, Programme and Abstracts, University of Pisa, p.35.

Key words: Palynology, sedimentary rocks, Chitral.

A/449. Amin, K.M., 1999. Hydrogeophysical studies for groundwater exploration in the vicinity of Quaid-i-Azam University, Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 81p.

Key words: Geophysics, groundwater exploration, Islamabad.

A/450. Amin, M., 1982-84. Geology and Petrotectonic Study of Shino-Kaghan-Batal Area, District Mansehra Pakistan. M.Sc. Thesis, Punjab University, Lahore, 189p.

This field report comprises a complete geological study based on a first time mapping of nearly 328 km² of Central Kaghan Valley. Special emphasis has been put on, describing the stratigraphy and deciphering petrotectonic relationships of the rocks. A tentative stratigraphic correlation of the rock units has also been attempted. Between Shino and Batal a large number of rock unit including volcanics, tillites, metaconglomerates, schists, quartzites, marble, granites and migmatites are encountered. A stratigraphic sequence has been worked out. The rocks extend in age from Permo-Trias to Precambrian, have been correlated with Panjal Volcanics, Agglomeratic Slates, Tanols, Slates (Hazara/Dogra) and Salkhalas/Sharda Group.

Structurally, the rocks are folded into a number of major structures, which are now separated from each other by mostly north dipping high angle thrust faults. The area thus comprises a large number of thrust sheets over riding

each other. A study of the petrostructural relationships of the various rock units brings out the very interesting discovery of a third suture in NW Himalayas. This suture is much older than the two already described (MKT & MMT) and coincides with the position of MBT. In the field of economic geology a number of new potential economic deposits including quartzites, marble graphite and gypsum being reported. This report also includes a petrographic description of the rock units as well as numerous sketch sections and photographs, illustrating the geology of the area.

Key words: Petrology, Tectonics, Kaghan, Mansehra.

A/451. Amin, M., 1988. Shallow seismic refraction survey in Fateh Jhang area District Attock. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 121p.

Key words: Seismic refraction, Fateh Jhang, Attock.

A/452. Amin, M., 2000. Fault solution of a part of Northern Pakistan during period, 1993-96. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 43p.

Key words: Structure, seismology, Faults.

A/453. Amin, M.T., 1981-83. Geology of Paras-Bela-Jared Area, central Kaghan valley. M.Sc. Thesis, Punjab University, Lahore, 148p.

This report gives an account of lithostratigraphic mapping and, Tectonic and structural observation of the area between Paras and Jared in Kaghan valley. Some details of the geomorphology of the area is also given.

Key words: Lithostratigraphy, Mapping, Kaghan.

A/454. Amin, R.S., 1998. To understand the unconformity in seismic reflection section. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 27p.

Key words: Seismic reflection, structural geology.

A/455. Amir, M., 1987. The electrical resistivity survey for groundwater exploration. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 34p.

Key words: Geophysics, electrical resistivity, groundwater.

A/456. Anczkiewicz, R., 1998. Structural and geochronological study of the Indian-Kohistan arc collision, lower Swat region of Pakistan, NW Himalaya. Ph.D. thesis, Swiss Federal Institute of Technology, Zurich.

The NW Himalayan collisional system comprises three distinct crustal domains. From south to north they are: the Indian plate, the Indus Suture Zone (Main Mantle Thrust) and the Kohistan paleo-island arc (KIA). The studied area is located in the Mingora-Alpurai region, Lower Swat district of Pakistan, where the Indus Suture Zone (ISZ) forms one of the largest exposures. Structural mapping of the Indus Suture Zone lithologies and neighbouring parts of the northern Indian margin and of the basal part of the Kohistan arc were carried out. Geochronological studies were conducted in order to provide time constraints on pre- syn- and post-collisional magmatic, metamorphic and deformational evolution in the three domains. In addition, geochronological studies were carried out on the garnet granulites of the KIA in the Jijal-Patan area were conducted.

The Indian plate

The lowest crustal level in the Indian plate domain is represented by the Swat and the Choga granite gneisses. The Choga granite gneiss consists of peraluminous granites, whose U-Pb zircon dating yielded a 468 ± 5 Ma magmatic emplacement age. The alkaline Swat granite, which intruded overlying Alpurai metapelite, yielded a 268 ± 7 -3 Ma

U-Pb zircon age interpreted as the time of intrusion. The granitoids together with the overlying Alpurai and Saidu schists underwent amphibolite and greenschist facies metamorphism during collisional time. The earliest, collision related, deformational phase is associated with southward-directed thrusting and formation of large-scale recumbent folds. This period was followed by the reactivation of the ISZ as a normal fault. As a result of normal faulting the greenschist facies Saidu schists were juxtaposed against amphibolite facies Alpurai schists. Strike-slip faulting, most likely, occurred at this stage. The extension related structures are folded by N-S trending folds, whose formation is probably contemporaneous with building of the Besham syntaxis.

Sm-Nd dating of garnet from the Alpurai schists and $^{40}\text{Ar}/^{39}\text{Ar}$ dating of hornblende and muscovite indicate that the Lower Swat region remained under lower amphibolite facies conditions (or higher) until ca. 35 Ma. The main period of exhumation is most likely related to the extensional period. Its maximum age was constrained by dating late kinematic alkali granite dykes, which post-date the main metamorphism and are deformed by the extension related N-vergent folds. U-Pb zircon dating yielded 29.3 ± 0.2 Ma magmatic emplacement age, which was also confirmed by a 28.6 ± 1.4 Ma Ar/Ar muscovite age.

Indus Suture Zone

A new subdivision of the Indus Suture Zone lithologies is proposed. The main mapped units represented by Sheared Olistostromic Unit, Interlayered Blueschists and Greenschists, Volcaniclastic metaturbidites and serpentinised ultramafics. They are separated by fault contacts and form a zone of imbricated blocks, which underwent multiphase deformational history. Due to different rheological properties and strong brittle overprint structural comparison between the units is ambiguous. Very well preserved extensional structures within the 'Sheared Olistostromic Unit', similar to those observed in the Indian plate, suggest that Indian plate and the ISZ lithologies have shared a similar deformational history since this stage or earlier.

Rb-Sr dating of blueschist facies assemblages yielded ages of 77.0 ± 0.4 and 79.7 ± 0.4 Ma. This was confirmed by a 80.4 ± 0.7 Ma $\text{Ar}-\text{Ar}$ muscovite age. These dates are interpreted as reflecting peak blueschist facies conditions. Lack of collision-related metamorphic overprint is probably due to underplating of the blueschists to the hanging wall of the MMT prior to collision or earlier obduction onto the Indian plate.

Kohistan arc

Sm-Nd and Rb-Sr garnet dating of the Kamila amphibolites in Kwazakhela area yielded concordant ages of 94.6 ± 5.3 and 99.5 ± 15.7 Ma, respectively. Similar ages were obtained for the amphibolitised garnet granulite, from the Jijal-Patan complex, which yielded 95.7 ± 2.7 and 101.3 ± 10.4 Ma by Sm-Nd and Rb-Sr techniques, respectively. Petrological observations and comparison with other studies indicate that garnet is a relic of the earlier, granulite facies metamorphism. These dates are interpreted as reflecting, or shortly postdating the granulite facies metamorphic peak. Rb-Sr and $\text{Ar}-\text{Ar}$ dating of the amphibolitisation process leads to more

Key words: Structure, geochronology, collision, Kohistan arc, Swat.

A/457. Ancykiewicz, R., Burg, J.P., Hussain, S.S., Dawood, H., Ghazanfar, M. & Chaudhry, M.N., 1998. Stratigraphy and structure of the Indus Suture in the lower Swat, Pakistan, NW Himalaya. *Journal of Asian Earth Sciences* 16, 225-238.

We present a geological map, detailed structural description and new subdivisions of the Indus Suture Zone lithologies in northeast Pakistan (Lower Swat region). The Indus Suture Zone is a dominantly fore-arc related assemblage obducted onto the Indian Plate. Initial southward thrusting was followed by the reactivation of the Indus Suture as a ductile-brittle normal fault. Significant strike-slip faulting may have taken place at this stage. Later brittle reverse faults demonstrate that shortening outlasted normal faulting. The comparison of the structural evolution of the Indus Suture Zone and the Indian Plate shows that both remains were sharing the deformational history, possibly since the earliest stage of collision. The Lower Swat area records a full orogenic cycle from early rifting through continent-arc collision to orogenic collapse. We present a geodynamic model that integrates all these elements.

Key words: Stratigraphy, structure, Indus Suture, Swat.

A/458. Ancykiewicz, R., Burg, J.P., Meier, M., Oberli, F., Vance, D., Dawood, H., Hussain, S., Ghazanfar, M. & Chaudhry, M.N., 1997. Tectonometamorphic evolution of the Indus Suture viewed by structural and isotopic data, lower Swat, Pakistan NW Himalaya. Abstract volume, 12th Himalaya- Karakorum-Tibet International Workshop, Rome, Italy, 2-4.

In NW Himalaya the Indus Suture separates the Kohistan paleo-Island Arc (KIA) from the Indian continent. The Indus Suture in the Mingora-Alpurai region of Lower Swat (NE Pakistan) represents a complex exposure of greenschist and blueschist facies mafic, ultramafic and metasedimentary rocks wedged in-between ortho-amphibolites of KIA to the north and metapelites of the Indian plate to the south (map).

In the studied area Indian plate lithologies comprise the Manglaur schists, associated Swat granite gneiss, and overlying metapelites. These rocks were subsequently metamorphosed during the Kohistan-India collision. Preliminary U-Pb zircon dating of the Swat granite-gneiss (map, samp. 95/198) yielded an upper intercept age $276 \pm 40/-9$ Ma which represents the time of magmatic emplacement. Amphibolite facies metamorphism dated by Sm-Nd techniques on metapelitic schists of the Alpurai group (map, samp. 94/1) at 36 ± 2 Ma. This event was followed by a second magmatic episode expressed by syn- to post-kinematic pegmatitic dikes, which intrude the Swat granite gneiss.

The dominant style of deformation within the Alpurai para-amphibolites and overlying Saidu schists is characterized by asymmetric, north-vergent folds with gently to moderately south dipping axial planes. Similar style of folding is also observed in the basal unit of the Indus Suture Zone where extension is indicated by numerous shear bands and normal faulting (cross-section). Comparable north-vergent folds from the neighboring Naran region were shown to be synconvergent collapse features related to the backsliding of the Kohistan arc.

The lithologies of the Indus Suture Zone represent a sequence of imbricated blocks that bear evidence of metamorphism and deformation prior to collision. This early phase is indicated by the age of blueschist facies metamorphism and conjugate box type folds preserved in metacherts, which underwent first phase of deformation probably in the forearc environment. All units were juxtaposed, metamorphosed and deformed when collision occurred. The Kohistan amphibolites show features mainly related to southward directed shearing which resulted in anastomosing shear zones and south verging folds. Rare asymmetric quartz clasts mark a late stage of northward-directed movement. The latest stage of ductile deformation is expressed by NE-SW trending strike-slip faults with unconstrained amounts of vertical and horizontal displacement.

Key words: Tectonics, Metamorphism, Isotopes, Structure, Indus Suture, Swat.

A/459. Anczkiewicz, R., Oberli, F., Burg, J.P., Meier, M., Dawood, H. & Hussain, S.S., 1998. Magmatism south of the Indus Suture, lower Swat, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 7-9.

The lower Swat magmatism is dominated by the so-called Swat granite, which intruded the Manglaur Formation and is unconformably overlain by the Alpurai schists (Fig.1). Its age of emplacement has been assumed to be similar to that of the Mansehra granite, which gave a Rb-Sr total-rock isochron of 516 ± 16 Ma age (Le Fort et al., 1980). We present results of petrological, geochemical and geochronological studies of the Swat granitoids in the northern part of the Loe Sar dome and Alpurai regions (Fig. 1).

At the northern edge of the Loe Sar dome the granitoids occur as two sill-like bodies. We investigated the upper sill at the northern edge of the dome. It exhibits dominantly augen and flaser type textures, which show alkaline composition. U-Pb single zircon dating of sample 95-198 (Fig. 1) yielded $268 \pm 7/-3$ Ma. Preliminary dating of sample 95-196 confirms the Permian age, which we interpret as the time of magmatic emplacement. The body is intruded by alkaline syn- to post kinematic pegmatitic dykes, which are truncated and sheared at the contact with the overlying Alpurai schists (Fig. 2a). U-Pb zircon dating gave an age of 29.2 ± 0.2 Ma interpreted to represent an intrusion age. This date establishes also the maximum age for shearing. Scarce kinematic indicators suggest a thrust sense of movement. Thus, the Tertiary alkaline volcanism appears to be associated with regional thrusting (see also Le Bas et al., 1987) rather than rifting as proposed by Kempe and Jan, 1980.

Taking into account field observations and age data we suggest an intrusive rather than an unconformable nature for the contact between the Swat granite gneiss and the Alpurai schist. This interpretation is based on i) the existence of a fine-grained fabric at the border of the granite gneiss, ii) the occurrence of xenoliths of garnet-amphibolite that may have been derived from the Alpurai schists and iii) the Permian age of the granite, which has intruded Middle Carboniferous to Permian beds at the base of Alpurai schists (Marghazar Formation of DiPietro et al., 1997). Regional shearing at ca. 30 Ma is responsible for the truncation of the pegmatitic dykes at the Swat granite gneiss / Alpurai schists interface and have obscured the original intrusive character of this contact.

Based on similar stratigraphic position with respect to the Alpurai schists, the Choga granite gneiss (Fig. 1, 2a,b) of the Alpurai region has been commonly assigned to the Swat granitoids. Microprobe analyses of major mineral phases in sample 95-21 1, however, are different from those of samples 95-198 and 95-196, which originate from the northern part of the Loe Sar dome (Fig. 1). This observation is corroborated by a U-Pb zircon age of 468 ± 5 Ma

obtained for Choga granite, which we interpret as an intrusion age. Based on similarities in major mineral geochemistry, we consider the Choga granite to be related to the granitoids in the core of the Loe Sar dome (lower sill).

Because our investigations have been focussed on a rather limited part of the Swat granitoids, it is still uncertain, whether the Permian age determined for their northern margin is representative for the entire upper unit or whether the Permian magmatites form smaller intrusions within Cambro/Ordovician granitoids. The results extend the spatial distribution of alkaline magmatism, previously restricted to the Peshawar Plane igneous province, to the Swat area. Furthermore, they give clear proof that this magmatism was generated in at least two cycles unrelated in age.

Key words: Magmatism, Indus Suture, Swat.

A/460. Anczkiewicz, R., Spencer, D.A., Hussain, S.S., Dawood, H., Chaudhry, M.N. & Ghazanfar, M., 1995. Emplacement and subsequent tectonic history of the Indus Suture in the Mingora-Shangla-Malam Jabba area (NW Himalaya, Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

A complex exposure of the Indus Suture in the Northwestern Himalayan area is situated on the western side of the Besham Syntaxis (northeastern Pakistan). Between Mingora and Lilauni, the Indus Suture bifurcates into a wedge-shaped complex, which comprises of predominantly mafic rocks of blueschist and greenschist facies grade. It is separated by the tectonic contacts from the amphibolites of the Kohistan Island Arc to the north and from the metasediments of the Indian Plate to the south. The enclosed Indus Suture Mélange Group was previously subdivided into three units: the Mingora Ophiolitic Mélange, the Charbagh Greenschist Mélange and the Blueschist Mélange. These were suggested to have been separated by major thrusts that were active when the continental collision occurred. The mélange units are thought to represent oceanic crust material, which is of either Island Arc, Mid Oceanic Ridge or subduction zone origin.

Preliminary results of fieldwork in the Mingora, Shang La and Malam Jabba areas indicate that the interpretation of a mélange-type subdivision can no longer be sustained. We were not able to confirm the existing divisions of the three units separated by the thrust contacts. Only the lower and upper contact of the suture zone are marked by the presence of distinctive shear zones which show a thrust sense of movement, although occasionally evidence for extensional movement is found.

Initial petrological studies of the Alpurai schists revealed distinct variation in the metamorphic and deformational history within this unit. Schists from the vicinity of the village Kashora show two stages of the growth of garnet which postdate the formation of the main foliation while schists from Makad show one stage of growth and are cut by the main foliation.

Key words: Tectonics, Indus Suture, Mingora, Shangla, Malam Jabba, Himalaya.

A/461. Anczkiewicz, R. & Vance, D., 2000. Isotopic constraints on the evolution of metamorphic conditions in the Jijal-Patan complex and Kamila belt of the Kohistan arc, Pakistan Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 321-331.

Pressure-temperature data and Sm-Nd and Rb-Sr garnet ages presented for retrogressed granulitic rocks of the Jijal-Patan complex and the Kamila Amphibolite Belt. Despite the retrogression and hydration, the two samples contain garnet and hydrous minerals that yield pressures and temperatures similar to previous estimates for pristine granulite facies rocks from the same area. The Sm-Nd and Rb-Sr garnet ages are concordant at 95-100 Ma for the two samples and for both isotopic systems, these ages are interpreted as dating cooling through 700-800°C following magmatic crystallization and granulite facies metamorphism. In the case of the garnet amphibolites from the Kamila Belt, the garnets system is very close to the recorded temperatures. For these reasons, the age of 100 Ma must represent a time close to that when the pressure and temperature preserved in the mineralogy and its chemistry was recorded. The isotopic equilibrium between garnet and paragonite at 90-100 Ma suggest that the regional hydration event that affected the lower crust of the Kohistan arc also occurred at this time. Cooling rates calculated from the Rb-Sr and Sm-Nd ages for the partially retrogressed granulite give a minimum of 3-6°C Ma⁻¹ and imply a different

tectonic mechanism for the exhumation of the lower crust than is typical for granulites. This process may be related to early regional decompression following the collision of the Kohistan arc with Eurasia.

Key words: Isotopes, metamorphism, Jijal, Pattan, Kamila, Kohistan arc, Himalaya.

A/462. Anczkiewicz, R., Villa, I.M., Miller, W., Burg, J.P., Meier, M., Dawood, H. & Hussain, S.S., 1998. Rb/Sr and $^{39}\text{Ar}/^{40}\text{Ar}$ dating of blueschist facies metamorphism in Shangla region, Pakistan, NW Himalaya. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 9-10.

Geochronological studies of high-pressure rocks in many metamorphic terrains show that Ar-Ar dating often yield ages inconsistent with other dating techniques (e.g. Li et al., 1994). Therefore an independent control by other isotopic geochronometers is needed. We present preliminary results of coupled Rb-Sr and $^{39}\text{Ar}/^{40}\text{Ar}$ dating of the Shangla blueschists.

The Shangla blueschists are squeezed within the Indus Suture Zone, on the western limb of the Besham (Indus) syntaxis (Lower Swat region of Pakistan). As such, they outcrop within the so called 'm61ange zone' between the Indian plate and the Kohistan. The blueschist facies event has been previously dated at ca. 80 Ma by $^{39}\text{Ar}/^{40}\text{Ar}$ phengite dating (Maluski and Schaeffer, 1982; Maluski and Matte, 1984). Glaucophanes yielded $^{39}\text{Ar}/^{40}\text{Ar}$ data scattered between > 450 and 50 Ma (Schams 1980; Maluski and Schaeffer, 1982; Maluski and Matte, 1984).

Prior to dating, we carried out detail microprobe analyses in order to eliminate samples exhibiting retrograde features (invisible on the micro-scale) and detect possible mixing between various phases. Back-scattered electron imaging and quantitative microprobe analyses of the blue amphiboles showed no or very weak zoning. Compositions are all within the range of glaucophane-riebeckite series. Similarly, phengites do not display any significant zoning. Blue amphiboles eventually contain sub-microscopic inclusions of phengites.

Two metasedimentary and three metavolcanic types of blueschists were selected for the geochronological studies. Both show crossite/ glaucophane+epidote paragenesis, which is diagnostic for the transitional blueschist-greenschist facies, typical for the Shangla region. Five glaucophanes and three phengite high-purity mineral concentrates derived from five rock samples were subjected to $^{39}\text{Ar}/^{40}\text{Ar}$ dating by stepwise heating technique. In addition, two of them were dated by the Rb-Sr method.

Rb-Sr isochrons of blue amphibole-phengite pairs allow to better ascertain the age of blueschist facies metamorphism. Low $^{87}\text{Rb}/^{86}\text{Sr}$ ratios for blue amphiboles together with high ratios for phengite (see table 1) allow precise age determination at 77.0 ± 0.4 and 79.7 ± 0.4 Ma (errors with 95% c.l.). The estimated thermal peak for the Shangla blueschist (300-380°C) (Jan 1981; Guiraud, 1982) is significantly lower than the commonly accepted closure temperature for Rb-Sr system in phengite and amphibole. Therefore, we interpret our age determination as representing time of metamorphic crystallisation under transitional blueschist-greenschist facies conditions at ca. 80 Ma. $^{40}\text{Ar}/^{39}\text{Ar}$ dating was performed on 5 glaucophane samples. Extensive handpicking and preliminary K concentration measurements ($K < 500$ ppm) let us hope to have eliminated 'contamination' by phengites. However Ca/K vs. Cl/K trajectories coupled to mass balance calculations show that true blue amphibole has $K < 23$ ppm, and about 0.4% modal phengites intergrowths by far dominate the K-Ar budget. All ages group around 80 Ma and agree with Rb/Sr dating. Three out of 5 glaucophanes preserved pre-blueschist facies amphibole (?) relics, which give reproducible step ages around 400 Ma in the last 5% of the gas release. This corresponds to about 1 modal % 'relict amphibole', which appears to preserve a signature of the Ordovician volcanism.

Key words: Blueschist facies, metamorphism, geochronology, Shangla, Himalaya

A/463. Anderson, B.W., 1966. Transparent green grossular-a new gem variety; together with observation on translucent grossular and idocrase. Journal of Gemmology 10, 113-119.

Transparent green grossularite from Pakistan has been identified as a new gem variety, similar to previously described chrome-rich grossularite and having an x-ray pattern typical for nearly pure grossularite. Difficulties in distinguishing between grossularite and idocrase can be resolved through density determinations and study of absorption patterns.

Key words: Grossular, gemstones.

A/464. Anderson, R.V.V., 1928. Tertiary stratigraphy and orogeny of the Northern Punjab. Geological Society of America, Bulletin 38, 665-672.

The Tertiary of the Punjab is divided into two principal parts, the marine and estuarine Eocene (Nummulitic) system below, and, unconformably overlying this, a great succession of nonmarine beds representing continental sedimentation from the Oligocene to the late Pliocene or early Quaternary. This nonmarine succession, here named the "Ni-madric System," includes the Murree and Siwalik series. It comprises over 20,000 feet of fairly well stratified, alternating sandy and silty beds, mainly fine-grained, but coarsely conglomeratic in its uppermost division. It is interpreted as the product of mainly fluvial, but in part eolian, deposition over fairly flat plains, under a semitropical climate of medium rainfall. The plains extended into the region now occupied by the Himalaya. Evidence of the validity of thickness measurements is afforded by the comparative constancy of individual fine-grained formations, the great thicknesses superimposed in single sections, and by the record here presented of a well 6,000.

Key words: Stratigraphy, orogeny, Tertiary, Punjab.

A/465. Andrews, S.C.P. & Brookfield, M.E., 1982. Middle Paleozoic to Cenozoic geology and tectonic evolution of the Northwestern Himalaya. Tectonophysics 82, 253-275.

Previously published data and data collected by the authors from the northwestern Himalaya are summarized and assessed. The account focuses on Kohistan and the Karakorum Range in Pakistan, and on Ladakh and the Zaskar Range in India.

Five palaeotectonic units are recognized. From south to north these are:

- (1) Palaeozoic-Eocene continental shelf sequence on the northern margin of the Indian continent;
- (2) a Triassic-Jurassic continental slope sequence: the Lamayuru unit of the Indus zone and of the Spongtag klippe;
- (3) the Cretaceous-Tertiary Kohistan-Ladakh magmatic arc, which includes the Kohistan sequence, the Ladakh batholith, the Dras unit, the Spongtag klippe, the Indus molasse unit and the Shyok zone;
- (4) the Karakorum batholith: a late Tertiary zone of granitoid magmatism and metamorphism;
- (5) a Palaeozoic-Mesozoic continental shelf and slope sequence deposited on the southern margin of an Asian continent.

The following sequence of events is tentatively proposed:

- (1) Permian-Carboniferous continental rifting;
- (2) Triassic-Jurassic collapse of continental shelf, and formation of deep (oceanic?) basin;
- (3) Cretaceous formation of Kohistan-Ladakh magmatic arc, in response to subduction from the south as ocean closed;
- (4) Late Cretaceous-Eocene emplacement of Kohistan arc and of thrust sheets of Indus zone (magmatic arc units and Lamayuru unit) southwards onto Indian continental margin, as India approached and collided with magmatic arc;
- (5) silicic phases of Ladakh batholith (Palaeocene-Eocene) and Karakorum batholith (Miocene) may be related to subduction of oceanic basin between magmatic arc and Asian margin. Alternatively, they are late- and post-collisional products;
- (6) the Shyok zone, between the Ladakh and Karakorum batholiths, was emplaced to the south in Oligocene or Miocene time;
- (7) final collision between India, the magmatic arc and Asia in Oligocene-Miocene time was followed by continued crustal shortening which disrupted thrust units.

Key words: Tectonics, geochronology, NW Himalaya.

A/466. Andrieux, J. & Brunel, L., 1977. L'évolution des chaînes occidentales du Pakistan. Geological Society of France, Memoir 8, 189-207.

Key words: Structural geology, tectonics.

A/467. Angiolini, L., 1994. 1 brachiopodi del Permiano del Karakorum. Studio tassonomico e biostratigrafico. Ph.D. Thesis. Dipartimento di Scienze della Terra. Univ. Studi di Milano, Italy, 202p.

Key words: Permian, paleontology, brachiopods, biostratigraphy, Karakoram.

A/468. Angiolini, L., 1995a. Permian Brachiopods from Karakorum. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Large collections of Permian brachiopods were assembled during four Italian expeditions (1986, 1991, 1992) on the Pakistan side of Karakorum. The first three expeditions visited the Upper Hunza valley and its laterals, Chapursan valley, Abgarch valley and Shimshal valley. The last expedition was led in the western termination of the Karakorum, in the Chitral-Baroghil-Karambar sector.

Permian brachiopods from western Karakorum (Baroghil pass) were first collected by Hayden (1915) and described by Reed (1925). A small collection of Permian brachiopods from Upper Hunza valley, collected by Desio (1962), was described by Fantini Sestini (1965).

Five brachiopod assemblages have been recognized, from the Asselian-Sakmariafl to the Murgabian-Midian. The first association, named Trigonotreta lyonsensis-Punctospirifer afghanus assemblage, has been collected in the Asselian-Early Sakmarian Gircha Fm. of Upper Hunza Valley. The second assemblage, Hunzina electa-Cleiothyridina ailakensis association, characterizes the Sakmariafl Lupghar Formation, Mb. 1 of Upper Hunza valley and the Sakmarian Lashkargaz Fm., Mb. 1 of Baroghil-Lashkargaz area (Chitral). The third assemblage, with Orthothetina convergens-Aldina hexilis as index-species, is Bolorian in age and it has been collected at the top of Lashkargaz Formation, Mb. 2 of Lashkargaz (Chitral). The fourth association, Waagenochoncha (Gruntochoncha) macrotubercolata-Callytharrella sinensis assemblage, is Kubergaridian in age and characterizes the Panjshah Formation, Mb. 1 of Upper Hunza Valley and the Lashkargaz Fm., Mb. 4 of Baroghil-Lashkargaz area. Finally the youngest association, named Stenoscisma armenica-Chapursania tatianae assemblage, has been collected in the Panjshah Formation, Mb. 2 of Upper Hunza Valley and it is Late Murgabian-Midian in age.

The evolution of the assemblages testifies for a warming of the climate conditions, due to the northward drifting of the Karakorum block during the Permian. Furthermore the youngest assemblages show a greater number of endemic taxa than the oldest ones which have species in common with W Australia, SE Pamir, Afghanistan and NW Tibet faunas.

Key words: Permian, Brachiopods, Karakoram.

A/469. Angiolini, L., 1995b. Permian Brachiopods from Karakorum (Pakistan), Part I (with Appendix). *Rivista Italiana de Paleontologia e Stratigrafia* 101, 165-214.

Consult the preceding account for further details.

Key words: Permian, Brachiopods, Karakoram.

A/470. Angiolini, L., 1996a. Permian brachiopods from Karakorum (Pakistan). In: Brachiopods. Copper, P., and Jin, J. (Eds.), Balkema, Rotterdam, 13-17.

Key words: Permian, Brachiopods, Karakoram.

A/471. Angiolini, L., 1996b. Permian brachiopods from Karakorum (Pakistan). Part II. *Rivista Italiana di Paleontologia e Stratigraphia*, 102, 3-26.

Key words: Permian, Brachiopods, Karakoram.

A/472. Angiolini, L., 2001. Permian brachiopods from Karakorum (Pakistan) part. III. *Rivista Italiana de Paleontologia e Stratigrafia* 107(3), 307-344.

Late Wordian (Guadalupian) brachiopods from Member 2 of the Panjshah Formation in the Karakorum (N Pakistan) are described. The brachiopod assemblage, dated by the associated fusulinids and conodonts, consists of 29 genera (3 of which are questionable and 1 unidentifiable) of the orders Productida, Orthida, Rhynchonellida, Athyridida,

Spiriferida and Terebratulida. Hunzininae, a new subfamily of the Spiriferellidae is proposed; it includes *Darbandia* n. gen., with type species *D. vagabunda* n. sp. and *Elivina chapursani* n. sp. A third new species is assigned to the genus *Anchorhynchia* of the family Wellerellidae: *A. cimmerica* n. sp.

A quantitative biostratigraphic analysis demonstrates two major faunal changes in the *Elivina chapursani*-*Chapursania tatianae* Assemblage Zone of the upper part of Member 2, which are not strictly linked to lithological changes. This biozone is correlated with the brachiopod faunas of the Gnishik Formation of Armenia and those of the basal Takhtabulak Formation of SE Pamir.

The faunal elements of the *Elivina chapursani*-*Chapursania tatianae* Assemblage Zone are an admixture of wide-ranging, Tethyan (particularly abundant), Gondwanan and endemic (Cimmerian) genera, representing a transitional fauna and a biostratigraphic tool for intercontinental correlation, which are particularly problematic in this time interval. The Panjshah transitional fauna demonstrates the persistence of the Transhimalayan Province of the Cimmerian Region into the late Guadalupian, which originated at the end of the Cisuralian and occupied Armenia, Central Afghanistan, Karakorum and SE Pamir. It provides also some insights into the biodiversity pattern before the mass extinction at the end of the Guadalupian, and suggests that this event was as rapid as the end-Permian mass extinction, at least in Central Asia.

Key words: Permian, Brachiopods, biostratigraphy, Karakoram.

A/473. Angiolini, L., Brunton, H., Gaetani, M. & Andra, Z., 1997. The once and future quest: The Carboniferous in Karakorum. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 5.

The quest for the Carboniferous in the sedimentary cover of N Karakorum has been one of the main goals of the Italian expeditions from 1986-96. However, it takes us 10 years to discover and its relationships with the Permian and Devonian successions are still unclear. So the term quests and the adjectives once and future are really appropriate.

In the Upper Hunza Valley, and its side valleys, the sedimentary succession starts with the terrigenous Gircha Formation, which contains Lower Permian brachiopods in its middle part. No Carboniferous fossils have been found in this formation but its base is possibly Late Carboniferous.

Westward in the Upper Yarkhun Valley (Baroghil area), crinoidal limestones with shaly intercalations have been tentatively attributed to the Early Carboniferous (Gaetani et al., 1996), due to their stratigraphic position between the Late Devonian Shogram Formation and the Gircha Formation in the Baroghil Unit. But again no well-preserved fossils have been found to prove this age assignment.

The 1996 Italian expedition investigating the region from the Chapursan Valley (Upper Hunza Valley) to Chitral was finally successful in finding Carboniferous fossils near the Karambar Pass and in the Showar Shur area (Upper Yarkhun Valley).

The newly discovered fossiliferous Carboniferous succession belongs to a tectonic unit located northward of the Baroghil Unit and stacked above it along a SW vergent thrust. Westward of the Karambar Pass, the Carboniferous succession is deformed by intensive folding and thrust stacking. Eastward, the Carboniferous succession passes to a monotonous sequence of black slates and arenites probably ranging up into the Permian. To the north, this unit is tectonically bounded by the Tash Kupruk Unit. The base of the Carboniferous succession is still unclear: In the Showar Shur gully it is truncated by a SW vergent thrust, whereas in the Karambar Pass area it is not exposed. However, west of the Karambar Pass, on the left (southern) side of the valley, a thick terrigenous succession, probably including the Carboniferous, overlies the Devonian Shogram Formation.

From the base to the top, the Carboniferous succession consists of at least 200 m of black marly limestones with thick intercalation of massive bioclastic limestones, passing upward to 100 m of black marly limestones, calcareous siltites, calcareous sandstones and hybrid limestone containing Late Carboniferous brachiopods such as *Pustula* sp., *Rhipidomella* sp., *Choristites* sp., *Martiniopsis* sp., *Spirifer* sp., *Gypospirifer* sp., and *Composita* sp. At the top, about 30-50 m of massive, cross bedded sandstones and conglomerates crop out, followed by 20-40 m of varicolored calcareous siltites, arenites and hybrid limestones containing Moscovian to Kasimovian brachiopods such as *Densepustula* sp., *Brachythyris* sp., *Rhipidomella* sp., *Septacamera dowhatensis*, and *Alispirifer middlemissi*. This mixed sedimentary succession is topped by 30-100 m of massive bioclastic limestones containing crinoids and recrystallized brachiopods and corals. A very thick (500 m?) terrigenous unit follows, chiefly consisting of dark slates and fine arenites with coarse sandstones and conglomerates which may correspond to the Gircha Formation of the Baroghil, Sost and Gujal Units. In fact on the path leading from Suinji to the Karambar Pass brachiopods similar to those of the lower Permian Gircha Formation (*Trigonotreta* sp., *Spirelytha* sp.) have been collected in the

scree. The Carboniferous brachiopods of N Karakorum are very similar to those collected in the Late Carboniferous of the Himalaya (Manang, Spiti, Tibet).

Key words: Carboniferous, Karakoram.

A/474. Angiolini, L., Brunton, H., & Zanchi, A., 1999. Late Carboniferous brachiopods from Karakorum, Pakistan. *Rivista Italiana di Paleontologia e Stratigrafia*, 105, 3-22.

Carboniferous rocks from North Karakorum display sharp lateral variations in lithology and thickness suggesting accumulation in half-grabens during continental rifting between the Karakorum block and northern Gondwana. Different Carboniferous successions, belonging to distinct tectonic units, have been detected. Thin, poorly fossiliferous successions of arenites and crinoidal limestones contrast with very thick terrigenous-carbonate successions comprising two distinct fossiliferous horizons. The lower fossiliferous horizon yielded brachiopods (*Pustula* sp., *Rhipidomella* sp., *Choristites* sp., *Martiniopsis* sp., *Afghanospirifer* sp., *Gypospirifer* sp., *Composita* sp.) of Bashkirian age. The upper fossiliferous horizon, lying about 90 m above the former, contains corals, crinoids and brachiopods (*Densepustula* cf. *losarensis*, *Dowhatania sulcata* n. sp., *Brachythyris* sp., *Rhipidomella* sp., *Septacamera dowhatensis*, *Alispirifer middlemissi*) of Moscovian to Kasimovian age. The Carboniferous brachiopods of North Karakorum are similar to those collected in the Late Carboniferous of Central Afghanistan, Himalaya (Manang, Spiti, Tibet), and Lhasa Block (Xainza area).

Key words: Carboniferous, Brachiopods, Karakoram.

A/475. Angiolini, L., Gaetani, M. & Nicora, A., 1993. The Permian succession of the Baroghil area (E Hindu Kush). Abstract Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 57-58.

During the 1992 Pakistani-Italian expedition from Chitral to Karambar a complete Paleozoic succession was discovered and analyzed. In particular the Permian part of the succession is extensively exposed in the Baroghil-ShoWar Shur area. There was the great opportunity to visit the Baroghil section, which was studied by Hayden in 1914 and then only shortly visited by Talent and Tahirkheli in 1973. The area was then strictly closed because of the Afghan war.

Three stratigraphic sections for about 2000 m in development have been measured along the Permian part of the Paleozoic succession, with at least 250 samples collected.

The Lower Permian overlies Lower Carboniferous crinoidal packstones and it is represented by a quartzarenitic to litharenitic unit, at least 600 m-thick. This unit has been named Gircha Formation because of its correlatability with the Gircha Formation of the Hunza region.

Then a mixed carbonate-terrigenous succession, several hundreds m-thick follows, named Lashkargaz Fm. It consists of four members; the first, mostly terrigenous, contains Sakinarian conodonts (*Adetognathus* thus *paralautus*) and brachiopods (*Globiella* cf. *G. rossiae*, *Elivina tibetana*, *Spirigerella* sp., *Cleiothyridina ailakensis*) at the top. The second member consists of fusulinids packstones and limestones locally crowded with oncolites, corals and gastropods. The third member is only 40-50 m-thick and consists of siltites and arenites. The fourth member chiefly consists of limestones with chert rich in fusulinids, conodonts (*Sweetognathus whitei*, *Gondolella bisselli*, *Gondolella* Cf. *G. idahoensis*, *G. intermedia*, *Anchignathodus* sp., *Iranognathus* sp.), brachiopods (*Costiferina* sp., *Marginifera* sp.), corals and bryozoans. Marly lixnestones may be present. The age of the fourth member is Artinskian to Bolorian on the basis of conodonts.

At the top of the Lashkargaz Fm., above an erosional surface, the Gharil Fm. crops out. It consists of red microconglomerates and arenites with phosphate nodules. Then a huge peritidal dolomitic formation, 700 m-thick follows. In the lower and middle part of this formation Upper Permian small foraminifers (*Daqmarita chanackiensis*, *Paraglobivalvulina* sp., *Globivalvulina* sp., *Lanqella* sp., *Climacammina* sp.) have been detected, whereas in the upper part foraminifers and algae are present and may suggest an Early Jurassic age. The Paleozoic succession is repeated at least three times within three thrust sheets, with slightly different facies in the Baroghil area. On the contrary we have poor informations about most of the Mesozoic.

In contrast to the Upper Hunza and Shimshal valleys (Karakoram), where deep-water sediments are present from the Midian upwards, in the upper Yarkhun-Karambar area the shallow water environments seems to persist throughout the Permian. Correlations may be inferred with the Helmand Block in Central Afghanistan.

Key words: Stratigraphy, Permian, Baroghil, Hindukush.

A/476. Angiolini, L., Gaetani, M., Olivini, G. & Zanchi, A., 2001. Geology and Stratigraphy of the Carboniferous of Western-Central Karakoram. *Journal of Asian Earth Sciences* 19, p.2.

Key words: Stratigraphy, carboniferous, Karakoram.

A/477. Angiolini, L. & Rettori, R., 1995. *Chitralina undulata* gen. n. sp. n. (foraminifera) from the Late Permian of Karakoram (Pakistan). *Rivista Italiana de Paleontologia e Stratigrafia* 100, 477-492.

Chitralina undulata gen. n. sp. n. (Foraminifera) has been found for the first time in the Permian successions of Karakoram (Pakistan). Biostratigraphic analysis based on fusulinids, brachiopods, conodonts and small foraminifers pointed out that *Chitralina undulata* gen. n. sp. n. occurs from the Kubergandian to the Late Murgabian-Midian. Morphologically, *Chitralina undulata* gen. n. sp. n., is comparable to *Rectostipulina quadrata* Jenny-Deshusses, 1985, differing from it by means of the thickness and composition of the test and for the presence of marked longitudinal costae. The stratigraphic range of *Rectostipulina quadrata* spans the Midian-Dorashamian time-interval. The new genus *Chitralina* is a very similar to the Permian genus *Giraliarella* Crespin, differing from it by means of the absence of transverse growth constrictions. The new family *Chitralinidae* fam. n., is also described herein.

Key words: Palaeontology, biostratigraphy, Permian, Chitral, Karakoram.

A/478. Anjum, K.M., 1981-83. Lithostructural mapping of Mansehra Susal and Matial Area District Mansehra, with special reference to structural studies. M.Sc. Thesis, Punjab University, Lahore, 109p.

Lithostructural mapping with preliminary structural studies have been made of Mansehra, Khaki, Rihar area district Mansehra at a scale, of 1:1000. An attempt has been made to delineate the boundaries of igneous and metamorphic rocks precisely. Physiographic/Stratigraphic studies and various structural contour diagrams have been drawn to determine axis of minor folds. Orientation of joints has been determined with the help of Rose diagram. Thin sections have been studied to determine different phases of deformation. Attempt has been made to analyse the strain with Flinn's and Ramsay's plots.

On the basis of microscopic and mesoscopic analysis it has been tried to interpret the structure and macroscopic scale. On the basis of Kinematic Studies, structure of the area is interpreted.

Key words: Structure, lithostratigraphy, Mansehra.

A/479. Anton, B., 1964. The pink pearls of Pakistan. *Gems and Gemology* 11, 175-179 & 191. Thirteen photos.

Key words: Pearls, Gems.

A/480. Antonio, G., 1991. Stratigraphy, Metamorphism and Tectonic of the Hazara-Kashmir Syntaxis Area. *Kashmir Journal of Geology* 8 & 9, 39-65.

The stratigraphical and metamorphic features of the rocks belonging to the Hazara-Kashmir Syntaxis are described. A large-scale subdivision of the area in the classical Sub, Lesser and Higher Himalayan tectonic elements is proposed. A model for the tectonic evolution of the area, based on a coherent and continuous development of the observed small-and large-scale structural and metamorphic features, is suggested.

Key words: Stratigraphy, metamorphism, tectonic, Hazara.

A/481. Anwar, I., 1964. Soapstone deposits of Sherwan, District Hazara. *Pakistan Journal of Scientific and Industrial Research* 2(3), 19-24.

Key words: Soapstone, economic geology, Sherwan, Abbottabad.

A/482. Anwar, J., Khan, R.D. & Mehdi, S.S., 1977. Geological report on Chromite deposits, Malakand division, N.W.F.P: Internal report of Pakistan Mineral Development Corporation, 86p.

This report describes the geological investigations which indicate that chromite is occurring as disseminated, massive, layered and nodular ore in the rocks of Dargai Ultramafic Complex. The complex is constituted by dunite, harzburgite, peridotite, serpentinite and gabbro. Significant and economically important occurrences of chromite are restricted to dunite bodies in the form of intermittent layers. The layers are generally concordant to sub-horizontal and vertical layering in the host rocks. Chromite is graded as low to medium quality refractory ore containing 7.8% to 41.4% Cr₂O₃; 10.0% to 32.17% FeO, 4.2% to 31.2% TiO₂ and 6.2% to 33.6% SiO₂. Traces of Nickel and Cobalt have been confirmed in the chromite ore samples. Since these elements and other trace elements like Platinum etc. are usually associated with ultramafic rocks, therefore, there is a possibility of finding these minerals in Dargai Ultramafic Complex. Other minerals like asbestos in ultramafic rocks and quartz in schistose group are also present in the area and could be considered for exploitation. A total tonnage of all grade chromite ore has been estimated to be 580,098 tonnes which includes 290,548 tonnes of probable and 289,550 tonnes of possible reserves.

Key words: Chromite, economic geology, Malakand.

A/483. Anwar, M., 1962-63. Geology of Rawalpindi Area, Hazara (Baghpur). M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Rawalpindi, Hazara.

A/484. Anwar, M., 1976. Thesis on Lithostructural mapping and geology of Chalt Hini area, Hunza valley (Gilgit Agency) with special emphasis on the tectonics. M.Sc. Thesis, Punjab University, Lahore, 150p.

Key words: Lithology, Structure, Chalt, Hunza.

A/485. Anwar, M., 2000. Mineral statistics of Pakistan. GSP, Special Issue, 42p.

Key words: Mineral deposits, statistics.

A/486. Anwar, M., Beech, M. & Dennelle, R., 1992. Preliminary study of carnivore accumulation in the Upper Siwalik of the Pabbi Hills, Punjab, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.51.

The fossil specimens for this study come from a locality (362) in the Soan Formation in the Pabbi Hills, situated about 4 km southwest of the village Sohawa and 10 km west of Kharian, District Gujrat. The formation consists of varicoloured sandstone, silts and minor beds of conglomerate. The age of the formation ranges from 2.5 MaBP to about 1 MaBP, but the locality's age is thought to be about 1.6 MaBP. Preliminary study of the fossils recovered through surface collection and excavation of the site indicates the presence of Accipitridae, Hyaenidae, Giraffidae, Proboscidae, bidae, Rhinocerotidae and perhaps Suidae at the locality. Seventeen axial elements including six skull fragments, thirty-eight appendicular elements, and fifty five indeterminate fossil fragments constitute the surface collection while the excavated bone accumulation is represented by seventy three axial elements including six skull fragments and five teeth, seventy two appendicular elements, and thirty three indeterminate fragments. Comparison of the surface and excavated specimens indicates that surface assemblage gives a reasonable indication of the wealth of a fossil site but the surface collection is unlikely to show the full faunal variety. Several taphonomic features of the assemblage recovered from the locality suggest a biological mode of selection with negligible influence of fluvial transportation and sorting. Such features that favour the biological accumulation are the presence of punctures and striations on a few herbivore specimens, larger number of individuals but only of six to eight families, domination of limb bones over other skeletal elements, and the presence of several skeletal parts of hyaena in the

mblage. The Influence of fluvial sorting was minimal' as the mblage contains a few articulated/semi-articulated very delicate skeletal elements (e.g. Oспенis), co-occurrence of denser and lighter bones and the virtual absence of any polished/rounded bones in the assemblage. All these features are Indicative of the assemblage being accumulated in a carnivore den, probably the Crocuta den whose remains are embedded along with the hunted bones due to sudden collapse of the den.

Key words: Paleontology, fossils, Soan Formation, Siwalik Molasse.

A/487. Anwar, M., Fatmi, A.N. & Hyderi, I.H., 1992. Revised nomenclature and stratigraphy of Musakhel and Baroch Groups, Surghar Range, Pakistan. *Pakistan Journal of Geology* 1, 15-28.

Key words: Stratigraphy, Musakhel, Surghar Range.

A/488. Anwar, M.S., Kazmi, K.R., Gohar, R.A. & Sheikh, N., 1992. Processing of Besham lead-zinc ore for the production of lead-zinc based chemicals. *Pakistan Journal of Scientific and Industrial Research* 35(1-2), 58-00.

Lead and zinc concentrates from Besham lead-zinc ore were produced by forth flotation method. A number of alternative frother/collectors and depressant were tested and flotation parameter including pH, conditioning time, frother/collector concentration and pulp density were optimized. A series of flotation test were carried out on bench scale as well as on pilot plant scale to produce the lead and zinc concentrates. The grade of each one of the concentrated was about 50% metal content. These concentrates were used as a raw material to produce lead and zinc based chemicals.

Key words: Mineral resources, lead-zinc, ore-processing, Besham.

A/489. Anwar, S. & Khan, N.R., 1997. Aspects of mud logging and well site geology with special reference to Chanda Oil Well, Potwar Plateau, N.W.F.P. M.Sc. Thesis, University of Peshawar, 120p.

Key words: Mud-logging, hydrocarbon, Chanda, Potwar.

A/490. Appel, E., Schill, E., Gautarn, P., Zeh, O., Singh, V.K. & Waldhdr, M., 1998. Block rotations along the India-Asia collision zone - Their significance on different scales detected by Magnetic Remanences. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 13-15.

The India-Eurasia collision has caused crustal deformations of enormous magnitude. Patzelt et al. (1996) presented direct palaeomagnetic evidence for a "Greater India" prior to collision (about 1500 km extent of the northern margin at 89oE, compared to the present outline). Palaeodeclinations (PD) were used to estimate the magnitude of rotational underthrusting (Klootwijk et al. 1985, Appel et al., 1991, Patzelt et al., 1996). Angles between expected and observed PDs allow the quantification of oroclinal bending. Fig. 1 shows the principle of restoring the former margin of the Indian Plate by incremental rotations. The expected PD is calculated from the apparent polar wander path assuming no relative movements at the northern margin of India. Observed PDs are brought into coincidence with the expected PD by stepwise rotations starting in the western syntaxis (pivot PI) and progressing to the east. In Fig. 1, this is demonstrated for the simple case of two segments. The extent of 'Greater India' is finally determined by a parallel displacement of both segments to the north until the palaeolatitude matches the result of Patzelt et al. (1996) at a longitude of 89oE.

The reconstruction is disturbed by local and mesoscale block rotations superposed on the regional movements. Data from NW Zaskar (Appel et al. 1995) demonstrate that systematic differences even occur within a few tens of kilometres. In the Pamir and along the Indus Yarlung suture zone (Otofui et al. 1995) PDs are strongly dependent on major faults. In order to get a reliable data base for the incremental rotation model of Fig. 1, systematic palaeomagnetic sampling is conducted to recognise and to isolate block rotations on different scales. In a first step, about 140 sites have been sampled from the Tethyan Himalaya (TH) of Spiti (NW India), Larkya and Shiar areas

(Central Nepal). The TH rarely contains primary remanences, but is well known to record a stable secondary components carried by pyrrhotite. The remanence acquisition of pyrrhotite can be related to exhumation and cooling of the Central Crystalline and represents a thermoremanence with blocking temperatures around 300°C.

A nearly one-component behaviour (pyrrhotite only) is observed in the Larkya area. A systematic local scatter appears with a mean in situ remanence of Larkya area, $D=010$, $I=54$ (12 sites, $k=9.5$, $\alpha_{95}=13.6$). In the Shiar area, the pyrrhotite to magnetite ratio is decreasing towards the east. As a preliminary result from 4 sites, the pyrrhotite component yields an in situ direction of $D=205$, $I=-12$ ($k=82.6$, $\alpha_{95}=82.6$). In Spiti, magnetite dominates the magnetic remanence. The varying content of pyrrhotite can be related to a different grade of metamorphism. The magnetite component carries a syntectonic remanence direction ($k=14.4$, 26 sites, Lower Pin Valley), whereas for the pyrrhotite component of the Upper Pin Valley a consistent in situ remanence direction of $D=006$, $I=32$ (12 sites, $k=16.9$, $\alpha_{95}=10$) is obtained. In Fig. 2, the rotations in respect to 'stable' India are shown together with earlier results.

In our further study, several other areas will be sampled, and rotations on different scales will be analysed quantitatively to evaluate a more sophisticated model of oroclinal bending and rotational underthrusting.

Key words: Palaeomagnetism, crustal deformation, plate movement, tectonics, India-Asia.

A/491. Arbab, M.S.H., 1967. Geology of parts of Balakot and Dadar areas. M.Sc. Thesis, Punjab University, 81p.

Key words: Geology, Balakot, Dadar, Mansehra.

A/492. Arbab, M.S.H., 1970. Some rocks and mineral showings of the Mohmand Agency. Proceedings National Seminar on Mineral Development. 20-23rd April 1970, Lahore, Abstract, 4p.

Key words: Minerals, Mohmand Agency.

A/493. Arbab, M.S.H., 1972a. Emerald of the Mohmand, Agency. Proceedings National Science Conference, Peshawar, 4p.

Key words: Emerald, Mohmand Agency.

A/494. Arbab, M.S.H., 1972b. A note on the emerald of Mohmand Agency (N.W.F.P). Geological Survey of Pakistan, Geonews II, No. 2, 56-58.

Key words: Emerald, Mohmand Agency.

A/495. Arbab, M.S.H., 1973. A discovery of topaz in Katlang, Mardan. Scientific Society of Pakistan Annual Science Conference (in Urdu), Lahore, 3p.

The reported discovery of Topaz in village Katlang, Mardan district found its way to news media and hence drew a large scale attention from different quarters. The present report is the result of a very short visit to the site for the purpose of collecting first hand preliminary information regarding the deposit. Topaz is found in a small solitary hillock, locally known as Ghundao, about 3 miles from Katlang on the eastern side of the Katlang.

Key words: Topaz, Katlang, Mardan.

A/496. Arbab, M.S.H., 1984. Monitoring use behavior of the land resources of the Peshawar Basin with the help of the landsat data. Seminar on Remote Sensing Application for Land Resources Management. 19-22nd November. 1984. Kuala Lumpur, Malaysia, ESCAP/ MARD/ BANGKOK, Appendix XX, 145-152.

Key words: Land Resources, remote sensing, Peshawar Basin.

A/497. Arbab, M.S.H., 1987. A short note on the Bagrian Pegmatite, Mansehra district, NWFP, Pakistan. Geological Survey of Pakistan Information Release 308, 8p.

Key words: Pegmatite, Bagrian, Mansehra.

A/498. Arbab, M.S.H., 1988. Reporting of the occurrences of Sinoroldic and Columbite in Begrian pegmatite, Mansehra. Geological Survey of Pakistan Information Release 308a.

Key words: Pegmatite, Begrian, Mansehra.

A/499. Arbab, M.S.H., (Ed.), 2000. Geological Map of Chitral district, NWFP, Pakistan. Geological Survey of Pakistan, District Map Series, NWFP. Map No. 1.

Key words: Geological map, Chitral.

A/500. Arbab, M.S.H. & Khan, R.N., 1972. Geology of Dir and Northern part of Timurgara quadrangle, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 49, 36p.

Key words: Geology, Dir, Timurgara.

A/501. Arbab, M.S.H., & Khan, R.N., 1973. Ruby Corundum in Timurgara, District Dir, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 56, 5p.

During the course of regional mapping of Timurgara and Dir quadrangles, the corundum bearing rocks of Timurgara were briefly examined. The general rock type of this area is amphibolite intruded at random by igneous rocks of granodiorite, diorite and ultramafic (Peridotite, serpentinite and hornblendite) nature. Quartz veins and aplite and pegmatite dykes are also common. Sparsely dispersed corundum crystals are found in amphibolite rock south-east of Timurgara (34 49 lat. 71 53 long). The corundum is opaque and fractured and hence cannot be used as a gemstone. The crystals moreover, are much too few and thus the possibility of its use as an abrasive is also ruled out.

Key words: Ruby, Corundum, Timurgara, Dir.

A/502. Arbab, M.S.H. & Qureshi, I.H., 1972. Topaz mineralization in Ghundo hillock, Katlang village, Mardan District, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 50, 4p.

The reported discovery of Topaz in village Katlang, Mardan district found its way to news media and hence drew a large scale attention from different quarters. The present report is the result of a very short visit to the site for the purpose of collecting first hand preliminary information regarding the deposit.

Topaz is found in a small solitary hillock, locally known as Ghundao, about 3 miles from Katlang on the eastern side of the Katlang.

Key words: Gemstones, Topaz, Katlang, Mardan.

A/503. Arbab, M.S.H. & Shah, M.R., 1995. Geological map of Kohat ((38 O/7). Geological Survey of Pakistan.

Key words: Geological map, Kohat

A/504. Arbab, M.S.H. & Shah, S.H., 1996. Geological Map of Azad Jammu and Kashmir. (Scale 1:500,000). Geological Survey of Pakistan, Geological Map Series.

Key words: Mapping, Azad Jammu Kashmir.

A/505. Arbab, M.S.H. & Shah, S.H., 1997. Mineral Map of Azad Jammu and Kashmir (Scale 1:500,000). Geological Survey of Pakistan, Mineral Map Series.

This map shows the localities of all minerals of economic interest reported in Azad Jammu and Kashmir.

Key words: Minerals, mapping, Azad Jammu Kashmir.

A/506. Arbab, M.S.H. & Siddiqi, R.A., 1972. Reconnaissance geology of the southern half of the Mohmand Agency and Tangi area of Peshawar District, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 47, 16p.

Key words: Reconnaissance geology, Mohmand Agency, Tangi, Peshawar.

A/507. Arbaret, L., Burg, J.P., Chaudhry, M.N., Dawood, H., Hussain, S.S. & Zeilinger, G., 1998. Different sets of anastomosing shear zones in the "Kamila Belt", Kohistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 15-17.

The Kohistan Complex (NW Pakistan) is squeezed between the Indian and Asian continental plates [1]. Among the different units identified in the Kohistan Complex, the Kamila amphibolitic belt separates the Chilas calc-alkaline gabbro-noritic complex to the north from the deeper ultramafic Jijal Complex to the south [2]. The southern part of the "Kamila Belt" is mainly composed of retrograde metagabbro and norite with locally preserved igneous layering intruded by hornblende bodies and plagioclase-quartz±amphibole rich veins. The latter comprise synmagmatic differentiation veins that display the same mineralogical components as the bulk rock. The metagabbro and norite are deformed by numerous anastomosing shear zones with variable spacing and size [2]. In this poster we describe three sets recognized during fieldwork:

Set 1 is composed of conjugate; centimetre scale discontinuous shear zones (Fig. 1) that curve the homogeneous foliation and layering without important change in grain size. The conjugate directions are both striking 130°. One plunges 40°±10° to the NE and corresponds to southwestward thrusts. Conjugate shear zones plunge 20°±10° to the SW and lay along Riedel orientations consistent with a general southwestward sense of shear along a bulk plane dipping 40° to the NE. Limited grain size reduction and measurements of the curved foliations indicate shear strain $\gamma < 5$.

Set 2 is characterised by an anastomosing pattern of mylonitic shear zones (Fig. 2) with an average thickness of 10 cm and a marked grain size reduction. They result from the lengthwise connection of set I shear zones, the conjugate directions wrapping around lenses of less deformed gabbro. These centimetres to decametre big lenses have an average shape ratio of 2.5 with their long axis plunging to the Northeast. Set 1 shear zones may occur within the lenses. The anastomosing shear zones contain leucocratic, garnet-bearing veins due to partial melting of the mylonites which, therefore, are high temperature shear zones. The anastomosing shear zones occur also in the northeastern part of the garnet granulites of the Jijal Complex (Southwest of Patan). Grain size reduction points to shear strain higher than 5 within these shear zones.

Set 3 corresponds to 10 cm up to 5 m thick shear zones which are continuous and undulate with large wavelength over 50 m (Fig. 3). Shear took place along horizontal to 30° Northeast dipping planes striking 130°. Strong grain size reduction and presence of centimetre size rotated porphyroclasts of plagioclase derived from stretched pegmatitic veins indicate shear strain of more than 10.

Intersections observed in the field show that these 3 sets were formed successively. Nucleation and growth of set 1 and set 2 shear zones along the same conjugate directions are interpreted as progressive localisation of shear deformation at various scales during southwestward thrusting. Relationships between veins and shear zones indicate

that deformation began during the waning magmatic stage of the gabbro-noritic body. Set 3 shear zones occurred later and are post-dated by east-west striking, c.45° north dipping amphibolitic sheared rocks located in the Northeast part the study area [3]. They represent the ductile continuous shearing developed during the upper to lower amphibolitic facies retrogression.

Key words: Shear zone, Kamila, Kohistan.

A/508. Arbaret, L., Burg, J.P., Chaudhry, M.N., Dawood, H., Hussain, S.S., & Zeilinger, G., 1998. Different sets of anastomosing shear zones in the Kamila Belt, Kohistan. In: Khan, M.A., Treloar, P.J., Searle, M.P. and Jan, M.Q. (Eds.). *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society London, Special Publication No. 170, 15–17.

Consult the preceding account for further details.

Key words: Shear zone, Kamila, Kohistan.

A/509. Arbaret, L., Burg, J.P., Zeilinger, G., Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1999. Pre-collisional deformation in the Kohistan complex (NW Pakistan). *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 5.

The Kohistan Complex (NW Pakistan) is a paleo-island arc obducted onto India after closure of the Tethyan Ocean at ca 55 Ma (Coward *et al.*, 1986). The plutonic rocks of the lower southern part of the Kohistan Complex are comprised of calc-alkaline meta-gabbro, hornblende-gabbro and diorite laccoliths that were emplaced during the arc activity (Khan *et al.*, 1993). In the Patan area, the coarse grained Sarangar gabbro lies to the north of, and above the deeper granulitic gabbro laccolith commonly attributed to the upper part of the Jijal Complex (Figure 1). The Sarangar gabbro is intruded, to the north, by hornblende-gabbro and diorite laccoliths. We describe the structures and textures related to primary composite strain overprinted by anastomosing shear zones due to sub-horizontal continuous SW-ward shearing from sub-solidus to amphibolite facies conditions. The deformation history is dated between 101 and 83 Ma, which is, therefore, older than the arc collision.

Two anisotropy intensities of the regional strain, defined by heterogeneously distributed foliations with associated mineral lineations, were recognized. The weak one (<20%) is recorded in the core of both the granulitic and the Sarangar gabbros. In the granulitic gabbro, it is associated with NW-dipping foliations bearing a NW-plunging lineation. In the Sarangar gabbro it is associated with an E-W trending sub-vertical foliations bearing a W-plunging lineation. These fabrics correspond to the shape preferred orientation if the magmatic assemblages characterized by cumulate textures. Their difference in orientation reflects differences of magmatic flow in separate plutons.

The higher anisotropy intensities (> 20%) progressively replaces towards the laccolith boundaries the low intensity magmatic fabric by plastic deformation of plagioclase and rigid rotation of pyroxene and other mineral phases. Local S-C structures and the angular relationship between the mineral fabric and magmatic layering indicate a bulk SW-ward shear recorded in the crystallised margins of the plutons. Therefore, these low and high anisotropy fabrics are related to the magmatic emplacement of the gabbros dated between 96 and 101 Ma (Anczkiewicz and Vance, 1997).

Further shear strain localization is responsible for three successive sets of shear zones that formed in a continuum from magmatic emplacement to solid state deformation during cooling of the plutons. Set 1 is composed of two populations of discrete, 1 m long and a few centimetres wide shear zones forming a Riedel association. One consists of normal SW-ward shear zones, which represent Riedel shears R. The second is composed of NE-dipping thrust P shear zones. Stable magmatic parageneses in the most deformed centre zones, cut by millimetre-thick feldspar-rich magmatic joints, point to sub-solidus conditions.

Set 2 is the most spectacular anastomosing pattern of mylonitic, N-dipping, SW-verging reverse shear zones branching into horizontal to W-dipping, SW-verging normal shear zones. The change in attitude accommodates the asymmetric shape at all scales of rock lenses whose their long axes plunge to the Northeast. The asymmetric shape and the strongly dominant SW-vergence indicate that set 2 shear zones developed during distributed, non-coaxial deformation. Partial melting in set 2 mylonites generated quartz-plagioclase-garnet bearing segregation veins pointing to temperatures exceeding 650°C under pressures of >0.8 GPa. The minimum age for set 2 shear zones is inferred from the 87 Ma old amphibole-epidote-paragonite assemblage that has partially overprinted the granulitic assemblage in the granulitic gabbro (Treloar *et al.*, 1990).

The lower amphibolite facies set 3 shear zones are differentiated by larger strain recorded in the thicker mylonitic zones and widening of the spacing between shear zones during cooling.

These three sets formed by growth and coalescence of set 1 shear zones leading to set 2 shear zones, which in turn have evolved into set 3 shear zones.

Laccoliths forming the lowest part of the Kohistan Complex have recorded the dynamic evolution during their magmatic emplacement from sub-solidus to solid state deformation. Regionally distributed magmatic-related fabrics and subsequent sets of anastomosing shear zones occurred successively between 101 and 83 Ma during SW-ward shearing, probably imposed by subduction of the Tethys lithosphere below the Kohistan arc Complex because the collision, around 55 Ma, is significantly younger.

Key words: Deformation, Kohistan complex.

A/510. Arbaret, L., Burg, J.P., Zeilinger, G., Chaudhry, M.N., Hussain, S.S. & Dawood, H., 2000. Pre-collisional anastomosing shear zones in the Kohistan arc, NW Pakistan. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 295-311.

Ductile strain localization commonly forms a pattern of shear zones anastomosing around lenses of less deformed rock. Initiation and development of anastomosing shear zones are studied through description of the structures and deformation history of plutonic rocks that from the lower crust of the Kohistan arc. Structures and textures developed in these rocks result from primary magmatic to solid-state regional strain, overprinted by anastomosing shear zones. The primary strain was mainly acquired during magmatic emplacement at 100-90 Ma. Strain localization took place continuously from magmatic emplacement to solid-state deformation cooling of the plutons and formed their successive sets of shear zones. Set 1 is composed of associated discrete Riedel and thrust shear zones developed above solidus conditions during southwestward thrusting. Continuous deformation from solidus to amphibolite facies conditions between 100 and 83 Ma formed the second set of shear zones. The lower amphibolite facies set 3 shear zones are differentiated by larger strains recorded in the thicker mylonitic zones and enlargement of the spacing probably represents arc-related deformation during subduction of the Tethys oceanic lithosphere below the Kohistan arc.

Key words: Shear zone, Kohistan arc.

A/511. Arcangeli, A., 1934. Isopodi terrestri raccolti nel Karakorum dalla Spedizione di S.A.R. il Duca di Spoleto. *Ann. Reg. 1st Sup. Agrario di Milano* 1, 1-23, Parma.

Key words: Terrestrial isopods, Karakoram.

A/512. Argles, T., Edwards, M. & Foster, G., 1999. Structural and metamorphic constraints on the evolution of the Main Mantle Thrust, eastern margin of the Nanga Parbat-Haramosh Massif, N. Pakistan. *Terra Nostra* 99 Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 6-7.

Organic research is increasingly concerned with the early stages of mountain-building, as well as the pre-collisional configuration of orogenic regions. Recent advances in geochemical, particularly isotopic, techniques have allowed together constraints to be placed on orogenic processes, and at the same time techniques have become more discriminating. Theoretically this could result in the determination of more detailed orogenic histories. To complement these geochemical methods, however, similarly detailed and rigorous fieldwork is required.

Investigations on the evolution of the Nanga Parbat Haramosh Massif (NPHM) provide a case in point. While isotopic studies emphasized the rapid recent exhumation of the massif (e.g. Zeitler et al. 1982, 1993) other studies (e.g. Wheeler et al. 1995) recognized the importance of the polymetamorphic nature of the Indian plate rocks in particular. Neogene events in the NPHM have obscured much of its earlier evolution, but the degree of overprinting varies within the massif. Structural and metamorphic overprinting are not always concentrated in the same parts of the massif, and the different properties of basement and cover rocks results in both strain partitioning and various degrees of metamorphic reworking. The western margin is dominated by Neogene processes (e.g. the Liachar thrust, Butler and Prior 1988), whereas the eastern margin preserves many earlier Himalayan structures. Structural mapping

of the eastern margin reveals a ductile contact zone preserving many features of the original Main Mantle Thrust (MMT) which emplaced the Ladakh Island Arc (LIA) over the Indian margin in the late Cretaceous. The sequence of ductile deformation was controlled both by the contrasting rheologies of the LIA and the MMT footwall, and the changing thermal regime during subduction, collision and burial, which may have included dissipative shear heating. Preliminary P-T estimates indicate conditions during southward thrusting on the MMT of Ca. 650°C and 9.5 kbar; this thermobarometry is directly correlated with MMT thrust fabrics showing top-to-the-south shear sense (after unfolding of the syntaxial antiform).

An episode of later deformation (post-dating garnet growth) in some cover units took place at Ca. 500°C and 7.4 kbar. These estimates are from rheologically weak, staurolite-grade metasediments just west of the MMT mylonites on the eastern margin. The kinematics of these rocks are complex, with conflicting shear senses in adjacent layers. We interpret this as indicating partial overprinting of the metamorphic assemblages (and modification of the tectonic fabrics) during an episode of extensional (N-directed) shear in the footwall of the MMT. The extensional strain was partitioned into this narrow zone due to the comparative strength of adjacent units (overlying mafic MMT mylonites and underlying coarse orthogneiss, or basement paragneiss). No direct dating of this event has yet been attempted, but if there was significant exhumation of the region at this time, it could correspond to a period of cooling at around 25-16 Ma previously recognized in N. Pakistan (Treloar et al., 1989; Chamberlain et al., 1991).

The concordant fabrics and lithological boundaries on either side of the contact are only disrupted by a NW vergent, brittle thrust south of the village of Subsar (Indus Gorge) which cross-cuts the steepened MMT zone. This thrust appears to be related to the neotectonic Raikhot fault on the western margin of the massif and is interpreted as an expression of the regional tectonics at the western termination of the Himalayan arc (Seeber and Pêcher 1998). This late thrusting followed formation of the syntaxial antiform in Neogene times, and is the sole major evidence for Neotectonic activity on this segment of the eastern margin.

Key words: Evolution, structure, metamorphism, MMT, Nanga Parbat-Haramosh.

A/513. Argles, T., Edwards, M. & Foster, G., 2000. Synconvergent, Ductile N-Directed Shearing on the Western Margin of the Nanga Parbat Syntaxis, N. Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, Chengdu (China), 128-129.

A key issue in orogenic research today is the recognition and explanation of normal faulting in the heart of collisional mountain belts. The active Himalayan system remains an ideal locality for studying this phenomenon, both as E-W synconvergent extension of the Tibetan plateau and normal motion on the South Tibetan Detachment System (STDS). However, these processes are difficult to correlate with the evolution of the northwest Himalaya, particularly the Nanga Parbat syntaxis where a Neogene tectono-thermal overprint partially obscures the early collisional history. An integrated programme of structural mapping, petrography, thermobarometry and isotopic dating is presented that places important constraints on both the early and pre-Himalayan evolution of the syntaxis. These data include evidence for synconvergent, ductile extension predating syntaxis development, and improved isotopic correlation of the tectonic units with the familiar central Himalayan thrust sheets, building on the work of Whittington et al. (1999).

Recent studies have focused on the rapid exhumation of the Nanga Parbat-Haramosh Massif (NPHM) during the last 10 Ma and the related Neogene thermal effects dominating the core of the massif (e.g. Zeitler et al. 1982, 1983). However, the degree of both structural and metamorphic Neogene overprinting varies within the massif, becoming weaker away from the summit region. In addition, the considerable variation in rock-type outside the gneissic core results in both strain partitioning and various degrees of metamorphic reworking. Thus several workers (e.g. Wheeler et al. 1995) could reconstruct elements of the early and pre-Himalayan history from field relations and mineral assemblages virtually untouched by Neogene processes. The eastern margin of the massif, in contrast to the active western margin, has remained largely unchanged during the Neogene, except for essentially passive rotation on the limb of the major syntaxial antiform. The original, ductile Main Mantle Thrust (MMT), which emplaced the Ladakh Island Arc (LIA) over the Indian margin in the Late Cretaceous, is preserved in a steepened orientation. Dextral shear sense indicators in this steep fabric can be clearly related to southward thrusting on the MMT at peak metamorphic conditions during the early Himalayan stage (600~700°C and 900~1200 Mpa) once the N-S trending syntaxial antiform is unfolded.

Detailed structural mapping and petrography has revealed distinct horizons of sinistral shear in the first few kilometers of Indian Plate rocks below the MMT (i.e. the upper most MMT footwall). Localities characterized by sinistral shear are generally in rheologically weak lithologies (e.g. mica schist), but there are some localities where an unambiguous timing relationship between sinistral and dextral shear sense indicators exists. Sinistral shear

overprints dextral in all cases, most commonly in the form of discrete, mylonite, sinistral shear zones cross-cutting dextral shear fabrics. In some cases, these sinistral shear zones are associated with leucogranite material. The sinistral shearing post-dated prograde garnet growth but is characterized by ductile behaviour and microstructures indicating temperatures above 300°C. Thermobarometry on schists re-worked during this event suggest deformation occurred at 500~500°C and 600~900 Mpa. We interpret this deformational event as an episode of N-directed, extensional shear in the footwall of the MMT (prior to the syntaxial folding).

The amphibolite grade of deformation suggest (a) that this event occurred soon after the metamorphic peak before substantial cooling or decompression, and (b) that the extension ceased before the rocks entered the greenschist field. This suggests that exhumation during this event occurred at a deeper level than previously documented, mostly greenschist-grade extension in northern Pakistan (Burg et al., 1996; Vince and Treloar 1996). Dating of the extensional fabrics is planned; at present the extensional event is bracketed by garnet growth (40-45 Ma, Foster et al. 1998) and Ar-Ar mica and hornblende cooling ages on the eastern margin (ranging from ca. 10~40 Ma, Zeitler and Chamberlain, 1991; Winslow, 1996; Whittington, 1997). Thus the extension could correlate with a period of cooling at around 25~16 Ma previously recognized in N Pakistan (Treloar et al., 1989; Chamberlain et al., 1991), tentatively related to orogen-wide extensional tectonics on the STDS; or it could have occurred at an earlier stage, and/or on a different fault, suggested in the recent model by Chemenda et al., (2000).

Key words: Structural geology, Nanga Parbat.

A/514. Argles, T.W., 2000. The evolution of the Main Mantle Thrust in the western syntaxis, Northern Pakistan. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 101-122.

Neogene events in the Nanga Parbat-Haramosh massif have obscured much of its earlier evolution. However, structural mapping of the eastern margin reveals a ductile contact zone preserving many features of the original Main Mantle Thrust that emplaced the Ladakh island arc over the Indian margin in the late Cretaceous. The sequence of ductile deformation was controlled both by contrasting rheologies of the Ladakh island arc and the Main Mantle Thrust footwall, and the changing thermal regimes during subduction, collision and burial. Preliminary P-T estimates indicate conditions during southward thrusting on the Main Mantle Thrust of c. 650 °C and 9.5 kbar, with later deformation (post-dating garnet growth) in some units at c. 500°C and 7.4 kbar. The concordant fabrics and lithological boundaries on either side of the contact are only disrupted by a NW-vergent, brittle thrust south of the village of Subsar (Indus gorge) which crosscuts the steepened Main Mantle Thrust Zone. This thrust is related to the neotectonic Liachar Thrust on the western margin of the massif, and is an expression of the regional tectonics at the western termination of the Himalayan arc. This late thrusting followed formation of the syntaxial antiform in Neogene times.

Key words: Structural geology, MMT.

A/515. Arif, A.H. & Khan, M.A., 1970. Groundwater investigations on the right bank of Kabul River, Peshawar Valley with emphasis on water logging problems. Bulletin 17, Water and Soil Investigation Department (WSID) Publication 84.

Key words: Ground water, Kabul River, Peshawar.

A/516. Arif, M., 1970-71. Thesis on geology and mineralogy of Swat Hornblende complex in the Charbagh-Khwazakhela Area, Swat. M.Sc. Thesis, Punjab University, Lahore, 91p.

The Charbagh –Khwazakhela area is dominantly occupied by the Hornblendic complex, the composition of which ranges from peridotite to diorite. In the south amphibolite is exposed while the eastern side is prevailed by sedimentary and metamorphic rocks. This big complex runs to Kalam in the north, to Gilgit in the north-east and to Dir State in the west.

Key words: Geology, Charbagh, Swat.

A/517. Arif, M., 1985. Stratigraphy and chronology of vertebrate fossils localities in Mirpur area, Azad Kashmir. Geological Survey of Pakistan, Information Release 264.

Key words: Stratigraphy, vertebrate paleontology, Mirpur, Azad Kashmir.

A/518. Arif, M., 1987. Fauna and age of a vertebrate fossils locality a near Mirpur, Azad Kashmir. Geological survey of Pakistan, Information Release 323.

Key words: Vertebrate paleontology, Mirpur, Azad Kashmir.

A/519. Arif, M., 1990. Mineral chemistry of the chromite occurrences from Shangla (Swat), N.W.F.P. and Bela, Baluchistan. M.Phil. Thesis, University of Peshawar, 166p.

The partly to wholly serpentinized ultramafic rocks of the Shangla and Bela areas contain disseminated grains and massive bodies of segregated chromite. Field, petrographic, and chemical characteristics of the segregated chromite from both the areas resemble those of podiform chromite deposits. Compared to accessory, the segregated chromites generally contain higher amounts of Cr, Mg, and lower Fe, Al and Mn. Composition also varies amongst as well as within individual grains. Such variations are much more pronounced in the accessory chromite due probably to a greater degree of re-equilibration with the associated silicates. The within-grain variation is more frequent and drastic in the Shangla chromite and mostly involves enrichment in Fe, (Mn and Ti), and depletion in Al, Mg, and Cr, leading to the development of ferritchromite and, rarely, magnetite along fractures and margins of individual grains. The composition of Bela olivine ranges from FO 89.0 to FO 91.2 in the silicate ultramafites. The very high 100 $Mg/(Mg+Fe)$ ratios of mafic minerals (olivine: 99.7; clinopyroxene: 97.1-98.0; and orthopyroxene: 96.0-96.4) in chromitites reflect an $Mg=Fe$ exchange between them and the associated chromite. The high to very high 100 $Cr/(Cr+Al)$ ratios of their chromite group the Bela rocks with the alpine peridotites of arc-related petrogenesis. The Shangla rocks display cumulus texture but contain abnormally magnesian olivine (FO 96.0-98.5). The 100 $Cr/(Cr +Al)$ ratios (56-86) of their chromite suggest a complex origin. These rocks may have formed under conditions transitional between those of arc and oceanic settings. The Shangla rocks underwent a low to ?medium-grade metamorphism as indicated by the development of talc and antigorite. This prograde metamorphic process probably also accompanied for the drastic chemical zoning of the Shangla chromite.

Key words: Ophiolite, chromite, Shangla, Swat.

A/520. Arif, M., 1994a. Studies of ultramafic rocks from the Swat valley ophiolite, northwestern Pakistan: Implication for the genesis of emerald and Ni-rich phases. Ph.D. thesis, Leicester University.

Key words: Ultramafic, ophiolite, emerald, Nickel mineralization, Swat.

A/521. Arif, M., 1994b. Occurrence of maucherite in Shangla (Swat), northwestern Pakistan. Geological Bulletin, University of Peshawar 27, 131-132.

Besides zoned grains of chrome spinel, the variably altered ultramafic rocks of the Swat valley ophiolite, northwestern Pakistan, contain trace amounts of highly reflectant phases. These are mostly sulphides. However, the finely disseminated, discrete grains in some of the completely serpentinized samples from the Barkotaki village in Shangla were found to be of arsenide. The chemical composition of this latter phase is rather simple and consist almost entirely of Ni (57.33 – 59.14 at. %) and As (39.11 – 41.04 at. %), with only traces of Fe (<0.06 – 0.33 at. %), Co (0.83 – 1.02 at. %), and S (0.28 – 0.66 at. %). The calculated metal (Ni + Fe + Co + Cu) to arsenic ratio ranges from 1.406 – 1.514 and corresponds to that of maucherite (Ni_3As_2), one of the three arsenides of nickel (i.e. niccolite, maucherite and orcelite or rammelsbergite).

Key words: Ophiolite, chemistry, Shangla, Swat.

A/522. Arif, M., 1996. Chemical characteristics of chrome spinel in the magnesite-rich rocks from Swat, northwestern Pakistan. *Geological Bulletin, University of Peshawar* 29, 9-15.

The magnesite-rich rocks (magnesite $\pm$ talc $\pm$ quartz $\pm$ fuchsite $\pm$ tourmaline $\pm$ chlorite), which locally host emerald mineralization, contain trace to accessory amounts of disseminated grains as well as nodular segregations of chrome spinel. The spinel displays unusually high Cr/(Cr+Al) and low Mg/(Mg+Fe²⁺) ratios. A detailed investigation reveals that the present chemical characteristics of the chrome spinel are probably the result of modification related to the formation of the host rocks by a low-grade metamorphism in the presence of a CO₂-bearing fluid.

Key words: Chrome spinel, magnesite, Swat.

A/523. Arif, M., 2000a. Petrology and mineralogy of the Ahingaro serpentinites, Kabal (Swat), NW Pakistan: Implications for their tectonic setting and timing of emplacement. *Geological Bulletin, University of Peshawar* 33, 29-38.

A small (-6 x 1 km), lens-shaped body predominantly consisting of ultramafic rocks, occurs at the Ahingaro Banda Kandao near Kabal, Swat. This body is enclosed within the Kamila amphibolites that constitute the basal part of the intraoceanic Kohistan island arc. The ultramafic rocks are highly fractured and almost completely serpentinized. They consist of abundant fine-grained serpentine, varying amounts of a variety of bastites after orthopyroxene, veins and stringers of magnetite, invariably altered disseminated grains of chrome spinel, trace amounts of relict clinopyroxene and traces of rather sparsely disseminated granules of sulphide (pentlandite). Some of the samples also contain thin veins of calcite.

The Ahingaro serpentinites display both pseudomorphic and non-pseudomorphic textures. The serpentine predominantly consists of the lizardite and chrysotile varieties, whereas the antigorite occurs rarely. The chrysotile is mostly distributed as veins. A detailed petrographic and mineralogical comparison with the serpentinized rocks of the Indus suture melange zone suggests that the Ahingaro serpentinites most probably represent the original Tethyan lithosphere that served as a substratum or platform for the construction of the KIA. These rocks were emplaced together with the enclosing amphibolites along the Kohistan fault during post-Early Oligocene.

Key words: Petrology, mineralogy, serpentinite, Swat.

A/524. Arif, M., 2000b. Zincian, manganiferous chrome spinel from the Swat valley ophiolite, NW Pakistan. *Geological Bulletin, University of Peshawar* 33, 103-110.

Metamorphosed basic volcanic rocks of the Swat valley ophiolite locally contain trace to accessory amounts of disseminated chrome spinel. The grains of chrome spinel are invariably altered along margins and fractures. They, therefore, consist of low reflectance (grey) cores patches that are bordered and traversed by highly reflectant (bright) zones. Compositionally. The cores are high-Cr. almost Mg-free chromites, containing unusually high amounts of Zn and Mn, and may thus be described as a solid solution of three end-member spinel compositions, i.e. chromite, gahnite and galaxite. The bright zones of alteration lack any notable amount of Zn or Mn and range from Cr-magnetite to magnetite. Compositional and textural relationships suggest that the markedly zincian and manganoan character of the spinel grains is the result of a hydrothermal activity that took place before the magnetite-forming alteration process. The Zn-, Mn-bearing hydrothermal fluids either reacted with the parental lava prior to or during its solidification or, alternatively, invaded the host rocks after their formation leading to the addition of Zn and Mn to, and concomitant removal of Mg from the already crystallized magmatic chromite through dissolution-recrystallization.

Key words: Chrome-Spinel, ophiolites, Swat.

A/525. Arif, M., 2001. The Gujar Kili area, Swat, NW Pakistan: Nickeliferous phases in the emerald-hosting rocks. Abstracts, 4th Pakistan Geological Congress, Islamabad, 1-2.

The occurrence of three different types of mélanges, namely the blueschist mélange, the greenschist mélange and the ophiolitic mélange, mark the westward continuation of the Indus suture zone in northwestern Pakistan. The ophiolitic member of this group of mélanges occurs as blocks that are distributed within the metamorphosed sedimentary rocks of the northern margin of the Indo-Pakistan plate. In addition to typical ophiolitic lithologies, e.g.

mafic-ultramafic plutonic rocks, pillow lavas and pelagic sediments, the ophiolitic *mélange* contains carbonate (magnesite and, rather rarely, dolomite)-rich assemblages, which at places, such as the Mingora and Gujar Kili areas, host emerald deposits. Abundant quartz veins, which at places constitute stockworks, have traversed these rocks. Locally, their close spatial association with serpentinized ultramafic rocks suggests that the rocks under discussion might have formed from the latter through the process of carbonate-alteration. In addition to abundant magnesite and/ or dolomite, the emerald-hosting rocks of the Gujar Kili area contain talc or quartz as an essential mineral. Besides, chrome spinel (chromite, ferritchromite and/or Cr-magnetite) is a common accessory constituent of these rocks. Some of the rocks, especially those invaded by quartz veins, contain tourmaline and/or chlorite. Furthermore, some of the magnesite rich rocks of the Gujar Kill area contain highly reflectant opaque phases, which occur in the form of very fine-grained disseminations as well as veins. A detailed investigation through chemical analyses reveals that these phases are of two types, i.e. sulphide and sulpharsenide. The former category includes pentlandite, violarite, mackinawite, pyrrhotite and pyrite. Gersdorffite and, rarely, cobaltite are the two sulpharsenides that occur in the emerald-hosting magnesite-rich rocks of the Gujar Kili area. As they locally occur as veins that cut across the host magnesite-rich rocks, the formation of these phases clearly post-dates that of the latter. Some of these phases, e.g. gersdorffite, are reported to occur as inclusions in the Swat emeralds. This clearly suggests that the hydrothermal activity that resulted in emerald mineralization in Swat is also responsible for the formation of the investigated sulphides and sulpharsenides.

Key words: Ophiolite, sulphide and sulpharsenide, mineral chemistry, Gujar Killi, Swat.

A/526. Arif, M., Abbas, S.G. & Gingerich, P.D. 1997. First Paleocene-Eocene mammal from South Asia. *Geological Survey of Pakistan, Records*, 109, 76-77.

Key words: Vertebrate paleontology, mammal, Paleocene, Eocene.

A/527. Arif, M., Fallick, A.E. & Moon, C.J., 1996. The genesis of emeralds and their host rocks from Swat, northwestern Pakistan: a stable isotope investigation. *Mineralium Deposita* 31, 255-268.

Emerald deposits in Swat, northwestern Pakistan, occurring in talc-magnesite and quartz-magnesite assemblages, have been investigated through stable isotope studies. Isotopic analyses were performed on a total of seven emeralds, associated quartz (seven samples), fuchsite (three samples) and tourmaline (two samples) from the Mingora emerald mines. The oxygen isotopic composition of emeralds shows a strong enrichment in ^{18}O and is remarkably uniform at $+15.6 \pm 0.4\text{permil}$ (1sgr, $n = 7$). Each of the two components of water in emerald (channel and inclusion) has a different range of hydrogen isotopic composition: the channel waters being distinctly isotopically heavier ($\delta\text{D} = -51$ to -32permil SMOW) than the other inclusion waters ($\delta\text{D} = -96$ to -70permil SMOW). Similarly the oxygen isotopic compositions of tourmaline and fuchsite are relatively constant ($\delta^{18}\text{O} = +13$ to $+14\text{permil}$ SMOW) and show enrichment in ^{18}O . The $\delta^{18}\text{O}$ values of quartz, ranging from $+15.1$ to $+19.1\text{permil}$ SMOW, are also high ($+16.9 \pm 1.4\text{permil}$ 1sgr, $n = 7$). The mean δD of channel waters measured from emerald ($-42 \pm 6.6\text{permil}$ SMOW) and that of fluid calculated from hydrous minerals δD calculated ($-47 \pm 7.1\text{permil}$ SMOW) are consistent with both metamorphic and magmatic origin. However, the close similarity between the measured δD values of the hydroxyl hydrogen in fuchsite (-74 to -6permil SMOW) and tourmaline (-84 and -69permil SMOW) with pegmatitic muscovite and tourmaline suggests that the mineralization was probably caused by modified (^{18}O -enriched) hydrothermal solutions derived from an S-type granitic magma. The variation in the carbon and oxygen isotopic composition of magnesite, locally associated with emerald mineralization, is also very restricted ($\delta^{13}\text{C} \text{ sim } -3.2 \pm 0.7\%$, PDB; $\delta^{18}\text{O} \text{ sim } +17.9 \pm 1.27\text{permil}$ SMOW). On the basis of the isotopic composition of fluid ($\delta^{13}\text{C} \text{ ap } -1.8 \pm 0.7\text{permil}$ PDB; $\delta^{18}\text{O} \text{ ap } +13.6 \pm 1.2\text{permil}$ SMOW calculated for the 250-550 °C temperature), it is proposed that the Swat magnesites formed due to the carbonation of previously serpentinized ultramafic rocks by a CO_2 -bearing fluid of metamorphic origin.

Key words: Emerald, geochemistry, genesis, Swat.

A/528. Arif, M. & Hussain, S.T., 1992. Upper Siwalik vertebrate faunal correlation in sub-Himalayan. Abstracts, First South Asia Geological Congress, Islamabad, p.5.

The Upper Siwalik fluvial sedimentary history and paleontology of the Mangla-Samwal anticline (Azad Kashmir) have been studied, and faunal correlations are made with the Bhattani-Marwat Range in the west, Jammu Hills in the east and Pabbi Hills in the south. The rocks in this anticline are divided into the Samwal and Kakra Formations (ca. 3.4 to 1.1 Ma). The Samwal Formation was deposited by large and small river systems, whereas the conglomerates of the Kakra Formation were deposited as a result of the uplift of the Pir Panjal Range.

The study of vertebrate fossils indicates that the overall faunal composition in these areas is identical and they contain the characteristic Upper Siwalik fauna (e.g. *Equus*, *Cervus*, *Hexaprotodon* and *Elephas*). The faunal similarity also suggests that during the Plio-Pleistocene (the time for deposition of the Upper Siwaliks) these areas belonged to the same bio-province.

Key words: Vertebrate paleontology, Sub-Himalaya, Siwalik Molasse.

A/529. Arif, M. & Jan, M.Q., 1992a. Mineral chemistry of chromite and associated phases from Shangla, NW Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.5.

The partly to wholly serpentinized ultramafic rocks of the Shangla area, constituting the northern part of the Mingora ophiolitic melange, contain disseminated grains and massive bodies of segregated chromite. Field, textural, and chemical characteristics of the segregated chromite closely resemble those of podiform chromite deposits. The chemical composition of the chromite varies considerably from sample to sample with model proportion, from grain to grain within the domain of a thin section, and from core to margin within individual grains. In general, the segregated chromites are richer in Cr, Mg, but poorer in Fe, Al and Mn than the accessory chromites. The inter- and intra-granular chemical variations are much more common and drastic in the case of accessory chromite due probably to a greater degree of subsolidus re-equilibration with the associated silicates. The intragranular variation, probably a result of alteration, mostly involves enrichment in Fe, (Mn and Ti), and depletion in Al, Mg, and Cr, leading to the development of ferritchromite and, rarely, magnetite along fractures and margins of individual grains.

The Shangla rocks display cumulus texture but contain abnormally magnesian olivine (Fo₉₆-G_{98.5}). The 100Cr/(Cr+Al) ratios of their chromite suggest a complex origin. These rocks may have formed under conditions transitional between those of arc and oceanic settings. The Shangla rocks underwent a low-to medium grade metamorphism as indicated by the development of talc and antigorite. This prograde metamorphic process probably also accounted for the drastic chemical zoning of the Shangla chromite.

Key words: Ophiolite, Chromite, Shangla, Swat.

A/530. Arif, M. & Jan, M.Q., 1992b. Mineralogy of the Indus Suture ophiolite and an investigation of the associated mineralizations in Swat, NW Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 4-5.

The Main Mantle Thrust (MMT), which signifies collision of the Indo-Pakistan plate with the Kohistan island arc in northwestern Pakistan, is marked by the occurrence of an assorted zone of rock sequences. These consist of blueschist, greenschist and ophiolitic mélanges and are well exposed and easily accessible in the region between Mingora town and Lilauni village of the Swat valley. The ophiolitic rocks in this area constitute a discontinuous belt of mafic-ultramafic and metasedimentary units which occur as thrust sheets and lenses incorporated within the continental metasediments of the Indo-Pakistan plate. The mafic and ultramafic rocks include bodies of peridotite, metamorphosed gabbros, greenstone, metabasalt and pillow lavas. The metasedimentary rocks, comprising both calcareous and siliceous varieties, are interbedded with lavas. The quartz-rich metasediments are locally manganeseiferous.

The varying degree of alteration of the ultramafic rocks has, at places, given rise to a zonal pattern consisting of a core of least altered dunite and peridotite surrounded by a broad and extensively developed zone of partly to wholly serpentinized rocks followed by a locally developed peripheral shell of talc-magnesite lithologies. Besides hosting uneconomically small, lenticular bodies of chromite and containing disseminated grains of chrome spinel, the relatively fresh and the partly serpentinized rocks of the central and middle zones contain tiny grains of heazlewoodite, millerite and, rarely, relict pentlandite. The mineralization of Ni in the wholly serpentinized rocks is mostly in the form of an arsenide, maucherite. In contrast, the non-oxide opaque mineralization in the talc-magnesite rocks include more Fe-rich sulphide phases such as phases such as pentlandite, pyrrhotite, violarite and

secondary Ni-pyrite. Locally, the talc-magnesite rocks also contain tiny grains of gersdorffite and host emerald deposits which are being mined, notably near the Mingora town.

The non-carbonatized ultramafic rocks, apparently 'residual' peridotite in chemistry, are characterized by high to very high amounts of MgO [100MgI(Mg+Fe)=87-94] and very low to low contents of CaO (mostly less than 2.0 wt %) and Al₂O₃ (not more than 3.0 wt %). The olivine in these rocks, occurring both as veins as well as a matrix phase with serpentine and, rarely, pyroxene, is also very highly magnesian [100MgI(Mg+Fe)=89-98]. It is usually associated with abundant grains and host preferentially oriented, submicroscopic lamellae of magnetite. The grains of pyroxene, dominantly diopside, have bent and kinked cleavages, are locally spindle-shaped and usually partly to wholly bastitized. The serpentine in these rocks is almost exclusively antigorite displaying interpenetrating textures. The grains of chrome spinels are invariably zoned with dark gray Cr-rich cores surrounded by thin to fairly thick and highly reflecting rims of ferritchomite and/or magnetite containing higher amounts of NiO (up to 1.5 wt %). In contrast, chrome spinel in the talc-magnesite rocks is a high Cr chromite without any compositional zoning. Moreover, these rocks are devoid of any of the primary mafic silicates, i.e., olivine and pyroxene.

The field and mineralogical characteristics indicate that these ophiolitic rocks suffered a prograde greenschist facies metamorphism under oxidizing conditions in the presence of abundant CO₂-rich hydrous fluids. The antigorite-serpentinites and talc-magnesite assemblages, so developed, at the expense of the ultramafic rocks, represent a gradient in the H₂O and CO₂ contents of the original fluid. Although the fluids were dominantly metamorphic in origin, they probably carried a Be-rich and S- and As-bearing hydrothermal/magmatic component that, at places, gave rise to the mineralization of emerald and sulpharsenides in the talc-magnesite rocks.

Key words: Mineralogy, Ophiolites, Indus Suture, Swat.

A/531. Arif, M. & Jan, M.Q., 1993. Chemistry of chromite and associated phases from the Shangla ultramafic body in the Indus suture zone of Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society London, Special Publication 74, 101-112.

The partly to wholly serpentinized ultramafic rocks of the Shangla area constitute the northern part of the Mingora ophiolitic mélange which lies along the Main Mantle Thrust (MMT) zone between the Kohistan island arc and the Indo-Pakistan plate. These rocks contain disseminated grains and massive bodies of segregated chromite. Field, textural, and chemical characteristics of the segregated chromite closely resemble those of podiform chromite deposits. The chemical composition of the chromite varies considerably from sample to sample with modal proportion, from grain to grain in the domain of a thin section, and from core to margin within individual grains. In general, the segregated chromites are richer in Cr and Mg, but poorer in Fe, Al and Mn than the accessory chromites. The inter- and intragranular chemical variations are much greater and more common in the case of accessory chromite due probably to a greater degree of subsolidus re-equilibration with the associated abundant silicate matrix. The intragranular variation, probably a result of alteration, mostly involves enrichment in Fe, Mn (and Ti), and depletion in Al, Mg and Cr, leading to the development of ferritchromite and, rarely, magnetite along fractures and margins of individual grains.

The studied rocks from the Shangla area display cumulus textures but contain abnormally magnesian olivine (Fo_{96.0-98.5}). The 100Cr/(Cr + Al) ratios of their chromite suggest a complex origin. These rocks may have formed under conditions transitional between those of arc and oceanic settings. The Shangla rocks underwent a low- to ?medium-grade metamorphism as indicated by the development of talc and antigorite. This prograde metamorphic process probably also accounted for the extreme chemical zoning of the Shangla chromite.

Key words: Chromite, ultramafics, Shangla, Indus Suture zone.

A/532. Arif, M. & Khattak, M.U.K., 1999. The emerald-hosting magnesite-rich rocks from Swat, NW Pakistan. Geological Bulletin, University of Peshawar 32, 63-70.

The Main Mantle Thrust melange zone in Swat contains carbonate rich rocks (Manganese ± talc ± quartz ± chrome spinel/ Cr-magnetite / ferritchromite ± fuchsite ± tourmaline ± chlorite) which locally host emerald mineralization. Detailed field and mineralogical studies suggest that these rocks were probably formed by talc carbonate alteration of the spatially associated, previously serpentinized ultramafic rocks in the area. This transformation may have taken place at 250 – 550 °C and was probably caused by CO₂ – bearing fluid released by the metamorphism of the underthrust sedimentary rocks of the Indian Plate.

Key words: Magnesite rocks, emerald, Swat.

A/533. Arif, M. & Moon, C.J., 1994. Occurrence, chemistry and genesis of the nickel-rich phases in the ultramafic rocks from Swat, northwestern Pakistan. *Geological Bulletin, University of Peshawar* 27, 29-41.

Trace amounts of finely disseminated Ni-rich phases, including heazlewoodite, pentlandite, millerite, godlevskite, violarite and awaruite, occur in the variably serpentinitized ultramafic rocks of the Swat valley. The mode of occurrence, textural relationships with each other and with the associated silicate and oxide phases, relative modal abundance and chemical variation; all indicate that only the pentlandite represents the original sulphide phase. The rest are derived from pentlandite by the process of alteration. The additional amount of Ni, required for the conversion of pentlandite to heazlewoodite and other Ni-richer phases, was possibly derived by the serpentinization of primary olivine.

Key words: Ophiolite, ultramafics, nickelifeous minerals, Swat.

A/534. Arif, M. & Moon, C.J., 1996a. Chemistry of tourmaline from the emerald-hosting rocks in Swat, NW Pakistan. *Geological Bulletin, University of Peshawar* 29, 81-89.

The ophiolitic emerald-hosting carbonated ultramafic rocks (magnesite + talc and / or quartz $\pm$ chrome spinel) in the Swat valley contain disseminated grains, clusters and veins of tourmaline and / or fuchsite. These late-stage hydrothermal minerals are especially abundant where the host rocks are traversed by ubiquitous veins and stockworks of quartz. Crystals of emerald, tourmaline and fuchsite also occur in the quartz veins. Besides, the metasedimentary rocks that are spatially associated with the emerald's host rocks also contain tourmaline. In contrast to that in the metasediments, tourmaline in the emerald-hosting altered ultramafic rocks and the invading quartz veins contain variable but distinctly high amounts of Cr_2O_3 , MgO and NiO, and relatively low concentration of TiO_2 . These chemical features, mode of occurrence and nature of associated phases suggest that the tourmaline may have been deposited from Si-rich, Al-, Be-, B- and K-bearing hydrothermal fluids which passed through and extracted Mg, Cr and Ni contents from the host carbonated ultramafic rocks.

Key words: Ophiolite, tourmaline, emerald, Swat

A/535. Arif, M. & Moon, C.J., 1996b. The platinum-group element geochemistry of chromitites and silicate rocks from Swat, northwestern Pakistan. *Geological Bulletin, University of Peshawar* 29, 1-8.

The concentrations of the platinum-group elements (PGE) and Au were determined in a limited number of samples which represent chromitites, altered ultramafic and mafic rocks of Swat valley ophiolite. The PGE characteristics of the chromitites mostly conform to trend exhibited by the podiform chromitites. However, being sulphide-poor and containing Cr-rich chromite, the Pd content of one of the samples is anomalously high compared to similar chromitites from other areas. This enrichment in Pd is probably caused by a localized hydrothermal activity. The Ir content of the chromite-poor, altered ultramafic rocks is remarkably uniform (4ppb) and close to the values in mantle materials but their Pd (10 ± 3.7 ppb) and Au (5 ± 3.5 ppb) abundance are distinctly higher than the latter. These features of PGE and Au concentration of the host ultramafic rocks are consistent with an origin involving partial melting followed by hydrothermal alteration.

Key words: Ophiolite, platinum-group elements, chromite, Swat.

A/536. Arif, M., & Moon, C.J., 1996c. Textural and chemical characteristics of olivine and pyroxenes in the ultramafic rocks from the Indus suture zone in Swat, NW Pakistan: implications for Petrogenesis and alteration. *Schweiz. Mineral. Petrograph. Mtg.*, 76, 47-56.

Key words: Olivine, pyroxene, ultramafic, Indus Suture, Swat.

A/537. Arif, M. & Moon, C.J., 1997. Mineralogy and geochemistry of ultramafic rocks from the Indus Suture ophiolite in Swat, NW Pakistan: Petrogenetic implications. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.9.

In the area around Mingora (Swat), the Main Mantle Thrust (MMT) is exposed in the form of a wedge-shaped complex zone containing lithologies with diverse geochemical characteristics and genetic affinities (blocks and slices of blueschist, greenschist, bodies of ultramafic rocks, mafic plutonic and volcanic rocks as well as metasediments) separated by faults of different ages. This assortment of rocks, collectively termed as the Main Mantle Thrust Mélange Group (MMTMG), is distinguished into three principal groups, each of which is itself a composite of lithologies, or a mélange -the blueschist mélange, greenschist mélange and ophiolitic mélange.

The ultramafic rocks (locally containing chromite pods), constituting a part of the ophiolitic member of the MMTMG, occur as lenticular bodies, distributed along the marginal part of the Indo-Pakistan plate. The majority of these rocks consist of abundant, fine grained serpentine, subordinate amounts of partly to completely bastitised, medium to coarse grained orthopyroxene, trace to accessory amounts of partly altered (zoned with ferritchromite and/or magnetite) chrome spinel, variable proportions of olivine, and accessory amounts of diopside. Thus the ultramafic rocks are dominantly harzburgitic in mineralogy and, therefore, the ophiolite as a whole can be classified as the harzburgite sub-type. The present petrographic characteristics and mineral-chemical composition of these rocks appear to be the result of a number of phenomena including partial melting, serpentinization, metamorphism and talc-carbonate alternation.

The only trace of the primary mineralogy are the relic (unaltered) cores of the original chrome spinel grains and the occurrence of pyroxenes. The former is Cr-rich [$\text{Cr} \# = 100 \times \text{Cr}/(\text{Cr}+\text{Al}) = -50\sim70$],

TiO_2 -poor and has more or less uniformly low Fe^{3+} content. The pyroxenes are highly magnesian and contain relatively low amounts of Al (with Al_2O_3 mostly <2.5 wt %). Consistent with these mineralogical characteristics, the bulk chemistry of the rocks is characterized by low to very low amounts of the easily fusible oxides (CaO, Al₂O₃ and TiO₂), low concentration of the moderately incompatible components (Sc, V, Cu, Zn and Ga) and high levels of the moderately to highly compatible elements (Fe, Mn, Cr, Co, Ni and Mg). These mineralogical and geochemical features suggest that the major bulk of the studied ultramafic rocks originated as a residue of the upper mantle. Geochemical comparison with residual rocks from other areas shows that, prior to their emplacement along the MMT, the studied rocks had suffered an intermediate degree (> 15 to $< 30\%$) of partial melting.

Key words: Mineralogy, geochemistry, ophiolites, Indus Suture.

A/538. Arif, M. & Moon, C.J., 1998. Parentage and evolution of magnesite-rich rocks from the Indus Suture Zone in Swat, NW Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 17-19.

The Indus-Tsangbo suture between the Indo-Pakistan plate and Kohistan-Ladakh arc assumes a broad wedge-shaped complex zone in the Lilaunai-Mingora area of Swat and contains diverse rock assemblages. This assortment of rocks, collectively known as the Indus Suture mélange group, is distinguished into three principal types of mélanges: the blueschist mélange, the greenschist mélange, and the ophiolitic mélange (Kazmi et al., 1984).

Rocks of the ophiolitic mélange occur as small to large lensoidal bodies distributed along the northern edge of the Indo-Pakistan plate. They possess well-preserved ophiolitic characteristics and consist of variably altered ultramafics, gabbros, lavas of basic to intermediate composition, and pelagic sediments including cherts as well as plagiogranites and albitites. Furthermore, carbonate-rich assemblages, which are known for producing one of the world's finest gemstone quality emeralds, form an integral part of the different occurrences of the ophiolitic rocks in the study area.

In most of the ophiolitic rock occurrences, the fine-grained, emerald-hosting carbonate-rich rocks are spatially associated with variably serpentinized ultramafic rocks. Although also present as small patches within the serpentinized rocks in some places, they mostly occur along the contact between the serpentinites and metasediments. These rocks are also traversed by abundant veins, locally producing stockworks, of quartz.

The studied rocks invariably consist of abundant magnesite and accessory to trace amounts of spinel (mostly Cr-magnetite-ferritchromite and, in some cases, Mg-poor but Cr-rich chromite) accompanied with one or more of such phases as talc, quartz and dolomite. The different relative proportion of these minerals has given rise to three major types of assemblage: (i) talc-magnesite or magnesite-talc, depending upon whether magnesite or talc is more abundant; (ii) talc-magnesite-dolomite; and (iii) quartz-magnesite. The texture of these rocks is related to the relative

proportions of the different minerals, especially the absence or presence of talc in the paragenesis. That is, whereas the talc-free or talc-poor quartz-magnesite assemblages are massive, the talc-magnesite rocks are strongly foliated. In addition to the phases, mentioned above, some of the investigated magnesite-rich rocks also contain fine-grained disseminations, veins, and/ or clusters or clots of fuchsite and/ or tourmaline. The tourmaline is a Cr-rich dravite and the fuchsite shows variable but, in most analyses, anomalously high concentration of Mg and Ni and Ni (NiO reaching up to 9 wt.%).

Most of the geochemical characteristics of the investigated lithologies are broadly similar to those of typical ultramafic rocks. More importantly, the overall ranges for most of their major, minor as well as trace elements are almost identical to those of the carbonate-free, serpentinized ultramafic rocks in the area. This is particularly true for the concentrations of Al_2O_3 , MnO, TiO_2 , Cr, Ni, Co, V, Zn, Sc as well as Ga. Therefore, it seems reasonable to assume that the investigated rocks could be the result of alteration (carbonation) of the previously serpentinized ultramafic rocks in the area. The close spatial association between the two categories of the rocks lends further support to interpretation. Furthermore, comparison in terms of modal mineralogy and mineral chemical data with broadly similar assemblages from other occurrences in the world suggest that this transformation probably took place at 250-550°C and was brought about by CO_2 -bearing metamorphic fluids.

Although most of the major and trace element contents of the investigated rocks fall within the corresponding limits for ultramafic rocks, the amount of SiO_2 in some of them is anomalously low. On the other hand, the SiO_2 content of a few of the samples is higher than most others. Besides, compared to typical ultramafic rocks, some of the rocks under discussion contain distinctly high amounts of some of the incompatible trace elements.

The distinctly high content of SiO_2 in some of the studied rocks could be due to the fact that precursors to these rocks, unlike the most others, were originally orthopyroxenites rather than peridotites or dunites. On the other hand, the abnormally low SiO_2 contents in the quartz-magnesite varieties of the studied rocks (less than 10 wt.%) cannot be attributed to original compositional differences because a type of ultramafic rocks having such a low amount of SiO_2 does not exist. The possibility for an alternative explanation that these lithologies were originally some sort of impure carbonate rocks of sedimentary parentage (e.g. siliceous dolomite) can easily be ruled out because their trace element contents (especially high amounts of Cr, Ni and Co) are typical of those occurring in ultramafic igneous rocks. The point to make here is that the low SiO_2 content in the studied rocks is probably a result of the process of carbonation. As their SiO_2 shows a strong negative correlation with the LOI values variable amounts of this component were probably removed from the rocks during the process of talc-carbonate alteration (Fig. 1).

As mentioned above, some of the studied samples, especially those representing the mining sites of emerald, contain distinctly high amounts of Be, B, Li, K, As, Pb, W, Zr, Y, Ba, Rb and/ or Sr. As the average abundance of elements like these is negligibly small in typical ultramafic rocks, their notably high values in the studied may have been the result of enrichment during later processes. The lack of a meaningful correlation of any one of these elements with the values of LOI precludes the possibility for their enrichment by one of the two main processes of alteration, i.e. serpentinization and/ or carbonation. Alternatively, the textural relations and mineralogical composition suggest that the mentioned incompatible elements may have been added to the studied rocks during a late-stage hydrothermal activity, most probably the one producing the quartz veins and associated phases, i.e. fuchsite, tourmaline and emerald.

Key words: Ophiolite, Paragenesis, Magnesite rocks, Indus Suture, Swat.

A/539. Arif, M. & Moon, C.J., 1999. Geochemistry of magnesite rich rocks from the Indus suture in Swat, NW Pakistan. Geological Bulletin, Punjab University 33 & 34, 111-118.

Key words: Geochemistry, magnesite, Indus Suture, Swat.

A/540. Arif, M. & Moon, C.J., 2000. Mineralogy and geochemistry of ultramafic rocks from the Indus Suture ophiolite in Swat, NW Pakistan. Abstract Volume, 15th Himalaya- Karakoram- Tibet Workshop, Chengdu (China), 113-114.

Genetically diverse lithologies, which include blueschist, greenschist, ultramafic, mafic plutonic, e.g. gabbros, and volcanic, e.g. pillowed basalts, and metasedimentary rocks, occur as a wedge-shaped zone in the area to the north of the Mingora town in Swat, NW Pakistan. This zone of fault-bounded rock bodies and blocks is distinguished into three principal groups, each of which is itself a composite of lithologies, or a mélange- the blueschist mélange, greenschist mélange and ophiolitic mélange. All these lie along the Main Mantle Thrust (MMT)- the westward

extension of the Indus-Tsangbo Suture Zone and the locus of collision between the Indo-Pakistan Plate and the Kohistan Island-Arc- and, are therefore, collectively termed as the Main Mantle Thrust Mélange Group (MMTMG). The ultramafic rocks, locally containing chromite pods and constituting a part of the ophiolitic member of the MMTMG, occur as small to large lenticular bodies, distributed along the marginal part of the Indo-Pakistan Plate. They are invariably serpentinized to varying degrees and, therefore, consist of abundant, fine grained serpentinite which is mostly accompanied by subordinate amounts of completely bastitised, medium to coarse grained orthopyroxene, trace to accessory amounts of commonly altered (zone with ferritchromite and /or magnetite) chrome spinel, variable proportions of olivine, and accessory amounts of diopside. In other words, the ultramafic rocks are mostly harzburgitic in mineralogy and, therefore, the ophiolite as a whole can be classified as the harzburgite sub-type. Detailed field and mineralogical studies show that the present petrographic characteristics and mineral-chemical composition of these dominantly harzburgitic rocks are the result of a number of phenomena involving partial melting, serpentinization, metamorphism and talc-carbonate alteration.

Relict (unaltered) cores of the original chrome spinel grains and the occurrence of pyroxenes are the only primary mineralogical features of the studied ultramafic rocks. The former is Cr-rich [$\text{Cr} = 100\text{XCr}/(\text{Cr} + \text{Al}) = 50\sim 70$], TiO_2 -poor and has more or less uniformly low Fe content. The pyroxenes are highly magnesian and contain relatively low amounts of Al [mostly $w(\text{Al}_2\text{O}_3) < 2.5\%$] and Ti [$w(\text{TiO}_2) < 0.2\%$]. Consistent with these mineralogical characteristics, the bulk chemistry of the rocks is characterized by low to very low amounts of CaO, Al_2O_3 and TiO_2 , low concentration of the moderately incompatible components (Sc, V, Cu, Zn and Ga) and high levels of the moderately to highly compatible elements (Fe, Mn, Cr, Co, Ni and Mg) (Fig. 1). These mineralogical and geochemical features suggest that the major bulk of the studied ultramafic rocks originated as a residue of the upper mantle left after partial melting. Geochemical comparison with residual rocks from other areas shows that, prior to emplacement, the studied rocks suffered an intermediate degree ($>15\%$ to 30%) of partial melting. The emplacement of these residual rocks was accomplished during the Cretaceous-Tertiary collision between the Indo-Pakistan Plate and the Kohistan arc along the MMT.

Key words: Mineralogy, geochemistry, ophiolites, ultramafic, Indus Suture, Swat.

A/541. Arif, M., Moon, C.J. & Christidis, G., 1996. Garnierites from the ultramafic rocks in Swat, northwestern Pakistan. Geological Bulletin, University of Peshawar 29, 69-79.

The serpentinized and / or carbonated ultramafic rocks of Swat valley ophiolite locally contain accessory to trace amounts of microscope to megascopically visible grains of garnierite. Such grains mostly occur in samples where the serpentinization and /or carbonation are rather pervasive and accompanied by supergene alteration. Their optical properties and chemical composition are extremely variable and differ greatly from spot to spot within individual grains which appear to be intimate mixture of different compositions. The highly variable and, in most cases, high to very high concentration of FeO (up to ~ 54 wt. %), and abnormally high CaO contents (ranging up to ~ 3 wt. %) in the chemical analyses make them distinct from the serpentine varieties of garnierites reported from other localities. Most of the garnierite grains seem to be pseudomorphic after, and contain relic patches of, pentlandite, and might have developed as a result of reaction between the 'normal' matrix serpentine or talc and the original magmatic sulfide. As their occurrence along fractures in the rocks is clear at least in some cases, their formation probably took place after the main episodes of serpentinization and carbonation and was probably brought about by the processes of weathering and supergene alteration. The association of calcite with garnierites in some of the rocks indicates that the fluid, which caused the alteration, was charged with calcium and CO_2 and this factor probably also accounted for the anomalously high values of CaO in the garnierites.

Key words: Garnierites, ophiolite, ultramafic, Swat.

A/542. Arif, M., Mulk, A., Mehmood, M.T. & Shah, S.M.H., 1999. Petrography and mechanical properties of the Mansehra granite, Hazara, Pakistan. Geological Bulletin, University of Peshawar 32, 41-49.

Rocks of granitic composition occur along the area around Mansehra (Hazara), Pakistan. These rocks are mostly used as building/ construction materials. In order to study the petrography of these rocks in detail and determine their geotechnical properties, representative samples were collected from different parts of the area. Detailed studies reveal that, compared to granitic rocks from elsewhere in northern Pakistan, the investigated rocks have very low values of compressive strength. This could be due to their older age, coarser texture, unevenness of grain size,

deformed/ metamorphosed character and weathered/ altered nature. Therefore, they cannot be recommended for use in the construction of large-scale engineering structures such as tunnels and dams. However, the compressive strength values and Cs/Ts ratio of the studied rocks are high enough for their use as building stones in the construction of railway tracks, bridges, roads, canals, drainage and embankments.

Key words: Petrography, geotechnics, granite, Mansehra.

A/543. Arif, M., Rafiullah & Hussain, S.H., 1989. Geology of Mir Pur area, Azad Kashmir. GSP, Information Release 445.

Key words: Geology, Mir Pur, Azad Kashmir.

A/544. Arif, M., Rehman, F. & Amjad, A., 1984. Petrology of Khawaza Khela area, upper Swat. M.Sc. Thesis, Peshawar University, 92p.

Key words: Petrology, Khawaza Khela, Kohistan arc, Swat.

A/545. Arif, M., Shah, S.M.I. & Vos, J.D. 1992a. *Cervus Triplidens* (Mamalia, Cervidae) from the upper Siwaliks of Pakistan. GSP Memoir 17(1).

This describes *Cervus Triplidens* from the upper Siwaliks of northern Pakistan.

Key words: Paleontology, Siwalik Molasse.

A/546. Arif, M., Shah, S.M.I. & Vos, J.D. 1992b. “*Cervus Rewati*” sp. Nov (Mamalia Cervidae) from the upper Siwaliks, Pakistan. GSP Memoir 17(2).

This describes *Cervus Rewati* from the upper Siwaliks of northern Pakistan.

Key words: Paleontology, Siwalik Molasse.

A/547. Armbruster, J., Seeber, L. & Jacob, K.H., 1978. The northwestern termination of the Himalayan Mountain Front; active tectonics from micro earthquakes. *Journal of Geophysical Research* 83, 269-282.

The seismicity of the northwestern Himalayan syntaxial bend and the geologically complex area to the west, between the Hazara thrust system (HTS) and the higher mountains of Indus-Kohistan, is examined in a wider tectonic context by using data from about 1,800 microearthquakes. The microearthquake data were obtained from a telemetered seismic network in northern Pakistan centered at Tarbela dam on the Indus River and were collected during an 11-month period prior to impounding of the Tarbela reservoir. The observed seismicity indicates that a branch of the main boundary thrust (MBT) traverses the region as a straight northwesterly extension of the Murree thrust, the mapped section of the MBT southeast of the syntaxial bend along the Kashmir Himalayas. Seismic release on this extension of the MBT, here named the Indus-Kohistan seismic zone (IKSZ), is highest in the upper 25 km of the crust and correlates with a pronounced topographic step. Deeper activity on the IKSZ extends to a depth of 70 km. Seismicity in the lower crust defines a second lineation 100 km southwest of the IKSZ and parallel to it. The syntaxial bend and the eastern HTS, microseismically virtually inactive at present but associated with recent and historical microseismicity, overprint the two northwesterly seismic lineaments. The two tectonic regimes may be simultaneously active at different depths separated by an incompetent layer. A set of steeply dipping faults, either parallel or perpendicular to the IKSZ, is active in the region between the HTS and the IKSZ. Seventeen composite fault plane solutions show a predominant pattern of either reverse or strike slip faulting with the inferred slip vectors oriented such that north-south compressional stresses are relieved. Such a stress field is compatible with the north-south convergence between the Indian and Eurasian plates inferred from plate tectonics.

Key words: Seismology, active tectonics, mountain front, Himalaya.

A/548. Arshad, C.M., 1985-87. The geology of Parrai-Dodaheera Area, District Swat N.W.F.P. with special emphasis on mineralogy and petrology. M.Sc. Thesis, Punjab University, Lahore, 78p.

The topic of this thesis is Geology of Parrai-Dodaheera area with special emphasis on mineralogy and Petrology. The prescribed area lies in the lower Swat region. The area consists of about 35 sq. miles. It lies between latitudes $34^{\circ} 41' 30''$ to $34^{\circ} 45' 00''$ Longitude $72^{\circ} 11' 30''$ to $72^{\circ} 15' 00''$ in toposheet No.43 B/2

The area was mapped by the part through foot traverses on eight times enlarged toposheet 1:50000. Notes were taken on different units, their lithology and contact relationship, geomorphology, and also on social set up of the people. Details regarding the structure of the area i.e. folds, faults, fractures, joints, foliation and lineation were taken. Stations were marked on the map. Samples were also collected. Photographs of geological and geomorphic features were also taken. Back in Laboratory, petrographic study of the thin section was carried out by microscope.

The project area is not very rich in economic minerals. No mine is present. However, the following rocks and minerals are of economic importance. These are Marble, graphitic schist, graphite and garnet.

Key words: Petrography, petrology, structure, Swat.

A/549. Arshad, M., 1977-79. Mineralogy and Petrology of Shangla Par Area, District Swat. M.Sc. Thesis, Punjab University, Lahore.

The Shangla Par Alpurai-Bazarkot area is a part of District Swat, situated about 13 miles from Khwaza Khela eastward on Khawaza Khela-Besham road.

The area comprised of igneous and metamorphic rocks. These rocks were originally deposited in eugeosynclinal conditions are argillaceous sediments and afterwards, these rocks are metamorphosed to schists and phyllites. Some amphibolites of para nature formed as result of regional metamorphism on calcareous sediments is also suggested. Subsequently the area has been strongly disturbed and intruded by ophiolites, which have now been metamorphosed to serpentinites and talc carbonate rocks. Blue schist rocks from Topsin and Shangla illustrate typical assemblages as are taken to mark plate subduction or obduction zones of Indian and Siberian plates. These are originated by the metasomatic metamorphism. The rocks form a part of lower Swat Buner Schistose group of Paleozoic age (Martin et al, 1962). By way of certain stratigraphical reasoning, a Paleocene age was attributed to the Shangla Blueschist. The area lies on the northwestern limb of the syntaxis and therefore, the prominent strike is South West-North East.

Key words: Petrography, petrology, structure, metamorphism, Swat.

A/550. Arshad, M., 1986. Gravity studies in the Margalla and Hazara Ranges. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 67p.

Key words: Gravity, Margalla, Hazara.

A/551. Arshad, M. & Shams, F.A., 1983. Geology and petrology of the Shangla blueschist zone, Swat Himalaya, NWFP Pakistan. Geological Bulletin, University of Punjab 18, 25-31.

Based on detailed mapping of the Shangla zone, Swat, petrographic description is given of various lithologic units. Major and trace element analyses are reported of blueschist rocks along with discussion on their petro-tectonic importance.

Key words: Petrology, blueschist, Shangla, Swat.

A/552. Arshed, A., 1981-83. Geology and Petrology of Shewa and Shahbaz Garhi Area, District Mardan, NWFP. M.Sc. Thesis, Punjab University, Lahore, 43p.

This report covers a comprehensive study of Shewa and Shahbaz Garhi area. The principal emphasis has been on detailed geological mapping of the area on the scale of 1:8333. The rocks in the area are porphyries, quartzitic schists and dolerites.

A fairly detailed account of the Geology is being given and the report also includes a detailed account of petrography of the porphyries based on extensive sampling.

Numerous photographs and sketches have also been included to illustrate the geology of the area. In the light of field, laboratory work and previous work petrogenesis of the porphyries has been discussed at length.

Key words: Petrology, mapping, Shewa Shahbaz garhi, Mardan.

A/553. Asad, A., 1996. Prospects of mineral resources and industries in the northern area of Pakistan. Geological Survey of Pakistan, Mineral Information Release 16.

Key words: Mineral resources, Industries, Northern Areas.

A/554. Asad, A.F., 2000. Feasibility study of Limestone of Gandghar Range and Associated deposits for Cement manufacturing. M.Phil. Thesis, University of Peshawar.

Limestone is a valuable raw material, which is widely used in the chemical and construction industries throughout the world. With huge deposits of limestone in Pakistan it is immensely used as cement manufacturing. The extensive deposits of pre-Cambrian limestone are exposed in Gandghar, Cherat and Khyber ranges around the southern Peshawar basin. It is light grey in colour, medium to thick bedded and massive. The limestone of Gandghar range has been evaluated mineralogically and chemically for its use for cement manufacturing during present study. Mineralogically, the studied limestone is dominantly calcite very fine grained. Quartz as anhedral small clastic sand grains, chert and chalcedony, some carbonaceous matter is also present in the form of layers or bands. Iron leaching and some of clay minerals by mixing of various raw material in different proportions then the portland cement of desired composition can be obtained. Chemically, the studied limestone of Gandghar range are compared with that of the normal and argillaceous limestone elsewhere in the world. All the three varieties of the studied limestone (Shekhai, Utch Khattak greenish grey) have more silica than normal limestone but less than that of the argillaceous limestone. Al_2O_3 , and Fe_2O_3 are relatively high in the studied limestone as compared to that of normal limestone, MgO in the studied limestone is less as compared to that of the normal limestone and more as compared to that of argillaceous limestone, Al_2O_3 and Fe_2O_3 are relatively high in the studied limestone as compared to that of normal limestone, MgO in the studied limestone is less as compared to that of normal limestone and more as compared to that of argillaceous limestone. The CaO is high in the studied limestone as compared to that of both normal and argillaceous limestone. Total alkalies in the studied limestones are relatively as compared to that of normal limestone. The average chemical compositions of various cements manufactured in N.W.F.P. are within the ASTM limits. The studied limestone of Gandghar range is generally free of dolomitization and has no other deleterious substances. This pre-Cambrian limestone of the Gandghar range is therefore, recommended.

Key words: Limestone, cement, Gandghar Range.

A/555. Asghar, M., 2001. Geophysical investigations of landslide in Murree Hill area. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 64p.

Geophysical investigations of three landslides in Murree were carried out by using seismic refraction, electrical resistivity and radon exhalation detection methods. The seismic data was acquired employing reverse shooting scheme and Conventional and Hagedoorn methods were used for velocity modeling. The resistivity data was interpreted in terms of true resistivity of subsurface material by curve matching technique. The radon emission was determined as track densities for every detector planted on the surface in a profile. The results of all the methods employed were interpreted and correlated in the light of geology of the area, meteorological and anthropogenic factors.

The study reveals that geological structure and lithologies play a major role in the formation of thick weathering layer which when wet/moistened exerts more downslope force thus causing landslides. The thickness of weathering layer determined by seismic refraction and resistivity methods for all the three landslides are in agreement. Also the radon emission measurements have delineated the stable and unstable areas within a landslide zone. Such investigations are recommended on all the major landslides of the area prior to damage control measures.

Key words: Geophysics, landslides, Murree.

A/556. Asghar, M., Ali, Ch.A. & Hussain, T., 1979. Geology of the Jogha Banj Saiqa Banda area with special emphasis on petrography of amphibolites and mixed zone. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrography, amphibolites, Kohistan arc, Swat

A/557. Ashfak, M. & Wakeel, A., 1969a. The study of the joint patterns and the other structures of the Manki slate and the Attock shale. M.Sc. Thesis, University of Peshawar, 42p.

Consult the following account.

Key words: Structure, Manki Slate, Attock Shale.

A/558. Ashfak, M. & Wakeel, A., 1969b. The study of the joint patterns and the other structures of the Manki slate and the Attock shale. Geological Bulletin, University of Peshawar 4, 24-32.

On the basis of a comprehensive study of the structures, especially the joint patterns of the Manki Slate and the Attock Shale, the two distinct argillaceous units of the Attock Group, it has been established that there was, most probably, a considerable lapse of time between their depositions. The Manki Slate, as a result of a powerful compression from the north, was later pushed over the Attock Shale along a thrust striking E – W.

Key words: Structure, Manki Slates, Attock Shale.

A/559. Ashok, S. & Kad, S., 1998. Initiation and Development of Northwestern Lesser Himalayan foreland basin: An Overview. Geological Bulletin, University of Peshawar 31. Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.173.

Excellent sections are available in Northwestern Lesser Himalayan region of India and Pakistan to document the evolution of Foreland basin that has taken place south of rising Himalayas. The present Indo-Gangetic basin is the southernmost and youngest in a series of foreland basin development which include the Siwaliks and Eocene-Oligocene i.e. mainly Murree group basins, which are the oldest, highly tectonically disrupted and most uplifted of all such basins.

The present paper attempts to understand initial stages of development of these Foreland basins spanning the first 25 m.y. of this development. It is based on investigated sequences in Dharampur-Kuniarhatti section, Dagshai type section and Subathu section in Shimla Himalayas and Kalakot, Sind-Khatuti sections in Jammu Himalayas.

The transition of a marine to continental basin is best studied in Dharampur, Dagshai and Kalakot sections. Transition is marked by a thick orthoquartzite band extending along the length of the basin delineating the transition. In most of the sections studied it is generally marine sequence below the orthoquartzite band but in Dharampur-Kumarhatti section, which makes an exception, some red beds are below this orthoquartzite band. It is generally believed, that a thick orthoquartzite layer may have been coeval with India -Asia collision and all sediments above represent initial stages of subsiding basin.

The initial stages of this subsiding basin are characterised by alteration of Sandstone and shale usually red in colour to multiple palaeosol horizons with reworked nodular beds. They are poorly fossiliferous in nature except for some organic debris along with thin shale partings. Next stage of development in the foreland basin are Kasaulis which suggest a certain degree of stability and uplift of Murrees.

Key words: Foreland Basin, Lesser Himalaya.

A/560. Ashraf, A., 1989. Electrical resistivity survey for groundwater investigation in the area between Malpur and Quaid-i-Azam University. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 44p.

Key words: Resistivity survey, groundwater, Islamabad.

A/561. Ashraf, K.M. & Ismail, M., 1984. Characteristics of alluvial aquifers of Potwar Plateau. Abstracts, First Geological Congress, Lahore, 3-4.

Potwar Plateau exists in the northern part of Punjab Province, extending from the foothills of Himalayas to Jhelum River, and covers an area of about 9000 square miles; Potwar Plateau and its adjoining drainage basins were investigated on scientific basis for groundwater exploration by Hydrogeology Directorate, WAPDA, Lahore.

Geologically, the area is folded, faulted and over-thrusted. The rocks of the area are generally sedimentary in origin and range in age from Pre-Cambrian to Recent. The unconsolidated deposits of Sub-Recent to Recent age consisting silt, sand, gravel and clay form the main groundwater reservoir of the area while the consolidated rocks are far less permeable and in general serve as barriers to movement of groundwater. The aquifer material in Potwar occurs in lenses and strings 4 to 152 feet thick, elongated along the present and abandoned river channels. For determining the aquifer characteristics of alluvial deposits aquifer tests/pumping tests were performed at selected sites in the area. The data collected during these tests were evaluated and analysed by different analytical methods for different parameters of aquifer. The coefficients of transmissivity, permeability and storage determined by these methods range from 7000 gpd/ft, 86 gpd/ft² and 5.7×10^{-5} to 218000 gpd/ft, 4100 gpd/ft² and 7×10^{-2} respectively. The specific capacity of tubewells ranges from 4.6 gpm/ft of drawdown to 489 gpm/ft of drawdown.

Key words: Alluvial aquifer, groundwater, Potwar Plateau.

A/562. Ashraf, M., 1965. Geology of the Khaki area, Mansehra, District Hazara. M.Sc. thesis, Punjab University, Lahore.

This is a preliminary account of the geology of the Khaki area. Petrographic descriptions of low grade metamorphic rocks and a granitic intrusions are given.

Key words: Geology, Mansehra, Hazara.

A/563. Ashraf, M., 1969. Magnetite bearing amphibolites near Mari Banda, Swat. Geological Abstracts, 11th Annual Conference, Scientific Society of Pakistan, Multan, p. 22 (In Urdu).

Brief description of small magnetite lenses in amphibolites near Shah Dheri in Upper Swat is given. The host rock belong to what is now called southern amphibolite belt of the Kohistan magmatic arc.

Key words: Magnetite mineralization, amphibolite, Kohistan arc, Swat.

A/564. Ashraf, M., 1972. Geological and chemical characteristics of dolomite from Hazara and Mardan Districts. Pakistan Journal of Scientific Research 9, 62-66.

Key words: Chemistry, dolomite, Hazara, Mardan.

A/565. Ashraf, M., 1974a. Geochemistry and petrogenesis of acid minor bodies of Mansehra and Batgram area, Hazara District. Ph.D. Thesis, Punjab University, Lahore.

The acid minor bodies in the Mansehra and Batgram area were emplaced in the granitic rocks and the associated met sediments. These bodies have been identified as (1) Albitites, (2) albite-aplites/pegmatites, (3) albite-(microcline)-apilites /pegmatites, (4) albit-microcline-apilites/tit/pegmatites, (5) microcline-albiteapilites/pegmatites and (6) complex apilites/pegmatites. The first 4 types occur as independent and composite bodies in the interior-lateral zone (1750 to 5500 feet above sea level), types 4 and 5 occur in the interior-marginal zone (5000 to 9000 feet above sea level) and types 5 and 6 are present in both interior-marginal zone and marginal exterior zone (over 9000 feet sea level). Field, mineralogical and chemical evidences show that the acid minor bodies are genetically related with the granitic rocks of the area. This genetic relationship is significant due to continued enrichment of soda in the granites from Susalgali granitic gneiss (a potassic facies) to Hackle tourmaline granite and Chail sar micro granite. The enrichment of soda is due to gradual cooling and increases in vapor pressure of the complex (in tightly closed environments) more than 10 kbs, where the acidic fluids shifted toward the albite apex. From this the release in external pressure at within the interior-lateral zone gave rise to soda rich liquids being deposited in the fissures. These fissures provided

the local in pressure by the opening the metasediments during the welling up and the expansion of the granites in the diapiric and much room like structures. Therefore, as the vapour pressure decreased with further cooling, the behavior of the system was reversed gradually, meaning thereby that quantity depended on the release in $p(H_2O)$ in the three structural zones. The mineralogy and chemistry of these structural units is quite contrasting with the exception of some overlapping at places. Therefore, the present investigations show that the pegmatite residual solutions were derived from the albite rich solutions gradually with the introduction of K_2O and volatiles. This derivation is excellently exemplified by negative correlation of Na_2O and positive correlation of K_2O with SiO_2 and gradual but significant increase in the rare elements.

Key words: Geochemistry, petrogenesis, pegmatite, Aplite, Mansehra, Batgram, Hazara.

A/566. Ashraf, M., 1974b. Geochemistry and petrology of acid minor bodies from Mansehra and Batgram area, Hazara District, Pakistan. Geological Bulletin, University of Punjab 11, 81-88.

The acid minor bodies are emplaced in the granitic and the associated metamorphic rocks. The bodies identified are 1) albitites, 2) albite-aplites/pegmatites 3) albite- (microcline)-aplites/pegmatites, 4) albite-microcline-aplites/pegmatites, 5) microcline-albite-aplites/pegmatites and 6) complex aplites/pegmatites and 7) various quartz veins. Field, mineralogical and chemical evidences show that the acid minor bodies are genetically related with the granites.

Key words: Petrology, Mansehra, Batgram, Hazara.

A/567. Ashraf, M., 1975. Composite albitite-aplite and pegmatite from Mansehra and Batgram areas, Hazara District, Pakistan. Special Issue IMA Papers 9th Meeting, Berlin. Fortschs, Miner 52, 329-344.

Key words: Pegmatite, albitite, aplite, Batgram, Mansehra, Hazara.

A/568. Ashraf, M., 1976. Origin of myrmekite of the acid minor bodies of Mansehra and Batgram areas, Hazara District. Geological Bulletin, Punjab University 12, 103-104.

Key words: Myrmekite, Mansehra, Batgram, Hazara.

A/569. Ashraf, M., 1977. Geology and mineral composition of various lithologic units presents in the Kingriali Formation of the Surghar Range. Geological Bulletin, University of Punjab 14, 55-62.

Kingriali Formation of Triassic age has seven lithologic units, which can be distinctly recognized in the field on the basis of color, porosity, and compaction of the rocks. The thickness of individual units varies from 8 – 42 meters. The thickest unit is massive, white to pink colored and porous at places (sucrosic dolomite). The deposits were evaluated in the laboratory for their microscopic, chemical, differential thermal analyses (D. T. A.) and X-ray properties. The studies clearly indicate that most of the units are quite rich in dolomite mineral, (as MgO is 20 to 21% and CaO is 29 to 31%) with minor amount of Kutnoharite and ferrian dolomite.

Key words: Lithology, Kingriali Formation, Surghar Range.

A/570. Ashraf, M., 1983. Geochemistry of the acid minor bodies associated with the Hazara granitic complex, Hazara Himalayas, northern Pakistan. In: Shams, F.A. (Ed.), Granites of Himalayas, Karakorum and Hindu Kush, 123-141.

Consult the following account for further information.

Key words: Geochemistry, granitoids, Mansehra, Hazara.

A/571. Ashraf, M., 1992a. Petrogenesis of acid minor bodies of Mansehra granitic complex, Hazara Himalaya, NW Pakistan. *Kashmir Journal of Geology* 10, 1-26.

The acid minor bodies in the Mansehra and Batgram area were emplaced in the granitic rocks and the associated metasediments. These bodies have been identified as (1) Albite, (2) albite-aplites / pegmatites, (3) albite - (microcline) – aplite / pegmatites, (4) albite – microcline – aplites / pegmatites, (5) microcline – albite-aplites / pegmatites and (6) complex – aplites / pegmatites. The first 4 types occur as independent and composite bodies in the interior – lateral zone (1675m above sea level), and the types 4 and 5 occur in the interior- marginal zone (1525 to 2750 m above sea level) and types 5 and 6 are present in both interior – marginal zone and marginal – exterior zone (over 2750 m above sea level). Field, mineralogical and chemical evidences show that the acid minor bodies are genetically related with the granitic rocks of the area. This genetic relationship is significant due to continued enrichment of soda in the granites from Mansehra granitic gneiss (a potash facies) to Hake tourmaline granite and Chail Sar microgranite. The Mansehra granitic complex is itself a product of partial melting of Hazara and Lower Tanol Formations when they reached to metamorphic grade of kyanite-silliminite. The enrichment of soda is due to gradual cooling and increase in vapor pressure of the complex (in tightly closed environment) more than 10 Kb, where the acidic fluids shifted towards the albite apex. From this release in external pressure at place within the interior-lateral zone gave rise to soda rich liquids being deposited in the fissures. These fissures provided the local release in pressure by the opening of tension fissures parallel to the foliation of the granite and the metasediments during the swelling up and the expansion of the granites in the diapiric and mushroom lie structure. Therefore, as the vapor pressure decreased with further cooling the behavior of the system was reversed gradually, meaning thereby that SiO_2 and K_2O would be released along with the volatilize, and their quantity depended on the release in P (H_2O) in the three structural zones. The mineralogy and chemistry of these structural units is quite contrasting with exception of some overlapping at places. Therefore, the present investigations show that the pegmatitic residual solutions were derived from the albite rich solutions gradually with the introduction of K_2O and volatilizes. This derivation is excellently exemplified by negative correlation of Na_2O and positive correlation of K_2O with SiO_2 and also gradual but significant increase in the rare elements.

Key words: Petrogenesis, geochemistry, Himalaya, Mansehra, Hazara.

A/572. Ashraf, M., 1992b. Asymmetrically zoned complex pegmatite of Bagarian area North of Oghi, Mansehra District, Hazara Himalaya, Pakistan. *Kashmir Journal of Geology* 10, 93-104.

The Bagarian asymmetrically zoned complex pegmatite occurs associated with Mansehra granitic complex in the interior-marginal zone near Oghi subdivision of Mansehra District. This pegmatite body is the most developed zonally and is most evolved with contrasting mineral composition on both sides of the quartz core. The zones on east of core are border + wall zones with oligoclase, muscovite quartz and tourmaline; outer intermediate zone-microcline graphic granite; inner intermediate zone-subgraphic albite, quartz and muscovite. The zones on west side of quartz core are border + wall zone with albite, tourmaline, quartz and muscovite; outer intermediate zone-microcline perthite and minor muscovite; and inner intermediate zone-microcline perthite with minor quartz. Mirolitic cavity filled minerals of aqueous vapor phase are beryl columbite, samarskite Rb-rich translucent microcline, Rb and Li-rich muscovite. The Mansehra granitic magma was formed after 40% partial melting of Hazara and Lower Tanol Formation pelites, which in turn gave rise pegmatitic magmatic solution to develop Bagarian pegmatite and aqueous phase modified for mirolitic minerals. It is envisaged that 75-90% fractional crystallization of granitic rest magma was responsible for the present shape of Bagarian pegmatite.

Key words: Zoned pegmatite, Mansehra, Hazara.

A/573. Ashraf, M., 1993. Application of a two-dimensional numerical groundwater flow model to investigate changes in the hydrogeology of the selected part of National Park area, Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 77p.

Key words: Hydrogeology, groundwater, national park, Islamabad.

A/574. Ashraf, M., 1994. Bagrian complex pegmatite associated with Mansehra granitic complex, Hazara Himalaya. Abstracts, Second SEGMIITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, p. 20.

The Bagarian asymmetrically zoned complex pegmatite occurs associated with Mansehra granitic complex in the interior-marginal zone near Oghi subdivision of Mansehra district. This pegmatite body is the most developed zonally and is most evolved with contrasting mineral composition on both sides of the quartz core. The zones on east side of core are border+wall zones; intermediate zones graphic granite; the zones on west side of quartz core are border+wall zones, intermediate zones, dominantly microcline perthite. The Mansehra granitic magma was formed after 40% partial melting of Hazara and Lower Tonal Formation pelites, which in turn gave rise pegmatitic rest magmatic solutions to develop Bagarian pegmatite. An aqueous phase formed miarolitic minerals like beryl, columbite, samarskite, Rb-rich microcline and Rb and Li - muscovite. It is envisaged that 75-99% fractional crystallization of granitic rest magma was responsible for the present shape of Bagarian pegmatite. The petrographic and chemical composition of western pure microcline intermediate zone and quartz of core show that they are excellent materials for ceramic and glass industries. Bi, Nb, U etc. occur as miarolitic minerals.

Key words: Complex pegmatite, granite, Mansehra, Hazara.

A/575. Ashraf, M., 1995. Lagarban-Tarnawai phosphorite deposits of Abbottabad, Pakistan. Abstracts, International Symposium and Field Workshop on Phosphorites and other Industrial Minerals, Abbottabad, p.36.

Lagarban-Tarnawai phosphorite is the only sedimentary deposit known so far in Pakistan. Total reserves are of the order of about .19-million tones out of which 7.5 million-tonnes are of measured category as reported by SDA. The phosphorite occurs in the upper Sirban formation of Cambrian age, which is associated with dolomite, siltstone and red beds. The phosphorite is considered to have been deposited as a single bed within upper Sirban Formation. Subsequent repetition is due to imbrication with plunge of deposit towards north as a result of Himalayan orogeny. The repetition of the ore bodies has been identified and explored as (1) Eastern Phosphorite, (2) Lagarban South phosphorite (3) Batakna phosphorite and (4) South phosphorite. Assaying revealed that average P₂O₅, MgO, and H₂O₃ in the above mentioned ore bodies are 29%, 0.26% and 3.47%; 28.6%, 2.2% and 3.7%; 30.2%, 3.8% and 2.2%; and 29.6 %, 2.5% and 2.8% respectively. Collophane is dominant phosphate mineral with minor as dahlite. The gangue minerals are dolomite, chalcidony, opal, quartz, goethite, chlorite, pyrite, mica, clay minerals, and organic matters. The phosphorite was deposited in a relatively calm sea in Lagarban to Batakna whereas the East phosphorite was deposited in a very shallow sea with abundant wave activity.

Key words: Phosphorite, economic geology, Abbottabad.

A/576. Ashraf, M., 1997. The principle subdivisions of the Kamila amphibolites redefined in Kohistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 10.

The so called Kamila amphibolite was studied in details and was subdivided. The Kamila amphibolite in the area around Kamila-Dassu along the Indus canyon was subdivided into Dassu, Kayal, and Pattan complexes. The former Dassu is typical amphibolite formed from the metamorphism of plutonic rocks which is extremely deformed, poly-metamorphosed, epidote-garnet amphibolite banded gneiss. The metamorphic P-T conditions for Dassu are 5.5-6.5 kb and 520-580°C. The Kayal and Pattan plutonic complexes are locally metamorphosed to amphibolite with igneous hornblende and layering. The Dassu complex has limited aerial extent toward west whereas it extends beyond Thak valley in the east without Kayal and Pattan. The Pattan complex, however, is exposed intermittently westwards with outcrops near Khwazakhela, Landai, Tighak, Shahpur (Aspanr), etc. The ocean floor related tholeiitic amphibolites herein are called as Dir amphibolites which are found west of Lilunai everywhere as continuous outcrops to sporadic occurrences showing underplated relationship with calc alkaline arc related stuff like Chilas complex, Dassu, Kayal and Pattan complexes. Therefore, the Kamila amphibolite term may be disregarded and new subdivisions be followed which are different mineralogically/chemically and environmentally.

Key words: Amphibolite, Kamila, Kohistan.

A/577. Ashraf, M., 1998. Dir Amphibolite as an Ocean Floor Theolites Underplated by Kohistan Calcalkaline Rocks in N. Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 20-22.

Geological mapping of 673 km² area of Timargara-Lal Qila and Wari of District Dir NWFP was recarried out for the study of Petrology, structure, geochemistry etc. (first detail work after Chaudhry et. at., 1974 and 1974a). The area is part of the western extremity of Kohistan Island Arc, where the Mesozoic amphibolitized ocean floor of Kohistan in the south is sutured to the gneisses of Indian plate.

The amphibolites exposed in the southern and northern extreme of the mapped area were the parts of a single ocean floor under which the arc was built. These amphibolites were formed by the metamorphism of basic volcanics and pillow lavas of tholeiitic affinity. The subordinate interlayered sediments of argillaceous, arenaceous and carbonate composition were deposited on ocean floor away or near mid oceanic ridge (MOR). The concentration of metasediments in the southern exposure is relatively less and thin as compared to northern part of amphibolites where thick piles of these sediments were evident (Chaudhry et al., 1974a). The amphibolites exposed in the Dir area are different from Kamial amphibolites which were formed by the metamorphism of basic plutonic rocks like Dassu and Kayal complexes (Ashraf, 1997; Loucks et al., 1992). The Dassu complex represent the base of Kohistan Island Arc and is exposed near or around Nanga Parbat Syntaxis due to uplifting and uncovering of base rocks. Whereas Dir amphibolites represent the supra crustal material of Kohistan under which the arc was built.

The discrimination diagrams show that Dir amphibolites are basalts and of tholeiitic character, as is evident from the SiO₂ and total alkalies (Cox and Panhurst, 1979) plots. The K₂O-TiO₂-P₂O₅ diagram (after Pearce et al., 1975) plots of Dir amphibolites show mainly oceanic floor volcanic nature. In AFM diagram (after Irvine and Baragar, 1971) most of the Dir Amphibolites plot in the tholeiitic field. Similarly, trace elements plots also indicate the tholeiitic nature of Dir Amphibolites.

The plutonic rocks exposed in the area consist of norite, gabbro-norite, diorite, tonalite, trondhjemite, granite/adamellite, and quartz porphyries/aplites/pegmatites are intruded in the Dir amphibolites and were exposed due to uplifting and uncovering of amphibolites. But the presence of small and large roof pendant of amphibolite in these plutonic rocks (which previously were called xenoliths and screens of amphibolites) evident the presence of amphibolites over there.

AFM diagram for norites, gabbro-norites, diorite, tonalite, granites, adamellites, aplites and quartz porphyries display a calc alkaline nature of these rocks, Al₂O₃ Vs An reveal calc alkaline nature for the plutonic rocks in the Irvine and Baragar (1971) diagram. The Babien (1980) diagram plots Tio₂ Vs FeO/MgO for the Dir Plutonic rocks classifying them as orogenic rocks showing emplacements of plutonic magma during collision, underplating the oceanic crust of MORB nature.

Generally three types of ultramafic rocks are exposed in the mapped area. The first type of ultramafic are highly altered and metamorphosed. These ultramafic rocks are present as exotic blocks in amphibolites; the second types are those, which are present as roof pendent over the surface of some plutonic, rocks (i.e. granite adamellite and diorite). These ultramafic were emplaced in oceanic crust (amphibolites) during its development at MOR. The third type of ultramafics which are mostly hornblendites and scyelites are exposed both in amphibolites and plutonic rocks, were probably fractionated as hydrous magma and ascended to higher levels due to buoyancy acquired by their magmas as a result of residual liquid enrichment.

Structural studies shows that the rocks of Kohistan Island Arc exposed in the area are folded into northward dipping southward verging tight folds in the south (near MMT) which opens up northwards. The amphibolites has undergone at least two phases of isoclinal folding. In the first phase of recumbent or isoclinal folding S1 axial planner foliation was developed in these rocks. The first phase of deformation is probably related to the subduction of Kohistan mass under Eurasian plate. In the second phase these rocks were again folded. The second phase is probably related to the subduction of Indian plate under Kohistan. The rocks of Kohistan mass have undergone a third phase of deformation, which produced the shear zones and a retrograde metamorphism to chlorite grade.

The southern part of Dir amphibolites near MMT mostly trend EW and dips 65 to 80° northwards, which is almost parallel to the trend of MMT. In the central portion of the mapped area, the plutonic rocks trend NE to SW and their dips varies from 40° to 70° NW and SE. Most of the fold axis in plutonic sequence is parallel to each other which mostly trend NE to SW and plunges from 12 to 50°. The northern part of Dir amphibolites mostly trend NE and dips 150 to 60° SE.

Key words: Amphibolite, petrology, Kohistan arc, Dir.

A/578. Ashraf, M., Ahmad, M. & Faruqi, F.A., 1976. Jurassic bauxite and kaolinite deposit of Chhoi area, Kala Chitta Range, Punjab, Pakistan. Geological Bulletin, University of Punjab 12, 41-54.

Sedimentary reworked bauxite and kaolinite deposits have been found in the Kala Chitta area for the first time. These deposits are of Jurassic age and they occur on an erosional unconformity at the top of Triassic rocks. Due to reworking of bauxite and kaolinite from the same source area the physical appearance of these deposits is almost identical. The bauxitic zones are occasionally more compact than the kaolinite zones. The basal bed always consists of kaolinite. The alternations of bauxite and kaolinite continue upward. This cyclic deposition is conceived due to alternate deposition of kaolinite and bauxite. Moreover, the occurrence of bauxitic nodules in the kaolinite zone at places show that the whole deposit is of reworked nature and cyclic. These bauxite and kaolinite zones have been evaluated in detail by chemical, X-ray and D. T. A. methods.

Key words: Economic geology, bauxite, kaolinite, Jurassic, Kala Chitta, Punjab.

A/579. Ashraf, M., Ali, R.S., Khan, H., Hamood, O., Asghar, I. & Zaidi, S.H., 1997. Some new informations on the geochemistry and economic geology of Timargara area, Dir District, NWFP. Geological Bulletin, Punjab University 31 & 32, 69-78.

Key words: Geochemistry, economic geology, Timargara, Dir.

A/580. Ashraf, M. & Chaudhry, M.N., 1974a. Geology of Dadar pegmatites, Mansehra area, Hazara District, Pakistan. Geological Bulletin, University of Punjab 10, 59-66.

Six complex pegmatite bodies have been located in the Dadar area. They are zoned. Most of the zones have been completely reconstituted. It is conceived that they are granite pegmatites, which have been derived from sodic solutions with gradual enrichment in potassic phase. The reconstitution occurred at pneumatolytic stage forming cleavelandite, muscovite and beryl. Replacement by tourmaline is local. In one of the pegmatites the replacement by cleavelandite is so extensive that small islands of microcline perthite are left as relicts in the intermediate zone, even the outermost zone (wall zone) has also not survived replacement.

Key words: Pegmatites, Mansehra, Hazara.

A/581. Ashraf, M. & Chaudhry, M.N., 1974b. Quartz, quartz-ilmenite and quartz-kyanite veins in the Mansehra Batgram area of Hazara District. Geological Bulletin, University of Punjab 10, 67-72.

Simple quartz, quartz-ilmenite and quartz-kyanite veins have been found in the area. Simple quartz veins occur both in the metamorphics as well as in the granites. But quartz-ilmenite and quartz-kyanite veins have only been found in the metamorphics so far. They range from mere stringer to many hundreds of feet in dimensions. They are lensoid, lenticular and lenticular branching type. They are thought to be products of hydrothermal solution and metamorphic differentiation.

Key words: Quartz-Ilmenite/Kyanite Veins, Mansehra, Hazara.

A/582. Ashraf, M. & Chaudhry, M.N., 1974c. The geochemistry and petrogenesis of albitites from Mansehra and Batgram area, Hazara District, Pakistan. Geological Bulletin, Punjab University 11, p.97.

Consult Ashraf and Chaudhry, 1976 below.

Key words: Geochemistry, petrogenesis, albitite, Mansehra.

A/583. Ashraf, M. & Chaudhry, M.N., 1976a. Geology and classification of acid minor bodies of Mansehra and Batgram area, Hazara Division, Pakistan. Geological Bulletin, University of Punjab 12, 1-16.

Seven types of acid minor bodies have been identified in the Mansehra and Batgram region of Hazara division on the basis of their mineralogical composition and structures. The acid minor bodies classified are 1) albitites, 2) aplites, 3) simple pegmatites, 4) complex pegmatites, 5) albitized or replacement bodies, 6) composite bodies and 7) quartz veins. Subclasses of these minor bodies are made possible by detailed field and microscopic studies. They are distributed in the area in such a way that each type has a direct bearing on the site where it has crystallized. Three zones have been recognized, i) Interior-lateral zone (1750-5500 feet above sea level, containing albitites, albite-aplites/pegmatites, albite-(microcline)-aplites/pegmatites), ii) interior-marginal zone 5000 to 9000 feet above sea level containing albite-microcline-aplites/pegmatites, microcline-albite-aplites/pegmatites and some complex pegmatites), and iii) marginal exterior zone (over 9000 feet above sea level; containing mainly complex pegmatites). The acid minor bodies vary in thickness from less than a centimeter to over 20 meters and in length from one to 100meters and occur as lensoid, lenticular branching, pinch and swell, patch, pod, pyroclastic, tabular bodies with regular and sharp boundaries and irregular to diffused contacts in a few cases. Internal structure of the bodies varies from one type to another. Zonation is perfect in some pegmatites. In other types the textural variation is marked from wall inwards.

Key words: Classification, acid bodies, Mansehra, Batgram, Hazara.

A/584. Ashraf, M. & Chaudhry, M.N., 1976b. The geochemistry and petrogenesis of albitites from Mansehra and Batgram area, Hazara District, Pakistan. Geological Bulletin, University of Punjab 13, 65-85.

Albitites are present in the granites and associated metamorphic rocks of the Mansehra and Batgram area. They have been classified as syenitic albitites of three distinct types: 1) pegmatitic albitites, 2) medium-grained albitites and 3) fine-grained albitites, the two former being associated with the granites and the latter with the metamorphic rocks. The albitites occur as streaks stringers and 1 – 10m wide and 5 – 70m long bodies. They occur either independently or as composite bodies and are associated with albite-aplites and albite-(microcline) aplites. The shape of these bodies is tabular to lensoid, showing usually sharp contact relationships with the granite and metamorphics. Mineralogically these rocks are usually formed of albite with quartz, muscovite, rutile, sphene, chlorite and apatite; zircon, tourmaline and magnetite may also be present. Chemically they contain SiO₂ 66-67 %, Al₂O₃ 19-21%, Na₂O 9-11%, K₂O 0.2 – 0.7%. The origin of these rocks is evaluated in the light of recent experimental work in the granitic system at 4 to 10 Kbs and it has been suggested that at a water vapor pressure 10 Kbs the granitic system shifts towards albite, thereby forming albititic solutions whose deposition and crystallization took place in fissures of the host rocks with gradual cooling of the system.

Key words: Geochemistry, petrogenesis, albitite, Mansehra.

A/585. Ashraf, M. & Chaudhry, M.N., 1976c. Origin of chessboard albite present in the acid minor bodies of Mansehra and Batgram area, Hazara Division, Pakistan. Geological Bulletin, University of Punjab 13, 93-98.

Primary chessboard albite is widely developed in the albitites and albite-aplites/pegmatites. Replacement and stress or deformation is also postulated for the development of chessboard albite on a minor scale. Exsolution chessboard albite is found only in a few complex pegmatites in the outer intermediate zone. Exsolution is shown by microcline.

Key words: Albite, Mansehra, Batgram, Hazara.

A/586. Ashraf, M. & Chaudhry, M.N., 1977a. A discovery of carbonatite from Malakand. Geological Bulletin, Punjab University 14, 89-90.

Carbonate rocks carrying vermiculite and iron oxides were reported by Fayyaz and Shafiq from near the village of Silai Patti which is 19 miles from Dargai (in the Malakand Agency) on the Dargai Bajaur road. The

authors studied the area and carried out laboratory studies on the rocks and concluded that the rocks were carbonatite bodies. Following is a brief description of the occurrence.

The carbonatites occur as dykes, sills and ring type bodies in the pelitic-psammitic schists of possibly Pre-Cambrian age (The dykes and sills are from 50' x 10 feet to 300' x 60 feet). The pelitic rocks have been thrust against calcareous and quartzitic rocks of Cambrian age intruded by granites (Chaudhry et al. 1976, E.C.L. 1977).

The rocks are composed of calcite, arfvedsonite, siderite, ilmenite/magnetite, vermiculite, apatite, chlorite and some feldspar. The minerals show uneven distribution and local segregation. The rocks are coarse grained and from porphyritic to subporphyritic. Calcite is the main mineral and ranges from 50 to 90% in most cases. However, where Fe-Ti oxides or vermiculite increase in amount the amount of calcite may fall below 50%. Some siderite crystals are also present.

Vermiculite occurs unevenly distributed and ranges in size from 1 mm to 3 mm and occasionally upto 8 cm in size. Fe-Ti oxides (magnetite/ilmenite) are generally below 5% however, at a few places they may be as high as 50% as pods and lenses). These oxides occur from subhedral to anhedral crystals. Arfvedsonite ranges from 2 to 25% of the rock. It forms subhedral to euhedral crystal. Apatite ranges from 2 to 12%. It occurs as subhedral to anhedral crystals. It may be partly enclosed by the carbonates. Vermiculite and amphibole at places alter to chlorite. K-Feldspar ranges from 0 to 5%. It occurs as randomly distributed crystals.

Key words: Carbonatite, Hazara.

A/587. Ashraf, M. & Chaudhry, M.N., 1977b. A chromium muscovite bearing zoned complex aplite from hill Khwar, Batgram area Hazara Division, NWFP, Pakistan. Geological Bulletin, University of Punjab 14, 39-44.

A chromium muscovite bearing zoned complex aplite has been reported for the first time from the Batgram area of Hazara Division. The aplite, which occurs in the pelitic metamorphics close to the contact of the granite gneiss, shows two well-developed zones i.e., an intermediate zone and a core. One chemical analysis, one spectrographic analysis and one modal analysis of each of the zone along with their normative composition is presented. One analysis of chromium muscovite is also presented. Both the zones contain chromium muscovite but the core is distinctly rich in this mineral. The intermediate zone contains 800ppm and the core contains 1000ppm chromium. The relative enrichment in chromium in such a body is attributed to contamination with the host metamorphics.

Key words: Muscovite, Hill Khwar, Batgram, Hazara.

A/588. Ashraf, M. & Chaudhry, M.N., 1980. Clayey bauxite and clay deposits of Kotli District, Azad Kashmir. Contribution to the Geology of Pakistan 1, 87-112.

Bauxite and underlying fireclay deposits occur over an erosional unconformity of possibly post Mesozoic age in the two big inliers of Kotli District, Azad Kashmir. Thickness of the bauxite so far noted is highly variable, being at a maximum in Nikial area (upto 2.4 m thick). The thickness of clay ranges from 0.6 to 2.5 m. Irregularities in thickness are mainly erosional/depositional. Dip of the deposits generally varies between 10^0 to 20^0 . Mineralogically the bauxite consists of boehmite, gibbsite, kaolinite, quartz/chalcedony, haematite/limonite, pyrite, carbonaceous matter and chlorite. The fireclay consists of major kaolinite and minor gibbsite, boehmite, quartz/chalcedony, haematite/limonite, pyrite, carbonaceous matter, calcite, chlorite and tourmaline (studied by microscopic, D. T.A. and X-ray methods).

Chemically the bauxite rocks contain Al_2O_3 (X=49.8B, S= 7.08), SiO_2 (X= 27.93, S= 8.10), Fe_2O_3 (X= 4.87, S= 4.96). The fireclay Rocks contain Al_2O_3 (X= ~8.47, S= 9.34). SiO_2 (X= 41.54, S= 9.34) and Fe_2O_3 (X= 2.68, S= 3.27).

The results of spectrochemical studies are also presented.

Industrial studies show that the silica content is difficult to reduce by physical processing methods. Soda-lime sinter process and/or pechiney acid process may be applicable for the ore. Bricks were prepared using four samples of fireclay of Kotli mixed with plastic clay from Mianwali. A mixture containing 35% plastic clay gave better results compared to a mixture with 25% plastic clay. The crushing strength of the former was higher than the latter. The proved and inferred reserves of the bauxitic ore are of the order of 2.722 million tons and 5.577 million tons respectively. And that of the fireclay are 3.228 and 21.177 million tons respectively.

Mining of the exposed deposits along with fireclay deposits will be possible by open cast/quarrying method. The working face be laid out in steps. The bauxite step will be leading by 15 feet.

Key words: Bauxite, Economic geology, Kotli, Azad Kashmir.

A/589. Ashraf, M. & Chaudhry, M.N., 1984a. A Cambrian unconformity represented by Galadanian Formation in Abbottabad District, North West Frontier Province, Pakistan. Abstracts, First Pakistan Geological congress, Lahore, 19, 19-20.

Consult Ashraf and Chaudhry, 1987 below.

Key words: Unconformity, Galadanian Formation, Cambrian, Abbottabad.

A/590. Ashraf, M. & Chaudhry, M.N., 1984b. Petrology of Lower Siwalik Rocks of Poonch Area Azad Jammu and Kashmir. Kashmir Journal of Geology 2, 1-10.

Sandstone (lithic arenites) and shale of Lower Siwalik of Poonch area have been studied petrographically, chemically and spectro-chemically. By comparing the overall composition of these rocks and specially the types and compositions of the rocks fragments in sandstone, it has been established that these rocks have been derived from the crystalline as well as sedimentary rocks lying due north towards the Pir Panjal Ranges.

Key words: Petrology, Siwalik Molasse, Poonch, Azad Kashmir.

A/591. Ashraf, M. & Chaudhry, M.N., 1985. Crystalline graphite deposits of Agra-Silai Pattai area Malakand Agency, NWFP, Pakistan. Kashmir Journal of Geology 3, 1-12.

The crystalline graphite occurs in Agra-Silai Pattai are at a distance of 32 to 40 km by truckable road from Dargai railway station. The graphite is a part of the pelitic-psammitic rocks of the area. Important graphite bearing rocks occur in Silai-Patti, Haspur South, Haspur North, Agra and Rang Dheri localities. The thickness varies from about 5m to 52m and the deposits extend intermittently over a length of 8 km. The petrographic study showed that graphite and predominant grain size upto 0.25mm. While flakes more than 0.5 to 1mm were rare. The crystalline graphite contents in the rock are 19.32, 18.32, 21.70 and 17.53% on average in the localities mentioned above.

The dominant gangue minerals in the rock are quartz ($X=31.8$ to 40.79), muscovite ($X=23.01$ to 35.83), geothite/limonite/haematite ($X=7.43$ to 9.57), boehmite ($X=1.19$ to 4.10), and minor andalusite, pyrite, feldspar, clay, magnetite, epidote, chlorite, tremolite, sillimanite etc. The ore microscopy and X-ray studies confirm the presence of crystalline graphites.

Chemically the graphite rocks contain carbon ($X=14.99$ to 17.82), amorphous carbon ($X=1.41$ to 1.80), SiO_2 ($X=50.78$ to 54.15), Al_2O_3 ($X=12.48$ to 14.113), Fe_2O_3 ($X=7.20$ to 7.39), FeO ($X=0.60$ to 0.87), MgO ($X=1.27$ to 2.02), CaO ($X=0.29$ to 1.13), Na_2O ($X=0.63$ to 0.81), K_2O ($X=2.43$ to 3.08), H_2O ($X=0.99$ to 1.22).

Textural relations suggest that graphite may be released as particles passing about 70 BBS mesh. This limits the recovery of flakes of appropriate size which would have otherwise produced flakes in appreciable quantities. However, optimum liberation of graphite was found to be between 200 to 250 BBS mesh for achieving better flotation. Reserves of inferred category are 16.10 million tonnes which include 2.94 million tonnes of indicated category.

Key words: Graphite, Economic geology, Silaipatti, Malakand.

A/592. Ashraf, M. & Chaudhry, M.N., 1986. Plate tectonic and mineralization associated with alkaline province, N.W.F.P., Pakistan. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 1-2.

Nepheline syenite and associated alkaline rocks are known from north western part of Pakistan as an alkaline igneous province trending WSW-ENE. Important exposures so far known are at Loe Shilman, Warsak, Malakand, Shewa, Koga and Tarbela. The distribution of the alkaline magmatism in a narrow belt suggest a zone of crustal weakness during late Eocene/Oligocene in the Indian block and was caused by the influence of compression. Butt Chaudhry and Ashraf (1980) proposed that while the leading edge of the Indian plate was being collided with Asian

block, compressional features were produced within the zone of deformation a complimentary zone of tension was created within Indian block. These tensional opening provided sites for intrusion of highly alkaline magmas.

The economically important alkaline magmatism is seen in Koga area as medium to coarse grained nepheline syenite, sodalite nepheline syenite, foyaites, litchfieldite and carbonatites. The first four rocks are prone to beneficiation to produce a product useful for the manufacture of colourless glass and quality ceramic wares. The carbonatites are quite interesting as they contain Ce (0.07%), Sr (0.9 to 2.46%), Y (0.005%), Ba (0.09%). Apatite contents are quite interesting as it is about 15 & 18% in two samples of carbonatites, 5 and 6% in fenite and lamprophyres.

Interesting occurrences of carbonatites are found by Ashraf and Chaudhary (1977) in Malakand. They occur as composite bodies having Nb (100-300 ppm), Sr (0.3%), V (0.01%), Y (100 to 200 ppm), Zr (0.01%), Sc (traces) La (400 ppm) and Yt (3 to 5 ppm). P₂O₅ in the six samples studied is 6 to 12%. Loe Shilman is also very interesting deposit regarding trace/rare earth elements and phosphate contents.

Key words: Mineralization, nepheline syenite, plate tectonics, alkaline provinces.

A/593. Ashraf, M. & Chaudhry, M.N., 1987. A Cambrian unconformity represented by Galdanina Formation in Abbottabad District, NWFP, Pakistan. *Kashmir Journal of Geology* 5, 43-49.

In Abbottabad District Galdanian Formation is formed at the top of Abbottabad Formation. The Upper Abbottabad Formation contains marine phosphorite deposit which laterally changes over to turbidite phosphorite bed associated with Galdanian variegated beds and to Galdanian continental deposits. It is evident from such lithologies that in Upper Abbottabad times the geological environments were such that deep sea conditions were lacking. However, the continental to shelf environments were dominating. In the deeper shelf conditions normal inorganic precipitation of phosphorite was in progress whereas bauxitization and lateritization was occurring continuously on projections (small islands) above sea level. The intervening zones between continental projections and sea conditions contained reddish to brown red siltstone, brownish red cherty dolomite, reddish cherty siltstone or chertstone and overlain fine-grained quartzose siltstone.

The present study, therefore, envisages that phosphorite is facies equivalent of Galdanian Formation whereas Hazira Formation is definitely younger than both of them and is possibly not related to Galdanian Formation.

Key words: Unconformity, Galdanina Formation, Cambrian, Abbottabad.

A/594. Ashraf, M., Chaudhry, M.N. & Baloch, I.H., 1991. Sedimentary petrology of Lagarban phosphorite, Northern Pakistan. *Kashmir Journal of Geology* 8 & 9, 25-38.

The Lagarban phosphorite of Cambrian age occurs in the Hazara District of Northern Pakistan in the upper dolomite member of the Sarban Formation. The geology is complicated by imbricate reverse faults which run more or less parallel to the regional strike and separate the phosphorite into the different structural blocks of Lagarban phosphorite, Bataknaala phosphorite, East phosphorite, South phosphorite and Middle phosphorite. The displacement along the imbricate faults appears to be large, because the rocks of different facies of phosphorite have been brought into juxtaposition. The faults separate the East phosphorite of shallow water marine facies from the western phosphorite of open-marine facies. This is confirmed by petrographic study of the two major types. The former type shows evidence of reworking of the phosphate and associated sediments, whereas the latter type is represented by undisturbed, normal deposition of phosphate oolites and associated dolomite.

Key words: Sedimentology, petrology, phosphorite, Abbottabad, Hazara.

A/595. Ashraf, M., Chaudhry, M.N., & Hussain, S.S., 1979a. Magnetite deposits of Lower Kohistan district, Hazara division. *The Pakistan Metallurgist*, 1, 2. & 1980, 2(1, 2), 15-23.

Key words: Mineral deposits, magnetite, Kohistan, Hazara.

A/596. Ashraf, M., Chaudhry, M.N. & Hussain, S.S., 1979b. Petrology of Koga nepheline syenites and pegmatites of Swat District. *Geological Bulletin, Punjab University, Special Issue*.

Key words: Petrology, nepheline syenite, pegmatite, Swat.

A/597. Ashraf, M., Chaudhry, M.N. & Hussain, S.S., 1979c. Molybdenum mineralization associated with igneous-metamorphic rocks in Kohistan-Swat Districts along Karakoram Highway. *Pakistan Metallurgist* 1 & 2, pp. 11-14.

Key words: Mineralization, molybdenum, igneous, metamorphic, Kohistan, Swat.

A/598. Ashraf, M., Chaudhry, M.N. & Hussain, S.S., 1980. General geology and economic significance of the Lahore granite and rocks of southern ophiolite belt in Allai Kohistan area. *Geological Bulletin, University of Peshawar* 13, 207-213.

Geological mapping of the toposheets (43 ^B/₁₃ and ^F/₁) carried out shows the following rock units in Besham-Kohistan and Allai areas: (1) Granitic rocks: Lahore granite and associated Shang granite gneiss and Mansehra (Susalgali) granite gneiss (2) Metamorphics: Thakot group, Tanawal group, Salkhala series, Hazara type slates and dolomitic rocks and amphibolites (garnet amphibolite and normal ortho-amphibolites) (3) Jijal ultramafics: dunite/peridotites and pyroxenites. Economic mineral deposits found so far are magnetite (in skarns, hornblendites and ultramafics), sphalerite/galena (in skarns, veins and altered granite), chromite (in dunites/peridotites and pyroxenites) and molybdenite (in silicified skarns, altered, altered granites and pegmatites). Anomalous values of Sn, W, Bi, Cd and Mn mineralization have been found in skarns, altered and silicified Lahore granite. The skarn type mineralization appears to be associated with the Precambrian Lahore granite rocks, which have intruded into the rocks equivalent to Salkhalas. This granite is unconformably overlain by Hazara type slates and Abbottabad Formation (dolomitic).

Two very important structural features have been noted in the area. They are one older thrust separating Thakot group and associated Lahore granitic rocks and Tanawal group and associated Mansehra granite gneiss. The other very major thrust is the Main Mantle Thrust bringing ophiolite/amphibolite rocks onto Lahore granite, Thakot group, Tanawal group, Mansehra granite gneiss and the Salkhalas.

Key words: Granites, economic geology, ophiolites, Lahore, Allai Kohistan.

A/599. Ashraf, M., Chaudhry, M.N. & Hussain, S.S., 1987. Mineralization associated with the alkaline rocks and carbonatites in NWFP, Pakistan. *Kashmir Journal of Geology* 5, 51-64.

Nepheline syenite and associated alkaline rocks are known from northwestern part of Pakistan as alkaline igneous province trending WSW-ENE. Important exposures so far known are at Loe Shilman, Warsak, Malakand, Shewa, Koga and Tarbela. The distribution of the alkaline magmatism in a narrow belt suggests a zone of crustal weakness during late Eocene/Oligocene in the Indian block and was caused by the influence of compression. Butt, Chaudhry, and Ashraf (1980) proposed that while the leading edge of the Indian plate was being collided with Asian block, compressional features were produced within the zone of deformation, a complimentary zone of tension was created within Indian block. These tensional opening provided sites for intrusion of highly alkaline magmas.

The economically important alkaline magmatism is seen in Koga area as medium to coarse-grained nepheline syenites, sodalite nepheline syenites, foyaite, litchfieldites and carbonatites. The first four rocks are prone to beneficiation to produce a produce useful for the manufacture of colorless glass and quality ceramic wires. The carbonatites are quite interesting as they contain Ce (0.07%) Sr (0.9 to 2.46%), Y (0.005%), Ba (0.09%). The P₂O₅ contents are quite interesting as they range from 15 & 18% in two samples of carbonatites, 5 and 6% in fenite and lamprophyres.

Interesting occurrences of carbonatites were found by Ashraf and Chaudhry (1977) in Malakand. They occurs as composite bodies having Nb (100-300 ppm) Sr (0.3%) V (0.01%), Y (100-200 ppm), Zr (0.01%), Sc (traces), La (400 ppm) and Yt (3-5 ppm) P₂O₅ in the six samples studied is 5 to 11%. Loe Shilman is also very interesting deposit regarding rare earth elements and phosphate contents.

Key words: Mineralization, alkaline rocks, carbonatites, NWFP.

A/600. Ashraf, M., Chaudhry, M.N. & Hussain, S.S., 1994. Geology of the lead - zinc-molybdenum, copper and iron skarns of Besham area Kohistan, NWFP, Pakistan. *Kashmir Journal of Geology* 11 & 12, pp. 1-27.

At the leading edge of Indo-Pak plate magnetite, sphalerite, galena, chalcopryrite, molybdenite etc. bearing skarn mineralizations occur in the Besham group of rocks. Geologically the Besham group of rocks consists of psammites, pelitic psammites, pure to impure carbonates, graphitic pelites and Lahor basement granitic complex including small to large acid pegmatite bodies. Exotic small ultrabasic to basic metamorphosed intrusions are also found at places. Base-metal mineralization has been found in rocks of carbonate character i.e. they are pure carbonate to impure carbonate rocks. In the former magnetite is the dominant replacive mineral as grain, streaks, patches, lenses etc. with overall contents of 12 to 96%. The impure carbonate rocks formed well-developed skarn mineralogy with sphalerite and galena as major base-metal minerals with contents of 1 to 15% along with molybdenite at places.

It is envisaged that magmatic solutions evolving from Lahor granitic complex and its derivatives were responsible for the development of skarn mineralogy and base-metal precipitation in three stages. The stage I was magnetite carbonate skarn. The stage II was for the formation of dense base-metals, developing in impure carbonate rocks with skarn minerals like pyroxene (CPX), amphibole, calcite/dolomite, pyrite/pyrrhotite, garnet, epidote, pyrolusite/puenselite etc. This is overlapped by silicification of stage II mineralogy (surrounding metasediments and apophyses of granite, as patches lenses and lenticular bodies increasing the base - metal contents in them. The stage III is subsequently developed from stage II as vein formation.

Key words: Skarns, Metallic mineralization, Besham

A/601. Ashraf, M., Chaudhry, M.N. & Malik, R.H., 1984. Bituminous/anthracitic coal of Kotli District, Azad Kashmir. Abstracts, First Geological Congress, Lahore, 54-55.

Consult the following account.

Key words: Coal, Kotli, Azad Kashmir.

A/602. Ashraf, M., Chaudhry, M.N. & Malik, R.H., 1986. Bituminous and anthracitic coal of Kotli District, Azad Kashmir. *Kashmir Journal of Geology* 4, 1-12.

Coal occurs at two horizons within Patala Formation in the Kotli anticline (a continuation of Riasi anticline in Jammu). Most commonly the coal lies over the bauxite as in Sawar, Tattapani, Dondili and Karela. The second horizon occurs within the carbonaceous shales about 9 to 15m above bauxite bed as in Kamroti, Barmoch, Bangang and Nikial. The exposed thickness of individual seams ranges from 0.02 to 1.0m which in underground working is from 1.0 to 2.2m in thickness.

Petrographic studies of coal show the presence of carbonaceous matter (X=63), Clay (X=30.14), quartz (X=2.79) haematite/limonite (X=2.53), carbonate (X=0.12), and muscovite/sericite (X=0.24). Carbonaceous shale has the same minerals as in coal but in quite different proportions. Chemical studies of the coal indicate a wide range of variation. The coal samples can be classified as high fixed carbon (max. 86.75%) to low fixed carbon (35.31%), low volatile matter (7.25 to 13.56%) low ash (down to 3%) and high ash (26 to 49%) Coal.

Washability study on coal samples shows that using sink/float, heavy media separation and flotation techniques on different size fractions such as 25X4 mm, 4X0.5 mm and less than 0.5 mm reduced ash from 34% to 21% and sulphur from 3.4% to 1.2%. This shows that coal is amenable to cleaning to a limited extent as ash forming mineral matter is uniformly and finely disseminated in the coal. Some coal samples collected from Balmi, Sohra Seri, Kamroti, Bangang and Kandel are low in ash (3.32% to 14.61%) and high in fixed carbon (51.56 to 86.75%). These coals can be blended with clean coal from other localities of Kotli to obtain a product containing 14 to 16% ash. Such a coal blend may be used for cooking purposes. The Kotli coal is of bituminous to anthracitic variety having decidedly better rank than any of the coal deposits found in Pakistan so far. The numerous coal exposures all along the strike on both limbs of eroded anticline are encouraging and are indications of the occurrence of large coal deposits.

Key words: Coal, Kotli, Azad Kashmir.

A/603. Ashraf, M., Chaudhry, M.N. & Qureishi, K.A., 1983. Stratigraphy of Kotli area of Azad Kashmir and its correlation with standard Type areas of Pakistan. *Kashmir Journal of Geology* 1, 19-30.

In Kotli area, rocks, Precambrian to Pleistocene age have been found and studied. The Precambrian rock formation is, Dogra Slate which has been reported by author for the first time in Nail Nala. Cambrian rocks are correlated with Abbottabad Group (consisting of basal boulder bed and overlain by thick sequence of Sirban dolomite/quartzite). In this area apart from Cambrian (Abbottabad Group) all the formation of Paleozoic and Mesozoic are missing. Either they were not deposited or were weathered to form bauxite/laterite-representing an unconformity of a big gap. In the Tertiary period Patala Formation, Margalla Hill limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy etc.

Key words: Stratigraphy, Kotli, Azad Kashmir.

A/604. Ashraf, M. & Faruqi, F.A., 1973. Diaspore and clay deposits of Kala Chitta Range, Punjab. Abstracts, 24th Pakistan Science Conference, Islamabad, p.H-6.

Key words: Diaspore, clay, mineral deposits, Kala Chitta, Punjab.

A/605. Ashraf, M. & Hamood, O., 1997. Tectonic reinterpretation constraints of the Western most Kohistan complex in Timargara, Dir District, Pakistan. *Geological Bulletin, University of Peshawar*, 30, 311-323.

No detailed tectonic and structural studies were carried out in the western most extremity of the Kohistan area. People have been concentrating mostly along Indus canyon and Swat valley for geotectonic, structural, petrological and geochronological studies. Present investigation is the first study to thoroughly work out tectonic reinterpretation constraints of the western most Kohistan complex particularly in Timargara quadrangle and adjoining area of Warai consisting of 673 sq.km. The concept of underplating for the emplacement of major plutonic complexes is advocated in this area as well, as was also found out in Swat and Indus canyons, i.e., the Balambat norite and Timargara gabbro-norite which are different from Chilas complex magma type underplated the Dir tholeiitic amphibolites. These plutonic rock types are more evolved than those of main Chilas complex. The latter underplated Dassu metaplutonic complex of Kamila amphibolites. The Kamila amphibolites are further subdivided into Kamila group metaplutonic calc-alkaline amphibolites and Dir metavolcanic tholeiitic amphibolites or precisely as Kamila amphibolites and Dir amphibolites which are advocated to be adopted due to their different provenances.

Key words: Tectonics, Kohistan complex, Timargara, Dir.

A/606. Ashraf, M., Hamood, O. & Khan, H., 1999. Structural geology of the western extremity of the Kohistan Island Arc in Dir area, NWFP. *Geological Bulletin, Punjab University* 33 & 34, 71-81.

Structural studies show that the rock of Kohistan island arc exposed in the area are folded into northwards dipping southwards verging tight folds in the south (near MMT) which opens up northwards. The amphibolite have undergone at least IWO phases of isoclinal folding. In the first phase recumbent or isoclinal folding S1, axial planar foliation was developed in these rocks. The first phase of deformation is probably related to the subduction of Kohistan Island Arc under Eurasian plate. In the second phase these rocks were again folded. The rock of Kohistan Island Arc has undergone a third phase of deformation which produced the shear zones resulting into retrograde metamorphic chlorite grade rocks. That is related most probably to the collision of India plate with Kohistan complex. The southern part of the Dir amphibolite near MMT mostly trend EW and dips 65' to 80' northwards which is almost parallel to the trend of MMT. In the central portion of the mapped area the plutonic rocks trend NE to SW and their dips varies from 40' to 70' NW and SE. Most of the fold axes in the plutonic sequences are parallel to each other which mostly trend NE to SW and plunges from 12' to 50'. The northern part of the Dir amphibolites mostly NE and dips 150 to 60' SE.

Key words: Structure, Kohistan island arc, Dir.

A/607. Ashraf, M., Haq, R., Qureshi, M.H. & Faruqi, F.A., 1971. Magnesite occurrence in Hazara District. *Pakistan Journal of Scientific and Industrial Research* 14, 538-541.

Magnesite occurs as three lens-like bodies near Sherwan (Hazara) in the Abbottabad Formation of Upper Paleozoic system. Total length of two outcrops is around 900 ft and width about 150 ft. The third outcrop is 150 ft. long and 20 ft wide. The deposit is probably hydrothermally metasomatized type. The properties of the magnesites were determined by utilizing microscopic, chemical, X-ray diffraction and differential thermal techniques.

The conclusion drawn from the results obtained is that ores are fairly rich in magnesite with some minor impurities such as calcite, hematite, clay, siderite, quartz and limonite.

Key words: Magnesite, economic geology, Hazara

A/608. Ashraf, M. & Hussain, K. 1994. Economic geology and mineralogy of PGE-Au in dunite of Chilas, northern area-Pakistan. Abstracts, Second SEGMRITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, 20-21.

Platinum group elements (PGE)-gold (Au)-copper (Cu) occur in dunite rocks of Thurli and Chilas in northern area of Pakistan. Dunite rocks in Thurli are dominantly fresh olivine rich from 93-98%. The impurities are CPX 2 to 5%, chromite/magnetite 1 to 2% and sulphides like covellite, chalcopyrite, bomite, pentlandite, chalcocite and pyrrhotite containing PGE and Au from 0.2 to 2%. The olivine is dominantly forsterite (Fo 85-92%). In a 50m dunite zone near Thurli Cu is about 0.4%, Ni 0.2%, PGE + Au 800 ppb to 2800 ppb. The POE minerals are moncheite, michenerite and merenskyite with electrum and tetra-aurocuprite as Ag, Au and Au.Cu alloys. Texturally dunite in Chilas area is very compact to moderately compact with grain size of about 0.3 to 2mm. The valuable POE+Au+Cu+Ni bearing minerals of Thurli dunite can be liberated by crushing the dunite rocks down to 0.3 to 1.0mm size. With the removal of valuables, the tailings obtained are pure forsterite sand. The size of such deposit near Thurli is about 30 million tonnes and the one that is pure compact forsterite is 50 million tonnes near Chilas.

Key words: Economic geology, platinum-group mineralization, dunite, Chilas Complex.

A/609. Ashraf, M. & Hussain, S.S., 1983. Chromite occurrences in Indus Suture ophiolites of Jijal, Kohistan, Pakistan. In: Sinha, K.A. (Ed.), *Contemporary Geoscientific Researches in Himalaya* 2, 129-132. Singh, Dehra Dun, India.

Key words: Chromite, Jijal, Indus suture, Kohistan.

A/610. Ashraf, M., Khan, M.A. & Asghar, I., 1999. Geotechnical properties of Balambat norite, Panjkora diorite and hornblendite of Timargara area, Dir District, NWFP. *Geological Bulletin, Punjab University* 33 & 34, 149-156.

Gabbro-norite, norite, diorite and hornblendite occur as very large to large deposits in the Kohistan Island Arc of Timargara area Dir district. These rocks are very fresh and compact at many places. Texturally Balambat norite and Panjkora diorite are fine to medium grained whereas hornblendite are medium to coarse grained. The rocks were tested to know their geotechnical properties for usefulness as building material and as polished dimension stones/slabs. The tests carried out are like absorption of water, soundness, compression/crushing strength. Absorption value of norite is 0.59% maximum, of diorite is 1.01%, and that of hornblendite is 0.98%, soundness value for fine losses is 0.83%, 1.05% and 1.05% respectively for sieve size 35". Unconfined compressive strength is 8644, 6483 and 6915 PSI respectively. These rocks take good to very good polish and are thus useful as decorative stones and for building purposes.

Key words: Geotechnical, norite, diorite, hornblendite, Dir.

A/611. Ashraf, M. & Khan, M.S., 1992. General geology & stratigraphy of Muzaffarabad and Poonch area in Azad Jammu & Kashmir. Abstracts, First South Asia Geological Congress, Islamabad, p.51.

General Geology and stratigraphy of the Poonch and Muzaffarabad areas are quite interesting due to fact that various formations in Hazara, Azad Kashmir and occupied Kashmir are continuous in Precambrian to Cambrian & Tertiary Time and discontinuous during rest of the Paleozoic and Mesozoic times. From this it appear that there were definitely some stratigraphic barriers in those areas but they were not as reported by Ghazanfar and Chaudhry (1987) the three stratigraphic provinces. In our view the three regions had same geological environments during Precambrian times, depositing Sharda/Salkhala sediments overlain by Hazara/Dogra Slates and Tanol quartzites and pelites. The Cambrian conditions remained similar as well in all the three areas by depositing dolomites, limestone etc of Abbottabad Formation, with Tanakki unconformity at base. In all the three stratigraphic areas, during Late Cambrian times unconformity is seen in Hazara in the form of Galdanian Formation, (Ashraf et al. 1983), with subsequent non-deposition till the formation of Datta/Sarnanuk Formation of Jurassic and further Cretaceous formations. But there are no such formations even upto Late Cretaceous times in the Muzaffarabad -Kotli basin. That is, a pre-Tertiary unconformity is regionally present in Hazara, Kashmir, Potwar & Salt Range. Whereas in Kahuta-Pir Panjal Range Gondwana Formation of Carboniferous age occurs and are not seen in other two basins. Panjal Group of rocks consisting of pyroclasts and lava flow occur as rift related submarine to aerial rocks in both Kahuta and Muzaffarabad areas with Triassic sediments at places. And lastly there was only one basin/geosyncline forming Paleocene to Lower Miocene rocks everywhere.

Key words: Stratigraphy, Poonch, Muzaffarabad, Azad Kashmir.

A/612. Ashraf, M., Khan, M.S., Awan, M.A., Yasir, A., Warraich, M.Y., Khan, A. & Awan, M.S., 1991. Geology and petrology of Jijal and Pattan layered ultramafic-mafic complexes in the vicinity of Jijal, Duber and Pashto, NWFP, Pakistan. *Kashmir Journal of Geology* 8 & 9, 193-196.

The project area covers about 300 km² located in the vicinity of Jijal, Duber and Pashto (Fig. 1) in Districts of Kohistan and Mansehra. Geological mapping was carried out of the area on a scale 1:50,000 of toposheet No. 43A/12, 43A/16, 43E/4 and 43F/1 of Survey of Pakistan.

The geological sequence of Jijal complex consists of ultramafic and mafic cumulates. The ultramafic cumulates are divided into dunite, wehrlite, websterite, garnet-pyroxenite and garnet-hornblendite whereas mafic cumulates are garnet gabbro. The geological sequence of Pattan complex also consists of ultramafic and mafic cumulates, the ultramafic cumulates are chromite, dunite and (meta)-wehrlite, whereas mafic cumulates are divided into two pyroxene gabbro and two pyroxene quartz-diorite.

Previously, the metamorphosed mafic complexes of the Kohistan island arc have been lumped together as an undifferentiated mass called Kamila amphibolite. Now, the Kamila amphibolite has been divided into three complexes i.e., Dassu complex, Kayal complex and Pattan complex. The Dassu complex is the oldest pluton which is polymetamorphosed, isoclinally folded and banded amphibolite augen gneiss that grades from metatonalite at its top downward to melanocratic garnet amphibolite at its base some 5 to 6 km down section. Dassu complex is underplated by the Kayal complex, has a metamorphosed agmatitic intrusive breccia at its roof and grades downward from moderately banded metadiorite gneiss in its upper part to melanocratic garnet-amphibolite at its base. Again Kayal complex is being underplated by the Pattan complex which is least metamorphosed partly to greenschist facies. The Pattan complex is underplated by Jijal complex.

Field evidences suggest that the Pattan complex was emplaced along the pre-existing metamorphosed Kayal cumulate complex. The top of the Pattan complex is marked by a spectacular, intrusive, polymictagmatite breccia. In Duber and NW of Duber the Pattan complex is overthrust on to the Jijal complex. While in Pattan area and SE of Pattan, there is a faulted (strike slip) contact between Pattan complex and Jijal complex.

The Jijal complex is the southern most, layered ultramafic-mafic cumulate complex of the Kohistan tectonic province, the Main Mantle Thrust (MMT) is the southern boundary of the Jijal complex, which in turn is the southern boundary of Kohistan arc complex. The Main Mantle Thrust (MMT) and Duber thrust wedges out Jijal complex NW of Duber near Charri, on the other hand Main Mantle Thrust and Pattan fault (strike slip fault) wedges out the Jijal complex on the eastern side near Pashto.

Key words: Petrology, ultramafic complex, Jijal, Kohistan.

A/613. Ashraf, M. & Loucks, R.R., 1991. Platinum-group element mineralization in high-pressure, layered, ultramafic-mafic cumulates of the Jijal and Chilas complexes. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, 8-9.

Key words: Platinum-group mineralization, mafic-ultramafic, cumulates, Jijal, Chilas.

A/614. Ashraf, M. & Loucks, R.R., 1992. New concepts in geology, petrology and economic potential of the Kohistan island arc, northwest Himalayas, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.5.

Key words: Petrology, economic geology, Kohistan arc, Himalaya.

A/615. Ashraf, M., Loucks, R.R., & Awan, M.A., 1989. Serpentinization of cumulate ultramafites and development of Heazlewoodite-Pentlandite-Awaruite-Magnetite and Pentlandite-Chalcopyrite-Pyrrhotite association in Alpurai and Khishora, Swat, Pakistan. Kashmir Journal of Geology 6 & 7, 8-18.

Ultramafics of Alpurai and Khishora areas of Swat District have been found to occur as cumulates. These ultramafic bodies occur along the Main Mantle Thrust which marks the part of the suture zone between the Asina and Indo-Pakistan plates. The present study elaborates the classification of ultramafics of the two areas, their chemico-mineralogical composition, distribution of minor elements, ore microscopy and electron microprobe composition of some sulfides. The Alpurai rocks are found to be, stratigraphically upward, harzburgites, olivine websterite, wehrlite, dunite, wehrlite, websterites, dunite and ilmenite. All these members are altered variably to serpentine minerals. The Kishora rocks are dominantly a part of an ultramafic mantle tectonite i.e., a harzburgite which is overlain by dunite. All these rocks are pervasively serpentinized. In both Alpurai and Kishora areas nickel mineralization is present in two distinct ore mineral assemblages as heazlewoodite-awaruite-pentlandite-magnetite and pentlandite-chalcopyrite-pyrrhotite-pyrite associations respectively. These associations appear to have developed from hydrothermal alteration of ultramafic rocks by the introduction of water, sulfur and or carbon dioxide. The Ni values found in the ultramafic rocks appear to be low i.e. 1500-2000 ppm. But most of Ni is in the form of nickel sulfides and alloy.

Key words: Ultramafics, Metallic mineralization, Alpurai, Kishora, Swat.

A/616. Ashraf, M. & Malik, M.I., 1983. Prospects and development of phosphate deposits of Lagarban area Abbottabad, Pakistan. Kashmir Journal of Geology 1, 77-82.

Sedimentary Phosphorite of Lagarban is 7.831 million tonnes as in-situ rock and is 5.093 million tonnes recoverable reserves from East, Batakna, Southern and Lagarban South Phosphorite. 840 tonnes can be mined per day. The undiluted ore contain 28.55 to 30.20 % P₂O₅ in the four ore bodies. Mineralogically the ore consists of collophane with minor dahllite as phosphorite minerals. The other ubiquitous to accessory minerals are dolomites, chalcedony, chert, quartz, goethite, pyrite, chlorite, clay, mica, organic matter etc. It is that variation in grade and the proportion of impurities is a function of original sedimentary variations, and the amount and nature of contamination and dilution during and after the deformation are by physical & chemical mechanisms. The beneficiation of the ore is possible by HMS and acid leaching methods but the proposition appears expensive. However, ROM blending with Jordan ore may be viable after some more plant trials and tests.

Key words: Phosphate, mineral deposits, Abbottabad.

A/617. Ashraf, M., Qureshi, M.H. & Faruqi, F.A., 1972. Geological and chemical characteristics of dolomite from Hazara and Mardan Districts. Science and Industry, Pakistan, 9, 62-66.

Chemical analyses and brief mineralogical details are given for 14 samples of dolomite rock suitable for use in ceramics and metallurgy.

Key words: Economic geology, dolomite, Hazara, Mardan.

A/618. Ashraf, M., Qureshi, M.H. & Faruqi, F.A., 1975. Studies on quartzite and ganister—raw materials for refractories from NWFP and Punjab. *Geological Bulletin, University of Peshawar* 7 & 8, 89-100.

Quartzite and ganister have been located and studied from different areas of NWFP and Punjab for the manufacture of silica refractories. Brief geology of silica bearing rocks of those areas is given discussed. In the laboratory the samples were studied and analyzed for their mineral constituents and oxide components. Furthermore, their physical properties have been evaluated for suitable uses for the manufacture of silica refractories. It is found out that quartzite from Attock and Haripur area is one of the best for refractory purposes while ganister from Musakhel and quartzite from Swabi and Tarbela can be used for making semi-silica bricks.

Key words: Mineral deposits, quartzite, refractories, NWFP, Punjab.

A/619. Ashraf, R., 1989. Electrical resistivity survey for groundwater investigations in an area between Quaid-i-Azam University and Murree Road with special emphasis on anisotropy. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 35p.

Surface electrical resistivity measurements were made at 20 geophysical observation stations in an area between Quaid-e-Azam University and Murree Road (longitudes 73° 7' 48" to 73° 10' 40" E and latitude 33° 43' 55" to 33° 46' 33" N), Islamabad in order to delineate the suitable ground water aquifer zones using Schlumberger electrode configuration keeping the maximum current electrode spacing $AB/2 = 200$ meter with ABEM Terrameter. The interpretative results deduced various subsurface geological units named as clay, compact clay, gravels + clay + silt sand with minor amount of clay or silt, boulders (moist & dry).

For ground water investigation, the field resistivity data was interpreted by partial curve matching technique to obtain the interpreted electrical and geological sections in the form of vertical electrical and geological columns for each resistivity station. Besides, four geological sections have also been prepared. An anisotropic contour map has also been prepared to see the isotropic and anisotropic regions in the study area.

The combined interpretative results of all these maps indicate layers of permeable formations at various depths, but these formations are not good aquifers as the recharging mainly depends upon weather condition of the area, especially rain. The anisotropic contour map shows 3 anisotropic zones with a maximum anisotropy of 1.5. This anisotropy shows a good contrast in lithology which is due to boulder and compact clay.

Key words: Electrical resistivity, geophysics, groundwater, Islamabad.

A/620. Asif, M., Habib, M. & Jan, M.Q., 1985. Ultramafic and mafic rocks of Thurlly Gah and their relationship to the Chilas Complex, North Pakistan. *Geological Bulletin, Peshawar University* 18, 83-102.

Detailed field and petrographic studies in Thurlly area substantiate the idea of a two-fold subdivision of the Chilas Complex. Much of the area is occupied by the association of "Main Norites" with subordinate pyroxenites and anorthosites displaying only local layering. Apparently intrusive into these is the association of ultramafic-mafic rocks occurring principally in a 2.5x1 km lensoid body. These possess well-developed sedimentary features, especially layering and comprise dunite, peridotites, pyroxenites, troctolite, norite, anorthosite, and olivine/pyroxene pegmatites, there are distinct differences in the mineralogy of the two associations, especially in the composition of plagioclase and oxide minerals. It is suggested that the ultramafic-mafic association was derived from a picritic magma emplaced in the floor of crystallizing (main) noritic magma. There is a strong concordance in the planar structures of the two associations and the crystallization of the ultramafic mafic rocks apparently preceded all deformational events.

Key words: Ultramafics, Thurlly Gah, Chilas complex.

A/621. Asif, M., & Tahirkheli, T., 1980. Petrology and Mineralogy of Tarbela alkaline complex. M.Sc. Thesis, Peshawar University, 132p.

Key words: Petrology, mineralogy, alkaline complex, Tarbela.

A/622. Asim, M., Karim, A. & Khan, M.H., 1999. Geology of Shamoza area in Lower Dir District, NWFP, Pakistan. Geological Bulletin, University of Peshawar 32, 51-55.

Rocks of the Main Mantle Thrust and associated suites have been investigated in a 100 km² area in southwestern Dir district. Field investigations and thin section study reveal that the succession of rock units from south to north is that of the Indian plate rocks, ophiolitic mélange zone, and Kohistan arc terrane. The Indian plate rocks comprise granitic gneisses along with minor calcareous schists and phyllites. The ophiolitic mélange zone, which is reported for the first time from the area, mainly comprises serpentinized dunite, talc-carbonate schist and crystalline limestone blocks in a matrix of phyllite and minor graphitic schist. The arc terrane is represented by amphibolites, intruded by quartz porphyries and tonalites in a number of places.

Key words: Metamorphism, Shamoza, MMT, Dir.

A/623. Asim, M., Majid, M. & Shah, M.T., 2000a. Geology, geochemistry and tectonic setting of ophiolitic rocks from the Waziristan ophiolite complex, NW Pakistan. *Geologica* 5, 109-132.

The Waziristan Ophiolite Complex occupies about 5000 km (super 2) area in a north-south elongated belt in the north and South Waziristan Agencies. It demarcates the spatial disposition of the suture zone between the Indian plate and the Afghan block in the Waziristan area. The complex consists of a chaotically arranged stack of thrust slices. Section(s) showing a complete sequence is not preserved but all members of a typical ophiolite are separately present in the area. Basic volcanics, ultramafics and jasperites within the ophiolite belt respectively contain copper, chromite and manganese. A 40 km (super 2) area near Boya, west of Miranshah in the North Waziristan Agency was selected for detailed study. Dominant rocks of the study area include basic lavas, ultramafics and gabbros with subordinate amounts of mafic dikes, granites, and pelagic sediments. Representative samples were studied in thin sections and analyzed for major elements. The major elements data of the studied rocks have been interpreted to reveal the tectonic environment at the time of generation and emplacement of the ophiolite sequence. The petrochemical indices of the mafic volcanics, in particular, correspond to a transitional character (from tholeiitic to calc-alkaline) developed in an island arc environment in general and MORB in little. The geochemical parameters substantiates the assumed prevalence of the arc-related structures in the Waziristan section of the suture zone before collision of the Indian plate and the Afghan block. On the basis of geological and geochemical signatures of the constituent rocks, it is suggested that the WOC was formed in supra subduction zone setting probably by marginal basin or back-arc basin rifting and was later on obducted on to the Indo-Pakistan plate.

Key words: Geochemistry, tectonics, ophiolites, Waziristan.

A/624. Asim, M., Majid, M. & Shah, M.T., 2000b. Mineral chemistry and origin of ophiolitic rocks from the Waziristan ophiolite complex, NW Pakistan. Geological Bulletin, University of Peshawar 33, 39-52.

Consult the following for more information.

Key words: Mineralogy, geochemistry, ophiolites, Waziristan.

A/625. Asim, M., Majid, M. & Shah, M.T., 2001. Mineral chemistry and origin of ophiolitic rocks from the Waziristan complex, NW. Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.1.

The Waziristan ophiolite complex demarcates the spatial disposition of the suture zone between the Indian plate and the Afghan block in the Waziristan area. The complex is located along the western margin of the Indian plate and consists of a chaotically arranged stack of thrust slices. Section(s) showing a complete sequence is not preserved but

all members of a typical ophiolite are separately present in the area. Dominant rocks include basic lavas, ultramafics, gabbros, dikes, granites, and pelagic sediments. Major minerals (pyroxene, spinel, serpentine and plagioclase) within the rocks were analyzed using Jeol Superprobe Micro-analyser. Pyroxenes from basalts, apparently crystallized at temperatures above 1000°C, plot in the field of volcanic arc basalts and ocean floor basalts. Pyroxene and chromite data have been further interpreted to reveal the tectonic environment at the time of generation and emplacement of the ophiolite sequence. The pyroxene data show a transitional character (from tholeiitic to calc-alkaline) and ocean floor to island arc type environment. Chromite data, with moderate to high Cr#, also exhibit oceanic (abyssal) to arc affinities. The chemical data on pyroxene and chromite suggest a complex origin for the Waziristan ophiolite such as oceanic+island arc, back arc or infant arc.

Key words: Mineralogy, geochemistry, ophiolites, Waziristan.

A/626. Aslam, A. & Kaneda, H., 1993. Mineralogical study of the Kakul phosphorite deposit, Abbottabad District. *Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad*, 7, 17-33.

The present study has been carried out as a research exercise to improve and evaluate the analytical precision of the XRD and Microscopic techniques. The XRD and Microscopic investigation of the Abbottabad phosphorite ore deposit shows considerably important information related to ore mineralization and mineral resource.

The following mineral species have been identified by means of the XRD analysis; dolomite, ferroan dolomite, calcite, quartz, hematite, hydroxyapatite and fluorapatite. On the basis of XRD, volume and weight percentages of constituent minerals of ores have been determined. The volume percentage data shows that the carbonaceous minerals in the studied area consist mostly of ferroan-dolomite. Relatively large amounts of ferroan-dolomite occur within phosphorite ore beds and in the associated rocks. In particular, the ores from the northwestern sites (Q site in Figure 1) are rich in ferroan-dolomite, which occupy 24.5 volume % of all specimen. The volume % relationship among carbonate minerals, quartz and apatite minerals shows that ore samples from the Q site are relatively rich in carbonaceous minerals compared to quartz. The ore grade of the Q site is higher than the Kakul mine site. It is considered that ferroan dolomite and large amounts of carbonaceous minerals are associated with ore formation. The weight percent analysis has been performed on the basis of standard calibration method, and belongs to the technique of quantitative analysis. The data shows that the carbonaceous minerals / quartz weight values are quite different in the two sample sites. The carbonaceous minerals / quartz ratios vary from 0 to 0.5 for the mine site and on the contrary, range from 1.04 to 19.6 for the Q site. This suggests that the ore at the mine site is relatively rich in quartz. This result is identical with the data of volume percent analysis. Microscopic observation gives more useful information about the mineralogy and mode of occurrence of minerals. A major ores forming phosphorite mineral is cellophane which is an aggregate of amorphous P-bearing hydrous phases. The collophane often occurs in a host dolomite mass filling the interstices and cavities. The massive phosphorite ores show the following two distinctions with respect: to the minerals occurring along grain boundaries of collophane. One is that the cement is composed mostly of calcite, and another is that the cement is predominantly quartz. The former occurrence is from the Q-site, while the latter from the mine site. This occurrence under the microscope is concordant to the XRD results. It is concluded that carbonaceous minerals, in particular ferroan-dolomite and the carbonate/quartz ratio plays an important role in ore formation. In order to make clear the ore genesis and to evaluate the ore resources, mineralogical and geochemical studies are essential.

Key words: Phosphorite, economic geology, Abbottabad

A/627. Aslam, A. & Thewissen, J.G.M., 1996. Preliminary evaluation of paleosols and implications for the interpretation of vertebrate fossil assemblages, Kuldana Formation, northern Pakistan. *Palaeovertebrata*, 25, 261-277

Key words: Vertebrate Paleontology, Paleosols, Kuldana Formation.

A/628. Aslam, M., 1964. The chemical study of rocks contacts from Mansehra area, Hazara. M.Sc. Thesis, Punjab University, Lahore, 42p.

Key words: Geochemistry, Mansehra, Hazara.

A/629. Aslam, M., 1979. Uranium exploration in Pakistan. Proceedings, International Seminar on Mineral Exploitation Technology. PCSIR, Peshawar.

Key words: Mineral exploration, Uranium.

A/630. Aslam, M., Din, A. & Faruqi, F.A., 1984. Industrial minerals used in the glass industry. Abstracts, First Pakistan Geological Congress, Lahore, p.27.

Silica sand, feldspar, nepheline syenite, limestone and dolomite are the principal naturally occurring industrial minerals that are used in the glass industry. This paper describes briefly their occurrence, formation, mineralogy, physical and chemical characteristics and their utilization in the glass industry. Physical and chemical characteristics of these minerals suited to the glass industry have also been discussed. Since silica sand is the main and important constituent of all commercial glasses, samples of sand from all commercially exploited deposits were collected and chemical analyses of raw as well as washed samples, including grain size distribution and some other properties, have been determined and compared. Similarly, chemical and physical properties of some other minerals collected from different parts of Pakistan have been determined and discussed with particular reference to their use in the glass industry.

Key words: Minerals (Industrial), Glass industry.

A/631. Aslam, M., Khan, A. & Khan, R.N., 1999. Revised stratigraphy of the Khyber Agency, NWFP, Pakistan. Additional abstracts, IGCP 421, North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics, Peshawar Meeting, 1p.

Key words: Stratigraphy, biostratigraphy, Khyber Agency.

A/632. Aslam, M., Khan, A., Khan, R.N., 2000. Geological Map of Chitral district, NWFP, Pakistan. GSP Geol. Map Series, NWFP. Map 1.

Key words: Geological map, Chitral.

A/633. Aslam, M., Khan, M.A. & Sadin, M., 1982. Geology of Gandao quadrangle, Mohmand Agency, NWFP, Pakistan. GSP, Information Release, 130, 24p.

Key words: Gandao, Mohmand Agency.

A/634. Aslam, M. & Khan, S., 1979. Geology of pegmatites of upper Neelum valley, Azad Kashmir. GSP, Information Release 112.

Key words: Pegmatites, Neelum Valley, Azad Kashmir.

A/635. Asmatullah, Saeed, M. & Latif, M., 2002. Electrical resistivity investigation of groundwater in Rawla Kot area, Azad Kashmir. Geological survey of Pakistan, Information Release 762.

Key words: Geophysics, electrical resistivity, groundwater, Rawla kot, Azad Kashmir

A/636. Asrarullah, 1960. Geology of chromite in West Pakistan. CENTO Symposium on chrome ore, Ankara, Turkey, CENTO Publication, 38-53.

Key words: Chromite, geology.

A/637. Asrarullah, 1961a. Chromite and its mining in West Pakistan. Pakistan Geological Review 16(2), 1-13.

Key words: Chromite, chromite mining.

A/638. Asrarullah, 1961b. Chromite mining in Pakistan. Natural Resources 1(2), 17-22.

Key words: Chromite, chromite mining.

A/639. Asrarullah, 1962. Some decorative building stones of West Pakistan. Natural Resources Magazine 1(8), 21-24.

A compilation of data on the occurrence of marble, limestone, and granitic, dioritic, and other rocks suitable for building or ornamental stone in West Pakistan; includes descriptions of individual deposits

Key words: Decorative/Building Stones, Marble, Khyber, Swat.

A/640. Asrarullah, 1963a. Marble deposits of West Pakistan. CENTO Symposium on Industrial Rocks and Minerals, Lahore, 179-188.

Key words: Marble, Swabi, Khyber.

A/641. Asrarullah, 1963b. Rock salt resources of Pakistan. CENTO Symposium on Industrial Rocks and Minerals, Lahore, 303-313.

Key words: Rock Salt.

A/642. Asrarullah, 1963c. Rock salt resources of Pakistan. Pakistan Geological Review 18(1).

Key words: Rock Salt, Kohat, Salt Range.

A/643. Asrarullah, 1972. Non-glamorous economic mineral resources of North West Frontier Province. Geological Survey of Pakistan, Geonews II, No. 2, 47-55.

Key words: Mineral resources, NWFP.

A/644. Asrarullah, 1976. Iron ores in Pakistan. Geological Survey of Pakistan, Information Release 108, 33p.

Key words: Economic geology, Iron ore.

A/645. Asrarullah, 1978. Iron ores in Pakistan. National Seminar on Development of Mineral Resources, Lahore March 6-9, 116-137.

Key words: Economic geology, Iron ore.

A/646. Asrarullah, & Ahmed, Z., 1984. Water potential and climatology of the Parachinar Valley. GSP, Mineral Information Release 1, 33p.

This paper is a study of the Parachinar valley, describing the physiographic and climatic conditions of the area. Data are given on glaciers, mean monthly temperature and rain fall ranges and water resources along with recommendations for optimum use of water resources.

Key words: Water resources, climatology, Parachinar, Kurram Agency.

A/647. Asrarullah, Ahmad, Z. & Abbas, S.G., 1979. Ophiolites in Pakistan: An introduction. In: Farah, A. & DeJong, K.A. (Eds.), *Geodynamics of Pakistan*. GSP, Quetta, 181-192.

Key words: Ophiolites, Bela, Zhob, Waziristan, Kohistan.

A/648. Asrarullah, & Ali, S.I., 1963. Damar Nisar iron ore deposit of Chitral State, West Pakistan. *CENTO Symposium on Iron Ore*, Isphahan, CENTO Publication, 403-409.

Key words: Mineral deposits, iron ore, Damar Nisar, Chitral.

A/649. Asrarullah, & Hussain, A., 1984. Marble deposits of North West Frontier Province, Pakistan. *Geological Survey of Pakistan, Information Release 128*. 23p.

A study of marble deposits of the North West Frontier Province of Pakistan has been carried out in the years 1983 and 1984 primarily to update the previous work on this commodity and also to additionally investigate some of the new and the little known occurrences.

The marble deposits in the area under study are mostly associated with metasedimentary rocks of varying age and composition, displaying a wide array of colour shades and grain sizes. The marble from most of these deposits has a pleasing appearance, takes good polish and meets the standard specifications for specific gravity, water absorption, flexural strength and other physical properties.

Key words: Marble, Mullaghori, Khyber, Swabi, Swat.

A/650. Atudorei, V., Baud, A. & Sharp, Z.D., 1995. Late Permian and early Triassic carbon isotope and sequence stratigraphy of the northern Indian margin. *Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETCH Zurich) Switzerland*.

The Northern part of Great-India was subjected to an early rifting phase in the late Paleozoic, just at the end of the large scale Gondwanian glaciation. The beginning of the rifting processes is marked by large hiatuses and discontinuities (paraconformities) between the early or middle Paleozoic sedimentary succession and the discontinuous middle-late Permian Panjal Traps and transgressive sediments. The North Indian passive margin consists of the present High and Lower Himalaya and a small part of the Indian craton and its sedimentary cover (from Zaskar, Chamba and Kashmir synclinoria to the Salt Range), and belongs to an upper plate separated from a lower plate (Ladakh and Karakoram continental crust with their former sedimentary cover) at the end of the Permian (Baud et al., 1989). The Permian rift shoulder is partly located in the N Lahul-Kashmir Himalaya and part of it in the underthrust Lower Himalaya. The rim basin (landward of the shoulder) is developed in the Potwar-Salt Range area.

From rifting to drifting stages (early late Permian to early Triassic time) the sedimentary evolution is characterised by three transgressive-regressive (T-R) second order cycles. These overlie the Panjal Traps plateau basalts, which were deposited during the Murgabian time on the broad rift shoulder.

Profiles of inorganic carbon and oxygen stable isotopes were studied in marine carbonates from the Himalayan province (Guryul Ravine and Palgham, Kashmir; Salt Range, Pakistan; Thini Chu Valley, Kali Gandaki, Nepal).

The first T-R cycle (upper Murgabian to lower Dzulfian) is fully developed on the rim basin and consists of the transgression and the growth of the Wargal shallow carbonate platform. On the rift shoulder, this T-R cycle is present only in Kashmir with the sandy limestone of the Member A and B of the Zewan Formation. Positive $\delta^{13}\text{C}$

values (+2-4‰) occur within this first T-R cycle. In Central Nepal, stratigraphic indications are too scarce as to the age of the Thini Chu Group.

The second T-R cycle (Dzulfian-lower Changhsingian) corresponds to a sudden terrigenous influx occurring both on the rift side and on the land side. A shallow water mixed carbonate-clastic ramp is developed in the rim basin (Chhidru Formation) and overlies the Wargal shallow carbonate platform. To the north, the submerged part of the shoulder develops an offshore mixed clastic carbonate deltaic complex, the upper Zewan Formation (Member C and D). Positive $\delta^{13}\text{C}$ values (+2-4‰) occur for both areas, but a large shift of about 3‰ is recorded with the regressive phase of this cycle. This important negative excursion is documented worldwide. It is thought to be due to the oxidation and removal of the light organic carbon stored on the emerging continental shelf, after the huge regression marked by the Permian-Triassic boundary. On the emerged part of the shoulder, the marine Kuling sandstones and shales are transgressing on older sediments. This T-R cycle, with the marine submersion of the shoulder, indicates the beginning of the thermal subsidence and the transition to the drifting stage.

The third T-R cycle belongs to the Lower Triassic and is characterized by an important change in sedimentation. The age of the first transgressive sediments is still in dispute; it is either latest Permian or earliest Triassic (age of the lowest *Otoceras* zone and the problems of reworking during transgression). The first transgressive sediments consist of high energy dolomitic grainstone with glauconite and reworked quartzarenite (Lower Katwai Member) in the Salt Range area, of thin bedded *Claraia* limestones and shales with "Permian brachiopods" overlain by black shale with ammonoid lenses in Kashmir (Member E1 and E2 of the Khunamuh Formation) and of high condensed nodular limestone (*Otoceras* beds) in the Tethys Himalaya (Panjang member).

At the Kashmir sections, the negative excursion of $\delta^{13}\text{C}$ continue in the Early Induan *Otoceras* zone and the lowest value (-4‰) is reached in the overlying *Ophiceras* zone. Above the low $\delta^{13}\text{C}$ value samples in the *Ophiceras* zone, we note a progressive rise in the $\delta^{13}\text{C}$ values at the base of the overlying *Vishnuites* zone (late Induan).

For the Thini Chu Valley profile, samples from the Panjang member (sensu Hatleberg & Clark, 1984) and the lower part of Tamba Kurkur Formation show negative values ($\delta^{13}\text{C} = -0.5 \pm 0.7\%$) with no significant trend suggesting a lower Induan age and make possible the correlation with the E Member of the Khunamuh Formation from the Kashmir sections.

A generalisation of the pelagic limestone deposition corresponding to the maximum flooding surface is realised at the beginning of the late Induan time with the Lower Ceratite Limestone in the proximal part of the margin (Salt Range) and thin, condensed Limestones and shales in the distal part.

It is interesting to note that the $\delta^{13}\text{C}$ values for the Kali Gandaki and Kashmir sections are very low comparative with Salt Range section and others Tethyan sections, ranging from -9‰ to -12‰ (v.PDB). These low values can be explained by the thermal metamorphism process that affected the Kashmir and Nepal sections, documented by the high Color Alteration Index of conodonts (Wang, 1990; Garzanti et al. 1994). For the limestones from the base of Tamba Kurkur Formation (Kali Gandaki section) anomalous values of $-20 \pm 3\%$ occur. There is no correlation between carbon or oxygen values and the different types of carbonate cement.

Key words: Carbon isotopes, stratigraphy, Indian Plate, Late Permian, Early Triassic.

A/651. Auden, J.B., 1932/33. On the age of certain Himalayan granites. Geological Survey of India, Record 56, part 4, 461-471.

Key words: Granites, Himalaya.

A/652. Auden, J.B., 1934. Notes on the Biafo Glacier in Baltistan. Himalayan Journal 6, 67-76.

Godwin Austen, of the Survey of India, made the original survey of the Hispar and Biafo glaciers in 1860-1 (Survey Maps 42 P, 43 M), but did not reach their upper neve fields. He marked the Biafo as running almost due NW.-SE. In 1892 Martin Conway (now Lord Conway) made the first complete traverse of the two glaciers, starting from Hispar village, crossing the Hispar pass, and descending the Biafo to Askole. In his map the orientation of the Biafo glacier is more nearly NNW-SSE.

The Workmans visited the Biafo glacier twice, in 1899 and in 1908. The orientation of the glacier, as determined by them, corresponds more closely with that originally given by Godwin Austen. Neither Conway nor the Workmans were able to explore the snowfield or neve, called by the former Snow Lake, and on the modern map the Basin of the Biafo Glacier. The Workmans found snow conditions in this flat area too unpleasant.

On the 5th June we motored from Srinagar in heavy rain to Pahlgam, hoping to cross by Astanmarg and Amarnath to the Gamru valley, just below Machhoi (Map 43 N). The snow-line was found to be as low as 10,000 feet, and the Pahlgam coolies were unwilling to go over Astanmarg under such abnormal conditions. On the 6th we therefore motored back to Srinagar and on to Woyil bridge, marching the same day to Gund. The Leh route was followed over the Zoji La as far as the suspension bridge below Kargil (43 N, 52 B). We then branched down the Shingo river, dismissing our ponies at Olthing, and taking on men from there onwards at every stage. From Parkutta (43 M) we left early with excellent coolies for the ferry across the combined Shyok and Indus rivers. Across the ferry the Kiris coolies took us on to Narh. From Narh to Shigar is a short march. By taking this route one is saved a day, since the long detour through Skardu is avoided. Shigar was reached on the 16th. There was still too much snow on the south-west side of the Skoro La for that pass to be easily negotiable, so the longer route along the Shigar and Braldu rivers was followed. We hoped to reach Askole on the 20th, but were held up three miles from that village by late afternoon flooding of the streams, due to rapid melting of the glaciers by which they are fed.

There is little of interest along the route from Dras to Askole. The valley sides were barren and hot, and the apricots near the villages as yet unripe. We were unfortunately not told of the aquamarine mine at Dusso until arrival at Askole. At Chongo there is a series of hot springs which deposit extensive mounds of tufa. We bathed, buoyed up in bliss by effervescent bubbles of sulphuretted hydrogen. The temperature of the water in one spring was 98° F. De Filippi mentions it as 120° in 1909.

The 21st was spent at Askole collecting coolies. Besides the pukka coolies for transport, others were required for carrying up ata, and, after Camp 4, wood as well. After several hours of bickering, Gregory managed, with the help of some conjuring tricks with magnets and corks, to make them decide on a wage of Rs. 1 /1 per day, and a daily ration of 1 seer of ata. For economy we had not brought boots, except for the coolie mate or sirdar and one or two others. Apart from the factors actually responsible for the failure of the trip, this lack of boots would have eventually led to great difficulties, since the local paboos stand up very badly to wet snow conditions. In a good year it would not be necessary to provide boots for all the coolies, but solely for those taking part in the actual survey of the Snow Lake and in any climbing of the adjacent peaks. Under good conditions the glacier itself should be dry enough for the transport coolies to use their paboos.

Key words: Glaciology, Biafo, Baltistan.

A/653. Auden, J.B., 1935a. The snout of the Biafo Glacier in Baltistan, Geological Survey of India Records, 68(4), 400–413.

Key words: Glaciology, Biafo, Baltistan.

A/654. Auden, J.B., 1935b. Traverses in the Himalaya. Geological Survey of India, Records 69, 123-167.

Key words: Himalaya.

A/655. Auden, J.B., 1938a. Geological Results. In: Shipton, E. (Ed.), The Shaksgam Expedition, 1938. Geographical Journal 91, 335-336.

Key words: Expedition, Shaksgam.

A/656. Auden, J.B., 1938b. Resume of geological results, Shaksgam Expedition, 1937. Himalayan Journal 10, 40-48.

The area described in this account occupies about 2,000 square miles and is situated on both sides of the Karakoram Range, extending northwards up to the Yarkand river at approximately latitude 36° 22' N. It is included partly within the provisional issues of Survey of India J-inch maps 42 p, 43 m, and 52 a. Most of our time was spent in the area covered by the as yet unpublished map 51 d. The visit was made in the company of E. Shipton (leader), H. W. Tilman, and M. A. Spender. I wish to record my thanks to Shipton for the invitation to join his expedition and for the well-planned arrangements that were made throughout. Spender and I had little of the worry connected with coolies and the distribution of food supplies, and were spared the monotony of relaying, which Shipton and Tilman

unselfishly supervised. Moreover, when mountaineering difficulties did occur, it was often their experience and skill which allowed us to carry out our programme.

It is true that geological work would have been easier and more detailed if I could have been relieved of carrying a rucksack loaded with personal and survey equipment, and had there been no necessity of keeping rigidly to a timetable. For reasons of economy, however, it was imperative to cut down the porters to the absolute minimum, and the rapid flooding of the rivers in July necessitated our being on the Indian side of the Shaksgam by a settled date. The flooding of the rivers, both daily in the afternoons, and seasonal as the summer progressed, became for us the chief bogey. Indeed, it was a fortunate spell of cloudy and snowy weather at the beginning of July which, by lessening the melting of the glaciers and lowering the Shaksgam, allowed us ever to return across this river. When I reached the Shaksgam with Lhakpa and Mahadi on the 28th June, after crossing the Aghil col, we were somewhat dismayed at the expanse of water, and had fears of all of us having to go north again, over the Aghil pass, with food exhausted, and the prospect of an uncertain welcome by Yarkandis below Bazar Dara.

Apart from the reconnaissance map of Professor Desio, which included the Panmah and Sarpo Laggo valleys and part of the Shaksgam, there were no topographical data upon which to base a geological map. Geological sketch plans were made throughout the expedition, and it is hoped to adapt these to the topographical map on which Spender has been working since our return. Spender tirelessly carried out the main survey, based on K2peak, 28,250 feet, while Shipton and I used a light 3-inch theodolite, belonging to the Royal Geographical Society and fitted with a Leica photographic attachment, to fill in details of areas he was not able to visit. These included the K2 glacier, surveyed by Shipton, and the lower Shaksgam valley and Nobande Sobande glacier, done by myself. Spender has the more difficult and exacting task of incorporating these results in the general map.

Key words: Expedition, Shaksgam.

A/657. Auden, J.B., 1939. Glaciers. *Calcutta Geographical Review* 1, 48-52.

This is a brief account of the occurrence of the glaciers of the Himalayan mountains.

Key words: Glacier.

A/658. Auden, J.B., 1956. Report to the Government of Pakistan on geological reconnaissance of damsites in the former Frontier Province of Pakistan. United Nations, FAO, Report 476, 56p, Rome, Geological Survey of Pakistan, File No. 762-25.

Key words: Dams, reconnaissance.

A/659. Auden, J.B., 1974. Afghanistan-West Pakistan. In: Spencer, A.M. (Ed.), *Mesozoic-Cenozoic orogenic belts*. Geological Society of London, Special Publication 4, 235-253.

Key words: Orogenic belts, Afghanistan, Pakistan.

A/660. Austromineral, Vienna, Austria, 1976. Indus Gold Project. Austromineral, Vienna, Austria. Final Report, 235p.

This is a detailed report dealing with the exploration of gold in the middle Indus valley, including study of placer deposits.

Key words: Gold, Exploration, Himalaya.

A/661. Austromineral, Vienna, Austria, 1978a. Feasibility study, mineral exploration and mineral development in Chitral district. SDA, Peshawar. Report, Part I & II, 291p.

The Chitral area has many showings of mineral occurrences of possible economic interest. Detailed studies were carried out by Austromineral of the area concerning exploration of the mineral occurrences.

Key words: Mineral exploration, Chitral.

A/662. Austromineral, 1978b. Mineral exploration and mine development, Chitral District. Report for Sarhad Development Authority, Peshawar.

The Chitral area has many showings of mineral occurrences of possible economic interest. Detailed studies of the district were carried out by Austromineral. These studies concerned mineral exploration and mine development of the mineral resources.

Key words: Mineral exploration, mine development, Chitral.

A/663. Awais, M., 1991. Small scale mining and mineral based industries in North West Frontier Province. Proceedings, First SEGMENT Symposium, 1991, Peshawar, 27-33.

This paper gives a brief description and developmental cost estimates of some mineral deposits of the province. These include chromite, marble, barite, calcite, and abrasives.

Key words: Economic geology, NWFP.

A/664. Awan, A.R.A.A., 1986-88. Lithostructural mapping and Geology of Bagh-Sehri Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 106p.

Key words: Structure, mapping, Abbottabad.

A/665. Awan, M.A., 1973. Petrology of Thellich area with special emphasis on diorite complex (Gilgit Agency). M.Sc. Thesis, Punjab University, Lahore, 130p.

Key words: Petrology, diorites, Thellich, Gilgit.

A/666. Awan, M.A., 1989a. Application of the olivine spinel and two pyroxene geothermometer to the Dargai ultramafic complex Pakistan. Kashmir Journal of Geology 6 & 7, 51-56.

Seven olivine-spinel and two pyroxene geothermometers were applied to the Dargai Ultramafic Complex, Pakistan. Using olivine-spinel geothermometer, the temperatures were estimated between 675 °C-825 °C whereas the temperatures fall between 900 °C – 950 °C when pyroxene data were plotted on pyroxene quadrilateral. This discrepancy is attributed more likely due to various degree of re-equilibration in two thermometers.

Key words: Geothermometry, mineralogy, ophiolite, ultramafics, Dargai, Malakand.

A/667. Awan, M.A., 1989b. Metamorphism of the obducted Dargai ophiolite, Pakistan. Kashmir Journal of Geology 6 & 7, 57-60.

The secondary minerals in the rocks of the Dargai Complex resulted through polymetamorphism. Field petrologic, and geochemical studies show that the complex passed through hydrothermal metamorphism at the mid oceanic ridges. A retrograde metamorphic event is discerned from the gabbroic mineral assemblages. The syn-tectonic metamorphism involved the obduction of the Dargai Complex which produced the dynamothermal effects in the underlying metasediments. The presence of antigorite and garnet mica schist near the southern (lower) boundary contact is related to dynamothermal metamorphism.

Key words: Metamorphism, geochemistry, ophiolites, Dargai, Malakand.

A/668. Awan, M.A., 1992. Petrotectonic interpretation of the Dargai ultramafics complex Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.52.

Field observation support the interpretation that the Dargai ultramafic complex is an ophiolite. These include (i) lack of major thermal effects at margins ii) absence of lamination in tectonites, and iii) fault contact, not intrusive contact with structurally underlying rocks.

It is proposed here for the first time that Dargai Klippe is sitting on the Main Mantle Thrust (MMT). The trace of the MMT in the surrounding area is missing due to extensive erosion below the MMT into Indian Plate rocks. The southern boundary fault of the Dargai complex is the trace of the MMT while the northern boundary fault is related to post -Eocene southward thrusting.

Petrologic data also support the contention that the Dargai complex is a supra-subduction zone ophiolite that constitutes part of the fore-arc shelf of oceanic crust in front of the Kohistan Island Arc. Petrochemical discriminant diagrams show that its lithologies have compositions corresponding to Oceanic Ridge Crust.

Key words: Petrology, tectonics, ultramafics, Dargai, MMT, Malakand.

A/669. Awan, M.A., 2000. A petrologic approach origin of the Dargai ultramafic-mafic complex of Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.120.

The Dargai Ultramafic-Mafic Complex occupies fore-arc position with respect to Kohistan Island Arc. The chemistry of ultramafic Tectonite and a Ultramafic cumulates represent the differentiated nature of the Dargai Complex which is marked by presence of more Mg. rich olivine in Tectonites than in Ultramafic cumulates.

Major and trace elements data of the rocks from the Dargai complex are plotted in a number of discriminant diagrams, which show:

- i) Whole rock ppm Ba versus wt % SiO₂ indicates mid oceanic ridge affinity.
- ii) Al/Ti from pyroxenes of the Dargai complex also indicates ophiolitic nature.
- iii) Cr ppm versus TiO₂ Wt % of the Dargai ultramafic represents its formation at supra-subduction stage.

The Dargai complex is quite distinct from Jijal and Chilas complexes as increase of K₂O Wt % with respect to Na₂O Wt % confirm it fore-arc position from the Shangla subduction trench.

Key words: Petrology, ophiolite, Malakand.

A/670. Awan, M.A., Khawaja, A.A. & Jadoon, I.A.K., 1991. Strike-slip faulting along the western boundary of Indian Plate, in Pakistan. Kashmir Journal of Geology 8 & 9, 117-120.

In northern and western part of Pakistan some strike-slip faults are considered lateral ramps of thrust sheets. However, in this area, systems of strike-slip Riedel R and R' shears is expected to develop due to a dominant component of simple shear along the western transform boundary of the Indian plate. The majority of strike-slip faults trend between N-S and NNW-SEE, close to the expected orientation of R shears. A few strike almost parallel to the expected orientation of R' shears. Faults close to R shears show sinistral and those to R' shears show dextral sense of displacement.

Both the orientation and sense of displacement suggest that the majority of these strike-slip faults are secondary Riedel shears, developed in response to plate scale sinistral simple shear, along the Chaman transform fault.

Key words: Structure, Indian Plate.

A/671. Awan, M.S., 1988-90. The geology and petrology of Jijal and Pattan layered ultramafics-mafic complexes in the vicinity of Jijal & Duber with special emphasis on petrogenesis of these complexes. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 90p.

The project area covers about 368 sq. Km. located in the vicinity of Jijal & Duber, District Kohistan. The work has involved geological mapping of the area on a scale of 1:50,000 of toposheet No. 43 A/16 of Survey of Pakistan. This thesis deals with the geology, petrography and petrogenesis of the Jijal and Pattan complexes in particular and the relation of these complexes with other complexes of Kohistan Arc complex has also been discussed.

The geological sequence of Jijal complex consists of ultramafic and mafic cumulates. The ultramafic cumulates are divided into dunite, wehrlite, websterite, garnet-pyroxenite and garnet-hornblendite, whereas mafic cumulates are garnet gabbro. The geological sequence of Pattan complex also consist of ultramafic and mafic cumulates. The ultramafic cumulates are chromite, dunite and (meta) wehrlite, whereas mafic cumulates are divided into two pyroxene gabbro and two pyroxene-quartz-diorite.

Field evidences suggest that Pattan complex was emplaced along pre-existing metamorphosed kayal cumulate complex. The top of the Pattan complex is marked by a spectacular, intrusive polymagmatic breccia. In Duber and NW of Duber Pattan complex is overthrust onto the Jijal complex, which is also a layered cumulate complex. While in Pattan area and SE of Pattan there is a faulted (strike slip) contact between Pattan complex and Jijal complex.

The Jijal complex is southern most, layered ultramafic-mafic cumulate complex of the Kohistan-Ladakh tectonic province. The Main Mantle Thrust (MMT) is the southern boundary of the Jijal complex, which interns is the southern boundary of Kohistan Arc complex. The Main Mantle Thrust (MMT) Duber Thrust Fault wedges out Jijal complex NW of Duber near Chert. On the other hand Main Mantle Thrust and Pattan Fault (strike slip fault) wedges out the Jijal complex on the eastern side near Pashto. The Jijal and Pattan complexes are generated by precipitation from subduction generated, hydrous, low K, picritic high Mg tholeiitic magmas and there is a strong possibility of finding economic metallic mineral deposits with in these layered cumulate complexes.

Key words: Petrology, Jijal, Pattan, Kohistan.

A/672. Awan, M.Z., 1999-2000. Geological mapping of Kohala-Muzaffarabad area with special emphasis on rock failure due to shale undercutting and road widening along Muzaffarabad-Kohala Road. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 61p.

The slopes along Muzaffarabad-Kohala roadways are highly disturbed during most part of year due to differential weathering conditions. Along the road at left bank of river Jhelum Murree Formation is exposed. Murree Formation consists of alternate bedding of Shale, Sandstone, Mudstone, Claystone, Silty clay and Silt. The rocks are differently weathered and tectonically highly disturbed due to Main Boundary Thrust (MBT). The Shales and Claystone are highly weathered, erodible during severe weathering conditions and undercut due to differential weathering, undercutting of sandstone, mudstone, claystone and siltstone results in rockfall, rockslide, rock toppling and wedge failure in the area. The area is divided into the stable and unstable zones to prevent undercutting, which induced failure. The rate of undercutting is measured. Ten sites were located along Muzaffarabad-Kohala located road for evaluation. The sites consist of road cut for road widening shale, mudstone, claystone, and siltstone undercutting. The sites were selected because the road was undercut by blasting and shale was undercut by differential weathering.

The amount of each site was carefully measured along the entire length of the cut information regarding the data of road cut was collected from Highway Department record. The measured rate of undercutting at road cut and the age of cut were used to estimate the rate of shale undercutting since the time of excavation. Samples of the undercutting units were collected from each site and tested for slake durability and Atterberg limits. The results suggest the shale undercutting can be remediated by grouting or installing bericles to prevent rockfall, rockslide and toppling failure.

Key words: Mapping, natural hazards, Muzaffarabad, Himalaya.

A/673. Awan, T.R., 1986-88. Geology and petrology of the Eastern Chilas calc-alkaline complex in the vicinity of Chilas (District Diamir) with special emphasis on petrogenesis of the rock units. M.Sc. Thesis University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 105p.

A geological map of 301 sq. km. between Pain Ges Gah Helor Gah in the north of the Indus River and Thurlly Gah in the south in Chilas area is presented at the scale of 1:25,000 on toposheet No's 43 E/15, 43 I/9 and 43 I/7 issued by the survey of Pakistan.

Most of the project area lies in the vicinity of the north side of the eastern Chilas Complex. The exposed sequence of rocks in the project area is a part of the northern limb of the Chilas Complex, where ultramafic rocks occur in the core of the anticline and is overlain by norite, gabbro-norite and diorites. This is capped by metadiorites of Early Jurassic age which is a part of Kamila Amphibolite.

Field and petrographic study show that the rocks of the Chilas Complex are formed with in a separate magma chamber and igneous in nature. There is younger silt like leuco dioritic pluton emplaced in metadiorite. The leuco diorite hosts a small ultramafic body which has probably been formed by a magmatic protrusion of ultramafic composition and is not related to ultramafic rocks in core of the Chilas Complex.

Key words: Petrology, petrography, Chilas Complex, Diamir.

A/674. Ayub, A., Ali, Z. & Rahman, Z., 1983. Petrography and microfacies analyses of Shekhan Formation, Kohat quadrangle, North West Frontier Province. M.Sc. Thesis, University of Peshawar, 173p.

Key words: Petrography, sedimentology, Shekhan Formation, Kohat.

A/675. Ayub, M., 1976. Report on lithostructural mapping of Paras area, Kaghan Valley with special emphasis on petrography and petrogenesis. M.Sc. Thesis, Punjab University, 127p.

Key words: Lithostructure, mapping, petrography, petrogenesis, Kaghan.

A/676. Ayub, M., Yusaf, M. & Lodhi, S.A.K., 1987. Pegmatitic albitites and aplites of Mansehra area, N.W.F.P., as indigenous raw materials for pottery wares (Cornish stone). Abstract with Programs, Mineral Resources and Geology of Pakistan, Quetta, Pakistan.

Key words: Pegmatite, albitite, aplite, pottery, economic geology, Mansehra.

A/677. Ayub, M., Yusaf, M., Lodhi, S.A.K. & Ashraf, M., 1987. Pegmatitic albitites and aplites of Mansehra area, N.W.F.P., as indigenous raw materials for pottery wares (Cornish stone). Acta mineralogica Pakistanica 3, p.66.

Consult the following account for further information.

Key words: Pegmatite, albitite, aplite, pottery, Mansehra.

A/678. Ayub, M., Yusaf, M., Lodhi, S.A.K. & Ashraf, M., 1993. Geology and utilization of pegmatitic albitites and aplites of Mansehra Area, NWFP as indigenous raw materials for pottery wares. Pakistan Journal of Scientific and Industrial Research 36(10), 397-00.

Various samples of pegmatitic albitites and aplites were collected from Mansehra area NWFP of Pakistan. It was found that only pegmatitic albitites, albitite aplites and albitite-microcline aplites were the rocks suitable for making pottery wares. For this purpose petrographic and chemical analysis were carried out. The crushed samples were used for the purpose of making porcelain bodies as well for glazes to be used on their respective bodies; the presence of small quantity of TiO_2 and Fe_2O_3 was successfully used to impart cream to orange cream color to both bodies and glazes. The studies were carried out to replace conventional feldspar totally and quartz partially.

Key words: Pegmatite, albitite, aplite, pottery, economic geology, Mansehra.

A/679. Azam, J., 1976. Geological mapping of the Gandaf Irrigation Tunnel, Tarbela Dam Project with special emphasis on engineering geology problem associated with the tunnel alignment and its construction. M.Sc. Thesis, Punjab University, 127p.

Key words: Mapping, engineering geology, Tarbela.

A/680. Azam, M., 1983-85. Biostratigraphy of the Jhalar-the Kala Chitta Range, Attock District. M.Sc. Thesis, Punjab University, Lahore, 91p.

A geological map of the Jhalar area -the Kala Chitta Range, on a scale of 1" to 0.789 mile or 1:50,000 and covering an area of 16.43 square miles has been prepared to discuss the stratigraphy and micropaleontology of the area. An attempt has been made to discuss the importance of foraminiferal content of these rock units, for determining the

depositional pattern and age, the geological sequence of the Kala Chitta Range with a view to recognize the continuity or unique aspects of the lithostratigraphic units in the adjoining area.

The various geological events that occur in the area and their geological implications have also been discussed. In the Kala Chitta Range there are some eighteen lithostratigraphic units but the area under discussion comprises ten lithostratigraphic units mostly of marine environments and with non-marine units.

Key words: Biostratigraphy, Kalachitta range, Attock.

A/681. Aziz, M.A., 1968. Structure and geology of Ghari Habibullah, Taranna Area, Hazara. M.Sc. Thesis, Punjab University, Lahore, 77p.

A. B. Wynne was the first pioneer (1887-89) to work in this area followed by Middlemiss (1890-93). But the first complete map ever produced of the region including the project area was by D. N. Wadia on a 1" = 16 miles scale. Both D.N. Wadia and Middlemiss had included pisolitic formation of Rinjata in their Eocene (Geology of India PP 336) and Nummulitic (although he did that for convenience sake). This pisolitic formation is placed in cretaceous. This work is first of its nature in the subject area so far as details and accuracy is concerned.

Although repeated phases of orogenesis had to great, extent blurred the picture, a try has been made to give a clearer picture of the events that took place in the Geological past. Detailed study has revealed the presence of different sets of faults which have been differentiated on the basis of age, trend and direction of movement. Different behaviour of sedimentaries and metamorphics to the deformational forces has come to light. Presence of Syringoporoid corals is noted for the first time and the age of Kakul dolomites assigned. A close study of Talhatta metaconglomerates and quartzites is given.

Metamorphics of the area are found to grade from slates through phyllites to Biotite schist grade and described. Probable age of injection of acidic fluid in the Balakot Injection Gneisses and the probable reasons for injection only in these rocks are discussed. Reasons for no evidences of metamorphism in Kakul dolomite and younger sedimentaries of the area are discussed. An appendix is included to give the microscopic mineral determination & features of structural importance of various rocks.

Key words: Structure, Gari Habibullah, Hazara.

A/682. Aziz, N., 1994. The study of groundwater contamination of the Sihala Industrial Triangle Islamabad with a special emphasis on physiochemical, hydrochemical, biochemical and flow net analysis. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 74p.

This physiochemical, hydrochemical, and biochemical studies of groundwater aquifer of Sihala Industrial Triangle were made. Water sample collected randomly from thirty two preexisting dug wells/tube wells were analyzed in N.I.H. Laboratory. Chemical data was projected graphically on stiff pattern and trilinear piper diagrams using U.S.G.S Software. HC-GRAM. The STIFF PATTERN diagrams thus developed for each dug well/tube well are projected on location map to visualize the distribution of ground water chemistry. Bivariate statistical analysis were applied on scattered data points of TDS (total dissolved solids) and coliform bacteria h +ve and -ve growth of F. Coliforms to study their relationship. The equipotential line map was prepared to develop the flow net. Two plumes of contamination were marked in flow net map. Results indicate that study area has better groundwater on basis of physiochemical analysis and poor quality of groundwater on basis of Hydrochemical and biochemical analysis. Soan River behaves like an effluent stream.

Key words: Groundwater, contamination, Islamabad.

A/683. Aziz, Z., 1963. Geology of Mansehra, Oghi and Darband, Hazara. M.Sc. Thesis, Punjab University, 28p.

Key words: Geology, Mansehra, Darband, Hazara.

A/684. Aziz, Z., 1978-80. Litho-structural mapping and geology of Thandiani-Bins Gali Area, Distt. Abbottabad, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 179p.

Approximately 15 miles² of Tandiani-Bins Gali area in the form of a rectangle on the Northwest side of Abbottabad has been mapped at a scale 1:10,000. It is a mountainous humid region with fairly high relief. The stratigraphic sequence ranges from Pre-Cambrian Hazara slates to the Lockhart Limestone of Paleocene age. The structure of the area is in the form of a major synclorium, which is interrupted and deformed by high angle thrust faults. Over 50 thin sections were studied under the microscope and detailed petrography and petrogenesis are included.

Key words: Structure, stratigraphy, Abbottabad.

A/685. Azizullah, 1978. Report on lithostructural mapping on Paras area, Kaghan valley with special emphasis on tectonics. M.Sc. Thesis, Punjab University, Lahore.

Key words: Lithostructure, tectonics, mapping, Kaghan.

A/686. Azizullah, 1997a. Lithostratigraphy and depositional system of Siwalik of Shinghar-Surghar Range, Thatti Nasrati-Shanawah area, District Karak, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 11-13.

The Himalayan molasse sediments, the Siwalik Group, Pliocene to Pleistocene (in Trans-Indus) in the Thatti-Nasrati and Shanawah area were studied in order to understand the nature, origin and conditions of deposition.

The Siwalik Group is comprised of four formations i.e. Chinji, Nagri, Dhok Pathan and Soan Formation. The Rawalpindi Group is absent in this area. The Chinji Formation unconformably overlies the Mitha Khatak Formation (Fig-i). The Chinji Formation consists of maroon and reddish brown colour shale and subordinate sandstone horizons. The thickness of the Chinji Formation varies from 160m to 1400m. The Nagri Formation is marked by thick sequence of massive sandstone with lot of paleochannels. Shales are absent or present as thin patches. The thickness of the Nagri Formation varies from 1050m to 2075m. The Dhok Pathan Formation exhibits excellent development of cyclic deposition of alternate shale and sandstone sequence. The thickness of this formation varies from 950m to 1200m. The Soan Formation may be divided into Tatrot and Pinjor stages. The sandstones and shales of different colours are present here. A portion of Pinjor stage is absent in some area. The lower portion of Pinjor and Tatrot are represented by 300-500m thick sequence.

The study of lateral and vertical accretion deposits, presence of scouring, channel abandonment behaviour, facies occurrences and channel fill of the Siwalik Group show that it is mainly deposited by braided river system. The Siwalik Group of the Shinghar-Surghar range was deposited from 12 M.a. to 0.5 M.a. as compared to the Siwaliks of the Potwar Plateau, where these molassic sediments begun to be deposited prior to 15 Ma. The sedimentation rate of the Siwalik Group was generally higher in the Trans-Indus ranges than that of the Potwar Plateau area. The entire molasse sequence covering the time span of 12 M.a. to 0.5 M.a. is conformable. There was no tectonic activity except subsidence of basin till folding begun about 0.5 Ma. which stopped the Siwaliks sedimentation in the study area. These molassic sediments were deposited by high velocity streams as indicated by the presence of pebbles, cobbles and boulders. Poor sorting, angular to subangular rock fragments show immature nature of sediments.

The study area is covered by toposheet No.3 8 P/1 and 38 0/4, the latitudes and longitudes of the study area are as follows.

A.	71°03" / 32°48"	D.	71°15" / 33°00"
B.	71°03" / 33°00"	E.	71°09" / 32°57"
C.	71°15" / 30°05"	F.	71°09" / 32°41"

The area is mapped on 1:10,000 scale. The study area is 225 Sq. Km. it is accessible by jeepable roads both from Thatti-Nasrati as well as Isa Khel.

Three geological cross-sections were measured at suitable intervals for studying vertical and horizontal variations and stratigraphic correlation.

Detailed sedimentological studies were carried out on the rocks of the Siwalik Group exposed in the study area. All the four formations namely the Chinji, Nagri, Dhok Pathan and Soan Formation are well exposed.

In these studies, in general, the facies models presented by Miall (1977, 78, 85&88) have been utilized. General criteria for distinguishing, comparing and contrasting braided and meandering rivers presented by Miall have been used. Additional criteria have also been used for the Siwalik Group in order to distinguish between braided and meandering river systems. Observations of important sedimentological features in the area were made. This study helped in defining the fluvial facies and interpreting the conditions of deposition. It further helped to design the

hydrodynamic conditions during sedimentation. The rate of sedimentation depends strongly on the relief of the source area as well as subsidence of the basin during deposition. The relief in turn in the active collisional mountain ranges, depends strongly on factors like uplift and exhumation, which in turn depends upon the rate of convergence as well as total crustal shortening. Crustal shortening is accommodated by folding and thrust piling. Series of napes development in the collisional mountain ranges sometimes in a piggy-back fashion. During process of uplift and exhumation, successively deeper structural levels are exposed through tectonic erosion and denudation. Thrusting alone cannot explain the exposure of deeper crustal levels. This is only possible through a combination of thrusting and exhumation. Another mechanism which can expose deeper levels is the tectonic collapse and gravity structures in the mountain fold belts. Successive phases of uplift and exhumation are excellently reflected in the Siwalik molassic detritus of the foreland basin. The vertical sequences in these deposits have faithfully recorded the effects of successive uplift and exhumation phases.

Key words: Stratigraphy, Siwalik Molasse, Shinghar Range, Karak.

A/687. Azizullah, 1997b. Petrotectonic framework of the Siwalik group of Shinghar Range with special reference to its petrography. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.11.

No petrological/petrotectonic account from Thatti Nasrati Shava-Shanawah area (Shinghar Range) for the Siwalik Group with reference to its petrotectonic framework has yet been published. It was therefore, important to carry our detailed petrological/petrotectonic studies in order to understand the nature, origin and condition of deposition of Siwaliks in this area.

In the past, it was generally considered that the Siwaliks were deposited by the mighty Siwalik River (ancestral Indus). But subsequent studies have indicated that Siwaliks show great lithological as well as petrographic diversity. Siwaliks of different areas have been derived from different source of regions. Therefore, it was important to trace the sources of Siwalik sediments in this region and to relate them to an evolving petroTECTONIC framework.

Correlation of Siwaliks on the basis of gross lithological variation (sandstone/shale ratio) has not proved very satisfactory. Similarly, faunal correlation is not always possible, because the distribution of fossils is not uniform. So it was planned to correlate the Siwaliks of the area on the basis of petrographic studies. It has now enabled the author to build a better picture and develop a better understanding of the stratigraphy and sedimentation of the study area.

Petrotectonic studies require a thorough understanding of the tectono-stratigraphic evolution of the hinterland as well as the nature of detritus shed by them both in time and space. The focus of sedimentation and the basin geometry undergo changes concomitant with changes in the source regions.

In order to understand the dynamics of the tectono-stratigraphic evolution of the source areas and changing sedimentary pattern, lithologies and the composition of the sediments, and integrated scenario has been presented.

Key words: Tectonics, petrography, Siwalik Molasse, Shinghar Range.

A/688. Azizullah, 2001. Nuclear fuel potential of the Surghar Range, Bannu basin. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.13.

The collision of Kohistan island arc with Eurasian plate occurred at about 90-100 Ma. resulting in an Andean type of margin. At 40 to 65 Ma. the Indian plate collided with the Eurasian plate sandwiching the island arc. As a result of this collision the Himalayan molassic sediments started to deposit in S-shaped foredeep. Depositional environment was changed from marine to continental. Except for an arid red-bed paleoclimate represented by the Chinji Formation, the semi-arid and sub-tropical environments dominated during this period. Under these tectonic and paleoclimatic conditions in the foredeep basin, a paleo Siwalik drainage was developed and a thick fluvial sequence was deposited. Within this sequence the Dhok Pathan Formation controls the general distribution of the sandstone type uranium mineralization in Pakistan.

The sandstone type uranium mineralization discovered till today is mainly distributed in the east-west trend in the Dina-Kallar Kahar-Chakrala (Potwar Plateau) and in the north-south trend in Thatti Nasrati, Shanawah, Isa Khel and Simu Killi (Bannu Basin) and also in similar trend in Baghalchur, Rakhuchur, Nagar Nai and Rajanpur areas (the eastern flank of Sulaiman Range). Although uranium potential of these rocks is confirmed, however, the uranium resources so far discovered are not commensurate with the widespread mineralization phenomena observed on the outcropping area. It is therefore essential to understand the regional uranium mineralization in its true perspective.

Key words: Nuclear fuel, Surghar range, Bannu.

A/689. Azizullah & Khan, M.A., 1997. Petrotectonic framework of the Siwalik Group of Shinghar Range with special reference to its Petrography. Geological Bulletin, University of Peshawar 30, 165-182.

Detailed petrological/petrotectonic account from Thatti Nasrati Shava-Shanawah area (Shinghar Range) of the Siwalik Group with reference to its petroTECTONIC framework has yet been published. It was therefore, important to carry out through petrological/petroTECTONIC studies in order to understand the nature, origin and condition of deposition of Siwaliks in this area.

In the past, it was generally considered that the Siwaliks were deposited by the mighty Siwalik River (ancestral Indus). But subsequent studies have indicated that Siwaliks show great lithological as well as petrographic diversity. Siwaliks of the different areas have been derived from different source of regions. Therefore, it was important to trace the sources of Siwalik sediments in this region and to relate them to an evolving petroTECTONIC framework.

Correlation of Siwaliks on the basis of gross lithological variation (sandstone/ shale ratio) has not proved very satisfactory. Similarly faunal correlation is not always possible, because the distribution of the fossils is not uniform. So it was planned to correlate the Siwaliks of the area on the basis of petrographic studies.

PetroTECTONIC studies require a thorough understanding of the tectono-stratigraphic evolution of the hinterland as well as the nature of detritus shed by them both in time and space. In order to understand the dynamics of the tectono-stratigraphic evolution of the source areas and the changing pattern of composition of the sediments, an integrated scenario have been presented.

Key words: Petrology, petrography, tectonics, Siwalik Molasse, Shinghar Range, Karak.

B/1. Babar, M., 1993-95. The application of electrical resistivity technique for the detection of buried stream channels and ground water exploration in Saidabad Area, District Malakand, NWFP, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 190p.

Key words: Resistivity, groundwater, Malakand.

B/2. Baber, Z.A., 1981. Thesis on the geology and petrology with special emphasis on Calcareous quartzite and Chlorite and Biotite Schists of Sawani–Sheringal area, District Dir, NWFP. M.Sc. Thesis, Punjab University, Lahore.

Low grade metamorphosed Early Tertiary inter-arc sediments of the Kalam area appear to extend into Sheringal and Baraual area of Dir district. This thesis concerns the general geology and petrography of these rocks.

Key words: Petrology, metamorphism, Dir.

B/3. Badgley, C., 1984. Bibliography of the GSP-Yale Peabody Museum Research Project on the Miocene sediments, faunas, and hominoids of the Potwar Plateau, Pakistan, 1973-present. In: Shah, S.M.I. & Pilbeam, D. (Eds.), Contributions to the Siwalik of Pakistan. Geological Survey of Pakistan, Memoir 11, 19-42.

Key words: Bibliography, Miocene, siwalik molasse, Potwar.

B/4. Badgley, C., Bartels, W.S., Morgan, M.E., Behrensmeyer, A.K. & Raza, S.M., 1995. Taphonomy of vertebrate assemblages from the Paleogene of northwestern Wyoming and the Neogene of northern Pakistan. *Paleogeography, Paleoclimatology, Paleoecology*, 155, 157-180.

We compare the taphonomy of vertebrate assemblages from two long continental records—the early Paleogene of the Bighorn Basin, Wyoming, and the Neogene Siwalik sequence of northern Pakistan. Both sequences contain a similar array of fluvial facies, and the abundance of these facies differs among formations. We document environments of preservation of vertebrate localities over time to determine comparability of fossil assemblages within and between sequences. Changes in sample size and species richness are noted to reveal potential sampling effects on patterns of faunal turnover. Preservation history determined the environment, sample size, quality of specimens, taxonomic composition, and spatial and temporal resolution of fossil assemblages and thereby the quality of the fossil record and its suitability for further analyses.

In both sequences, changes in prevailing taphonomic processes reflect changes in lithofacies and habitat distribution. Correlated changes are found in fossil productivity, species richness, and faunal composition. Both sequences contain some episodes of apparent faunal change in which appearances and disappearances of rare taxa can be attributed principally to changes in sample size. The Paleogene record has high taxonomic resolution (i.e., to genus or species) for most mammalian fossil remains. Temporal and spatial averaging of Paleogene fossil assemblages changes with lithofacies. The Neogene record has higher taxonomic resolution for remains of small mammals (<2 kg) than of large mammals. All formations have several fossiliferous facies, with moderate to high degrees of temporal averaging and low to high degrees of spatial averaging.

Different preservational circumstances impose different constraints on paleoecological and evolutionary analyses. The best opportunities for paleocommunity reconstruction are provided by high taxonomic resolution, large samples, and varied environments of preservation. These circumstances are found in limited portions of each record. The best opportunities for documenting evolution within lineages and species-replacement patterns are provided by high taxonomic resolution, high temporal resolution, and consistent preservational context. These taphonomic attributes pertain to the more common Paleogene mammals, particularly from the rich paleosol localities of the Willwood Formation, and to the more common Neogene small mammals from abandoned-channel fills of the Siwalik record.

Key word: Palaeontology, vertebrate, Wyoming, Siwalik Molasse, Himalaya.

B/5. Badgley, C. & Behrensmeyer, A.K., 1980. Paleoeocology, middle Siwalik sediments and faunas of Northern Pakistan. *Paleogeography, Paleoclimatology, Paleoecology* 30, 133-155.

The Siwalik deposits of northern Pakistan are distinctive for their excellent sedimentary record and Neogene mammal faunas that include a family of homonoids, the Ramapithecidae. A 160-m interval was chosen from 3500 m of local section for study of lateral lithofacies variation, microstratigraphy and taphonomy of selected fossil localities. Field data consists of: (1) stratigraphic sections that span 30 km of lateral exposure, (2) microstratigraphic sections of fossil localities in presentative depositional environments, and (3) taphonomic sampling of a subset of these localities. These data form the basis for landscape, habitat, and community reconstruction. The physiography of the paleoenvironment was determined by braided and meandering river channels. Lateral distribution of channel and floodplain deposits suggests that a mosaic of vegetation types covered the entire drainage basin, including constantly renewed plant succession along channel margins and more stable associations on floodplains. Vertebrate fossils occur in three major depositional settings: channel-lags, channel-margin swales, and floodplain land surfaces. Most collected fossils come from channel-lag conglomerates. The predominant taphonomic influence on the overall fossil assemblage from this interval has been fluvial transport and sorting resulting in a sampling bias toward medium-sized taxa. However, rank abundances from the fossil samples may be valid for these taxa. Fluvial processes probably harvested bones from all habitats present, but no habitat associations of major taxa are detectable. A relatively high species richness of small to medium ungulate herbivores suggests the presence of diverse vegetation types that probably included forest, woodland, and grassland. The ramapithecids were uncommon, medium-sized members of this community.

Key word: Paleoeocology, sediments, fauna, Siwaliks.

B/6. Badgley, C. & Behrensmeyer, A.K., 1995. Two long geological records of continental ecosystems. *Palaeogeography, Palaeoclimatology, Palaeoecology* 115, 1-11.

The early Paleogene continental sequence of northwestern Wyoming and south central Montana (USA) and the Neogene Siwalik sequence of northern Pakistan are exceptionally long, fossiliferous, and well studied in terms of geology, paleontology, mammalian evolution, paleoeocology, and paleoclimatology. Each record spans about 15 myr of alluvial deposition in a foreland basin. The fluvial systems differed in size, drainage of floodplains, and change in alluvial architecture through time. Both sequences preserved abundant paleosols, which are a source of paleoclimatic signals in stable isotopes from soil carbonates. Fossil collections from both records are dominated by vertebrate remains and especially by mammals; the Paleogene sequence also preserved abundant floral remains. Patterns of vertebrate preservation differed markedly between the two sequences, placing inherent limitations on paleoeocological reconstruction and on the scope of evolutionary studies of mammalian linkages.

In this introductory paper, we summarize the major similarities and differences in geologic setting, chronology and time resolution, and mammalian faunal composition of these two long sequences. Finally, we present a brief overview of the organization of papers in this special issue.

Key Words: Continental ecosystems, Montana, siwaliks, Himalaya.

B/7. Badgley, C. & Tauxe, L., 1990. Paleomagnetic stratigraphy and time in sediments: Studies in alluvial Siwalik rocks of Pakistan. *Journal of Geology*. 98(4), 457-477.

Sediments may acquire magnetic remanence upon deposition and shortly after deposition. Hence, the paleomagnetic record of sedimentary rocks may provide a chronostratigraphic framework for rates and patterns of depositional and post-depositional processes over time scales intermediate between those of modern observation and those of the dated geologic record. Two applications of high-resolution magneto- stratigraphy in Miocene, alluvial rocks of Pakistan illustrate this point. (1) Transition stratigraphy-the dense sampling of a magnetic reversal-of correlated sections in the Dhok Pathan Formation revealed high variability in sediment accumulation rates (over several thousand to 10,000 yr), time-transgressive strata representing a paleosol and a floodplain marsh, and a pervasive post-depositional record mainly from pedogenesis. (2) Lateral tracing of paleomagnetic reversal boundaries in the Chinji Formation revealed a secular change in sediment accumulation rate and evidence for increased accumulation rate associated with extensive sandstones and the time-transgressive nature of certain sandstone units. Both studies demonstrate the significant lateral component to accumulation of lithological units, indicating that individual strata

may embody considerably greater time spans in their lateral extent than in any vertical transect. Hence, stratigraphic completeness should be evaluated in the lateral as well as the vertical dimension.

Key words: Palaeomagnetism, stratigraphy, siwaliks, Potwar.

B/8. Badshah, M.S., 1975. Geology of lower Gandao with main emphasis on silica sand. FATA DC, Record, 1, 32p.

The geology and various sedimentary rocks of the Gandao area in Mohmand Agency are described. The main emphasis has been laid on promising silica sand deposits.

Key words: Mineral deposits, silica sand, Mohmand Agency.

B/9. Badshah, M.S., 1979a. Geology of Bajaur and northern part of Mohmand. Geological Bulletin, University of Peshawar 11, 163-179.

Geological investigation in about 1000 sq. km of area in Bajaur and Ambhar Utmarkhel reveal that the area falls in the western tip of Kohistan with the Main Mantle thrust (MMT) running roughly east-west, following the course of Bajaur Khwar. The area is overlain by the tectonic slices, which moved from NW to SE.

The area exposes igneous and metamorphic rocks. Nawagai limestone of (?) Silurian-Devonian age lies to the south-west. The pelitic sediments include amphibolites, epidote chlorite schists, phyllitic schists, piemontite schists, talc carbonate schists, graphite schists and slates. Extensive distribution of garnet schists is observed in the Shamoza area, lying to the south-east.

The igneous masses comprise granites and diorites; ultrabasic and volcanic rocks. The granitic and dioritic rocks are not considered to be comagmatic. The intrusion of diorites started sometimes in the Late Cretaceous, while the whole magmatism ended with the last phase of granitic stocks and dykes in Middle Eocene. The late Upper Cretaceous to Eocene-Oligocene ultrabasic phases of serpentinite, peridotite and pyroxenite / hornblende lie "interbedded" with the metasediments. Eocene to Oligocene rocks of andesitic, rhyolitic and tuffaceous composition are also present.

Poor mineralization of copper, promising mineralization of manganese, soapstone and chromite along with large deposits of marbles are the noteworthy prospects in the area.

Key words: Petrography, MMT, Bajaur, Mohmand, Kohistan Arc.

B/10. Badshah, M.S., 1979b. Soapstone deposits of Daradar Valley, Kurram Agency. Federally Administered Tribal Areas Development Corporation, Information Release 11, 17p.

For further information consult the following .

Key words: Economic geology, soapstone, Kurram Agency.

B/11. Badshah, M.S., 1983a. Soapstone deposits of Daradar valley, Kurram Agency. Second National Seminar on Development of Mineral Resources, Peshawar, 1, 13p.

Soapstone deposits were mapped and studied along with geology of the area. Kurram Agency here is a part of the Precambrian of the Indian plate. Detailed exploration (involving pitting, trenching, aditing, sampling and chemical analyses) was carried out for grade; the reserves are estimated at 1.5 million tons.

Key words: Economic geology, soapstone, Kurram Agency

B/12. Badshah, M.S., 1983b. Geology and breccia pipe primary and secondary copper mineralization in Waziristan. Second National Seminar on Development of Mineral Resources, Peshawar, 1, 16p.

Key words: Economic geology, copper, ophiolite, Waziristan.

B/13. Badshah, M.S., 1985. Development potential of Waziristan copper. Records of the FATA Development Corporation, Peshawar, Pakistan 3, 1-35.

Key words: Economic geology, copper, Waziristan.

B/14. Badshah, M.S., Gnos, E., Jan, M.Q. & Afridi, M.I., 2000. Stratigraphic and tectonic evolution of the northwestern Indian plate and Kabul Block. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 467-475.

A 1:500 000 scale geological map covering large parts of the northwest Pakistan-southeast Afghanistan borders region between 31-34°N and 69-71°E has been completed. The map covers the tribal area of Kurram and of North and Waziristan in Pakistan, where the map is based on unpublished data of the Federally Administered Tribal Areas Development Corporation. The map area comprises Precambrian crystalline rocks of the Indian and Kabul blocks, Permian to Quaternary sedimentary rocks, and the Late Cretaceous-Palaeocene Kabul-Altimur and Zhob-Waziristan-Khost ophiolite complexes. The Himalayan collision resulted in extrusion of the Kabul Block along the Chaman Fault system and formation of the Katawaz Basin which was filled with clastic deposits of the 'Early-Indus' fan. Ongoing contractional tectonics led to southward thrusting of the Spinghar Indian crystalline basement over the Miocene Murree Formation. New names and type sections are proposed for six units in the Spinghar and South Waziristan. These units are the Daradar Dolomite, Spinghar Quartzite, Sikaram Series, Makai Limestone, Wana Schist and Kaniguram Slates.

Key words: Stratigraphy, tectonic evolution, Indian plate, Kabul block, Waziristan.

B/15. Bai Zhongyuan & Zhang Jinhua, 1980. Some features of radiation and heat balance of the Batura Glacier. In: Shi Yafeng (Ed.), *Professional Papers on the Batura Glacier in the Karakoram Mountains*. Science Press, Beijing.

Further information not available.

Key words: Glaciology, Batura Glacier, Karakoram.

B/16. Baig, M.A. & Faruqi, F.A., 1984. Industrial minerals for whiteware industry. Abstract Volume, First Pakistan Geological Congress, Lahore, 32p.

There are several occurrences of raw material, e.g., china clay, feldspar, that can be used in the manufacture of ceramics. This account gives some details of the raw material for ceramic industry.

Key words: Economic geology, industrial minerals.

B/17. Baig, M.A.A., 1967. Important economic minerals of Pakistan. Geological Bulletin, Sindh University, Jamshoro 3 (4), 18-27.

This is one of several such compilations by different authors. It gives a summary of the more important economic minerals discovered by 1967 in Pakistan.

Key words: Economic geology, mineral deposits.

B/18. Baig, M.A.A., 1970. Geological bibliography of Salt Range, Sulaiman Range, Potwar and Hazara areas. Sindh University, Geology Department, Jamshoro, Pakistan, 40p.

This document lists many of the publications on the three areas up to 1969. Those of Hazara and Siwaliks of the Salt Range are included in the present work.

Key words: Salt Range, Sulaiman Range, Potwar, Hazara.

B/19. Baig, M.A.S., 1984. Some observations about change of fluvial pattern in Cis-Indus and Trans-Indus exposures of Dhok-Patan Formation. Abstract volume, First Pakistan Geological Congress, Lahore, 46-47.

The paleocurrent measurements in the Dhok Pathan Formation at different parts of the Cis-Indus and Trans-Indus Siwalik exposures indicate different directions of paleoflow. The stream systems responsible for the deposition of Dhok-Pathan Formation in the Cis-Indus part of Potwar were flowing towards east while those which caused deposition of similar sediments in the Trans-Indus Potwar as well as in Sub-Suleman Ranges flew due south.

The Paleomagnetism data collected at Chinji and Khisor Range indicate a difference of about 5 million years in the depositional age of Chinji Formation sediments at both these places. This observation confirms the difference in depositional systems for Siwalik exposures in Cis-Indus and Trans-Indus areas. It is evident from this data that the fluvial systems responsible for the deposition of Dhok Pathan Formation were flowing due east similar to the present day Ganges and Yamuna river systems. Late, due to some structural disturbance, this flow changed and the river started flowing due south, parallel to the present day Indus river system, thus indicating two different depositional basins.

Key words: Sedimentology, siwaliks, Potwar, Salt Range.

B/20. Baig, M.A.S. & Pervaiz, K., 1995. Remobilized uranium mineralization: A record episodal uplift of frontal fold-thrust belt, NW Himalaya. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 18-19.

Salt Range-Potwar and Bannu basin were developed during the last phase of the Himalayan orogeny which is still active. The mechanism of uranium ore formation in Bannu Basin and Salt Range potwar suggests leaching of the Siwalik Molasse rock and its subsequent reprecipitation along the water table due to change in physio chemical conditions. An analysis of the uranium ore formation process indicates presence of ghost (depleted) ore bodies in the oxidized zone. These radioactive haloes represent paleo water tables which were developed due to episodal uplift. At least four such upheaval episodes have been registered in the Siwalik rocks of Bannu separated by periods of relative stability. This process seems to be still active.

Key words: Uranium mineralization, structural geology, Himalayan fold-thrust belt.

B/21. Baig, M.G., 1992-94. Geology and structure of Barian area, Hazara, Northwest Himalaya and sedimentology of Early Cretaceous Lumshiwal Formation and Early Eocene Chorgali Formation. M.Sc. Thesis, Punjab University, Lahore, 251p.

It is a study of the geology and structure of the Barian area (50 sq. km) along with sedimentological study of the Early Eocene Chorgali Formation and Early Cretaceous Lumshiwal Formation.

A large-scale geologic map of Barian area as (1: 10,000) is presented. The area comprises sedimentary rocks from Middle Jurassic to Early Miocene age, tectonically forming a part of the Lesser Himalayan sequence in the Galiat Area Hazara. The Palaeogene and older sequence is mainly limestone and shales of shallow massive shelf facies. The overlying Neogene rocks are gypsiferous marls, limestone and shale of supratidal to sabkha facies in the lower sandstone, shale molasse of Murree Formation in the upper part. Structurally the area comprises NE-SW trending cylindrical to double plunging folds constituting anticlinoria and synclinoria. The folded sequence is disturbed by numerous reverse faults. However small number of normal faults also exist. Faults are either dip slip or oblique slip and except for the MBT involves a maximum displacement of a few hundred meters. MBT is the major tectonic discontinuity of regional significance. At Darya Gali the thrust is high angle feature dipping to the northwest with opposing dips in the rocks on the two sides. A fault-related escarpment accompanies the surface expression of MBT and much degradation accompanied by land sliding.

Chorgali Formation has been divided into 3 facies and 20 microfacies. Basic microfacies, which repeat, are wackestone microfacies, shale microfacies, mudstone microfacies, and dolomite mudstone facies, calcareous shale microfacies and arenaceous dolomite microfacies.

XRD analysis shows that illite is the predominant clay mineral of shale. Other essential minerals are chlorite, kaolinite, quartz and smectite. Chorgali Formation represents open shelf subtidal to lagoonal environment. In lower part deposition appears to be cyclic with periods of clastic influx alternating with little clastic influx. Fossils present

are mostly broken and probably transported from high energy environment. Shale horizons were deposited in quite subtidal zone but not below 70m due to paucity of pelagic fauna. In upper part of the section dolomites are interbedded with shale. They also show cyclic deposition. Dolomites were probably initially deposited as mudstones in deeper part of shelf. They lack of pelagic fauna and evaporites. Dolomitization appears secondary. Non-ferroan microcrystalline calcite appears biological in origin.

Key words: Structure, sedimentology, Hazara, Himalaya.

B/22. Baig, M.I., 1997. Utilizing geothermal waters. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

This review paper briefly describes geothermal manifestations in form of warm and hot water springs both in northern mountains and in southern regions of Pakistan. The basic data on the thermal springs in Pakistan mainly comes from second half of the last century. It was compiled later almost independently by Waring (1965) and Bakr (1965). Later isolated work has appeared since independence. Areas of potential geothermal resource identified are northern mountain regions of the country, northern Baluchistan and Dadu in Sind. There are large number of manifestations reported: to mention a few, a number of springs in Garam Chashma in Chitral, along Astore river. Tatta Pani in Azad Jammu & Kashmir, Kohlu in Baluchistan and a number of springs in Dadu including super heated stream Issuing at Lakhra in Sind. Reservoir temperature calculated by workers at Murtza Abad in Hunza range 114-296°C, at Tatta Pani near Chilas. 130-239°C. In south, the super heated stream at Lakhra and the other more than 15 springs in Dadu be studied to determine potential underground source of energy in that load center of Pakistan.

This potential geothermal energy source is non-depleting and is non polluting. Its utilization can lessen the risk of depleting perishable source (oil, gas and coal) and to an extent we can avoid the danger of polluting our environment. While super heated steam is being utilized world over in production of electric power, the low enthalpy waters have been used for centuries for recreation, baths and as health spas for their curative effects (hydrotherapy), injuries, joint pains and cutaneous diseases. These waters are being used elsewhere for warming houses, heating green houses for larger productively in agriculture, poultry farming and fish breeding and even air conditioning. Natural reserves are generators of economic growth. A lot needs to be done to explore and harness this source of energy in the country. Plans need to be developed to collect reliable data to utilize this energy resource as a contribution to the development and in improving quality of life of those areas.

Key words: Energy, Himalaya, Hindukush.

B/23. Baig, M.S., 1980. Geology of Jurah-Doarbian area, Neelum valley, State of Azad Jammu and Kashmir. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Neelum valley, Azad Kashmir.

B/24. Baig, M.S., 1989. New occurrence of blueschist from Shin-Kamer and Marin areas of Allai-Kohistan, Northwest Himalaya, Pakistan. Kashmir Journal of Geology 6 & 7, 103-108.

In Allai-Kohistan, the Indus Suture Zone is represented by the Allai melanges. The Allai melanges constitute the Baleja ophiolitic melange, Shin-Kamer blueschist melange, and Matai greenschist melange. The Bela ophiolitic melange, Shin-Kamer blueschist melange, and Matai greenschist melange represents the Neotethys oceanic crust, Neothys trench, and island arc affinities respectively.

New in situ blueschist occurrence have been found from the Shin-Kamer blueschist melange, near the Shin-Kamer and Marin areas of Allai-Kohistan. The Shin-Kamer blueschist is composed of glaucophane, epidote, chlorite, quartz, white mica, with small amount of calcite and plagioclase. The mineral assemblage, suggest blueschist facies P-T conditions of about 380-450 °C and pressure of about 7-8 kbar.

In the blueschist melange, the high-pressure blueschist facie metamorphism is overprinted by the low-pressure greenschist facies metamorphism. During the greenschist facies metamorphism, the actinolite (rims around glaucophane), chlorite, and white mica overprinted the blueschist assemblages. Similar change from high-pressure to low-pressure metamorphic conditions also occurred in the Indus Suture Zone of Ladakh and Shangla areas of the Northwest Himalaya. The transition from blueschist to greenschist facies metamorphism in the Indus Suture Zone

can be relate to tectonic decompression along the Neotethys trench zone or due to a separate tectonic event related to melange emplacement.

Key words: Blueshists, melange, Allai-Kohistan, Indus Suture, Himalaya.

B/25. Baig, M.S., 1990. Structure and geochronology of Pre-Himalayan and Himalayan orogenic events in the Northwest Himalaya, Pakistan, with special reference to the Besham area. Ph.D. Thesis. Oregon State University, Corvallis, U.S.A. 300p.

Details of structural studies, geochronology (including large number of ^{40}Ar - ^{39}Ar dates) and tectonics of the Besham and neighbouring areas are presented in this thesis. The information has been published in a series of papers, including the following one and others listed here.

Key words: Geochronology, tectonics, Swat, Hazara, Himalaya.

B/26. Baig, M.S., 1991. Geochronology of pre-Himalayan and Himalayan Tectonic events, Northwest Himalaya, Pakistan. *Kashmir Journal of Geology* 8 & 9, 197.

In the northwest Himalaya of Pakistan, metamorphism, deformation and plutonism are the result of collision between the Indo-Pakistan and Asian plates. The timing of pre-Himalayan orogenic events remain uncertain, due to strong, pervasive Himalayan overprinting.

This study presents new field, structural and metamorphic date together with $^{40}\text{Ar}/^{39}\text{Ar}$ isotopic age data on hornblende, muscovite, biotite and K-feldspar for Besham, Mansehra, Swat and Hazara areas of northern Pakistan. These data provide the first detailed record of Early Proterozoic to Late Paleozoic events in the northwest Himalaya and combine with prior U/Pb, Rb/Sr, and fission track data record an orogenic history from the Early Proterozoic to Cenozoic. The Early Proterozoic orogenic events in the Besham basement complex occurred at (A) $2,031 \pm 6$ to $1,997 \pm 8$ Ma, (B) $1,950 \pm 3$ Ma, and (C) $1,887 \pm 5$ to $1,865 \pm 3$ Ma. These were followed by sodic granite intrusion at $1,517 \pm 3$ Ma.

Subsequently, flysch of the Kurmang, Gandaf, Manki, Hazara, Dakhner, Dogra and Simla formations was deposited unconformably on the basement rocks of the Indo-Pakistan plate. These units are unconformably overlain by the molasse of the Tanawal and Manglaur formations. The area underwent metamorphism and deformation at 664 to 625 Ma, and volcanism and plutonism at 850 to 600 Ma (Hazaran orogeny or Pan-African orogeny). Later metamorphism and deformation at $> 466 \pm$ Ma and plutonism at 550 to 450 Ma record an Early Paleozoic orogeny. This tectonic event is marked by the development of Cambro-Ordovician unconformity in the Himalaya. Alkaline magmatism (315 ± 15 to 297 ± 4 Ma), sodic granites ($> 272 \pm 1$ Ma), mafic Panjal volcanism (284 ± 4 to 262 ± 1 Ma) and metamorphism (333 ± 1 Ma), occurred during early rifting of the Cimmerian microcontinent from Gondwana. The early Himalayan metamorphism and deformation in northern Pakistan occurred between 70 to 64 Ma. The Late Cretaceous to Early Paleocene deformation and metamorphism is related to melange emplacement along the northwestern margin of the Indo-Pakistan plate. This tectonic event is marked by the widespread development of Paleocene unconformity in the Himalaya. $^{40}\text{Ar}/^{39}\text{Ar}$ dates of 51 to 36 Ma, 36 to 30 Ma, 30 to 24 Ma from shear zones, date successive shearing and thrusting and 24 to 5 Ma fission track dates show unroofing and tectonic erosion, during the development of the Indus syntaxis. The presence of active faults, seismicity and newly recognized 1600 m of uplifted Indus River terrace, show that the Indus syntaxis is an active feature, which has an uplift rate of about 1 mm/year since 5.2 Ma.

Key words: Geochronology, tectonics, Swat, Hazara, Himalaya.

B/27. Baig, M.S., 1992. New occurrences of blueschist from Indus Suture Zone of Allai-Kohistan, Northwest Himalaya, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.6.

In northern Pakistan, the Indus suture zone marks the collision boundary between the Indo-Pakistan plate and the Kohistan island arc. The Late Cretaceous blueschists have been reported from the Topsis and Shangla areas of the Indus suture zone.

This paper reports new blueschists occurrences from the ShinKamer and Marin area of the Indus suture zone of Allai-Kohistan. The blueschist is composed of glaucophane, epidote, chlorite,

quartz, white mica a minor plagioclase and calcite. The mineral assemblage suggests blueschist facies P-T conditions of about 7-8 kbars and 380-459 C. The new microprobe data on the blue amphibole show the rims of calcic amphibole (actinolite) around the cores of sodic amphibole (glaucophane). The presence of actinolite rims around the cores of glaucophane shows that the high-pressure blueschist facies metamorphism is overprinted by the low-pressure greenschist facies metamorphism. The change from the blueschist to greenschist facies metamorphism can be related to tectonic decompression or melange emplacement along the Indus suture zone of Allai-Kohistan.

Key words: Metamorphism, blueschist, Indus suture zone, Allai-Kohistan.

B/28. Baig, M.S., 2000. Precambrian polyphase pre-Himalayan deformation and metamorphism in the Indian plate, Indus syntaxis, North-West Himalaya Pakistan: $\text{Ar}^{40}/\text{Ar}^{39}$ constraints. Abstracts, Third South Asia Geological Congress, Lahore, 53-54.

South of Indus suture zone in northern Pakistan near the village of Besham, the Precambrian Besham Block rocks of the Indian plate in the core of the Indus syntaxis preserve polyphase pre-Himalayan deformation and metamorphism through the Tertiary Himalayan metamorphism. The Indus syntaxis is the basement-cored antiformal hinterland syntaxis similar to the Nanga-Parbat syntaxis. The Besham Block is separated from lower greenschist to upper amphibolite facies Precambrian to Mesozoic metasedimentary and metaigneous rocks of the Mansehra Block to the East and Swat Block to the West by high-angle oblique slip Thakot and Puran Faults respectively. The Besham block consists of Late Archaean to Middle Proterozoic metasediments, amphibolites, sodic granite gneisses and tourmaline-bearing graphic sodic granites of the Besham Basement Complex (BBC) and Late Proterozoic lower greenschist facies cover metasediments of the Karora Group (KG). The BBC is unconformably overlain by the KG. The BBC and KG rocks are intruded by Palaeozoic peraluminous sodic granites. The polyphase pre-Himalayan deformation, metamorphism and plutonism in BBC occurred before the deposition of the KG. The field evidence for pre-Himalayan metamorphism and deformation includes the truncation of gneissic fabric of the BBC at the base of the KG, the presence of BBC metasedimentary and metaigneous gneissic clasts in the phyllitic fabric of the basal metaconglomerate of the KG and the major change in metamorphic grade from amphibolite facies to lower greenschist facies across the KG unconformity. The field, fabric, petrographic and $\text{Ar}^{40}/\text{Ar}^{39}$ studies show three phases of pre-Karora group deformation (D1, D2 and D3), metamorphism (M_{B1} , M_{B2} and M_{B3}), fabric development (S_{B1} , S_{B2} and S_{B3}) and folding (F_{B1} , F_{B2} and F_{B3}). Early S_{B1} fabric related to M_{B1} upper amphibolite facies metamorphism is preserved as intrafolial fabric in sheath folds. S_{B1} fabric yields minimum age of 2031 - 1998 Ma (Hb Ar/Ar dates) for M_{B1} metamorphism. S_{B2} upper amphibolite facies penetrative gneissic to schistose fabric is axial planar to NS-striking, small scale tight to isoclinal folds. S_{B2} fabric yields minimum age of 1950 Ma (Hb Ar/Ar dates) for M_{B2} metamorphism. The epidote amphibolite facies S_{B3} spaced fabric is axial planar to N-S-striking tight to isoclinal folds, those deform S_{B2} fabric. S_{B3} fabric yields age of 1887-1865 Ma (Hb Ar/Ar dates) for M_{B3} metamorphism.

The Early Proterozoic polyphase deformation and metamorphism in BBC is postdated by 1500 Ma tourmaline-bearing graphic sodic granites. All of these deformational, metamorphic and plutonic events predated the unconformable deposition of the Late Proterozoic KG. The lower greenschist facies (up to biotite grade) D_{IV} deformation forms S_{K1} and S_{B4} fabrics in the KG and BBC respectively. S_{K1} occurs as relict fabric in intrafolial folds and microlithons and S_{B4} occurs as spaced fabric and actinolite rims around hornblendes. S_{K1} and S_{B4} fabrics predate the intrusions of 500 Ma and 272 Ma sodic granites. The Tertiary Himalayan deformation in the Besham block occurred at 66-64 Ma, 50-40 Ma and 36-26 Ma.

Key words: Metamorphism, deformation, Precambrian, Swat, Hazara, Himalaya.

B/29. Baig, M.S. & Lawrence, R.D., 1987. Precambrian to Early Paleozoic orogenesis in the Himalaya. *Kashmir Journal of Geology* 5, 1-22.

Precambrian to Paleozoic Himalayan rocks are metamorphosed from lower greenschist facies in the south to amphibolite, and granulite facies in the north. Two or possibly three, metamorphic episodes are preserved in the Precambrian shelf and platform sediments of the northern margin of Gondwana in the Indo-Pakistan plate. At least one metamorphic episode appears to be Precambrian to early Cambrian in age and significantly predates Himalayan metamorphism.

The late Precambrian to early Cambrian tectonism is evidenced by the presence of an angular unconformity, between the late Precambrian and early Cambrian rocks in Hazara, Kotli Azad Kashmir, and the Nepal Himalaya.

The unconformity is marked, by a basal conglomerate, which is composed of clasts of metamorphic rocks that are derived from the underlying Precambrian basement rocks of the Indo-Pakistan plate. The late Precambrian to early Cambrian tectonism is here designated the Hazaran orogeny, because it is well evidenced in the Hazara Himalaya of Pakistan. In the Hazara area, the early Cambrian Tanakki basal conglomerate of the Abbottabad Group above the angular unconformity is unmetamorphosed, whereas the underlying Precambrian Hazara Formation is metamorphosed to lower greenschist facies. The Tanakki conglomerate has cleaved metamorphic clast derived from the underlying Hazara Formation but the matrix of the unit is unclesaved. The Hazara Formation is deformed and has growth of new mica along, the axial plane cleavage, which is truncated by the Tanakki conglomerate. This confirms that the Precambrian metamorphism and tectonic occurred before the deposition of early Cambrian Tanakki conglomerate.

During the Hazaran orogeny, 600-900 Ma plutonic and volcanic rocks intruded into and extruded onto the Precambrian basement rocks of the Indo-Pakistan plate and predate the late Precambrian to early Cambrian unconformity. Somewhat after the Hazaran orogeny, 500-600 Ma peraluminous granites, with initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0.7102-0.7190, intruded the Precambrian as well as earliest Paleozoic rocks. The high initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios suggest that these plutons were derived by antaxis from the basement rocks of the Indo-Pakistan plate. The 500-600 Ma plutons of the Indo-Pakistan plate may be late Hazaran or post-Hazaran orogenic phase of the Hazaran orogeny. The Hazaran orogeny in the Himalaya occurred before the Permo-Triassic breakup of Gondwana and may correlate with the Pan-African, Batkalian, Cadomian, Katangan, and Assyntic orogenies of Africa and Europe.

Key words: Precambrian, Paleozoic, orogenies, Himalaya.

B/30. Baig, M.S., Lawrence, R.D. & Snee, L.W., 1988. Evidence for late Precambrian to early Cambrian orogeny in the northwest Himalaya, Pakistan. *Geological Magazine*, 125, 83-86.

An angular unconformity below Cambrian rocks is present in the northwest Himalaya in the Hazara district, Pakistan. Low-grade metamorphism and folding with axial planar cleavage present in Precambrian rocks below the unconformity, but not in those above it, confirm orogenic deformation at this time. This is the first clear evidence for such a deformation episode and it may be referred to locally as the Hazaran orogeny. Anatectic peraluminous granites of the Himalaya are of only slightly younger age and may be related to this orogenic episode.

Key words: Orogeny, Precambrian, Cambrian, Hazara, Himalaya.

B/31. Baig, M.S., Siddiqui, M.I., Zaman, Q., Khan, M.A. & Hussain, A., 1991. Structural events in the sub-Himalaya of Nikial Khuiratta area, district Kotli, Azad Kashmir. *Kashmir Journal of Geology* 8&9, 197-198.

This paper deals with structural events in sedimentary rocks of this sub-Himalayan area of the Himalayan fold-and-thrust belt

Key words: Structure, Kashmir, Sub-Himalaya .

B/32. Baig, M.S. & Snee, L.W., 1989. Pre-Himalayan dynamothermal and plutonic activity preserved in the Himalayan collision zone, NW Pakistan. *Geological Society of America, Abstract Program*, 21(6), A264.

Ar-Ar and K-Ar dates were determined for many rocks from Besham and adjacent areas of the western Himalaya of Pakistan. Many of the dates are pre-Himalayan. The history of the igneous activity and metamorphism and deformation extends into Early Proterozoic. For additional details, see B/34 and B/35.

Key words: Precambrian, tectonics, Indian Plate, Himalaya.

B/33. Baig, M.S. & Snee, L.W., 1991. A Discovery of Late Archean to Early Proterozoic Komatiite from the Northwestern Margin of the Indian Plate, Besham area, Northwest Himalaya Pakistan. *Kashmir Journal of Geology* 8 & 9, 19-24.

In northern Pakistan, near the village of Besham, the Besham block of Indian plate is exposed in the core of the Indus syntaxis. This basement block is separated from low-to high-grade Precambrian to Mesozoic metamorphic

rocks to the east and west by high-angle ramp faults and from low-grade to unmetamorphosed sedimentary rocks to the south by thrust faults. The Besham block consists of epidote-amphibolite to upper amphibolite facies Late Archean to Middle Proterozoic cover sediments of the Karora group.

Precambrian komatiites are known from the basement rocks of the southern Indian plate. No komatiites have previously been reported from the Indian basement. Early Proterozoic komatiites from the Besham basement complex of the Besham area, northwest Himalaya, Pakistan. It is the first report of komatiites from the northwest basement rocks of the Indian plate. An amphibolite from the Besham basement complex is herein characterized as an alumina depleted basaltic komatiite on the basis of high SiO_2 (55%), high MgO (15.94 %), $<0.5\%$ K_2O (0.24%), $<0.9\%$ TiO_2 (0.25 %), low Fe/Mg ratio (0.89) at given Al_2O_3 (3.77%) and $>\text{CaO/Al}_2\text{O}_3$ ratio (3.45).

Precambrian komatiites are commonly associated with the rift-related extensional environments. The presence of Late Archean to Early Proterozoic mafic komatiites in the Besham basement occurred during the rifting of Indian plate.

Key words: Komatiite, Precambrian, Late Archean, Besham, Indian Plate.

B/34. Baig, M.S. & Snee, L.W., 1997. Precambrian tectonics of the Indian plate, Indus syntaxis region, Northwest Himalaya, Pakistan: $\text{Ar}^{40}/^{39}\text{Ar}$. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 117-118.

In the northwest Himalaya of Pakistan, metamorphism and deformation are the result of collision between the Indian and Asian plates. The presence, timing and significance of pre-Himalayan orogenic events have previously been uncertain, due to the pervasive high-grade Himalayan tectonic overprint which apparently obscures any prior record (Baig and Lawrence, 1987; Baig and others, 1988). The study of the Indus syntaxis of northern Pakistan has discovered earlier pre-Himalayan events, which are dateable due to weaker Himalayan metamorphic overprinting (Baig and Snee, 1989; Baig and others, 1989, 1992; Baig; Treloar and Rex, 1990). New field, structural, metamorphic and stratigraphic data together with $^{40}\text{Ar}/^{39}\text{Ar}$ isotopic age data on hornblende and muscovite are presented for the basement and cover rocks of the Indian plate near Besham and Hazara areas. These data reveal a lengthy pre-Himalayan orogenic history initiated at least in the Early Proterozoic and /or in the Late Archean.

The newly recognized Besham basement complex of the Indian plate, in the core of the Indus syntaxis, consists of multiply-intruded epidote-amphibolite- to upper amphibolite-facies metasediments of the Besham group. $^{40}\text{Ar}/^{39}\text{Ar}$ dating of Indian basement rocks (Baig, 1990) confirms the following Precambrian events:

Archean to Early Proterozoic Besham group shallow water pre-to syn-rift sedimentation and associated mafic and komatiitic volcanism, mafic dike intrusions, Darwaza Sar potassic and Lahor sodic granite intrusion, upper amphibolite-facies metamorphism at $>2,000$ Ma ($^{40}\text{Ar}/^{39}\text{Ar}$ hornblende dates), upper amphibolite-facies metamorphism at $1,950 \pm 3$ Ma ($^{40}\text{Ar}/^{39}\text{Ar}$ hornblende dates), hornblende-biotite granodiorite and granite intrusions, mafic dike intrusions and epidote-amphibolite-facies metamorphism at $1,887 \pm 3$ Ma ($^{40}\text{Ar}/^{39}\text{Ar}$ hornblende dates). Proterozoic by tourmaline-bearing sodic granitic granites at 1,500 Ma ($^{40}\text{Ar}/^{39}\text{Ar}$ hornblende dates). The 2,000-1,500 Ma orogenic events define the Early to Middle Proterozoic Besham orogeny.

The Late Proterozoic syn- to post-rift Karora group was deposited subsequently with a breakup unconformity on the Archean to Middle Proterozoic Besham basement complex. It is composed of Amlo conglomerate Formation, Kurmang Formation and Kandoana Formation (Baig, 1990). The shallow water turbidite Kurmang Formation and its facies equivalent Manki, Dakhner, Hazara, Landikotal, Simla, Dogra, Phe and Salt Range formations show syn-rift sedimentation and associated local mafic Dogra and Khewra volcanisms. The Amlo conglomerate Formation marks the breakup unconformity at the base of this widespread unit in the northwest Himalaya. The Kurmang and Manki formations are conformably succeeded by post-rift shallow water carbonates of the Kandoana and Shahkot formations respectively.

The Eocambrian or Latest Proterozoic Hazaran orogeny initiated at 650 ± 25 Ma ($^{40}\text{Ar}/^{39}\text{Ar}$ sericite dates). The Hazaran orogeny uplifted and eroded the Precambrian basement and cover rocks of the southern Indian shield and deposited the Eocambrian Hazaran clastic molasse of the Tanawal and Manglaur formations north Panjal thrust in a pre-Himalayan subsiding Hazaran foreland basin. The Hazaran orogeny predated the unconformable deposition of the Early Cambrian fossil-bearing sedimentary strata in the northwest Himalaya of Pakistan. The Eocambrian Hazaran or Pan-African orogeny caused the amalgamation of Gondwana as a super continent.

Key words: Precambrian, tectonics, geochronology, Indian Plate, Himalaya.

B/35. Baig, M.S., Snee, L.W., Fortune, R.J.L. & Lawrence, R.D., 1989. Timing of Pre-Himalayan orogenic event in the Northwest Himalaya: $^{40}\text{Ar}/^{39}\text{Ar}$ Constraints. *Kashmir Journal of Geology* 6 & 7, 29-40.

In the Northwest Himalaya, pre-Himalayan metamorphism and deformation is present, which is postulated by early Paleozoic peraluminous granites. The early Paleozoic granites and the Precambrian basement rocks of the Indo-Pakistan plate were metamorphosed and deformed, during the pervasive high-grade Himalayan metamorphism and deformation, which caused uncertainty in the recognition of the timing of the pre-Himalayan metamorphism and deformation.

Field criteria such as intrusive age relationship of meta-igneous plutons, relative ages of deformation phases, overprinting of gneissic fabric by weak younger fabric, and an angular unconformity, can provide relative ages for the pre-Himalayan and Himalayan metamorphism and deformation. However, such data do not constrain the absolute timing of metamorphism and deformation, which must be constrain by isotopic dates. The new $^{40}\text{Ar}/^{39}\text{Ar}$ dating of the Precambrian basement rocks of the northwest Himalaya of Pakistan, confirms five pre-Himalaya metamorphic events. These metamorphic events occurred at $>2,000 \pm 6$ Ma, $>1,950 \pm 3$ Ma, $1,865 \pm 3$ Ma to $1,887 \pm 5$ Ma, 650 ± 2 Ma, and $> 466 \pm 2$ Ma. The 600-900 Ma plutonic, volcanic, metamorphic, and deformational events are related to the Hazara orogeny. The 550-450 Ma peraluminous granites and $> 466 \pm 2$ Ma metamorphism in the Himalaya, record a separate Cambro-Ordovician orogenic event. This orogenic event correlates with the Pan-Paleozoic orogenic events on the Indo-Pakistan plate occurred before the Permo-Triassic breakup of Gondwana.

Key words: Precambrian, tectonics, geochronology, Indian Plate, Himalaya.

B/36. Baig, S., 1995. Structural study of the Main Boundary Thrust in North West Himalaya, Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 76p.

It describes structures associated with the Main Boundary Thrust.

Key words: Structure, MBT, Himalaya.

B/37. Baig, Z.M., 1996. Environmental geochemistry of water, rock and soil of Gadoon and surrounding area, District Swabi, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 165p.

Elements like carbon, hydrogen and oxygen are considered as an essence for living organisms, while the trace elements have both benevolent and harmful effects to living organism upto certain limits. Environmental geochemistry is one of the science that deals with the interaction of the pollutants in our daily life. These pollutants may be either contributed by anthropogenic or natural processes or both. A wide range of industrialization throughout the country is flourishing on one side but poor management in this sector is polluting the water and soil with the toxic effluents that are coming from these industries. In Gadoon and surrounding areas natural and anthropogenic pollution is effecting the quality of water by adding pollutants such as SO_4 , NO_3 and trace metals like Cd, Cu, and Pb.

In the present study thirty-five samples of water (both surface and groundwater) and twenty-six sample of soil, from Gadoon and surrounding areas, were analyzed for different parameters. The most alarming issue of the study area is the higher concentration of sulfate and nitrate contents in the drinking water of Gandaf, and Biasak, where the concentration of SO_4 in the drinking water exceeds 1700 and 1525 mg/l respectively. The US-EPA & WHO recommended a permissible limit of 250 mg/l in drinking water. The source of this high concentration in the drinking water of the area is the contamination through the rocks of the Salkhala Formation. The rocks of the Salkhala Formation are enriched in sulfide minerals like pyrite. Sulfate as a pollutant is causing diarrhea, dehydration and gastrointestinal problems in the people of the area. The concentrations of NO_3 in the Gandaf and Miani wells also exceed 946 and 286 mg/l respectively. The US-EPA's permissible limit for nitrate is considered to be 10 mg/l. The higher concentration of nitrates in water is due to agricultural pollution (i.e. fertilizers and human feces. etc.). This enormous increase of nitrate in drinking water is due to the mixing of animal manure in the soil. Ultimately, this manure makes its way to water, due to the run-off from cultivated and fertilized field. In infants, nitrate contaminated water cause a disease called methemoglobinemia, a type of blood disorder in which red blood cells cannot carry oxygen.

Key words: Environmental geochemistry, Gadoon, Swabi.

B/38. Baig, Z.M. & Shah, M.T., 1997. Nitrate as an anthropogenic pollutant in the ground water of Gadoon area (N.W.F.P), Pakistan. Environmental Pollution 3rd National Symposium Abstract 106.

Key words: Groundwater, pollution, Gadoon, Swabi.

B/39. Baird-Smith, R., 1842. Notes on the recent earthquakes in the North-Western Frontier. Journal of the Asiatic Society of Bengal, N.S. 11, 242-255.

This is one of the early accounts of the earthquakes that occurred in the northwestern part of the subcontinental British India.

Key words: Earthquakes, NW Frontier, India.

B/40. Baird-Smith, R., 1843, Memoir on Indian Earthquakes, Pt. II, Journal of the Asiatic Society of Bengal, 12(2), New Series, 136, 1029-1056 .

This compilation , and the one following, also refer to earthquakes that occurred in the northwestern part of the subcontinental India.

Key words: Earthquakes, NW India.

B/41. Baird-Smith, R., 1844, Memoir on Indian Earthquakes, Pt. III, J, Journal of the Asiatic Society of Bengal, 156, 964-983.

This compilation , and the preceding one, refer to earthquakes that occurred in the northwestern part of the subcontinental India.

Key words: Earthquakes, India.

B/42. Bajwa, M.A., 1995. Shallow seismic reflection surveying for mapping the weathered layer velocity and lithology correlation in Attock District. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 35p.

Shallow Seismic Refraction Survey was carried out to map the low velocity weathered zone in Attock District for the completion of M.Sc. dissertation. For this purpose five parallel profiles were laid. Overall 52 Seismic spread were shot using reverse shooting technique. After plotting the observed refraction travel times, in the travel time versus distance graph, velocities V0, V1 and depth Ho were calculated.

The values thus obtained have been used to prepare isovelocity (Vo) map, isovelocity, (V1) map and isopach (Ho) map. Hawkin's method was also used for comparative study. Integrating the available geological information along with interpreted velocity depth picture, a relationship between velocity and lithology has been established. The low velocity of weathered layer ranging from 400 m/sec to 1100 m/sec, which shows unconsolidated material of alluvial deposits comprising of sand and clay. The high velocity of sub-weathered layer ranging from 1400m/sec to 3200 m/sec indicates the combination of sandstone, shale, clay and wet sand. The thickness of weathered layer varies from 2m to 8m in the project area.

Key words: Seismic reflection, Attock.

B/43. Bajwa, M.S., 1970. Geology and petrology of Swat Hornblendic Complex in the Chargah–Khawza Khela Area, Swat. M.Sc. Thesis, Punjab University, Lahore.

The geology and petrography of this area of the Kohistan magmatic arc is described. The principal rocks include amphibolites, metagabbros and their associates.

Key words: Petrology, amphibolites, Swat.

B/44. Bajwa, M.S., 1984. Petrology of Siwalik rocks of Chakri-Chauntra area, Attock and Rawalpindi Districts, Punjab, Pakistan. *Kashmir Journal of Geology* 2, 93-102.

A sequence nearly 3000 meters thick of the Siwalik Group of Late Cenozoic age is exposed in the Chauntra quadrangle, in Attock and Rawalpindi Districts. For the purpose of petrological studies, the sequence has been differentiated into Lower, Middle and Upper Siwaliks. The sandstones and clays of these sub groups have been studied lithologically, petrographically and chemically. The petrographical evidences suggest that sediments of the Siwalik Group were derived from igneous, metamorphic and sedimentary rocks of the adjacent Himalayan region and were deposited in a shallow fast sinking basin, after their short and rapid transportations.

Key words: Petrology, siwaliks, Attock, Rawalpindi.

B/45. Bajwa, M.S., 1997. Geochemical study of the detrital almandites of Murree and Siwalik Formations from Potwar, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.139.

The detrital almandites (garnets) of Murree and Siwalik formations of Miocene to Pleistocene ages, from Rawalpindi and Jhelum areas, eastern Potwar, Pakistan, were chemically analysed with the help of EPMA (Electron Probe Micro Analyser), at Kyoto, University, Japan. The data of more than three hundred almandites were plotted on Mg-Fe-Mn and Mg-(Fe+Mn)-Ca triangles. The distribution of the data points, based on Mg, Fe, Mn and Ca molecular percentage ratios in both the triangles showed a marked difference between Murree and the Siwalik strata. Some differences in the chemical trends of the garnets from the Lower, Middle and Upper Siwalik formations can also be seen in Mg-Fe-Mn triangles, but no such difference could be noted in the second type. It is evident that most of the garnets of Murree Formation have been concentrated in the high Fe, high Mn zones as compared to that of Middle and Upper Siwaliks, which have taken positions in the high Fe and high Mg areas. Whereas, the data of Lower Siwaliks are distributed almost equally in the zones of high Fe, low Mg and low Mn, but the trend towards Mn is a little higher. However, some evidences suggest that the almandite garnets of Murree Formation have been derived from low grade metamorphic rocks, those of Lower Siwaliks from medium and high grade, and Middle and Upper Siwaliks from high grade rocks from a source area situated in northern Pakistan.

Key words: Geochemistry, Murree Formation, siwaliks, Potwar.

B/46. Bajwa, M.S. & Akhtar, M., 1988. Preliminary bibliography of Siwalik rocks of Pakistan. Geological Survey of Pakistan, Information Release 343.

This bibliography lists available references on the Siwaliks up to 1987.

Key words: Bibliography, siwaliks.

B/47. Bajwa, M.S., Shams, F.A. & Shiki, T., 1987. Geochemistry of garnet grains from Murree and Siwalik Formation, Rawalpindi and Jhelum Districts, Punjab, Pakistan. *Geological Bulletin, Punjab University* 22, 1-12.

The Siwalik molasse heavy mineral assemblages also include garnet. There are many places in the north-west Himalaya where metamorphic and igneous rocks contain garnet, the source of for the Siwaliks. The analyzed garnets range from Fe-rich compositions to those having substantial amounts of Ca and/or Mg.

Key words: Geochemistry, garnet, Murree Formation, Siwalik Formation.

B/48. Bajwa, Z.A., 1991-93. Geology of Dubran Area District Haripur with microfacies study of Langrial Algal limestone. M.Sc. Thesis, Punjab University, Lahore, 127p.

Geological mapping of some 64-km² area around Dubran in District Haripur has been carried out at the scale 1:12500. The geomorphology, soils, stratigraphy and structure have been described. Stratigraphically a Mesozoic-Tertiary sedimentary cover is overlying a Precambrian to Eo-Cambrian basement of Hazara Group now

metamorphosed in the lower greenschist facies. Numerous faults, high angle north dipping Nathiagali Thrust is the main fault that passes through the area and has thrust the Precambrian Hazara Slates over the younger sedimentary sequence. Dubran syncline lying on top of a major anticlinorium makes an interesting structure.

Key words: Stratigraphy, geomorphology, microfacies, Langrial limestone, Hazara.

B/49. Baker, D.M., 1987. Balanced structural cross-section of the central Salt Range and Potwar Plateau of Pakistan: Shortening and overthrust deformation associated with a salt decollement. M.S. Thesis, Oregon State University, Corvallis.

This thesis concerns structures associated with salt décollement. Crustal shortening and overthrust deformation are described. A balanced cross-section of the central Salt Range to Potwar Plateau is presented.

Key words: Structure, deformation, Potwar Plateau, Salt Range.

B/50. Bakr, M.A., 1965a. Geology of parts of Trans-Himalayan Region in Gilgit and Baltistan, West Pakistan. Geological Survey of Pakistan Records, 11(3), 17p.

The Gilgit-Lower Hunza area comprises a range of volcanic rocks (Chalt Formation), some sediments, and major batholiths. This paper presents details of geology and petrography of the rocks. According to recent studies this region comprises Kohistan arc in the south and Karakoram plate in the north.

Key words: Petrography, Kohistan, Karakoram Plate, Gilgit, Hunza.

B/51. Bakr, M.A., 1965b. Vermiculite deposits of Pakistan. Geological Survey of Pakistan. Records, 16(1), 9p.

Key words: Mineral deposits, vermiculite.

B/52. Bakr, M.A., 1965c. Fluorspar deposits of Pakistan. Geological Survey of Pakistan. Records, 16(2), 6p.

Key words: Mineral deposits, fluorspar.

B/53. Bakr, M.A., 1965d. Thermal springs of Pakistan. Geological Survey of Pakistan. Records, 16(3), 4p.

This description includes the thermal spring of northern Pakistan, such as Garam Chashma in Chitral and Thatta Pani near Rakhiot on the west flank of the Nanga Parbat.

Key words: Thermal springs, Chitral, Gilgit.

B/54. Bakr, M.A. & Jackson, R.O., 1964. Geological map of Pakistan, Scale 1:2,000,000. Geological Survey of Pakistan, Quetta.

This is geological map of West Pakistan, East Pakistan (now Bangladesh) and Kashmir on a scale of 1:2,000,000. The compilation is based on whatever data were available by that time, a large area of the Kohistan terrene in Himalaya-Karakoram region is shown unmapped.

Key words: Geological map, Pakistan.

B/55. Bakhtiar, K. & Ahmad, W., 1979. Geology of Shewa Shahbaz Garhi Area, Mardan. M.Sc. Thesis, University of Peshawar, 79p.

Shewa Shahbaz Garhi area is occupied by silicic alkaline rocks ranging from tuffs to shallow intrusions. These rocks constitute a part of the Peshawar Plain Alkaline Igneous Province of Late Paleozoic – Early Mesozoic age. The thesis provides geological and petrographic data of the rocks.

Key words: Alkaline rocks, granitic rocks, Mardan.

B/56. Baldi, P., 1976. Magnetism of Karakorum and surrounding regions. In: *Geotectonics of the Kashmir Himalaya-Karakorum-Hindu Kush-Pamir orogenic belts*. Accademia Nazionale dei Lincei, 139-142.

Key words: Magnetism, Karakoram.

B/57. Balka, M.S., 1994. Delineation of surface trace of MBT along G.T. Road near Nicholson Monument by electrical resistivity, gravity, and magnetic methods. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 41p.

Geophysical methods have been applied to trace the Main Boundary Thrust of the Margalla hills near Nicholson monument.

Key words: Geophysics, Main Boundary Thrust, Margalla, Rawalpindi.

B/58. Balme, B.E., 1970. Palynology of Permian and Triassic Strata in the Salt Range and Surghar Range, West Pakistan. In: Kummel, B. & Teichert, C. (Eds.), *Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan*. Geology Department University of Kansas, Special Publication 4, 305-454.

This paper deals with the palynological examination of 57 samples of sediments, six of which came from a single locality in the Surghar Range, and the remainder from eight localities in the Salt Range, West Pakistan. The material ranges in age from Lower Permian (Artinskian) to Middle Triassic, but most of the samples are from the uppermost Permian and Lower Triassic.

Seventy-nine species of spores and pollen grains, 23 of which are new, have been described and illustrated. *Sirneonoshota* (type species: *S. khlonovae* sp. nov.) and *Paravittatina* (type species: *Decussatis!Jorites lucifer* Bharadwaj and Salujha) have been instituted as new form genera.

Implications of the palynological data are discussed in relation to biostratigraphy and the plant geography of late Paleozoic and early Mesozoic times. They provide evidence for sweeping floral changes in the Salt Range area, coincident with the Permian-Triassic boundary, and for further extensive modifications during the late Scythian. Spore and pollen assemblages from the Late Permian Chhidru Formation appear to have derived from a transitional flora, but to have much in common with those from strata of similar age in Madagascar. Triassic assemblages both in their composition and succession closely resemble those from the Perth Basin, Western Australia.

Key words: Palynology, Permian, Triassic, Surghar Range, Salt range.

B/59. Baloch, I.H., 1986. A mineralogical study of the industrial utilization of bauxitic clays of Nawa area, Kala Chitta Range, Attock District, Pakistan. *Acta Mineralogica Pakistanica* 2, 144-152.

This paper gives a detailed account of the mineralogy of the Bauxite clays of Nawa area from the Datta formation of early Jurassic age exposed in the Kala Chitta Range, Pakistan. The mineralogic studies show that the Kaolinite, diaspora and boehmite are the essential minerals, while chlorite, anatase, rutile, quartz and haematite are accessories. A brief account of the chemistry, phase transformation and detailed description of industrial utilization is also presented. Three grades of clays are found: one can be used as a high grade refractory, the second for ceramics and the third for common bricks.

Key words: Mineralogy, clays, economic geology, Kala Chitta Range, Attock.

B/60. Baloch, I.H., 1997. Petrogenesis of alkaline igneous province of Pakistan. Geological Bulletin, Punjab University 31 & 32, 169-176.

The Alkaline Igneous Province of Northwest Pakistan (AiPNP) extends from Loe-Shilman in the West to Tarbela in the East for a distance of about 150 Km. There are at least two distinct periods of magmatic / volcanic activity in the alkaline province. One is Permo- Carboniferous in age and is related to the break up of Gondwana land through Intra continental rifting.

The second activity is Tertiary in age. This is related to bending of Indian Plate during subduction. This bending caused tension and rifting. Tectonically the alkaline province falls in two Himalayan subdivisions: (a) Tarbela, Kogu, Ulla, Babaji, Ambela and Loe Shilman falls in the Lesser Himalaya South of the Main Central Thrust and (b) Sillai Patti and Jambil fall in the Higher Himalaya North of the MCT. It may therefore be concluded that alkaline province is not restricted to the Lesser Himalaya alone.

Key words: Petrology, alkaline rocks.

B/61. Baloch, I.H., 2001. The age of the carbonate cover to the basement of higher Himalayan crystalline. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.45.

The cover rocks of the Higher Himalayan Crystalline (HHC) in Swat are composed of a basal pelitic-psammitic unit overlain by a thick sequence of carbonates and calc-pelites. This cover has variously been considered as Pre-Cambrian or Triassic. Most of the workers have correlated this cover with Lesser Himalayan carbonates variously known as Bampokha group, Tursak marbles, Khasala Formation etc. The Lesser Himalayan carbonates have in turn been considered as Triassic/Jurassic to Siluro-Devonian.

The units equated with HHC cover rocks have been intruded at various places by Babaji syenite, Sills, dykes and minor apophyses of Babaji syenite intrude the rocks of Tursak/Bampokha/Khasala formations. Clear-cut hornfelsing in pelitic horizons has been identified at a number of places. Babaji Syenite has been dated as Carboniferous by U/Pb, Ar/Ar and Rb/Sr methods. The country rocks are therefore Pre-Carboniferous. If these rocks are correlated with HHC pelite/carbonate cover, then the HHC cover is older than Carboniferous.

Key words: Alkaline rocks, carbonates, stratigraphy, Swat.

B/62. Baloch, I.H., Ahmed, N., Mateen, A., Chaudhry, M.N. & Ghazanfar, M., 1999. K-Rb relations in the Koga Ijolite-feldspathoidal syenite complex, Buner Swat, Pakistan: Their bearing on the petrogenesis and comparison with similar alkaline undersaturated magma series of the world. Pakistan Journal of Geology 10 & 11, 20-33.

The Ambela granitic complex contains a range of alkaline rocks, including syenite, ijolite and carbonatite. This paper describes these alkaline rocks and uses geochemistry in drawing conclusions regarding their origin and comparison with other such rocks from other parts of the world.

Key words: Petrogenesis, alkaline rocks, Buner, Swat.

B/63. Baloch, I.H. & Chaudhry, M.N., 1991. Occurrence, geology, petrology and industrial applications of More Khun barite deposits of Northern Areas of Pakistan. Geological Bulletin, Punjab University 26, 71-73.

The Mor Khun barite deposit is a hydrothermal replacement deposit which occurs within Gujhal Dolomite close to the contact of Gircha Formation. It is exposed intermittently for hundreds of metres. The deposit is snow white and very pure with a specific gravity between 4.3 and 4.4. Chemical and physical characteristics of this deposit indicate a number of industrial applications.

Key words: Economic geology, barite, Northern Areas.

B/64. Baloch, I.H., Chaudhry, M.N. & Mateen, A., 2000. The mineral chemistry of the Koga undersaturated alkaline complex, Buner, Swat, North Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 130-131.

Mineral Chemistry of feldspathoids, feldspars, sodium pyroxenes and biotite-annite-siderophyllite series coupled with petrochemistry of the Koga Alkaline igneous complex has been studied and interpreted to understand the crystallization history of the undersaturated magma in the region.

The Koga feldspathoidal complex is comprised of feldspathoidal syenites, foyaites, melanite nepheline syenite, alkali syenites and sodalite-cancrinite rich pegmatites. The pegmatites are minor. The feldspathoidal syenites formed at pressure of < 5 kbar. These rocks comprised essentially of feldspar and feldspathoids. Pyroxene, biotite magnetite, garnet, sphene, apatite and zircon are minor to accessory minerals. The mafics along with sphene, apatite and zircon occur as tiny enclaves or microxenoliths. Cancrinite and sodalite generally occur as accessory minerals; however, in some pegmatites they assume the status of essential minerals.

The feldspar is a single phase highly exsolved feldspar with a K-feldspar host. The composition of nepheline is restricted to the Morozewicz-Buenger convergent field in the system Ne-Ks-Qz. Such a composition is characteristic of subsolvous nepheline syenites. Cancrinite and sodalite show constant composition with relatively high SiO₂ and Al₂O₃. However, CaO is comparatively low. The sodium pyroxenes fall within the narrow field of aegirine-Jadeite. Hedenbergite is lacking. The aegirine composition ranges from Ae₈₀ Jd₂₀ to Ae₇₅ Jd₂₅. The fractionation trend of pyroxenes in this complex is rather unique and does not duplicate other complexes of the world.

Within the Biotite-Annite-Siderophyllite series in the Koga undersaturated rocks, four compositional groups may be recognized. 1. An₉₀Sd₁₀ to An₇₃Sd₂₇ with as much as 30 to 50% phlogopite, 2. An₉₅ Sd₅ with 15 to 30% phlogopite. 3. An₈₀Sd₂₀ to An₆₅ Sd₃₅ with 5 to 15% phlogopite. 4. An₇₀ Sd₃₀ to An₆₀ Sd₄₀ with 0 to 5% phlogopite.

Key words: Alkaline rocks, mineralogy, Buner.

B/65. Baloch, I.H., Dunham, A.C. & Chaudhry, M.N., 1994. Mineral processing of the Koga feldspathoidal syenite complex, Northwestern Pakistan: Use in glass and ceramics. Pakistan Journal of Geology 2 & 3, 91-99.

Key words: Industrial mineralogy, alkali syenite, glass, Buner.

B/66. Baloch, I.H., Dunham, A.C. & Ghazanfar, M., 1996. Geology of the Koga feldspathoidal syenite complex, Northwestern Pakistan. Pakistan Journal of Geology 2(2) & 3(1), 1-8.

Key words: Alkali syenite, Buner.

B/67. Baloch, I.H., Ghazanfar, M., Dunham, A.C. & Chaudhry, M.N., 1997. First account of deep chemical weathering and its implications on the reserve and mining potential of Koga feldspathoidal syenite complex of north western Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

It is the first report and systematic study of deep chemical weathering affecting a plutonic igneous complex in Pakistan. Discovery that the patchy outcrop of Koga feldspathoidal syenite is not a result of separate intrusions but a result of the deep chemical weathering which has led to the isolation of the still intact patches which has been taken as separate intrusion in the past. Downwards below the zone of weathering the Koga feldspathoidal syenite must be fresh everywhere. This has a direct implication on reserve calculation. It throws light and invites further research on the nature and operation of deep-seated chemical weathering on feldspathoidal syenites. The new minerals found in the altered rock comprise kaolinite, illite, pyrophanite and siderite. It would be interesting to trace the exact sources of the ions required for these alterations. It is here suggested that aegirine, orthoclase and sphene have suffered partial breakdown. The CO₂ for the CO₃ had come from the rainwater and the soil.

It is interesting to note in the field that the weathered rock shows increase of volume and decrease of hardness which has resulted from the broad process of hydrolysis, carbonation and oxidation. The rock has become soft and swollen even though the broad textural fabric has been more or less maintained at many places. It is also significant that the total alkali content of even the highly weathered and altered rock does not fall below 10.84% from an average of 15%. This deficiency of alkali can be overcome by blending with high alkali foyaites which make it possible to utilize even the weathered material. This shows that the process of weathering though important from the mining, processing and academic point of view has not substantively affected the ore potential of the complex. Although

hydrothermal alteration of a small part of the Koga feldspathoidal syenite is known. However, implication of weathering for the mineability and reserve potential of this very important industrial rock deposit are profound. The deposit is composite in nature and composed of a number of plugs and dykes. But weathering gives a very wrong impression of the configuration of the internal structure of this complex. In the past composite outcrops, rising out of the weathered envelope were regarded as discrete intrusive bodies. Such an assumption fails to take into consideration the facts of weathering on the reserve and mineability.

Key words: Weathering, alkaline rocks, economic geology, Buner.

B/68. Baloch, I.H., Ghazanfar, M., Dunham, A.C. & Chaudhry, M.N., 1997. First account of deep chemical weathering and its implications on the reserve and mining potential of Koga feldspathoidal syenite complex of north western Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 149-159.

Consult preceding account for further information.

Key words: Weathering, alkaline rocks, economic geology, Buner.

B/69. Baloch, I.H., Mateen, A. & Chaudhry, M.N., 1998. Feldspars of the Koga feldspathoidal syenite-carbonatite complex, Buner, Swat, NW Pakistan. Pakistan Journal of Geology 7, 1-5.

Key words: Feldspar, Koga, alkaline complex, Buner.

B/70. Baloch, I.H., Mateen, A. & Chaudhry, M.N., 1999. Biotite-annite-siderophyllite series in feldspathoidal syenite of the Koga Alkaline Igneous Complex, Swat, NW, Pakistan. Geological Bulletin, Punjab University 33 & 34, 83-90.

The mineral chemistry of biotites has been investigated by the electron microprobe analysis performed on various rock units from the Koga feldspathoidal syenite complex. Four distinct groups- biotite-annite-siderophyllite series have been recognized; (1) $An_{70}Sd_{30}$ to $An_{60}Sd_{40}$ with 0 to 5% phlogopite (2) $An_{80}Sd_{20}$ to $An_{65}Sd_{35}$ with 5 to 15% phlogopite (3) $An_{95}Sd_5$ to $An_{73}Sd_{27}$ with 15 to 30% phlogopite (4) $An_{90}Sd_{10}$ to $An_{73}Sd_{27}$ with 30 to 50% phlogopite.

Key words: Mineralogy, Koga, alkaline complex, Buner.

B/71. Baloch, I.H., Mateen, A. & Chaudhry, M.N., 1999. Rare earth elements geochemistry of the Koga feldspathoidal syenites, Chamla-Buner valley, NW Pakistan. Pakistan Journal of Geology, 8(1), 1-5.

Key words: Geochemistry, REE, Koga, Buner.

B/72. Baloch, I.H., Mateen, A., Chaudhry, M.N. & Dunham, A.C., 1999. Petrography and petrochemistry of the Koga feldspathoidal syenites, Northwestern Pakistan. Pakistan Journal of Geology, 8 (1) 11-33.

Key words: Petrography, petrochemistry, syenite, Koga, alkaline complex, Swat.

B/73. Baloch, I.H., Mateen, A., Chaudhry, M.N. & Ghazanfar, M., 1998. K-Rb relations in the Koga feldspathoidal syenite complex, Buner, Swat, Pakistan: Their bearing on the petrogenesis and comparison with similar alkaline undersaturated magma series of the world. Pakistan Journal of Geology 7, 88-89.

Key words: Petrogenesis, alkaline complex, Koga, Buner.

B/74. Baluch, A.Q., 1981-83. Geological mapping and site investigations of dam site and reservoir area of Basha Dam (Chilas Diemer). M.Sc. Thesis, Punjab University, Lahore. 99p.

The electric power demand of Pakistan is very high and the present generation capabilities of the country are insufficient to cope with the increasing load created by industry, agriculture and domestic consumers. In order to tide over the situation water and power development of Pakistan initially identify thirteen sites on the Indus River upstream of Tarbela upto Skardu, because the drop along Indus plains show attractive locations for hydro power development.

To study the potential/plan the development of 13 identified sites and feasibility of one best site, first Canadian Technical Assistant has been arranged. Basha damsite is the site selected by the Canadian Consultant for the feasibility purposes which is located on the Indus river near the village Basha about 45 km downstream of Chilas in Gilgit Agency.

Key words: Engineering geology, Basha, Chilas.

B/75. Baluch, S.Q., 1998. Geotechnical aspects of hydropower projects in Indus Kohistan, Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 27-29.

A number of high head hydropower projects are being planned on the tributaries of the Indus River in Indus Kohistan. These projects, with locations as shown in Fig. 1, are at various levels of study and the first may come into operation around the year 2005. The estimated total installed capacity of 5,000 MW mostly in the form of peaking plants will significantly reduce the power deficit currently being faced by Pakistan. The main characteristics of these cascade schemes include storage dams at higher elevations with regulation facilities in the middle and lower catchment sections. As is the case with most high head hydropower projects, the planned schemes are in relatively remote areas and contain long waterways (tunnels) across areas of high overburden. High erosion rate in the Himalayan region will also result in deposition of sediments in the reservoirs requiring careful sedimentation management and provision of sediment handling facilities. Main geotechnical data available for the schemes is summarised and discussed in relevant detail. The Allai Khwar Hydropower Project is the most advanced and is a likely candidate for implementation ahead of others. The other cascade schemes on left bank of the Indus river in the adjacent catchments of Chor Nala and Spat Gah have been studied to conceptual and reconnaissance level, respectively. Based on geological and tectonic setting of the area, the process of site selection and establishment of design parameters are also presented.

The continued subduction and Arc-Continental collision (thrusting) induced several phases of faulting and metamorphism, resulting in a wide spectrum of low to high grade metamorphic rocks. The projects areas are in close vicinity of the Main Mantle Thrust (MMT); a major orogenic feature which marks collision boundary of the Indian plate to the Eurasian plate with intervening Karakoram micro-plate and Kohistan Arc. The alignment of MMT and other major tectonic features have been mapped within the projects area. Based on the regional geological conditions, the geotechnical zoning has been attempted to define expected geotechnical and geomechanical characteristics of rock mass along the long tunnel routes. Attempt has been made to predict tunnelling conditions and rock mass behaviour together with estimated rock support requirements.

Investigation techniques, including interpretation of satellite imagery, aerial photographs interpretation, engineering geological mapping, geophysical methods and core drilling is described together with their application from site selection to microlocation of the project structures. The paper describes the successful use of various geophysical investigation techniques and results obtained at the initial stage of site selection in these relatively remote and inaccessible areas. This allowed to replace expensive and time consuming drilling and other relevant rock mechanics testing. Systematic discontinuities surveys regionally and at selected sites were carried out to define characteristics of dominant discontinuities groups. Also presented is the use of this data in stability assessment of foundations, tunnels and slopes on various project sites. In the concluding section, recommendations are given for appropriate methodology and approach in obtaining geotechnical data and site selection for hydropower projects in northern areas of Pakistan.

Key words: Engineering geology, energy, Kohistan.

B/76. Baluch, S.Q. & Ali, I., 1998. Seismic risk assessment of hydropower projects with reference to the tectonic structure of northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 29-32.

Seismic phenomenon has been responsible for the severe damage to water-retaining structures in the ' world. Examples from USA include Sheffield dam, Hebgen Lake dam, Upper San Fernando dam, and Lower San Fernando dam. Similarly, Koyna dam; a concrete gravity structure in India sustained severe earthquake damage in 1967. However, a complete failure of a dam due to earthquake impact is virtually unknown. The safe design of dams to withstand destructive earthquakes is, therefore, extremely important because failure of such a structure may have disastrous consequences both on life and property. The paper briefly describes seismo-tectonic environment in the Himalayan region and its impact on existing dams in tilts area such as Bakhara-Nangal dam in India, Mangla and Tarbela dams in Pakistan. In addition, earthquakes that may pose a multitude of hazards to dams either by direct loading of the structure or by initiating a sequence of events that may lead to the dam failure are discussed with a special reference to tile tectonic structure of Northern Pakistan. The geological and tectonic setting of the Northern Pakistan is an example of Continental collision characterised by the occurrence of an ancient island arc. The continuing subduction and Arc-Continental collision (thrusting) induced several phases of faulting and metamorphism, resulting in a wide spectrum of low to high grade z-metamorphic rocks. The tectonic processes in the area have produced a mixed and very complex geological situation. The collision tectonics have resulted in formation of thrust and strike slip faults. Most of the high head hydropower projects planned in the Indus Kohistan area are located in close vicinity of the Main Mantle Thrust (MMT) and other major tectonic features. The rocks are foliated to cataclastic and mylonized with high degree of shearing and folding in vicinity of the MMT. The MMT, Indus Kohistan seismic Zone (IKZS), Thakot Shear Zone (TSZ) and the Main Boundary Thrust (MBT) in the form of a detachment fault underlying the project area are the main seismogenic features in the area. Relationship between distribution of seismic events and main seismo-tectonic features in Indus Kohistan is given in Fig. 1. The Northern areas of Pakistan are considered highly seismic and in spite of the fact that all the future main hydropower projects are being planned in this region, this area has never been covered by any seismic instruments in the past. Recently, M/S Allai Khwar Consultants (AKC) have managed a microseismic network study in Indus Kohistan area. The instruments installed at locations shown in Fig. 2 recorded several hundred seismic events during six months study period. The study indicated that the level of micro-seismicity in this region is fairly frequent and probably greater than in other parts of the Himalayan region. Another important aspect identified by the study is the shallow depth of seismic events. It is observed that even small magnitude events can produce high accelerations in Northern Pakistan. For example, an earthquake of April 17, 1970 with a body wave magnitude 4.9 produced 25% g and that of February 20, 1996 wave a magnitude 5.2 produced 27% g at the Tarbela site. Based updated geological information, historical earthquake data and preliminary results of the recent microseismic network study, design parameters such as Maximum Credible Earthquake (MCE), Operational Basis Earthquake (OBE) and acceleration (g) values are proposed. Relevance of various attenuation equations for this area are also discussed. Satellite imagery and aerial photographs to determine location and lengths of lineaments provided information on the probable extent of possible movement on major fault planes. Accurate geological and tectonic snapping allowed correlation of instrumental data with the known tectonic features. Based on the recommendations of the International Committee on Large Dams (IOCLD), the investigation methods used in site selection, classification of fault systems and identification of neo to recent tectonic activity are described. Relevant design features are proposed to minimise damage to dams avid appurtenant structures in case of extreme shaking during strong seismic events.

Key words: Seismology, engineering geology, energy, Kohistan.

B/77. Baluch, W.A., Begum, I., Aslam, M. & Shah, A., 1982. Geology of Shergarh-Sar Complex, Allai Kohistan, Hazara. M.Sc. Thesis, Peshawar University, 55p.

This report covers the Geology of an area located in the Allai Kohistan, Hazara division between 34° 50' to 34° 60' N latitudes and 73° 0' to 73° 10' E longitudes. A detailed petrographic study together with a geological map is presented in this manuscript. Broadly, the rocks types of the thesis area are divisible into two major groups, i.e. amphibolites and ultramafics. In the studied area the amphibolites are divided into three groups: 1) Epidote-Amphibolites, 2) Garnet-Epidote-Amphibolites, and 3) Garnet-Amphibolites.

The amphibolites may be inferred to be metamorphosed product of oceanic crust. Ultramafics are peridotites, pyroxenites, dunites, and serpentinites. These ultramafics represent the obducted ophiolites. The area is located along MMT, which is a vital tectonic element of the Himalayan geology. Due to the involvement of MMT, the area has undergone complex tectonic episodes in response to the collision of Indian plate and Eurasian continent.

Economic mineral chromite is found in ultramafics whereas gem quality garnet is expected to be found in amphibolites. Vein deposits like Pb and Zn are also expected but no comprehensive work has been done.

Key words: Petrography, Shergarh-Sar, Allai Kohistan.

B/78. Banaras, M. & Ghani, A., 1982. Petrography of the Tora Tigga Complex, Munda area, Dir District. M.Sc. Thesis, University of Peshawar, 157p.

This work presents a detailed geological map (1:12,500), petrography and a discussion regarding the petrogenesis of the ultramafic rocks of the Tora Tigga complex in Dir district (34°49' N, 71°44' E). The complex, covering about 7sq. km. area, is situated in the Southern Amphibolitic Belt along the Main Mantle Thrust. The amphibolites, hosting the ultramafic rocks, are divisible into metagabbros/ metanorites, banded- amphibolites and garnet-amphibolites. The metagabbros/metanorites consist of prograde hornblende and plagioclase (An₄₀₋₄₃) with or without quartz, white mica, apatite, rutile and ore. Clinopyroxene and orthopyroxene occur as relics, and chlorite and epidote as retrograde alteration products. The banded-amphibolites are composed of quartz, plagioclase (An₃₈) hornblende, biotite, sphene, and ore. The garnet-amphibolites are similar in composition to metagabbros except for the presence of garnet porphyroblasts and a slightly more calcic plagioclase (An₄₅). All these rocks have been metamorphosed under Barrovian-type amphibolite facies conditions. The ultramafic rocks are broadly classified into olivine-pyroxene-ultramafites and hornblendites. The olivine-ultramafites include peridotites, amphibole-peridotites, serpentinites and dunites. The pyroxene-ultramafites include hornblende - websterites - hornblende - orthopyroxenites, hornblende clinopyroxenites, hornblende-olivine-websterites and olivine-clinopyroxenites. There is a complete range from hornblende-pyroxenites to pure hornblendites, plagioclase (An₄₀₋₄₅) occurs in only a few hornblendites.

Felsic dykes, dykelets and veins, as well as epidote veins crosscut the hornblendites. The mineralogy of the felsic dykes and veins (hornblende- plagioclase (An₃₀₋₄₀) Quartz, epidote with or without garnet-biotite and rutile) is suggestive of metamorphism in the amphibolite-facies. However, retrogressive alteration accompanying shearing has led to the development of greenschist facies minerals (tremolite-actinolite-chlorite and secondary epidote).

The petrography of the ultramafites as well as the composition of the olivine (FO₈₉) and orthopyroxene (En₈₇) remain inconclusive regarding their petrogenetic affinity to one of the standard categories, i.e. alpine-, layered- or ring-complexes. They may represent an obducted slab of oceanic crust/upper mantle or a part of ultramafic rocks differentiated from a calc-alkaline or a basaltic magma. Most of the field and textural features suggest a metasomatic origin for the hornblendites generally at the expense of pyroxenites. They appear to have formed by the addition of H₂O, Al, Fe and (Ca) to the ultramafites. The metasomatism seems to have been synchronous with regional metamorphism and obduction of the ultramafites during the Early Tertiary.

Key words: Petrography, ultramafics, hornblendites, Tora Tigga, Dir.

B/79. Band, G., 1955. Road to Rakaposhi. 1st edition. Hodder and Stoughton, London.

Key words: Rakaposhi, Hunza.

B/80. Banerjee, D.M., 1992. Carbon isotopic excretion along PC/C boundary-evidences from Soltanieh Range in Iran, Hazara in Pakistan, Mussoorie Hills in India and Urandush Mountain, Mongolia. Abstracts, First South Asia Geological Congress, Islamabad, 6-7.

Black shale, dolomitic limestone and chert are the predominant host rocks of the phosphorites occurring along Proterozoic Cambrian boundary in several parts of Asia. Detailed sampling along three stratigraphically measured sections in India, Iran and Mongolia and random samples from Hazara in Pakistan, provided the material for stable isotope analyses of carbon and oxygen in the carbonate, apatite and organic fractions of the phosphorite. A marked negative inflexion of data points at the base of Cambrian succession is coupled with an abrupt change to a positive excursion. Markedly light carbon isotopic shift can be related to the methanogenesis in the black-shale rich phosphorites. Carbonate hosted phosphorites are associated with bacterial degradation products and therefore are

heavier in their isotopic composition. This phenomenon is more or less consistent through all the sections in 4 different countries and show conformity with the results obtained from Greenland, Newfoundland and China.

Key words: Geochemistry, isotope geology, phosphorites, Hazara.

B/81. Bangash, I.H., 1991. Petrology and geochemistry of the Southern Amphibolite Belt rocks from Mahak and surrounding area, Swat, Pakistan. M.Phil. Thesis, University of Peshawar.

The Mahak and surrounding area is located in the southern amphibolite belt of North, Pakistan. A detailed petrography and geochemistry of the Mahak area is presented. Rocks of the area are distinguished into amphibolite, Hornblendite, hornblende-pegmatite, diorites, metagabbros, metapyroxenites, and quartzo-felspathic veins and dykes. Amphibolites are the most abundant rocks of the area, and are distinguished into epidote-amphibolites, plagioclase-amphibolites, and epidote-plagioclase amphibolites. These are generally medium to coarse grained and consist of hornblende, plagioclase, epidote, clinopyroxene, orthopyroxene, sphene, quartz, ore, rutile, and chlorite. Hornblendites are usually monomineralic, but have a variable grain size. They are mainly composed of hornblende, cloudy plagioclase, epidote, chlorite, quartz, rutile and ore. Hornblende-pegmatites are coarse grained containing hornblende and plagioclase as dominant minerals, epidote, quartz, sphene, rutile and opaque minerals as accessories.

Key words: Petrology, geochemistry, amphibolites, Swat.

B/82. Banks, M.P., 1958. Rakaposhi climbed. Himalayan Journal, 21(6), 55p.

This is an account of the successful ascent of the Rakaposhi Range in the central Karakoram of Hunza. The expedition was conceived as a small but exacting experiment in international and inter-service co-operation. All the members were service officers and were drawn fairly equally from the Pakistan Army and the British Navy, Marines, Army and Air Force, making a total of nine climbers. Field-Marshal Sir Gerald W. R. Templer, G.C.B., G.C.M.G., K.B.E., D.S.O., Chief of the Imperial General Staff, and General Mohammad Ayub Khan, Commander-in-Chief of the Pakistan Army, lent their powerful support as joint Patrons; and the expedition committee was, appropriately, presided over by Major-General J. L. Moulton, C.B., D.S.O., O.B.E., Chief of Amphibious Warfare, and an officer of the Royal Marines.

The objective was the ascent of Rakaposhi, one of the unclimbed giants of the Karakoram Range. Rakaposhi has a long mountaineering history, closely associated with British climbers. In the dawn of Himalayan mountaineering, in 1892, Martin Conway (later Lord Conway of Allington) penetrated the Bagrot nulla to the south of the peak. The lower ramparts deterred him but he pronounced the upper mountain climbable. The peak lay unmolested until 1938 when two British climbers, Secord and Vyvyan, approached Rakaposhi from the West. They investigated the peak via the N.W. ridge but only attained a height of about 19,700 ft. The first determined attempt, which had some chance of success, was spearheaded by the celebrated 'Everester' H. W. Tilman in 1947. He was eventually turned back at about 19,000 ft. both on the N.W. ridge and on the S.W. spur. He regarded neither route as promising. In 1954, two expeditions had designs on Rakaposhi. An Austro-German expedition under Rebitch approached from the South but came to much the same conclusion as Conway had done sixty years earlier and they left the peak, dubbing it unclimbable from that direction as it most probably is. In the same season a Cambridge University expedition, under Tissi6res, and including Band who was on Everest in 1953 and was later to climb Kangchenjunga, again tried Tilman's routes. They discovered that the S.W. spur was the most hopeful line of approach and they reached about 20,800 ft. before their assault petered out through lack of impetus. The final 2,000 ft. of climbing had been up a great face of snow and ice called the Monk's Head. This was a most formidable obstacle, particularly for porters.

Key words: Rakaposhi, Hunza.

B/83. Bank, H., 1976a. Farblose topase aus Pakistan mit hoher lichtbrechung. Z. Deutsche Gemmologischen Gesell 25, 157-158.

Describe a topaz from northern Pakistan. Refractive index was measured at between 1.630 and 1.640 with a birefringence of 0.010.

Key words: Gemstones, topaz.

B/84. Bank, H., 1976b. Rosafarbige durchsichtige topase aus Pakistan. Zeits. Deutschen Gemmologischen Gesell 25, p.41.

This material, found in the Mardan District, Hill-Top pegmatite [probably Katlang], has $\alpha=1.632$, $\beta=1.636$, $\gamma=1.641$; and specific gravity of 3.53.

Key words: Gemstones, topaz, Mardan.

B/85. Bank, H. & Berdesinski, W., 1975. Durchscheinender fast durchsichtiger antigorit (serpentin) aus Pakistan. Zeits. Deutschen Gemmologischen Gesell 24, 157-159.

This antigorite serpentine has $\alpha=1.559$ $\gamma=1.561$, and birefringence of 0.002. The specific gravity is 2.57.

Key words: Gemstones, topaz.

B/86. Bank, H. & Okrusch, M., 1976. Über rubin-vorkommen in marmoren von Hunza, Pakistan. Z. Deutsche Gemmologischen Gesell 25, 67-85.

This is a report on the occurrence and properties of the ruby in marbles near Hunza.

Key words: Ruby, marbles, Hunza.

B/87. Bannert, D., Cheema, A., Ahmed, A. & Schaffer, U., 1992. The structure development of the western fold belt, Pakistan. Geologisches Jahrbuch, Reihe B 80, 3-60.

Key words: Structure, fold belt.

B/88. Bannert, D. & Raza, H.A., 1992. The segmentation of the Indo-Pakistan plate. Abstracts, First South Asia Geological Congress, Islamabad, p.7.

The Kirthar and Sulaiman ranges of western Pakistan and the Kohat and Potwar area adjacent to the northeast have been structurally analyzed using LANDSAT-MSS colour and black and white images at a scale of 1:250.000, literature studies, and a limited field survey. The pattern of tectonic deformation caused by the collision of the Indo-Pakistan Plate with the Eurasian plate have been analyzed. Tethyan oceanic crust covered by Triassic through Early Tertiary sediments, are preserved between the Eurasian Plate and the Indo-Pakistan Plate and called the Bela-Waziristan Ophiolite Zone. The oblique collision of the Indo-Pakistan Plate with the Eurasian Plate forced the Indo-Pakistan Plate to rotate in an anticlockwise mode. The collision further opened a number of basement faults that segmented the western part of the Indo-Pakistan Plate mostly on Pakistan territory -into several basement blocks, which were involved en-echelon in the collision. They are the Kirthar Basement Fault in the southwest, the Sulaiman Basement Fault, and the Jhelum Basement Fault in the northeast. The deformation of the sediments of the Indo-Pakistan Plate during the collision resulted in different tectonic patterns on the individual basement blocks.

Key words: Plate tectonics, collision, structural geology.

B/89. Baqri, S.R.H., 1984. The Correlation of Khewra Sandstone (Salt Range) with a Cambrian Sandstone, exposed near Abbottabad, Hazara Division, North West Frontier Province, Pakistan. Kashmir Journal of Geology 2, 75-78.

The detailed lithological units of the Khewra Sandstone (Salt Range) and Tanakki-Sanghargali members have been compared for their probable correlation. The probable correlation of the Khewra Sandstone with the Tanakki-Sanghargali member indicates that the Khewra Sandstone extends as north as Riwat Rawalpindi in the subsurface. It is also inferred that the Khewra Sandstone is not localized in Salt Range only but extends regionally towards Abbottabad.

Key words: Stratigraphy, sandstone, Cambrian, Khewra, Hazara.

B/90. Baqri, S.R.H. & Dawood, H., 1995. The stratigraphic importance of Pasu Slates and Gujhal dolomite and their stratigraphic relations with the Baltit Group. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 22-23.

The south western flank of the Sost anticline displays the exposures of the Pasu Slates and Gujhal Dolomite in the Upper Hunza Valley which form the most prominent and distinct lithological features, representing rugged topography and high cliffs. The Pasu Slates and Gujhal Dolomite represent the same lithological units as Misgar Slates and Kilk formation, respectively, exposed on the north eastern flank of the Sost anticline. The basal and upper contacts of the Pasu Slates and Gujhal Dolomite were studied at several places such as Pasu, Dih, Sost etc. as it is very difficult to observe these contacts at one place due to severe tectonic activity in the area.

The Pasu Slates unconformably lie over the Pak China Friendship Formation (mainly quartzites with lenticular pebbles and gravels) and are conformably overlain by the Gujhal Dolomite. The Pasu Slates are dark grey to grey, flaggy, thin to medium bedded, thinly laminated, sandy, silty, more arenaceous towards base and more calcareous/marly with lenticular limestone beds towards its top. The slates display the random distribution of the perfect diagenetic crystals of pyrite, the size of which increases towards the base. The slates are about 2000m thick and have been assigned a Permian age due to the discovery of the products fossils in the Gircha Formation. The Gujhal Dolomite overlies conformably on the Pasu Slates and is unconformably overlain by the Shanoz Conglomerate. The Gujhal Dolomite is dirty yellowish grey to grey, lenticular bedded, massive bedded, occasionally argillaceous and display two beds of lenticular intraformational conglomerates, near the base and the middle of the formation. The dolomite is about 750 m thick at Pasu and has been assigned a Permian age.

The Pasu Slates and Gujhal Dolomite are severely folded, faulted, intruded mostly by acid igneous rocks and display generally faulted contacts. They occupy stratigraphically same position as the Baltit Group exposed in the lower Hunza Valley. These studies revealed that the Pasu Slates and the Gujhal Dolomites were comparatively highly metamorphosed into schists, gneisses and marbles (Baltit Group) around the older original intrusive backed contacts with the Karakoram batholith (Cretaceous) in the southern areas at lower Hunza Valley as compared to the younger thrust contacts of the Karakoram batholith with these formations in the northern side in the upper Hunza Valley (north west of Husaini Village).

Key words: Stratigraphy, Pasu slates, Gujhal dolomite, Baltit Group, Hunza.

B/91. Baqri, S.R.H., Javed, M., Ahmed, Z. & Haq, A., 1995. The X-ray diffraction and geochemical studies of the Hunza ruby and associated rocks. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 21-22.

The sample of the dark pinkish red ruby and its associated carbonate rocks (marbles) were collected from the ruby mine of Hunza, located on Karakoram Highway, near Aliabad. The X-ray diffraction and geochemical studies on the Hunza ruby and associated rocks were conducted to understand the influence of the mother solutions during the mineralization of Hunza rubies and the nature of the lattice parameters. The Hunza ruby displays perfect X-ray diffraction pattern giving all the important reflections and may be called a well crystallized precious gem variety. The mother solutions originated during the intrusion of the Karakoram batholith into the country rocks.

Key words: Geochemistry, XRD, gemstone, ruby, Hunza.

B/92. Baqui, M.A., 1963. Geology of Palsala Bir, Haripur, Hazara, M.Sc. Thesis, Punjab University, 30p.

Details not available.

Key words: Geology, Haripur, Hazara.

B/93. Baranowski, J., Armbruster, J., Seeber, L. & Molnar, P., 1984. Focal depths and fault plane solutions of earthquakes and active tectonics of the Himalaya. Journal of Geophysical Research 89, 6918-6928.

We have compared synthetic seismograms with long-period body waves for nine earthquakes with epicenters in the Himalayan arc to determine depths of foci and to improve fault plane solutions. Focal depths are shallow (10–20 km). Inferred slip vectors are locally perpendicular to the mountain range; they plunge very gently ($\square 10^\circ$ in the eastern sections of the range and more steeply ($\square 25^\circ$) in western sections. Assuming India to be a rigid plate, the radially oriented slip vectors imply that southern Tibet extends at about half the rate of underthrusting in the Himalaya and therefore probably at about 5–10 mm/yr. The shallow depths and gentle dips of the fault planes, at least for the events in the eastern half of the range, are consistent with coherent underthrusting of the Indian plate beneath, at least, the Lesser Himalaya. The steeper dips of fault planes in the western part of the arc might reflect deformation of the overriding thrust plate or simply a steepening of the main underthrusting zone beneath the Greater Himalaya.

Key words: Seismology, neotectonics, earthquakes, Himalaya.

B/94. Barbieri, M., Caggianelli, A., Di Florio, M.R. & Lorenzoni, S., 1994. Plagiogranites and gabbroic rocks from the Mingora ophiolitic melange, Swat valley, NW Frontier Province, Pakistan. *Mineralogical Magazine*, 58, 553-566.

Major, trace element composition and Sr isotopic data were collected for gabbroic rocks, plagiogranites and albitites in the ophiolite assemblage from Swat Valley (NW Frontier Province, Pakistan). Petrographic study revealed that these rocks were subjected to important structural and mineralogical modifications due to greenschist-epidote-amphibolite facies sub-sea-floor metamorphism and to brecciation. On the other hand, the examination of whole rock chemical composition and of chemical trends showed that these rocks were affected by some chemical modifications, concerning especially Na₂O, K₂O and Rb. The very low contents of HFS (high field strength) and RE elements found in gabbroic rocks and plagiogranites were considered to be a primary magmatic feature pointing in part to their cumulitic nature and in part to an origin from a refractory parental magma. The Sr isotopic data indicate that gabbroic rocks and plagiogranites were subjected to exchange-with sea water. The particular chemical features shared by gabbroic rocks and plagiogranites suggested that fractional crystallization was a possible evolution process. In contrast, albitites are characterized by anomalously high contents in HFSE and LREE and by values of the ⁸⁷Sr/⁸⁶Sr ratio very close to sea water. These features suggest a more complex origin with respect to gabbroic rocks and plagiogranites.

Key words: Ophiolites, melange, petrology, Shangla, Swat.

B/95. Bard, J.P., 1978. Initiation of intra–continental subduction in the Himalayas. *Journal of Geophysical Research*, 83(310), 4975–4987.

Independent arguments based on topographic stress and crustal strength give upper limits of 200 bars and 300 bars, respectively, for the average shear stress on the intracontinental thrust fault that formed the Himalaya. According to either a one-dimensional or a two-dimensional fault model, such stresses could not have produced the Himalayan granites by friction, unless overthrusting velocity exceeded 30 cm/yr. More probably, Himalayan metamorphism was caused by exposure of continental crust to hot asthenosphere prior to the formation of the intracontinental thrust. Crust was exposed by peeling away of Indian subcrustal lithosphere in response to the force and moment exerted by the Tethyan slab. This detachment of buoyant crust from dense lithosphere better explains the metamorphic pattern and also explains why the distributed crustal shortening at the beginning of the collision orogeny was replaced by localized thrusting or intracontinental subduction.

Key words: Intracontinental, subduction, Himalaya.

B/96. Bard, J.P., 1983a. Metamorphic evolution of an obducted island arc: example of the Kohistan sequence (Pakistan) in the Himalayan collided Range. *Geological Bulletin, University of Peshawar* 16, 105-184.

In the northern Pakistan, the extraordinary 40km thick Kohistan sequence of mafic, ultramafic and calc-alkaline layered plutonic and volcanic (mainly andesitic and rhyodacitic) rocks has been interpreted as the only complete vertical section of an intraoceanic island arc presently exposed anywhere in the world. Plate-scale models have been suggested to explain the origin and the tectonic evolution of this arc in the Himalayan collided range. Despite some

noticeable differences in the models, there is a general agreement that the Kohistan sequence represents the crust of an arc obducted onto the Indian plate before the Oligocene collision of India against Asia.

The purpose of the present paper is to give new data on the tectono-metamorphic evolution of the Kohistan sequence and to try to estimate its changing metamorphic conditions on petrological, mineralogical and crystal chemistry grounds. The structural, textural and mineralogical data suggest two main tectono-metamorphic events that have affected the Kohistan arc before late lower grade overprints. From various geothermometry estimates as well as from field zonations, it is concluded that the major (D1) phase developed with a thermal structure strongly controlled by thermal anomalies in the metamorphic pile. These anomalies seem centered around isolated bodies of two-pyroxenes and cpx-garnet granulites. Because the petrographical evidences indicate the latter are derived from large pre-tectonic layered calc-alkaline intrusion(s), the former anomalies are interpreted as remnant magmatic heat source(s) within the arc. This interpretation fits nicely with theoretical thermal models. Assuming D1 is contemporaneous with obduction of the arc and together with the geochronological data, it is suggested that the tectonic emplacement of the Kohistan arc was 20 ± 5 m.y. after the intrusion of enormous calc-alkaline pluton(s) within the arc crust. Such a relatively short elapsed time between a strong magmatic activity and a tectono-metamorphic event may explain why the T-P paths during D1 produced sinuous geotherms in the petrogenetic grid, i.e., the dT/dp are varying from $350^\circ\text{C} \pm 50^\circ\text{C}/\text{km}$ upto $1000^\circ\text{C}/\text{km}$ in the 40 km thick pile.

The second (D2) phase is contemporaneous with syn-kinematic low- to mid-grade retrogression upto the epidote-amphibolite facies conditions. The T – P curve during this phase is a classical one and the D2 geotherm approached $250^\circ\text{C} \pm 50^\circ\text{C}/\text{km}$ within a re-equilibrated thermal structure. Scarce geochronological data suggest the D2 was contemporaneous with the Oligocene collision of India against Asia and possibly synchronous with the Oligocene Barrovian metamorphism which has affected the Indian plate south of Kohistan. The origin of the rocks of the Kohistan granulites as well as the significance of a blueschist belt under the Kohistan metamorphic pile are briefly discussed.

Key words: Metamorphism, petrology, Kohistan.

B/97. Bard, J.P., 1983b. Metamorphism of an obducted island arc: example of the Kohistan sequence (Pakistan) in the Himalayan collided range. *Earth and Planetary Science Letters* 65, 133-144.

In northern Pakistan, the extraordinary 40-km-thick Kohistan sequence of metamorphosed mafic, ultramafic and calc-alkaline layered plutonic and volcanic (mainly andesitic to rhyodacitic) rocks has been recently reinterpreted as the only complete vertical section of an intra-oceanic island arc presently exposed anywhere in the world. Plate scale-models have been suggested to explain the origin and the tectonic evolution of this arc in the Himalayan collision range. Despite some noticeable differences in the models, there is general agreement that the Kohistan sequence represents the crust of an arc obducted onto the northern edge of the Indian plate before the Oligocene collision of India against Asia. New data on the tectonometamorphic evolution of the Kohistan sequence have led to the conclusion that a first major D1 event developed with increasing metamorphic grades oriented downward the Kohistan pile but also toward “ensandwiched” basic-ultrabasic granulitic rocks. Rare geochronological data and petrological evidence indicate that the latter granulites (pyroxenites and various plagiopyroxenites, pyroxenites, metatroctolites, metawebsterites, metadunites, etc.) were parts of enormous Lower to Middle Cretaceous layered calc-alkaline plutons emplaced during the arc-building stages. As the D1 metamorphic event is correlated with the Upper Cretaceous obduction process of the Kohistan onto India, it is proposed that the D1 thermal structure was strongly controlled by remnant magmatic heat source(s) within the obducted arc. This interpretation fits nicely with recent theoretical thermal models since the obduction of the arc was probably shortly after (10–20 Ma) the emplacement of the former plutonic arc rocks. A blueschist “tectonic mélange” underlying the obducted arc was possibly synchronous to the obduction and not clearly linked to the older subductive process. The Oligocene collision of India against Asia was associated with a Barrovian overprinting metamorphism in the Kohistan arc. During this second event the dynamo-thermal structure was much more classical and not controlled by the occurrence of the Cretaceous metaplutonic rocks. A tentative model of the thermal structures during the major events which affected the Kohistan arc is proposed.

Key words: Metamorphism, petrology, Kohistan.

B/98. Bard, J.P., Jan, M.Q., Maluski, H., Matte, P. & Proust, F., 1979. Position et extension de la "ceinture" métamorphique à faciès schistes bleus dans l'Himalaya du Pakistan, Nord. 7e R. Ann. Terre Lyon, 29p.

This account describes the Indus suture mélange stretching from Kaghan to Shangla. It contains blueschists locally, such as those near Shangla. The high-pressure metamorphism is related to the suturing of the Indian plate and Kohistan island arc during the Late Cretaceous.

Key words: High-P metamorphism, blueschist, Indus suture, Himalaya.

B/99. Bard, J.P., Maluski, H., Matte, P. & Proust, F., 1980. The Kohistan sequence: crust and mantle of an obducted island arc. Geological Bulletin, University of Peshawar 13, 87-94.

The Kohistan sequence outcrops in the western part of the western Himalayan syntaxis. It is a thick pile (30-40km) of metamorphosed magmatic, volcanic and sedimentary rocks. It is composed of six main units i.e. from bottom to top: the southern amphibolite belt with basal ultramafics, the "pyroxene granulite" belt (10-15 km thick), the northern amphibolite belt, intruded by various dioritic bodies, a metasedimentary oceanic series (Kalam series), a volcanic calc-alkaline series (Utror Volcanics), up to 6-8 km thick, an upper detrital series (Yasin group, Lower Cretaceous). This sequence is interpreted as a complete cross-section of a mature island arc formed by subduction during Mesozoic in the southern part of the Neotethys and obducted onto the Indian plate in Upper Cretaceous time.

Key words: Petrology, tectonics, Kohistan.

B/100. Barndt, J., Johnson, N.M., Johnson, G.D., Opdyke, N.D., Lindsay, E.H., Pilbeam, D. & Tahirkheli, R.A.K., 1978. The magnetic polarity stratigraphy and age of the Siwalik Group near Dhok Pathan village, Potwar Plateau, Pakistan. Earth and Planetary Science Letters 41 (3), 355-364.

The magnetic polarity zonation of the terrestrial strata exposed in the Dhok Pathan area of Pakistan has been established utilizing data from 204 paleomagnetic sites. Individual magnetic transitions are traced laterally over 15 km and provide convenient time lines for correlating the fluvial facies of the middle Siwalik Group. A pervasive, normal polarity zone dominates throughout the region and has been interpreted as Magnetic Polarity Epoch 9. Based on this interpretation and using the absolute ages from the published magnetic time scales the average sedimentation rate in the area is calculated at 0.8 m/1000 years, and the average elapsed time between fluvial cycles is 56,000 years. Major sandstone units are minimally time transgressive in an east-west direction. The Nagri Formation in the Dhok Pathan area spans the time from 10.0 to 8.6 m.y. B.P. Ramapithecus and other hominoid primates are found in Epoch 9 at about 9 m.y.

Key words: Magnetostratigraphy, siwaliks, Potwar.

B/101. Barndt, D.E., 1977. The magnetostratigraphy of the type locality of the Dhok Pathan faunal stage, Potwar Plateau, Pakistan. M. A. thesis, Dartmouth College, Hanover, New Hampshire, U. S. A.

Consult the preceding for further information.

Key words: Magnetostratigraphy, Dhok Pathan, siwaliks, Potwar.

B/102. Barnett, D.E., Chamberlain, C.P. & Zeitler, P.K., 1991. Oxygen isotope constraints on the genesis of young (<5 Ma) leucogranites from the Nanga Parbat-Haramosh Massif. EOS 72, p.525.

The Nanga Parbat massif contains some of the youngest granitic intrusions in the world, less than 5Ma. This paper provides oxygen isotope constraints for the genesis of these young leucogranites.

Key words: Geochemistry, leucogranites, oxygen isotopes, Nanga Parbat-Haramosh.

B/103. Barnett, S.G., Kohut, J.J., Rust, C.C. & Sweet, W.C., 1966. Conodonts from Nowshera reef limestones (uppermost Silurian or lowermost Devonian), West Pakistan. *Journal of Paleontology* 40, 435-438.

Eighteen previously described conodont species distributed among 11 genera are described from the Nowshera reef limestones of the northern part of West Pakistan. The identified species are lowermost Devonian and are equivalent in part to the western European *Spathognathodus oesternhornensis* and *Icriodus woschmidtii* zones.

Key words: Palaeontology, limestone, reef, Siluro-Devonian, Nowshera.

B/104. Barnicoat, A.C. & Treloar, P.J., 1989. Himalayan metamorphism-an introduction. *Journal of Metamorphic Geology* 7, 3-8.

This is an introduction to a special issue of the *Journal of Metamorphic Geology* edited by the two authors. Following introductory comments on geological evolution of the Himalayas, very brief account of metamorphism and the contained papers is given. Two papers (Treloar et al. and Chamberlain et al.) dealing with Pakistan Himalaya are summarized elsewhere.

Key words: Metamorphism, Himalaya.

B/105. Barry, J.C., 1980. Occurrence of a Hyaenodontine Creodont (Mammalia) in the Late Miocene of Pakistan. *Journal of Paleontology* 54, 1128-1131.

A recently discovered hyaenodontine mandible from the Nagri Formation of northeast-ern Pakistan extends the stratigraphic range of the Creodonta into a considerably younger geological period than previously known. An estimated age of eight to nine million years (N. M. Johnson, pers. comm.) makes this specimen two or three million years younger than the proviverrine *Dissopsalis carnifex* Pilgrim, previously the youngest known hyaenodontid (Pilbeam et al., 1977). By comparison hyaenodontids apparently became extinct in North America during the early Arikareean Land Mammal Age at approximately 27 million years (Macdonald, 1970; Mellet, 1977); in Europe during the middle Miocene (Helbing, 1925); and in Central Asia in the middle or late Oligocene (Mellet, 1968, 1977). In East Africa creodonts were still present in the middle Miocene, approximately 14 million years ago (Savage, 1965, 1978), while in North Africa a specimen was found in beds that may be as young as 12 million years (Savage, 1978; Cooke, 1978). By contrast in Pakistan there were at least four genera of hyaenodontids as recently as 12 million years ago. The recently discovered mandible was found in situ by Grant Meyer (then of the Yale A recently discovered hyaenodontine mandible from the Nagri Formation of northeast- ern Pakistan extends the stratigraphic range of the Creodonta into a considerably younger geological period than previously known. An estimated age of eight to nine million years (N. M. Johnson, pers. comm.) makes this specimen two or three million years younger than the proviverrine *Dissopsalis carnifex* Pilgrim, previously the youngest known hyaenodontid (Pilbeam et al., 1977). By comparison hyaenodontids apparently became extinct in North America during the early Arikareean Land Mammal Age at approximately 27 million years (Macdonald, 1970; Mellet, 1977); in Europe during the middle Miocene (Helbing, 1925); and in Central Asia in the middle or late Oligocene (Mellet, 1968, 1977). In East Africa creodonts were still present in the middle Miocene, approximately 14 million years ago (Savage, 1965, 1978), while in North Africa a specimen was found in beds that may be as young as 12 million years (Savage, 1978; Cooke, 1978). By contrast in Pakistan there were at least four genera of hyaenodontids as recently as 12 million years ago. The recently discovered mandible was found in situ by Grant Meyer (then of the Yale Peabody Museum) at Yale-Geological Survey of Pakistan locality Y311. Judging from the preservation of a delicate predepositional fracture on the ascending ramus there is little possibility the mandible has been reworked. Locality Y311 is one of the richest localities yet found by the Yale-GSP group and is undoubtedly the same locality from which many fossils of Pilgrim's "Nagri Stage" fauna came (Pilgrim, 1939). This locality has also been worked by Dehm and von Koenigswald (Pilbeam et al., 1977). Locality Y311 is located in the type section of the Nagri Formation near the village Sethi Nagri. The locality has been dated by paleomagnetic methods at between 9.7 and 8.3 million years (N. M. Johnson, pers. comm.). The fauna is highly varied and includes among the mammals *Sivapithecus indicus*, *Gigantopithecus* cf. *G. bilaspurensis*, *Percrocuta carnifex*, the small bovid *Elachistoceras khauristanensis* (Thomas, 1977), and *Hipparion* (s.l.), as well as a probable para- doxurine carnivore. Other mammal

groups still being studied include several suids and bovids, giraffes, anthracotheres, tragulids, rodents, rhinoceroses, and a deinother. At least one bird has also been recovered. The ecological affinities of this fauna are not clear.

Key words: Palaeontology, vertebrates, Miocene, siwaliks.

B/106. Barry, J.C., 1983a. Biostratigraphic problems of the Siwaliks of the Potwar Plateau of Pakistan. *Geological Bulletin, University of Punjab* 18, 68-73.

Pilgrim's faunal zones of Neogene terrestrial sediments of Potwar are rejected. Instead biostratigraphic interval-zones are proposed, based on extinction of fauna. Four interval-zones, each of 2 m.y. duration, are characterized.

Key words: Biostratigraphy, siwaliks, Potwar Plateau.

B/107. Barry, J.C., 1983b. *Herpestes* (Viverridae, Carnivora) from the Miocene of Pakistan. *Journal of Palaeontology* 57, 150-156.

Fossil remains of small canivores from Pakistan are referred to as *Herpestes*, the common mongoose of Asia and Africa. The material belongs to three separate, but indeterminate species. The oldest species may be as old as 10 million years, while the youngest is 7 million years. These specimens are the first fossil records of *Herpestes* in Asia and may be the earliest record of the genus.

Key words: Palaeontology, vertebrate, siwaliks, Potwar.

B/108. Barry, J.C., 1984a. A summary of data file structure and data standards for the Yale-GSP Project-Siwalik fossil collections. In: Shah, S.M.I. & Pilbeam, D. (Eds.), *Contributions to the Siwalik of Pakistan*. Geological Survey of Pakistan, Memoir 11, 71-77.

Key words: Palaeontology, fossil collection, siwaliks.

B/109. Barry, J.C., 1984b. Middle Siwalik biostratigraphy of the Khaur region in northern Pakistan. *Geological Survey of Pakistan, Memoirs*, 11, 9-13.

Biostratigraphy of the middle siwalik of the Khaur area of Potwar is described. For comparison see Barry et al. 1980.

Key words: Biostratigraphy, siwaliks, Potwar.

B/110. Barry, J.C., Behrensmeyer, A.K. & Monaghan, M., 1980. A geologic and biostratigraphic framework for Miocene sediments near Khaur village, Northern Pakistan. *Peabody Museum Natural History, Yale University, Postilla* 183, 1-19.

This is a summary of the biostratigraphy of Miocene Siwalik molasse sediments near Khaur. The text is accompanied by three figures and three tables.

Key words: Biostratigraphy, Miocene, siwaliks, Potwar.

B/111. Barry, J.C. & Cheema, I.U., 1984. Notes on a small fossil collection near Gali Jagir on the Potwar Plateau of Pakistan. In: Shah, S.M.I. & Pilbeam, D. (Eds.), *Contributions to the Siwalik of Pakistan*. Geological Survey of Pakistan, Memoir 11, 15-18.

Key words: Palaeontology, siwaliks, Potwar.

B/112. Barry, J.C., Jacobs, L.L. & Kelley, J., 1986. An early middle Miocene catarrhine from Pakistan with comments on the dispersal of catarrhines into Eurasia. *Journal of Human Evolution*, 15 (6) 501-508.

An isolated catarrhine primate molar from the Kamlial Formation of northern Pakistan is shown by magnetic polarity stratigraphy to be 16.1 My old, making it the oldest securely dated catarrhine in Eurasia. It is most similar to small catarrhines from East Africa and China, particularly *Micropithecus* Fleagle and Simons, 1978, and *Dionysopithecus* Li, 1978. It is distinctly different from European pliopithecids, suggesting that the dispersal of catarrhines into Europe and Asia, while broadly contemporaneous, took place in the context of at least partly independent immigration events. In terms of morphology, the specimen sheds no more light on the ancestry of gibbons than do other small early Miocene catarrhines with a phenetic resemblance to gibbons. However, as part of the Siwalik Miocene provincial fauna which has clear affinities with the modern fauna of Southeast Asia, it is perhaps a more likely candidate for gibbon ancestry than other purported gibbon ancestors.

Key words: Magnetostratigraphy, palaeontology, siwaliks, Potwar.

B/113. Barry, J.C., Johnson, N.M., Raza, S.M. & Jacobs, L.L., 1985. Neogene mammalian faunal change in southern Asia: correlations with climatic, tectonic and eustatic events. *Geology*, 13, 637-640.

The fluvial Neogene Siwalik formations of northern Pakistan span long time intervals with only minor hiatuses and, being highly fossiliferous, are uniquely suited for studies of change in mammalian faunas. Magnetostratigraphic correlations of a critical stratigraphic section give dates for 45 middle and late Miocene biostratigraphic events. These mark either first appearances or extinctions in the mammal fauna and show that in the Siwaliks there were major fauna turnovers at between 20 and 16 Ma and at 9.5 and 7.4 Ma. Two minor faunal events are dated at 13.2 and about 12 Ma. Many species making their first appearance were immigrants from Europe or Africa and indicate when connections to those regions existed. Immigration and extinction were the dominant modes of faunal change; in situ evolution was much less important. The Siwalik biostratigraphic record correlates closely to climatic, oceanographic, and tectonic events, which probably controlled immigration into southern Asia. Abiotic events were therefore important factors affecting evolution of the mammal communities.

Key words: Palaeontology, tectonics, biostratigraphy.

B/114. Barry, J.C., Lindsay, E.H. & Jacobs, L.L., 1982. A Biostratigraphic zonation of the Middle and Upper Siwaliks of the Potwar Plateau of northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 37, 95-130.

Two biostratigraphic reference sections are designated for the middle and upper Siwalik formations of northern Pakistan. The stratigraphic ranges of 41 mammalian taxa are established in the reference sections and the two sections are correlated to each other and to the standard Magnetic Polarity Time Scale by the magnetic-polarity stratigraphy. The resulting stratigraphic and magnetostratigraphic framework is used to define four contiguous biostratigraphic interval-zones. The proposed interval-zones are bounded by five important faunal events which are identified in the reference sections. The four proposed interval-zones and the approximate ages in the reference sections of their lower and upper boundaries are: (1) the "Hipparion s.l." Interval-Zone 7.4–9.5 m.y. B.P.; (2) the *Selenoportax lydekkeri* Interval-Zone 5.3–7.4 m.y. B.P.; (3) the *Hexaprotodon sivalensis* Interval-Zone 5.3-2.9 m.y. B.P.; and (4) the *Elephas planifrons* Interval-Zone 2.9-1.5 m.y. B.P. The paleomagnetic and biostratigraphic evidence indicates that the Tatrot Beds, from which Pilgrim developed his "Tatrot Faunal Zone", are between 2.5 and 3.4 m.y. B.P., with a preferred maximum age of 2.9 m.y. B.P. The biostratigraphic evidence indicates the Sethi Nagri locality (Y311)—the primary source of Pilgrim's "Nagri Faunal Zone"—is in the "Hipparion s.l." Interval-Zone. The paleomagnetic evidence suggests an approximate age of 9 m.y. B.P. A major faunal event at 9.5 m.y. B.P. introduced equids, suids, and large giraffes from Eurasia into the Indian subcontinent. A second, more diffuse faunal event between 5.3 and 2.9 m.y. B.P. introduced several African taxa as well as Eques and cervids from Eurasia.

Key words: Biostratigraphy, magnetostratigraphy, siwaliks, Potwar.

B/115. Barry, J.C., Morgan, M.E., Flynn, L.J., Pilbeam, D., Jacobs, L.L., Lindsay, E.H., Raza, S.M. & Solouniass, N., 1995. Patterns of faunal turnover and diversity in the Neogene Siwaliks of northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 115, 209-226.

The fluvial Neogene Siwalik formations of northern Pakistan contain a long and richly fossiliferous sequence of terrestrial vertebrate faunas in which patterns of faunal turnover and changes in diversity can be documented and analyzed for intervals having durations of 0.5 m.y. The complete sequence extends from circa 18.5 to 1 Ma, but the part between 18.5 and 5.5 Ma is best sampled, and most intervals within it are well represented.

Thirteen orders of Siwalik mammals have been identified, with well-sampled intervals having 50 or more species. Most Siwalik mammals, however, are either rodents or artiodactyls. Bovids are the most common and most speciose of the larger mammals, while murid and "cricetid" rodents dominate the small mammal assemblages.

Between 18.5 and 5.5 Ma species diversity varied considerably. Among artiodactyls and rodents the number of species first increased between 15 and 13 Ma and then fell. Data on stratigraphic ranges of rodents and artiodactyls show that faunal change in the Siwaliks was episodic, occurring during short intervals with high turnover followed by longer periods with considerably less change. Maxima of first appearances occurred at approximately 13.5 and 8.5 Ma, while maxima of last occurrences were at 12.5 and 8.0 Ma.

Some of the observed faunal events can be correlated to climatic and environmental changes. The Middle Miocene diversification occurred during a period of global cooling, while the latest Miocene decline in diversity and increased turnover accompanied oxygen and carbon isotopic changes that correlate to globally increasing seasonality and aridity. Other correlations are ambiguous. The marked decrease in diversity and the major turnover events between 13 and 8 Ma do not correspond to known local or global events.

The Neogene Siwaliks and Paleogene Bighorn-Crazy Mountains sequence in Wyoming and Montana share many similarities. They have equivalent levels of temporal resolution and similar levels of completeness of their fossil records. Siwalik ordinal abundance and diversity patterns differ markedly from those of the Paleogene, but generic, and probably species, diversity was approximately the same, although the Siwalik faunas may have been slightly less diverse. Over time, changes in diversity were of comparable magnitude, with monotonic trends persisting for more than 5 million years. The magnitude of faunal turnover was also similar, ranging from less than half to 3.5 times that expected. In both sequences faunal change appears to have been episodic, with strong pulses between intervals of low turnover. The Siwaliks, in contrast to the Paleogene sequence, may have had more distinct pulses and longer intervals between pulses. Neither sequence has peaks of first occurrences coinciding with peaks of last occurrences.

Key words: Palaeontology, biostratigraphy, siwaliks, Potwar.

B/116. Barry, J.C., Morgan, M.E., Winkler, A.J., Flynn, L.J., Lindsay, E.H., Jacobs, L.L. & Pilbeam, D., 1991. Faunal interchange and Miocene terrestrial vertebrates of southern Asia. *Paleobiology*, 17, 231-245.

Problems of stratigraphic completeness and poor temporal resolution make analysis of faunal change in terrestrial sequences difficult. The fluvial Neogene Siwalik formations of India and Pakistan are an exception. They contain a long vertebrate record and have good chronostratigraphic control, making it possible to assess the influence of biotic interchange on Siwalik fossil communities. In Pakistan, the interval between 18 and 7 Ma has been most intensively studied and changes in diversity and relative abundance of ruminant artiodactyls and muroid rodents are documented with temporal resolution of 200,000 years. Within this interval, diversity varies considerably, including an abrupt rise in species number between 15 and 13 Ma, followed by a decline in ruminant diversity after 12 Ma and a decline in muroid diversity in two steps at 13 and 10 Ma. Significant changes in relative abundance of taxa include an increase in bovids between 16.5 and 15 Ma, a decrease in tragulids after 9 Ma, and a very abrupt increase in murids at 12 Ma. Megacricetodontine rodents also decrease significantly at 12 Ma, and smaller declines are recorded among myocricetodontine and copemyine rodents after 16 Ma. An increase of dendromurine rodents at 15.5 Ma is also observed. There is also a trend of progressive size increase among giraffoids and bovids throughout the sequence. We have also investigated relationships between biotic interchange and diversity, body size, and relative abundance, concluding that (1) the rapid increase in ruminant and muroid diversity was largely due to immigration, whereas in situ speciation had only a secondary role; (2) during intervals of increasing diversity, resident lineages did not have higher than average rates of in situ speciation; (3) during intervals with rising diversity, greater extinction did not accompany increased immigration; (4) during intervals with falling diversity, there may have been greater extinction in recently invading lineages; and (5) change in diversity was independent of changes in relative abundance and body size.

Key words: Palaeontology, magnetostratigraphy, biostratigraphy, siwaliks, Potwar.

B/117. Bartole, R., 1978. Structural lineaments of the Central Asian orogenic syntaxis from LANDSAT imageries. *Atti Rend Accademy Nazionale di Lincei*, series VIII. 64(5), 485-489.

Key words: Structure, orogeny, syntaxis, GIS.

B/118. Bashir, M., 1992-93. Structure, stratigraphy, micropalaeontology and petrography of Jabri-Bodla areas Districts Haripur & Abbottabad, Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 78p.

The Jabri-Bodla area lies in the Attock-Hazara fold-and-thrust belt of the northwestern Himalaya of Pakistan. Precambrian to Cenozoic sedimentary rocks are folded and imbricated during the Tertiary-Himalayan collision. The oldest exposed stratigraphic unit is the Precambrian Hazara Formation. The formation is composed of slates, shales and phyllites. The presence of ripple marks and graded bedding shows that the Formation is deposited in shallow water turbidity environments. The Middle Jurassic Samana Suk Formation, Late Jurassic to Early Cretaceous Chichali Formation and Early Cretaceous Lumshiwal Formation were deposited in shallow marine conditions. The late Cretaceous Kawagarh Formation was deposited in deep to shallow water shelf environment. The late Cretaceous to Early Paleocene uplift in the area caused the regression of the Tethyan Sea. The Tethyan regression initiated the deposition of ferruginous sandstone of the Hangu Formation. The lower Tertiary sequence of Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margalla Hill Limestone and Early to Middle Eocene Chorgali formation mark the complete cycle of transgression and regression of the Tethyan Ocean. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockharia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show the tropical sub-tropical open sea upper slope to outer shelf environments. The Paleocene-Eocene boundary cannot be marked on the basis of microfossils in the area because the Patala Formation lacks microfossils. However, the tentative Paleocene-Eocene boundary between the Patala Formation and the Margalla Hill Limestone can be marked at the base of Margalla Hill Limestone on the basis of first appearance of Early Eocene microfossils.

The structural analysis of the investigated area shows that the Precambrian to Eocene rocks record at least two major events of deformations i.e D1 and D1 deformation phases. The D1 deformation is divided into D1a and D1b deformation phases. The D1a is associated with the southeast-directed thrusts and southeast vergent F1 folds. The second phase of D1b deformation is related with the backsteeping of the major thrusts and northwest overturning of the major F1 folds. The northwest plunging F2 cross-folds are recognized as D2 deformation phase in the project area. These F2 cross-folds are related with the development of the Hazara-Kashmir syntaxis.

Key words: Structure, stratigraphy, palaeontology, petrography, Hazara.

B/119. Bashir, R.M. & Ahmed, Z., 1966. Report on Ambela area (Swat). M.Sc. Thesis, Punjab University, 89p.

The Ambela medium- to coarse grained granite covers a large area in Buner, which constituted the southern part of the former Swat State. Preliminary geology and petrography of the granitic and related rocks is given in this thesis.

Key words: Petrography, granites, Buner.

B/120. Basit, M.A., Hasan, S.K., Fazil, M. & Ahmed, Z., 1990. Total chlorine in Pakistan coal. *Proceedings, First SEGMITE Conference on Industrial Minerals*, Peshawar, 88-91.

The contents of chlorine, moisture, ash, volatile matter, fixed carbon, total sulphur and calorific values (BTU/Lb) are determined in coals in various parts of Pakistan, and the chlorine content is compared with averages of the coals from USA (Illinois Basin, eastern USA and western USA) and worldwide average. Total chlorine content as chloride in Makerwal is 155 ppm and in Kotli 1936.6 ppm, which are much much higher than those of the USA and the world.

Key words: Coal analysis, Makerwal, Salt Range, Kotli, AJK

B/121. Basra, M.A., 1994-96. Geotechnical studies for land slide problems along Karakoram Highway from Danyor to Aliabad. M.Sc. Thesis, Punjab University, Lahore, 124p.

This thesis mainly composed of the study of about land sliding along Karakoram Highway from Danyor to Aliabad. A brief description of other Geotechnical features is also included in the thesis. The Geological map shows the different types of socks present in the project area.

Detailed study has been made in the project area to collect the data about discontinuities as joints, which play the dominant role in case of sliding in hard rocks. This data has been plotted on equal-area stereonet to check the stability of the slopes. In case of sliding in soft material like alluvial fan, samples were collected and tested for detailed analysis. Finally, on the basis of this analysis, the road is classified into stable, potentially unstable and unstable regions.

Key Words: Engineering geology, landslides, Hunza, KKH.

B/122. Bassoulet, J.P., Boulin, J., Colchen, M., Marcoux, J., Mascle, G. & Montecat, C., 1980. L'évolution des domaines tethysiens au pourtour du bouclier indien du Carbonifère au Crétacé. BRGM memoirs, 115, 180-198.

This is not a Pakistan specific paper. It deals with the evolution of the Carboniferous to Cretaceous rocks of the Tethyan domains along the periphery of the Indian shield.

Key words: Tectonics, Tethys, Carboniferous, Cretaceous, Indian shield.

B/123. Bates, R.H., 1986. The Ulugh Muztagh. American Alpine Journal 28, 27-38.

For me the long quest began in 1966 on the slopes of Mount Russell in the Alaska Range, where I shared a two-man tent with Eric Shipton. Adams Carter had invited me to join him on an expedition and now we were sheltering from a week-long storm that drove in from the coast. Finally, we looked at each other and yawned.

"Eric," I said, "if you were doing everything all over again, what would you change?"

"Well, I certainly wouldn't spend six years trying to climb Mount Everest. That's too long for any mountain."

"What would you have done instead?"

"Somehow I would have got to the Ulugh Muztagh."

"The Ulugh Muztagh? What's that?"

"It's a big mountain in Central Asia—nobody knows how high—reached in the 1890s by an Englishman who surveyed it as being well over 25,000 feet. It's probably the hardest place in the world to get to, harder than the Antarctic, because the land around it is so high and nobody lives near it. Bill Tilman and I had hoped to get there but it is too far in."

That was all I knew about the mountain for years, but in 1973 I found that Nick Clinch had also talked to Eric. In no time, Nick and I decided to become partners in a quest: to get to the mountain, find its height and climb it—and together we began to push ahead. First Betsy Clinch, Nick's wife, found an article by an Englishman, St. George Littledale, in an 1896 issue of the Geographical Journal of the Royal Geographical Society. Littledale, his wife, his terrier and his nephew ("of Oxford University boating renown") in 1895 had passed the Ulugh Muztagh and surveyed it while attempting to reach Lhasa from the north. The article had a map showing his route from the Southern Silk Road into Tibet, and told how after three weeks on horseback they had reached the "Great Ice Mountain" (Ulugh Muztagh in Turki). Our next success was securing publicly available satellite photos of the mountain, showing great glaciers flowing out from it, but what we could not secure was permission from the Chinese to let us go there. In the days before ping-pong diplomacy we even tried to get permission for a joint China-Pakistan-U.S.A. expedition, under Pakistan leadership, but the Chinese turned that down too.

In February, 1979 in Beijing, I again applied, this time in person to Mr. Shi Zhan Zhun of the Chinese Mountaineering Association, but learned that "the area is not yet open to foreigners"; and annually thereafter we continued to apply until late January, 1985 when we learned that our mountain had suddenly been made available to somebody else. At this, Nick Clinch rose from a sick bed, flew to Beijing and discussed our previous negotiations. To our delight the Chinese agreed that the permission should be ours, but the agreement was not finally signed until May 30, and that only after Nick had made two more visits to China.

During the three months that followed, Nick Clinch, an old pro at organizing expeditions, showed his usual skill. By September 11, when the eight members of the expedition left by air from San Francisco, we were what we called a

“geriatric expedition.” I had told Nick I was by now too old to be any use, but he insisted on my going. The real climbers, in addition to Nick, starting with the oldest, were Pete Schoening (in charge of equipment), Tom Hornbein (also our doctor), Jeff Foott and Dennis Hennek. Peter Molnar and Clark Burchfiel, distinguished geologists from M.I.T, both with wide experience in China and Tibet, completed the party. The Chinese were supposed to have twelve climbers, but by the time we had flown to Beijing and on to Urumchi (Woolamoochi) the number had grown to 16, with 27 support personnel, including 12 drivers, a cook, 4 geologists, a doctor, a radioman, photographers, reporters, and so forth. This joint mountaineering expedition was to be the first the Chinese shared with Americans. (They had had only one previous joint expedition, one with the Japanese a few months before.) Also, as our Chinese hosts kept telling us, we were the first foreigners to be allowed into the southern part of the Xinjiang since Chinese Turkestan became part of the People’s Republic 30 years ago. Celebration of that event explained the size of our Chinese team, for ascent of the Ulugh Muztagh was to be a major part of the celebration activities. Chinese climbers are all paid professionals, and naturally success on the mountain was to be of the greatest professional importance to our partners.

Burchfiel and Molnar were already in China when the other six of us took off from San Francisco on September 11. We had 87 bags or boxes with us, including identical personal equipment items for eight Americans and twelve Chinese. In Beijing we were warmly greeted by old friends of the Chinese Mountaineering Association, who gave us a splendid banquet. It was here that we met Governor Tehmer of the Xinjiang; Lu Ming, head of the All China Sports Federation of the Xinjiang and our expedition’s overall leader (though she would not go to the mountain); and Wang Zheng Hua, in charge of transportation to and from the mountain, and of all Chinese on the mountain. He had led the recent attempt on Namcha Barwa.

In Urumchi, which we reached by air, we were generously welcomed again. It was here that we agreed on the purposes of the expedition: to climb the mountain, find its height, and whether or not it is a volcano. If it were, it would be the world’s highest. At Urumchi too, we checked the condition of our survey instruments. These consisted of a satellite surveyor (a computer that uses the Doppler effect to establish latitude, longitude and altitude), a Uniranger electronic distance measuring device (borrowed from Bradford Washburn of the Boston Museum of Science), a 7-crystal cluster to use with it (loaned by Cubic Precision), and a Kern T-2 theodolite and tripod loaned by the Thompson School, University of New Hampshire. All were in good shape, but when we opened the box whose bill of lading declared it held the antenna for the satellite surveyor, we found only spare parts. Someone had goofed. We were to leave at dawn two days later on our 1,100-mile safari to the mountain. We were shocked. It looked as if it would now be impossible to find the height of our mountain, a major responsibility of the expedition.

I won’t go into detail about what happened, but some brilliant work on the part of someone in the company, and by the Chinese Mountaineering Association in Beijing and Urumchi, ended with a jeep chasing us, three men taking turns driving night and day, and catching us near the point where they could no longer follow.

The 1100-mile drive to the mountain in seven huge army trucks, three land-rovers and two jeeps was in many ways the most interesting part of the expedition, but hard travelling. It took ten days, including two days off to work on the vehicles. At Korla, where we expected to find a small town, we instead found a city of 120,000, with ten hospitals, a tire factory, a washing machine factory, and so on. Beyond it a yellow brick road led us to Rojeng, formerly Charklik, where Marco Polo had stopped many centuries ago and Sven Hedin had wintered at the turn of the last century. From here we continued along the north side of the Altyn Tagh Range, finally crossing it on a beautifully engineered road. We also crossed the great Altyn Tagh fault before reaching a big asbestos mine, our jumping-off point. Now we headed out across the roadless desert, finding hard going for the trucks. After a night in a game warden’s house, the last habitation, we pushed on to Acchikul Lake, 40 miles long, where we saw brown-headed seagulls, Orongo antelope, wild asses, a number of yaks, bears, a wolf and a fox. On the second of October, long after the first view of our handsome peak, we crossed an arid valley, forced our way up a canyon and set up our Base Camp tents on the east side of the mountain at what we later learned was over 17,400 feet. Burchfiel and Molnar learned that the Ulugh Muztagh strictly speaking is not a volcano, though it is a result of volcanic processes*.

Our plan at Urumchi had been to hold a sort of short training camp at Base, testing one another’s skills, learning to work together despite language difficulties and becoming acclimatized, but Wang Zheng Hua was anxious to get to work on the mountain. After a flag raising ceremony involving the entire group, with Pete Schoening carrying the American flag, three Chinese went off to reconnoiter. The Chinese had been on the mountain for the first time a year before, when they had made a brief attempt to climb it. Accordingly we followed their choice of route, though a more thorough reconnaissance would have improved it. Soon all climbers began packing to Camp I, with every man responsible for carrying his sleeping bag, personal gear and a good load of expedition equipment, for there were no porters. At age 74, I was no longer good at load carrying and I determined to focus entirely on the survey and try to be useful at Base Camp thereafter.

By October 9 Camp I was well established at the snout of a glacier, reached by a climb over a rounded foothill and a descent of several hundred feet; and shortly afterward loads began to be cached five or six miles up the glacier at what was to be Camp II. Peter Molnar and Clark Burchfiel now showed the advantage of their acclimatization, built up during the past summer's geological expedition. They began to help the other load carriers. Hennek, Foott and Tom Hornbein were carrying big loads but Pete Schoening was getting over some sort of flu (which Nick caught later) and Nick is slow to acclimatize. Tom, as our climbing leader, was also working out routes and the logistics of where food and equipment would be needed, and how much.

Meanwhile our survey was moving along. All equipment had survived the rough bouncing around, and the Doppler Satellite Surveyor had by now been moved to a site on the great outwash plain below our canyon and left running. From there, despite a furious wind, Molnar, Burchfiel, Schoening and I completed our theodolite work. Peter Molnar's final computations from observations at three points on our seven-mile baseline, allowing for curvature of the earth and the difference between geoid height and sea level height, gave us at a much later date a final figure of 6,987 meters $\pm$ 10 meters for the higher peak—roughly a disappointing 23,000 feet.

On the 12th, Pete Schoening felt better and left Base Camp for Camp I. From then on he and Tom Hornbein spearheaded the route above Camp II, which by now had been occupied. Next day Nick Clinch returned to Base Camp with a bad cold that had settled in his chest and seemed more like pneumonia. He was utterly exhausted when he arrived and looked very ill. On the 13th Tom, Pete Schoening and Clark Burchfiel began putting in ice screws to fix the route to Camp III, but the wind was very bad. Weather continued bad with some snow on the 14th and wind and cloud on the 15th, but Pete and Tom moved higher and established a cache at 6,200 meters. At Camp II the next morning there was nearly a meter depth of blown snow and no possibility of climbing. On the 17th several Chinese and Jeff and Dennis returned to Base to conserve food packed to Camp II. They told of big drifts at II and development of potential windslab danger. We woke to light snow on the 18th, but the weather cleared and Foott, Hennek and several Chinese took loads to Camp II.

All of us by now were worrying about whether the mountain would be climbed in the time left to us. On the morning of the 19th I went with Zhou Zheng and the Chinese geologists to see where two continents had met long, long ago. We saw a mass of serpentine rock that had been sea bottom at the time Gondwanaland had pushed into southern Asia millions of years ago and formed India. The sea bottom had been thrust northward over the region of the Himalayas and even over the Kun Lun to reach its present position. On our return, to our great surprise, Foott and Hennek appeared at Base Camp. They were to have been our summit team, but a major misunderstanding had developed about the number of Chinese climbers they could safely lead to Camp III and higher. Original plans had been changed. At this point Foott and Hennek came down to Base. Nick, now feeling stronger, pushed back up to Camp II the same day, and Tom Hornbein and Pete Schoening came down to II to try to sort out the confusion. This put them out of position for an immediate summit climb. Tom had been pushing himself very hard and was not feeling well, and so after a discussion at II he continued on down to Base Camp to recuperate. Next day, October 20, the weather was perfect and so the Chinese at Camp III moved up to Camp IV within easy striking distance of the summit. Since bad weather was still likely any day and we had such a short time left, we urged Wang Zeng Hua to tell his man at IV not to wait for Pete Schoening, who was returning to III with Burchfiel and Molnar, intending to go for the summit on the 22nd. The night of the 20th-21 st two Chinese photographers lost the route near Camp IV, and were not found and brought in—too cold to speak—until three A.M. The members of the assault party were searchers, and the effort took a good deal out of them. They did not leave Camp IV until after lunch and did not reach the summit until 7:28. When they radioed the good news to Base Camp there was pandemonium, but we were all concerned about their getting down. They were Hu Fengling, Zhang Baohua, Ardaxi, Mamuti and Wu Qiangxing.

Pete Schoening and his companions at Camp III did not get the news that evening. They went to bed early, planning an early start so as to climb the peak and return the same day. When they waked at dawn on a clear, cold morning, however, they saw that there had been an accident. A figure was lying unmoving on a snowfield far below, while another, who seemed hurt too, was trying to pull him. That changed everything. You can't go for a summit when injured men you can help may be dying. They went down.

They reached the injured men at about the same time Nick Clinch did, for three members of the five who climbed the mountain had arrived in Camp II late the night before, but two were missing, and he had gone out to look for them. All had come down by a different route from the one they had used to go up—and after sunset! Both injured climbers had had a 500-meter fall. One of them, Hu, looked so badly hurt that Clinch and Schoening thought he might not live until they reached Camp II, but later it was determined that despite multiple bruises his worst injury was having badly frozen feet. His companion was badly bruised too, but somewhat better. Hu's friend Guo, our interpreter, had reached Hu before anyone else, and soon four Chinese and four Americans combined efforts and were able to get the injured ones across the ice and up to Camp II.

There was now no chance for a second climb of the mountain and the following morning (the 23rd) everyone on the mountain began moving to Base. Hu had to be carried, a process painful for him and for his carriers, while his companion and a third Chinese who had also had a fall were able to limp down on their own. It took a long time to get everyone down. Some arrived after midnight and Hu and his carriers did not get in until nearly seven on the morning of the 24th. Dennis Hennek and Tom Hornbein did marvelous work caring for them as they came in. Our interpreter at this point was so moved by the care the Americans were taking of the Chinese that he remarked, "Americans must be the kindest people in the world."

On the 24th there was a great sorting and breaking camp, and next day after the Base Camp area was in large measure policed the long journey back began. It was far colder than when we had arrived, we were low on food and everyone was eager to get back. We drove straight to Acchikul Lake, stopping only to pick up a fuel cache, but stayed only long enough to gulp some quick-cooking noodles. It was dark now, but we all wanted to go on. Tom Hornbein and I, who rode in truck number six, will never forget that bumpy drive across the endless, snow-covered, deserted land, shining in the moonlight. Siberia can not be more desolate. At dawn we stopped for an hour or more at the warden's cabin, then continued our hard driving to Mangyai Chen, which we reached 27 hours after leaving Base Camp. We were here a day, then drove on to Ro-jeng, where eight pretty dancing girls cavorted ahead of us as we marched two or three hundred yards through streets lined with people. Banners crossed the street exhorting people to "follow the example of the joint (sic) expedition." If they followed our example at the huge banquet that followed, the price of melons, pear-apples and all sorts of their delicacies must have soared, for we were very hungry. That day we continued on to Army Camp 34, where we were welcomed by another delicious banquet, which ended at one o'clock in the morning. Then on again towards Korla. Some 20 or 30 kilometers before we reached the city we found Lu Ming, the marvelous Chinese woman who was the joint leader, waiting for us. She hugged us all, with tears running down her cheeks, saying again and again, "Oh, I was so worried about you." She told us of a celebration in Korla and she was right. Welcoming banners flew across the street and several thousand people lined the sides. Flashbulbs popped, firecrackers went rat-a-tat, big drums boomed, school children squealed, hollered or tootled horns, and pretty girls came up to pin rosettes on us and give us big bunches of artificial flowers. Heady stuff.

Then there was a further welcome at Urumchi, with Governor Tehmer, and the Party Secretary and others standing in the snow to greet us. Two days later came the big celebration. We put on the black suits and knitted red ties especially made for a magnificent victory banquet in the newly built Great Hall of the People. A whole roast sheep was wheeled in as a special expression of friendship, and Chinese and Americans ate, drank and danced together with a warmth and enthusiasm none of us will ever forget.

A few days later, after warm send-offs in Urumchi and Beijing, and still wearing our hats from Korla, we were on the way home. Long before our arrival, however, there had been a moment when Nick and I looked at each other, raised a glass and murmured, "To ERIC SHIPTON."

Measurement of the Altitude of Ulugh Muztagh

The altitude and position of the Ulugh Muztagh were much easier to determine in 1985 than they were in 1895 because of the extraordinary array of new surveying equipment that has been developed in recent years. The Magnavox Company leased the party its latest position-finding Geociever, the University of New Hampshire loaned one of its light but precise Kern T-2 theodolites, and Boston's Museum of Science loaned its Keuffel & Esser Uniranger electronic distance-measuring instrument.

Bob Bates, who was in charge of these observations, working closely with Bradford Washburn, made detailed surveying plans long in advance of the actual expedition, knowing with certainty that the peak was surrounded with a treeless desert which would make intervisibility of many survey stations extremely simple. Also the high desert atmosphere seemed to assure virtually perfect visibility (given good weather, which was rarely the case!).

Because the peak was too far from Base Camp to make a single direct electronic distance-measurement from there to its summit, it was planned to have three valley-survey-stations, arranged so as to have a precise baseline almost twice as long as the Uniranger's 5-mile limit. The summit of the peak was also definite enough so that it could be clearly identified from all three stations without the need for installing a target on top-extremely lucky in view of the problems later encountered by the climbers who actually got there.

Using the theodolite and the Uniranger, a basic triangle was established with all three points intervisible and with both of the summits of the Ulugh Muztagh also visible from all three. The composite baseline was 10,460 meters (6.5 miles) long, giving excellent strength to this little survey network. The distances to the summit from these stations were 22, 18 and 14 km. (13.6, 11.2 and 8.7 miles).

The Magnavox Geociever was used to determine the geographical location of this base network, observing Doppler signals resulting from scores of passes by five navigation satellites. Unremitting cold, wind and cloudiness, as well as the 18,000-foot altitude, made this otherwise relatively simple work both miserable and difficult.

The results of the Doppler observations were computed for the expedition by the Defense Mapping Agency in Washington and the triangulation network computed and balanced by Prof. Peter Molnar.

This field work determined the altitude of the highest peak of Ulugh Muztagh to be 6987 meters (22,923 feet) with an estimated possible error of ± 6 to 10 meters. This is compared with the Chinese determination of the peak's altitude to be 6970 meters (22,867 feet)—and Littledale's 1895 estimate of 7723 meters (25,338 feet). The geographical coordinates of the Base Camp are now considered to be North Latitude: $36^{\circ} 25' 09.2357$ East Longitude $87^{\circ} 29' 47.264$ ".

Although the long-fabled Ulugh Muztagh did not turn out to be nearly as high as everyone had hoped it would be, it is still indeed a fascinating mountain massif in the midst of some of the world's most exciting geology.

A detailed account of these observations may be found in the full report of the expedition which is on file at the Library of the American Alpine Club in New York City.

Key words: Geography, Muztagh, Karakoram.

B/124. Baticci, G. & Poretti, G., 1988. Gravity models of the deep structures of the Karakorum Range. Abstracts, 4th Himalayan- Karakoram-Tibet Workshop, Lausanne, Switzerland, p. 8.

A gravimetric modeling of the Karakoram Range has been carried out taking into account all the geophysical data available. The regional behavior of the Bouger anomaly has been computed interpolating with 2nd order polynomial surface gravity data available in the area along the Hindu Kush and Karakoram mountain ranges.

Four two-dimensional orders have been considered along profiles crossing the Kohistan-Kashmir areas. The first along the 1978 DSS profile, runs from Nanga Parbat to Karakul in the USSR and takes into account the results of the seismic processing, establishing the possible average values of thickness and density for the upper crust underneath. The second model fits the residuals on the same profile and the remaining two on the profiles crossing the Kohistan island arc region. The modeling of the residual has been planned considering the geophysical and geological data available from surface observations and the surface measured and tabulated densities existing in recent literature.

These models fit reasonably well the field results for a discontinuity at 10-15 km depth. In order to get an acceptable regional model along the DSS profile, according to the data of seismic survey, it appears that the density of the upper crust must be higher than the standard 2.67 g/cm^3 value. The trend of the seismic layers fits the regional gravity anomalies with a density contrast of 2.25 gcm^3 between the upper and lower crust and 0.7 g/cm^3 between the lower and the upper mantle.

Key words: Gravity, structure, Karakoram.

B/125. Batool, A., 1996. Application of geoelectrical and hydrogeological parameters for groundwater investigation studies in the proposed area for Quaid-I-Azam University Housing Scheme Islamabad. M.Sc. Thesis, Quaid-i-Azam University, Islamabad.

As the title indicates, this is a geophysical and hydrological investigation for groundwater in the university housing scheme.

Key words: Geophysics, groundwater, Islamabad.

B/126. Beaux (De) O., 1935. Spedizione Italiana al Karakorum Comandata da S.A.R. il Duca di Spoleto (1929). Mammiferi. Atti Soc. Ligustica Sc. Lett. Genova, 14, 61-84.

Key words: Italian expedition, Karakoram.

B/127. Baud, A., Atudorei, V. & Sharp, Z.D., 1996. Late Permian and Early Triassic evolution of the northern Indian margin carbon isotope and sequence stratigraphy. *Geodinamica Acta*, 9, 57-77.

The Northern part of Great-India underwent an early rifting phase in the late Paleozoic, just at the end of the large scale Gondwanian glaciation. The beginning of the rifting processes is marked by large hiatus and discontinuities (paraconformities) between the early or middle Paleozoic sedimentary succession and the discontinuous middle-late

Permian Traps and transgressive sediments. The Northern Indian passive margin consists of the present High and Lower Himalaya and a small part of the Indian craton and their sedimentary cover. The Permian rift shoulder is located in the Higher Himalaya, with part being in the underthrust Lower Himalaya. The rim basin landward of the shoulder) is well developed in the Pottawar -Salt Range area. From the rifting to the beginning of the drifting stages (early late Permian to late early Triassic time), the sedimentary evolution is characterized by three transgressive-regressive (T-R) second order cycles, two in the late Permian and one in the early Triassic. The break-up of the rift occurred during the second cycle (late Dzhulfian).

In the Salt Range area, these three T-R cycles have been subdivided in eight third order sequences, five sequences for the upper Permian and three for the lower Triassic.

At the end of Permian, hiatuses, gaps and local erosion of part of the margin are direct consequences of a first order relative sea-level fall; this is also the time of the largest extinction event of the Phanerozoic that deeply affected the carbonate productivity and the stratal patterns. With the following worldwide sea-level rise, a rapid and large scale transgression occurred in the early Triassic, well dated and recorded on the whole margin. High rate thermal subsidence gave way to generalized pelagic deposits about 2 My after the transgression.

Profiles of whole rock inorganic carbon and oxygen isotopes from Guryul Ravine and Palgham sections in Kashmir, Nammal Gorge and Landu sections in Trans Indus Ranges (Pakistan), Thini Chu section in Kali Gandaki Valley, Central Nepal are presented in connection with the sequence stratigraphic analysis. The upper Permian record of high positive $\delta^{13}\text{C}$ values are closely correlated with the second order T -R cycles and the third order sequences. The results presented in this study confirm the drastic drop of $\delta^{13}\text{C}$ from the high positive values that characterized the upper Permian to lower values in the lower Triassic time. Stratigraphic correlation problems in the lower Triassic using carbon isotope geochemistry are briefly discussed. A positive $\delta^{13}\text{C}$ excursion of 4-5‰ near the Smithian-Spathian substages boundary is observed for the first time.

The $\delta^{18}\text{O}$ values of samples from all the sections display major variations suggesting that the oxygen isotope record has been significantly affected by meteoric diagenesis, deep burial diagenesis or land monsoon signature.

Key words: Sedimentary, glaciation, Permian, Triassic, isotopes, sequence stratigraphy, Himalaya.

B/128. Beck, R.A., 1995. Late Cretaceous ophiolite obduction and Paleocene India-Asia collision in the westernmost Himalaya. Ph.D. Thesis, University of Southern California, Los Angeles.

Some information from the thesis is extracted in the following two descriptions

Key words: Cretaceous, ophiolite obduction, collision, Himalaya.

B/129. Beck, R.A., Burbank, D.W. & Sercombe, W.J., 1995. Evidence for a very Late Cretaceous to Paleocene Collision between India and Asia: Paleogeographic, isotopic and climatic implications. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The collision of India and Asia strongly influenced Cenozoic earth history. Decades ago it was argued that the Indian-Eurasian collision instigated not only the formation of the Himalaya, Karakoram and Tibet, but the wider deformation of Asia (Argand, 1924; Molnar and Tapponnier, 1975). Others have boldly suggested that the collision drove global plate reorganization (Patriat and Achache, 1984). Regardless of disagreements on the details, many would argue that the Indian-Eurasian collision was the most important tectonic event of the Cenozoic or even the latest Cretaceous (see Burchfiel and Royden (1991) for summary).

More recent research has suggested additional fundamental links between the Indian-Eurasian collision and the Earth's oceanic circulation patterns (Stille, 1992), global biogeochemical cycles and the isotopic record (Raymo and Ruddiman, 1992; Edmond, 1992); Paleogene global warming (Kerrick and Caldeira, 1993; Beck, et al., 1994), Neogene global cooling, (Selverstone and Gutzler, 1993; Raymo and Ruddimari, 1992) and evolution (Jaeger et al., 1989). However, knowledge of the kinematics and timing of collision at several points along the Indian-Eurasian suture zone is necessary before hypothetical links between the collision and global change may be evaluated. A growing body of evidence from terrestrial paleomagnetism and sea-floor magnetic anomaly studies (Besse et al., 1984; Chen et al., 1993; Besse and Courtillot, 1988; Klootwijk et al., 1992), paleontology (Jaeger et al., 1989), stratigraphy (Cassaigneau, 1979; Tapponnier et al., 1981; Burg and Chen, 1984; Beck et al., 1995; Einsele et al., in press), radioisotope chronologies of metamorphism (Chamberlain et al., 1995; Searle et al., 1988; Spencer, 1993;

Tonarini et al., 1993), marine oxygen isotopes (Kerrick and Caldeira, 1993) and marine carbon isotopes (Beck et al., 1994) indicates that the Neo-Tethys was at least locally closed (our definition of collision) before the end of the Paleocene.

Evidence from several areas along the Indian-Eurasian suture zone suggests that the collision may have been relatively synchronous (i.e. latest Cretaceous to Paleocene) from NW Pakistan to Tibet (Bossart and Ottiger, 1989; Searle et al., 1987; Searle et al., 1988; Gaetani and Garzanti, 1991; Gaetani et al., 1983; Garzanti and Critelli, 1993). Some diachrony is likely, but its magnitude is unknown along the Indus-Tsangpo suture north of the Higher Himalaya. Diagnostic evidence regarding the timing of collision is difficult to find (Beck et al., 1995). Therefore further research regarding the kinematics and timing of collision is needed along the entire length of the suture.

We summarize the broad paleogeographic, kinematic, isotopic, and climatic implications of a Paleocene collision for Paleogene earth history in the context of recent research in the Waziristan and Kurram tribal areas of Pakistan's Northwest Frontier Province (Figure 1) (Beck et al., 1995). A graphic summary of our provisional, composite, tectono-stratigraphy for the NW Indian-Eurasian suture zone is shown in Figure 2. It is remarkably similar to that of the Indus-Tsangpo suture zone north of the Higher Himalaya (Gansser, 1964; Thakur, 1981; Sinha and Upadhyay, 1990; Searle et al., 1988; Gaetani and Garzanti, 1991; Gaetani et al., 1983).

The most important paleogeographic implication of an early collision is that pre-collisional India extended farther to the north and/or pre-collisional Asia extended farther to the south (Powell and Conaghan, 1973; Besse, et al., 1984; Besse and Courtillot, 1988; Achache, et al., 1983; Chen et al., 1993; Klootwijk and Bingham, 1980; Treloar and Coward, 1991) (Figure 3). Because our data are from the westernmost Himalaya, we cannot preclude the existence of early Eocene back-arc basins or small remnant oceans similar to the modern Mediterranean in areas to the east or south of our study area. Regardless, closure of the Neo-Tethys at any point would stop deep, through going, Neo-Tethyan ocean circulation between India and Asia. Loss of this component of circulation influenced the eastern Atlantic Ocean as recorded by an increase in marine $^{143}\text{Nd}/^{143}\text{Nd}$ values (Stille, 1992).

While the deep Neo-Tethys was at least locally closed by collision during the latest Cretaceous and Paleocene, a flexural marine foreland basin (Wells, 1984) formed via tectonic loading in front of the arc fragment/prism/trench complex as it was thrust onto the NW Indian craton (Yeats and Hussain, 1987; Gaetani and Garzanti, 1991; Bossart and Ottiger, 1989; Beck et al., 1998). At least one during the Late Paleocene, erosion regionally beveled the allochthonous Asian rocks before upper Paleocene shallow marine limestones were deposited above them (Davies, 1926, 1940b, 1950). The marine foreland basin gradually filled during the latter early Eocene with lacustrine, evaporitic and fluvial sediments (Wells, 1984, Pivnik and Sercombe, 1993) before a late middle Eocene transgression drowned the foreland and resulted in the deposition of regionally extensive shallow marine limestones (Davies, 1926b, 1937b; Wells, 1984; Meissner et al., 1974, 1975).

We reanalyzed the stratigraphic and paleontological work of Davies (1926, 1940) in the light of plate tectonic theory and new biostratigraphic, lithologic and structural data from the Waziristan and Kurram tribal areas to provide a more rigorous chronology for the collision. Upper Paleocene and upper lower Eocene shallow marine limestones separate and date two discrete and significant phases of thrusting which transported parts of Eurasia onto India during the Paleogene (Beck et al., 1995). Our scenario is summarized in Figure 4. The unconformable upper Paleocene shallow marine limestones overlap deformed and eroded remnants of the prism/trench complex and Indian outer shelf/slope. Similar upper lower Eocene limestones higher in the sequence unequivocally tie the Asian rocks to the Indian craton before 49 Ma (Davies, 1926; Beck et al., 1995).

This refined timing for two major phases of collision (66-55.5 and 55.5-49 Ma), along the westernmost Indian-Eurasian suture, has larger implications regarding the Paleogene marine isotopic record and global climate change (Beck et al., 1994). The revised timing for collision is consistent with hypothetical mechanisms for well substantiated early Eocene global warming. One of the most provocative hypotheses is that of Kerrick and Caldeira (1992, 1993), which invokes the volatilization of carbonates during early Eocene Himalayan metamorphism. This hypothesis, in its purest form, might satisfy the marine oxygen isotopic record ($\delta^{18}\text{O}_{\text{carb}}$) (Douglas and Woodruff, 1981; Zachos, et al., 1992) via an increase in pCO_2 and sea surface temperature but would tend to shift marine carbon isotope values ($\delta^{13}\text{C}_{\text{carb}}$) in the wrong direction relative to what is observed (Beck et al., 1994) (Figure 5). Although the Kerrick and Caldeira hypothesis is not precluded by this observation it must be part of a larger system in which very large fluxes of ^{12}C -rich carbon entered the biosphere during the early Eocene (≈ 58 -54 Ma) (Shackleton, 1987).

In view of the constraints imposed by the marine stable carbon isotopic record (Shackleton, 1987) and what little is presently known about the timing of collision, we have formulated an alternative hypothesis which links the Indian-Eurasian collision, the $\delta^{13}\text{C}_{\text{carb}}$ and $\delta^{18}\text{O}_{\text{carb}}$ records, pCO_2 , and early Eocene global warming (Beck et al., 1994) (Figure 6). We suggest that ^{12}C -rich organic carbon exhumed from the active and passive margins during the collision was oxidized to CO_2 , which entered the biosphere. New data regarding the organic carbon content of the largely

eroded continental margins (Table 1) has allowed us to construct organic carbon budgets, reduced by the amount reburied in Paleogene Himalayan flysch (Table 2), which satisfy published mass balances based on $\delta^{13}\text{C}_{\text{carb}}$ values for the interval (Shackleton, 1987). These imbalances in the late Paleocene/early Eocene carbon cycle exceed some published thresholds considered necessary for climate change by up to three orders of magnitude (Selverstone and Gutzler, 1993). Thus, our collisional organic carbon exhumation hypothesis might explain the rapid Paleocene-Eocene decline in $\delta^{13}\text{C}_{\text{carb}}$ values, contemporaneous global warming (Wolfe, 1990) and decreasing $\delta^{18}\text{O}_{\text{carb}}$ values.

If one considers the carbon and oxygen isotopic record of benthic foraminifera ($\delta^{18}\text{O}_{\text{benthic}}$ and $\delta^{13}\text{C}_{\text{benthic}}$) (Zachos et al., 1993) rather than bulk carbonates values ($\delta^{18}\text{O}_{\text{carb}}$ and $\delta^{13}\text{C}_{\text{carb}}$) (Shackleton, 1987), it might be argued that $\delta^{18}\text{O}_{\text{benthic}}$ values began to decline up to a million years before $\delta^{13}\text{C}_{\text{benthic}}$ values. This relationship implies that organic carbon exhumation was not the only mechanism involved Paleogene global warming. Given the complex network of feedbacks within the Earth's biogeochemical system, this is not surprising. The net climate signal is the sum of many processes (Raymo and Ruddiman, 1992). Some of these processes may have had little or nothing to do with the Indian-Eurasian collision.

Nevertheless, in view of the new evidence, which indicates at least part of the collision occurred between 66 and 55.5 Ma, it is tempting to consider other tectonic-climatic mechanisms. The first, which comes to mind is a decline of (rather than an end to) Trans-Himalayan volcanism and the production of sulfate aerosols. Sulfate aerosols are powerful cooling agents (Rampino and Self, 1991): one volcanic eruption can cool the Earth's atmosphere by 3-5°C for several years by reflecting a portion of incoming solar radiation (the "Pinatubo effect").

This hypothetical late Paleocene increase in global temperature due to a decrease in the "Pinatubo effect" is supported by existing geochronologic data. For example, volcanism in the Baluchistan-Afghan sector of the Trans-Himalayan arc declined markedly at 66 Ma with a few areas experiencing volcanism until 55 Ma (Debon et al., 1987; Wolfart and Wittekindt, 1980). Isotopic cooling ages indicate that magmatism in the Trans-Himalayan Batholith and Arc of what is now northern India and Tibet slowed between 60-50 Ma (Searle et al., 1988).

Deposition of the wide spread upper lower and lower middle Eocene "nummulitic" Tethyan limestones may have damped contemporaneous global temperatures through the storage of CO_2 as carbonate (Kerrick and Caldeira, 1993). Large quantities of organic carbon were contemporaneously sequestered in the Laramide basins of western North America and elsewhere, drawing down pCO_2 , and driving $\delta^{13}\text{C}_{\text{carb}}$ values upward. This phase of Rocky Mountain deformation may have been due in part to a global plate reorganization triggered by the Indian-Eurasian collision (Patriat and Achache, 1984). Further cooling of the Cenozoic Earth during the late Paleogene and Neogene could have proceeded due to deep subduction of carbon in the Alpine-Himalayan orogen (Selverstone and Gutzler, 1993) and/or the weathering of calcium silicates in the metamorphic core of the Himalaya and fertilization of the oceans during the Neogene according to the "Raymo hypothesis" (Raymo et al., 1988).

We hypothesize that the Indian-Eurasian collision may have been the dominant driver of the Earth's long-term (>1 My) climate throughout the entire Cenozoic by the following means: 1) Between 66 and 58 Ma the collision may have passively warmed the earth by extinguishing at least some explosive arc volcanism thus decreasing the "Pinatubo effect"; 2) From 58 to 54 Ma $\delta^{18}\text{O}_{\text{benthic}}$ and $\delta^{13}\text{C}_{\text{benthic}}$ values decreased and imply that the rate of net organic carbon burial decreased (Shackleton, 1987; Zachos et al., 1993) which suggests that the collision may have actively warmed the earth further by exhuming organic carbon from the colliding continental margins and increased the greenhouse effect (Beck et al., 1994); 3) From 54 to 52 Ma $\delta^{18}\text{O}_{\text{benthic}}$ and $\delta^{13}\text{C}_{\text{benthic}}$ values increased and imply that the rate of net organic carbon burial increased (Shackleton, 1987; Zachos et al., 1993) possibly due to deposition in the Himalayan foreland (Wells, 1984; Bossart and Ottiger, 1989; Burbank, et al., 1995) or other basins created by the collision; 4) From 52 to 48 Ma $\delta^{18}\text{O}_{\text{benthic}}$ and $\delta^{13}\text{C}_{\text{benthic}}$ values were relatively stable and suggest that carbon storage in upper lower and middle Eocene Tethyan "nummulitic" carbonates and shales (Kerrick and Caldeira, 1993) and to a lesser degree subducted eclogitic rocks (Selverstone and Gutzler, 1993) may have set the stage for Neogene global cooling; 5) From 48 Ma to 38 Ma $\delta^{18}\text{O}_{\text{benthic}}$ values steadily increased while $\delta^{13}\text{C}_{\text{benthic}}$ values remained relatively constant and suggest that cooling was driven by modest rates of calcsilicate weathering rather than organic carbon burial (e.g. Raymo, 1994); 6) From 38 Ma to <20 Ma $\delta^{18}\text{O}_{\text{benthic}}$ values generally exceeded $\delta^{13}\text{C}_{\text{benthic}}$ values and suggest that carbon was sequestered as carbonate because of high rates of calcsilicate weathering in the core of the Himalaya ("Raymo hypothesis") (see Edmond, 1992; Raymo, 1994), and to a lesser degree, as organic carbon (the "Monterey hypothesis" of Vincent and Berger, 1985; see Raymo, 1994).

Obviously some of these mechanisms overlapped in time and some acted in opposite directions with respect to the Earth's isotopic record and climate. However, it is the relative size of the associated chemical fluxes, which is important with respect to the Earth's long-term biogeochemistry (Berner, 1991; Edmond, in press; Edmond, 1992;

Raymo and Ruddiman, 1992; Raymo, 1994). Although the Indian-Eurasian collision was not the only event of the Cenozoic, its timing, magnitude and numerous interactions with the rest of the present lithosphere and biosphere, indicate that the hypotheses recounted above must be explored further in order to understand the long-term global context of the Himalaya, Karakoram, and Tibet.

Key words: Cretaceous, Paleocene, isotopic, climate.

B/130. Beck, R.A., Burbank, D.W., Sercombe, W.J., Khan, A.M. & Lawrence, R.D., 1996. Late Cretaceous ophiolitic obduction and Paleocene India–Asia Collision in the westernmost Himalaya. *Geodynamica Acta*, 9, 114–144.

Collision of the Kohistan island arc with Asia at similar to 100 Ma resulted in N-S compression within the NeoTethys at a spreading center north of the Indo-Pakistani craton. Subsequent India-Asia convergence converted the Neo-Tethyan spreading center into a short-lived subduction zone. The hanging wall of the subduction zone became the Waziristan, Khost and Jalalabad igneous complexes. During the Santonian-Campanian (late Cretaceous), thrusting of the NW Indo-Pakistani craton beneath Albian oceanic crust and Cenomanian volcano-sedimentary complex, generated an ophiolite-radiolarite belt. Ophiolite obduction resulted in tectonic loading and flexural subsidence of the NW Indian margin and sub-CCD deposition of shelf-derived olistostromes and turbidites in the foredeep. Campanian-Maastrichtian calciclastic and siliciclastic sediment gravity flows derived from both margins filled the foredeep as a huge allochthon of Triassic-Jurassic rise and slope strata was thrust ahead of the ophiolites onto the Indo-Pakistani craton. Shallow to intermediate marine strata covered the foredeep during the late Maastrichtian. As ophiolite obduction neared completion during the Maastrichtian, the majority of India-Asia convergence was accommodated along the southern margin of Asia. During the Paleocene, India was thrust beneath a second allochthon that included open marine middle Maastrichtian colored melange which represents the Asian Makran-Indus-Tsangpo accretionary prism. Laterites that formed on the eroded ophiolites and structurally higher colored melange during the Paleocene were unconformably overlapped by upper Paleocene and Middle Eocene shallow marine limestone and shale that delineate distinct episodes of Paleocene collisional and Early Eocene post-collisional deformation.

Key words: Cretaceous, ophiolite, obduction, collision, Himalaya.

B/131. Beck, R.A., Burbank, D.W., Sercombe, W.J., Riley, G.W., Barndt, J.K., Berry, J.R., Afzal, J., Khan, A.M., Jorgen, H., Metje, J., Cheema, A., Shafique, N.A., Lawrence, R.D. & Khan, M.A., 1995. Stratigraphic evidence for an early collision between northwest India and Asia. *Nature* 373, 55-58.

The collision of India with Asia had a profound influence on late Cretaceous and Cenozoic oceanography, climate, fauna extinctions and the motion of at least some of the Earth's lithospheric plates. As the collision ended a period of rapid Indo-Asian convergence, a precise knowledge of its timing (when the crust of the neo-Tethys ocean was completely subducted, at some point along the plate boundary) is important for understanding its wider consequences. But current estimates of the collision age range from 65 to 38 Myr before present⁶, 8–11. Here we report the results of extensive biostratigraphic analyses from Waziristan and Kurram in northwest Pakistan, which show that accretionary-prism and trench strata were first thrust onto the northwest Indian passive margin after 66 Myr but before 55.5 Myr. After this time, volcanic-arc fragments, the accretionary prism, trench material and imbricates of the north Indian slope were raised to shallow water depths and overlapped by upper Palaeocene shallow-water carbonates and shales^{12–14}, indicative of post-collision thrusting in this region. Finally, both the suture and the Indian craton were overlapped by continuous unconformable upper Lower Eocene shallow-marine strata, demonstrating that suturing was complete by 49 Myr.

Key words: Stratigraphy, collision, India, Asia.

B/132. Beck, R.A., Burbank, D.W., Shah, S.M.I. & Khan, I.A., 1987. Basin-scale isochronous paleocurrent study of chron 9 polarity interval, middle Siwaliks, Potwar Plateau, northern Pakistan. Abstracts, Mid-year Meeting, Society of Economic Paleontologists and Mineralogists, Austin, 6-7.

Key words: Paleocurrent, magnetic polarity, siwaliks, Potwar.

B/133. Beck, R.A., Sercombe, W.J. & Burbank, D.W., 1993. Structure, stratigraphy & geochronology of the Himalayan Indus-Tsangpo suture zone in NW Pakistan and E Afghanistan. Geological Society of America, Abstract Program, A-122.

Key words: Structure, stratigraphy, geochronology, Indus-Tsangpo suture, Himalaya.

B/134. Beck, R.A., Sercombe, W.J., Burbank, D.W., Khan, A.M. & Lawrence, R.D., 1995. Late Cretaceous ophiolite obduction and Paleocene India-Asia collision in the westernmost Himalaya. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p. 3.

The northwestern edge of the Indian plate collided with the Kohistan and Asian blocks during the Paleocene. The closure of the intervening ocean and obduction of the ophiolites onto the Indian plate during the Late Cretaceous provide a supporting evidence.

Key words: Ophiolites obduction, collision, Himalaya.

B/135. Beer, E.J., 1923. Report on Swabi Marble, made for Frontier Marble Syndicate. (Reference from Coulson, A.L. 1973), Geological Survey of India, Record 71(3), 342p.

Key words: Marbles, Swabi.

B/136. Beg, I.R. & Samad, A., 1966. Thermometric analyses of some samples of Potwar area. Pakistan Journal of Scientific and Industrial Research 9, 150-155.

Key words: Thermometry, Potwar.

B/137. Beg, M.I., 1978. Geothermal energy, an inexhaustible sources of energy. National Seminar on Development of Mineral Resources, Lahore March 6-9, 1978, 174-182.

Key words: Energy, geothermal.

B/138. Beg, M.I. & Awan, A.Q., 1971. Statistical properties and petrography of the Misri Banda quartzite, Nowshera Tehsil, NWFP Geological Bulletin University of Peshawar 6, 82-89.

This paper presents the statistical properties and petrography of the Devonian and Carboniferous Misri Banda Quartzite. It occurs interbedded and overlying the Nowshera Formation of Siluro-Devonian reef complex. The statistical analyses show that most of the quartzite samples fall in the well-sorted range and are unimodal in their distribution. The size frequency curves show maximum sorting towards the coarse grades and skewness towards finer grades. Kurtosis values of size distribution range between 0.27 and 0.24.

Microscopic examination of several slides reveals that quartz grains, embedded in a carbonate matrix, are elongated with their longer axis being parallel to each other and to the longer dimensions of calcite/dolomite grains. Well-rounded grains of zircon, tourmaline, and other heavy minerals are present in lesser amounts. The high degree of textural and mineralogical maturity of the Misri Banda Quartzite and its association with the reef carbonates indicate a long history of transportation, reworking, and winnowing in shallow waters dominated by stable shelf environments. Statistical data, heavy mineral distribution, and field observations indicate that the Misri Banda Quartzite conformably overlying the Nowshera Formation and beds and stringers of quartzite, occurring interbedded with the reef carbonates are one and the same derived from a common source.

Key words: Sedimentary petrography, Misri Banda Quartzite, Nowshera Reef.

B/139. Behrensmeyer, A.K., 1979. Stratigraphy and environments of early hominoids. Abstracts with Programs, Geological Society of America 11(7), p.386.

Key words: Stratigraphy, hominoids, siwaliks.

B/140. Behrensmeyer, A.K., Quade, J., Khan, I.A., Roe, L. & Littore, C., 1997. Lateral variations in stable isotopes in paleosols of the Miocene Siwalik sequence, Pakistan. Abstracts with programs, Geological Society of America, Annual Meeting, p. A34.

Key words: Geochemistry, Miocene, siwaliks.

B/141. Behrensmeyer, A.K. & Raza, S.M., 1984. Procedure for documenting fossil localities in Siwalik deposit of Northern Pakistan. In: Shah, S.M.I & Pilbeam, D. (eds), Contribution to the Geology of Siwaliks of Pakistan. Geological Survey of Pakistan, Memoir 11, 65-70.

Key words: Palaeontology, siwaliks.

B/142. Behrensmeyer, A.K. & Tauxe, L., 1982. Isochronous fluvial systems in Miocene deposits of northern Pakistan. *Sedimentology* 29, 331-352

A Palaeomagnetic isochron dated at about 8.1 Myr BP and detailed lithostratigraph of a 40 m interval exposed along strike for 40 km establish the depositional patterns of two contemporaneous, interfingering fluvial systems in the upper part of the Middle Siwalik sequence.

The two systems, referred to as the buff and blue-grey, differ in unit shape, lithofacies, bedding sequence, palaeocurrent direction and sand composition. Interfingering occurs along the south-west-north-east strike of the outcrops, with the palaeodrainage directions of the two systems generally perpendicular to this line. The axis of the blue-grey system, which deposited widespread sheet sands and silts, lay toward the south west end of the study area. The more complex axis of the buff system, which deposited shoe-string sand bodies and large volumes of silt and clay, lay toward the north-east. The source area for both systems was the rising Himalayan belt to the north and north-east of the study area. At maximum extent the blue-grey system occupied a channel belt at least 25 km wide. Channel belt widths and depths for the buff system are 1–3 km and 3–7 m, respectively. Current directions average 94° for blue-grey sands and 136° for buff sands. Blue-grey sands contain 20% more rock fragments and are otherwise less mature than buff sands.

The buff system shows a vertical pattern of avulsion, palaeosol formation and floodplain aggradation which we attribute to autocyclic processes of parallel rivers. The blue-grey system shows phases of erosion accompanied laterally by palaeosol formation, followed by valley fill and overflowing of interfluvial surfaces. This pattern may be caused by allocyclic processes affecting the source area. We interpret the blue-grey system as a major drainage from the interior Himalayas (perhaps the ancestral Indus) and the buff system as a complex of smaller drainages along the mountain front which were probably tributaries to the bluegrey system.

Vertebrate fossils including hominoid primates from the area are almost exclusively associated with lithofacies of the buff system, and this probably reflects both taphonomic and palaeoecological differences between the two systems.

Key words: Paleomagnetism, stratigraphy, fluvial systems, siwaliks.

B/143. Behrensmeyer, A.K., Willis, B.J. & Quade, J., 1995. Flood plains and paleosols of Pakistan Neogene and Wyoming Paleogene deposits - A comparative study. *Palaeogeography, Palaeoclimatology, Paleoecology* 115, 37-60.

Comparative study of fossil-bearing fluvial deposits in the Eocene Willwood Formation of northern Wyoming and the Miocene Chinji Formation of northern Pakistan indicate how tectonic and climatic processes operating at

different scales controlled physical and chemical features of floodplain environments and affected preservation of the paleontological record.

The architecture of Willwood Fm. floodplain deposits represents a combination of avulsion-belt sediment packages and overbank sediments that formed alluvial ridges. The architecture of the Chinji Fm. floodplain deposits was controlled by widely distributed crevasse-splay deposition and floodplain topography. Similarities in individual paleosol-bounded overbank sequences from the two formations indicates that the internal structure of such deposits can be independent of channel belt proximity to areas of aggradation. Chinji Fm. paleosols have little vertical zonation and show no consistent pattern of lateral change in relation to major channels, while overbank paleosols in the Willwood Fm, exhibit considerable soil horizon development and a pattern of increasing maturity from alluvial ridge to distal floodplain. The “pedofacies model” of Bown and Kraus (1987) based on such lateral trends in the Willwood paleosols is not applicable to the Chinji Fm.

Plant and animal fossils are abundant in the Willwood overbank deposits, with vertebrate remains concentrated in paleosol A horizons. Plant remains are rare in the Chinji Fm. and vertebrate fossils occur primarily in channel fills rather than in paleosols. These differences relate to contrasting patterns of floodplain deposition and to levels of oxidation that controlled penecontemporaneous recycling of organic material, particularly in paleosols. Different large-scale climatic and tectonic controls on temperature and rainfall, water table fluctuations, and soil biota are proposed to account for the differences in organic preservation. Large and small-scale environmental processes also affected spatial and temporal resolution of the organic record, resulting in important differences in the paleoecological and evolutionary information that can be reconstructed from the two sequences.

Key words: Sedimentology, fluvial deposits, Miocene, siwaliks, Wyoming.

B/144. Beiersdore, H., 1972. Schwermineraluntersuchungen an sedimenten aus West-Pakistan sowie vom angrenzenden Schelf. “Meteor”-Forsch. Ergebnisse C9, 74-83.

The paper describes heavy minerals in the sediments from former West Pakistan as well as from the adjacent shelf.

Key words: Heavy minerals, sediments.

B/145. Beinat, A., Eckart, M., Kettling, B., Marchesini, C., Marchesini, A., Palmieri, F., Poretti, G. & Puruckherr, R., 1997. Geodetic Surveys in the Pakistan Baltistan and new measurement of the height of Mount K-2. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, p.11.

In July-August 1996 GPS measurements along the profile from Skardu to Askole and to the K-2 Base Camp were performed. Along the route gravity and deflections of the vertical were measured. In the K-2 Base Camp Area, across the Godwin Austen glacier a topographic network was established with points on bedrock and on the moving glacier surface. A tripod with a sight target and two reflecting primes was installed at the top of K-2 in order to measure angles and distances from the points of the base network to the summit. Meteorologic observations were performed to determine the atmospheric refraction coefficient. Taking into account the movements of the glacier it was possible to link the summit of Mount K-2 to the trigonometric network of Pakistan improving the accuracy of the height of the mountain compared with the past measurements.

Key words: Geodesy, Baltistan, K-2.

B/146. Beljaewski, N.A., 1947. On the geology of KaraKorum. Izvestija Akademii Nauk SSSR, Geological Series 3, 100-116.

Key words: Geology, Karakoram.

B/147. Bell, I., Gardner, J. & De Scally, F., 1990. An estimate of snow avalanche debris transport, Kaghan valley, Himalaya, Pakistan. Arctic and Alpine Research 22, 317-321.

Debris transport by snow avalanches in the front ranges of the Himalaya in northern Pakistan is described using estimates of sediment concentration in avalanche snow deposits. Data were collected from two end-of-season

avalanche deposits in Kaghan Valley. Sediment concentration estimates and measurements of avalanche deposit volumes are used to produce estimates of total sediment load. From these, deposit area accretion values of 0.74 and 0.21 mm for the two deposits representing the 1986/87 avalanche season are derived

Key words: Glaciers, debris flow, sediment transport, Kaghan, Himalaya.

B/148. Belousov, V.V., Belyaevsky, N.A., Borsive, A.A., Volvovsky, B.S., Volvosky, I.S., Resvoy, D.R., Tal-Virsky, B.B., Khamarabaev, I.K., Kaila, K.L., Narian, H., Marussi, A. & Finetti, J., 1980. Structure of the lithosphere along the deep seismic sounding profile: Tien Shan-Pamirs-Karakoram-Himalayas. *Tectonophysics* 70, 193-221.

During 1973–1977, as part of the International Geodynamic Project, some seismic investigations of the Earth's crust have been carried out by geotraverses of the Tien Shan-Pamirs-Karakorum-Himalayas. The seismic data obtained together with other geophysical information, allow the construction and interpretation of the lithospheric section through the Pamirs-Himalayas structure. This section includes thick crust with complex layering, supra-asthenospheric and asthenospheric layers of the upper mantle. The thickness of the Earth's crust increases from 50–55 km in the north, in the Ferghana depression (Tien Shan), to 70–75 km in the south, near the Karakul Lake (Northern Pamir). It varies within 60–65 km for the Central and Southern Pamir, Karakorum and the Inner Himalayas. Its thickness is least (35–37 km) in the south, under the outer margin of the Himalayan foredeep. Extreme gravity minima and depressions on the geoid surface correspond to the regions with maximum thickness of the Earth's crust. The centers of the disturbing masses on the geoid surface are located in the vicinity of the asthenosphere's upper layer; this determines the effect of the whole lithospheric layer, including its asthenospheric layer, at intense changes of gravity anomalies. The asthenospheric upper layer is recorded at a depth of about 120 km, its base at a depth of 200 km, in the northern and southern regions, and 300 km in its central part (Southern Pamir, Karakorum). In the middle asthenospheric layer, wave velocities decrease to 7.5 km/sec, under the base they increase to 8.4 km/sec and reach 9.4 km/sec at a depth of about 400 km. In the supra-asthenospheric layer of the upper mantle, longitudinal and shear wave-velocities slightly increase (by less than 0.1 km/sec) towards its base.

Key words: Structure, seismic profile, Tien Shan-Pamirs-Karakoram-Himalayas.

B/149. Belousov, V.V. & Volvovsky, B.S., 1983. Geodynamics of the lithosphere of the Pamir-Himalaya region. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 147-149.

Key words: Geodynamics, Pamir, Himalaya.

B/150. Belousov, V.V., Volvovsky, B.S., Volvovsky, I.S., Kaila, K.L., Marussi, A., Narain, H., Tal-Virsky, B.B., Finetti, I. & Khamrabaev, I.Kh., 1983. General features of the lithospheric structures of the southern Tien Shan, the Pamirs, Karakorum and the Himalayas. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 151-161.

Key words: Structure, lithosphere, Tien Shan-Pamirs-Karakoram-Himalayas.

B/151. Belousov, V.V., Volvovsky, B.S., Volvovsky, I.S., Khamrabaev, I.Kh., Kaila, K.L. & Marussi, A., 1984. Deep structure of Central Asia along the Tien-Shan- Himalayas Geotraverse. 27th International Geological Congress, Moscow, 1984, Reports, volume 15, *Tectonics of Asia*, 29-51.

This region comprises very high mountains, adjacent to which are depressions where crustal blocks have sunk to great depth. The region is characterized by very high heat flow negative gravity anomaly, and high seismic activity. The gravity field of the traverse reflects the zoning of the geological structure of the upper crust. The principal role in the development of deep gravity anomalies is played by the Moho interface, and only to a small degree by the upper mantle inhomogeneity. The seismicity of the lithosphere in the region is controlled by geodynamic processes

that are manifested in its upper part by crustal block movements, and in the lower lithosphere by displacement of steeply dipping mantle blocks. The region has high seismicity originating in the intermediate part of the Earth's crust.

All these facts show that geodynamic processes that occur at depth under the Pamir-Himalaya are complicated. The upper mantle has a low density. In the Pamirs, considerable upwelling of the anomalously heated material from the Earth's deep parts is quite possible. This heated material might move NW-ward to the Pamirs and Tien Shan along the "weak zones" asthenospheric channels. It is along this direction that tensile stresses in the earthquake source show a horizontal alignment. Fields of intensive stresses of mechanical and thermal origin may concentrate above such regions and particularly along their periphery, and their release may result in intensification of seismic activity.

Key words: Geophysics, structure, lithosphere, Tien Shan, Pamirs, Karakoram, Himalaya.

B/152. Belyaevsky, N.A., 1965a. Main feature of the geology of Karakorum (translated from Russian). *International Geological Review* 8, 127-143.

There have been several publications in Russian literature on the transect from Tien Shan and Pamir to Himalaya, through the Karakoram – Hindukush ranges. This paper gives a summary of the geological contributions on the geology of the Karakorum range.

Key words: Geology, Karakoram.

B/153. Belyaevsky, N.A., 1965b. Major Geological features of Karakorum. *Soviet Geology* 1, 54–75 (in Russian).

This document is not very different from Russian version of Belyaevsky 1965a.

Key words: Geology, Karakoram.

B/154. Belyaevsky, N.A., 1976. Tectonics of the northern part of the Pamirs-Himalaya-Karakoram-Hindu Kush-Pamir. *Atti. Convengni. Lincei* 21, 29-42.

Key words: Tectonics, Pamirs, Himalaya, Karakoram, Hindu Kush

B/155. Bender, F.K. & Kazmi, A.H., 1995. Non-metallic raw materials. In: Bender, F.K., & Raza, H.A. (Eds.), *Geology of Pakistan*. Gebrüder Borntraeger, Berlin, 258-281.

The book, *Geology of Pakistan*, comprises papers on various aspects of geology of Pakistan. This particular paper deals with non-metallic minerals of the country. As can be seen, Pakistan is endowed with a fair number of non-metallic mineral occurrences.

Key words: Mineral deposits, raw material, non-metallic.

B/156. Bender, F.K. & Raza, H.A. (Eds.), 1995. *The geology of Pakistan*. Beihefte zur regionalen geologie der Erdd. Band 25, Berlin, Stuttgart: Gebrüder Borntraeger, 414p.

This wonderfully done book is the first of its kind on the geology of Pakistan. It contains chapters by ten different authors. Following General introduction (Chapter 1: Raza and Bender); it covers Geological framework (Chapter 2: Bender, D. Bannert, Raza & F.A. Shams); Sedimentary sequence (Chapter 3: A.H. Kazmi); Igneous and metamorphic rocks (Chapter 4: Shams); Tectonics and structure (Chapter 5: Bender, Shams and Bannert); Palaeogeographic and geodynamics evolution (Chapter 6: Bender and Bannert); Energy resources (Chapter 7: Raza, Bender, H. Porth, Kazmi, Shams, F. Barthel and H. Fohse); Metallic raw materials (Chapter 8: Shams); Non-metallic raw materials (Chapter 9: Bender and Kazmi); Water (Chapter 10: Bender); Soils (Chapter 11: F.H. Gurneberg). There is an extensive bibliography spread over 53 pages, and includes papers published up to 1992. The volume is accompanied by three sheets of a wonderfully drafted geological map on a scale of 1:500,000 covering the western fold belt. The book is nicely illustrated with 140 figures, 38 tables and ten foldouts (some colored).

Key words: Bibliography, tectonics, paleogeography, mineral resources, water, hydrocarbons.

B/157. Benn, D.I. & Owen, L.A., 1998. The role of the Indian summer monsoon and the mid-latitude westerlies in Himalayan glaciation: review and speculative discussion. *Journal of the Geological Society, London* 155, 353-363.

New dates for late Quaternary glaciations in the Himalayas show that, during the last glacial cycle, glaciations were not synchronous throughout the region. Rather, in some areas glaciers reached their maxima at the global glacial maximum of c. 18–20 ka bp, whereas in others glaciers were most extensive at c. 60–30 ka bp. Comparison of these data with palaeoclimatic records from adjacent regions suggest that, on millennial timescales, Himalayan glacier fluctuations are controlled by variations in both the South Asian monsoon and the mid-latitude westerlies.

Key words: Quaternary, glaciation, Himalaya.

B/158. Benson-Cooke, G., 1930. Oil occurrences in the north west Punjab. *Petroleum Times* 24, 613-615.

This is one of the earliest accounts on occurrence of oil in the Punjab province of the present day Pakistan.

Key words: Oil, Punjab.

B/159. Berthelsen, A., 1951. A geological section through the Himalayas. *Meddelanden fra Dansk Geologiske Forendlingen* 12, 102-104.

Key words: Geology, structure, Himalaya.

B/160. Bertrand, J.M. & Debon, F., 1986. Evolution tectonique polyphase de la chain du Karakoram (Baltoro, Nord Pakistan). *Comptes Rendus Hebdomadaires de Seances de l'Academie des Sciences Naturelles* 303, 1611-1614.

The paper describes polyphase tectonic evolution of the Baltoro region in central Karakoram.

Key words: Tectonics, Baltoro, Karakoram.

B/161. Bertrand, J.M., Kienast, J. & Pinardon, J., 1988. Structure and metamorphism of the Karakoram gneisses in the Braldu-Baltoro valley, North Pakistan. *Geodynamica Acta* 2, 135-150.

The structure and metamorphism of the Braldu-Baltoro area in the Karakoram is described.

Key words: Tectonics, metamorphism, Braldu, Baltoro, Karakoram.

B/162. Best, F., Gruber, G. & Kick, W., 1981. Das ende des Chogo-Lungma Gletschers 1979. Beobachtungen zu Veranderungen an einem der grossen Eisstromen des Karakorums mittels photogrammetrie (1902-1954-1970-1979). *Zeitschrift fur Gletscherkunde und Glazia Geologie* 17, 177-189.

The paper deals with major changes in the eastern Karakoram glaciation, notably that of Chogo-Lungma, using photogrammetry for the period 1902-1954-1970-1979.

Key words: Photogrammetry, Karakoram.

B/163. Bhatti, A.R., 1978. Geology, petrology and economic geology of Shangla Par-Alpurai area, Swat, with special emphasis on Basi granits. M.Sc. Thesis, Punjab University, 77p.

This area comprises low-grade sedimentary rocks. They contain a large body of ultramafic rocks which have been serpentized.

Key words: Petrology, economic geology, Shangla, Swat.

B/164. Bhatti, K.J.A., 1981-82. Geology and petrology of Tangir Valley (District Diamer) with special emphasis on the mineralogy/petrology of the intrusives. M.Sc. Thesis, Punjab University, Lahore, 144p.

Tangir covers 351-km² area located between Kohistan in the South and Yasin in the North. According to plate tectonic concept it lies in between Indo-Pakistan and Eurasian plates comprising a part of Kohistan Island Arc. The particular project area is mapped on a scale of 1:62500. In the thesis, an attempt is made to introduce the detailed Geology of the above area. Bulk geological sequence of the area is consisted of Norite, Diorite, Amphibolite, Granodiorite and Granite which is obducted on to the Paleozoic rocks of Indo-Pakistan plate in the south and subducted under the Eurasian plate towards the North. The Northern part of the area is in contact with Yasin Group, which is volcanic. So Tangir area constitutes the lower sequence of Kohistan Complex.

Key words: Petrology, Tangir, Diamir.

B/165. Bhatti, M.A., 1949. Orography and drainage of the Potwar Plateau. Pakistan Geological Review 14(1), 2-16.

Bhatti has described in this paper, the geographical and geomorphological aspects of the Potwar plateau. Details of Orography and drainage pattern of the area are elucidated.

Key words: Geomorphology, drainage, Potwar.

B/166. Bhatti, M.A., Bajwa, M.S., Kausar, A.B. & Khan, A.A., 1985a. Geological map of Fateh Jhang (7 (43C/10)). Geological Survey of Pakistan.

Key words: Geological map, Fateh Jhang, Attock.

B/167. Bhatti, M.A., Bajwa, M.S., Kausar, A.B. & Khan, A.A., 1985b. Geological map of Kot Fateh Jhang (15 (43C/11)). Geological Survey of Pakistan.

Key words: Geological map, Kot Fateh Jhang, Attock.

B/168. Bhatti, M.A., Jafferri, S.E.H. & Majeed, S., 1980. Geology and petrology of Usheri Darra, District Dir, Pakistan. M.Sc. Thesis. Punjab University, Lahore.

The Usheri area is a part of the Kohistan magmatic arc which comprises mafic to silicic igneous and some sedimentary rocks. This paper deals with such rocks in the Usheri area.

Key words: Petrology, Usheri, Dir, Kohistan.

B/169. Bhatti, M.M., 1981-83. Micropaleontology and stratigraphy of the Jhalar-the Kala Chitta Range, Attock District. M.Sc. Thesis, Punjab University, Lahore, 91p.

A geological map of the Jhalar area -the Kala Chitta Range, on a scale of 1" to 0.789 mile or 1:50,000 and covering an area of 16.43 square miles has been prepared to discuss the stratigraphy and micropaleontology of the area. An attempt has been made to discuss the importance of foraminiferal content of these rock units, for determining the depositional pattern and age.

The geological sequence of the Kala Chitta Range with a view to recognize the continuity or unique aspects of the lithostratigraphic units in the adjoining area. The various geological events that occur in the area and their geological implications have also been discussed.

In the Kala Chitta Range there are some eighteen lithostratigraphic units but the area under discussion comprises ten lithostratigraphic units mostly of marine environments and with non-marine units.

Key words: Palaeontology, stratigraphy, Kala Chitta, Attock.

B/170. Bhatti, M.T. & Khan, A., 1966. A survey of potash deposits in West Pakistan. *Pakistan Journal of Scientific and Industrial Research* 4 (1), 21-24.

Key words: Economic geology, potash deposits.

B/171. Bhatti, N.A., 1972. Phosphorite deposits of Kakul-Mirpur area, Hazara district, NWFP. *Pakistan. Geological Survey of Pakistan. Information Release*, 51, 33p.

Key words: Mineral deposits, phosphorite, Abbottabad, Hazara.

B/172. Bhatti, N.A., 1983a. Chronostratigraphic position of Panjal Formation in Azad Kashmir: A stratigraphic discrepancy. *Kashmir Journal of Geology* 1, 117-118.

Reported occurrence of Permo-Carboniferous fauna from the Panjal Formation and an interbedded nature of the Panjal Formation within Sirban Formation of Cambrian age in Azad Kashmir is in discrepancy. This is only explainable in the event of two isolated phases of volcanic activity. However, re-examination of the contact relationship between the two units-the Panjal Formation and Sirban Formation may finally clarify this discrepancy.

Key words: Stratigraphy, Panjal Formation, Azad Kashmir.

B/173. Bhatti, N.A., 1983b. Cathodoluminescence study of the dolomitized phosphate of Hazara. *Kashmir Journal of Geology* 1, 122.

Petrological examination of some of the Mg bearing phosphate rock of Hazara exhibits an illustrative relationship of the Phosphate deposition and the dolomitization process. MgO is an undesirable impurity in the phosphate ore and its higher values than the permissible limitations render the ore uneconomical.

Cathodoluminescence refers to the emission of light during electron bombardment. Energy levels of the light thus emitted are characteristics of the individual material and correspond with the chemical compositional and textural changes. These changes within a material itself, which are not otherwise discernable, become distinguishable under cathodoluminescence and are seen as variation in the intensities of the luminescence.

Different concentrations of Mg produce different colors and intensities in the phosphate rock. These colors and intensities are helpful in tracing the flow direction of the Mg bearing ions which in turn can be utilized in delineating the phosphate ore bodies of the low Mg content.

Cathodoluminescence can be an useful tool in locating the phosphate ore bodies of the desirable composition.

Key words: Phosphate, cathodoluminescence, Hazara.

B/174. Bhatti, N.A., 1983c. Deposition of phosphate in the Hazara Himalayas and the Precambrian glaciation. *Geological Bulletin, University of Punjab* 18, 18-21.

Tanakki Conglomerate in Hazara is located at the base of formation, which lies below the phosphate-bearing unit of Cambrian age. Though some diagnostic characteristics of mudflow as well as of aquatic preluvial sediments are evident in some parts of the outcrop but dominant compositional and textural features indicate this unit to be of glacial origin.

Regional stratigraphic location of Tanakki Conglomerate fits well into the global picture when viewed in the context of Late Precambrian glaciation. A broad correlation of Tanakki Conglomerate with Late Precambrian Tillites based on the comparison of dates from other continents and particularly from Tien Shan, China is proposed.

Considering various views on water cooling effects on the phosphate deposits, it is likely that Late Precambrian glaciation in this region could have contributed, though indirectly, towards deposition of phosphate in Hazara by raising the phosphorous concentration in the sea.

Key words: Phosphate, Hazara, Precambrian glaciation, Himalaya,

B/175. Bhatti, N.A., 1984. Deposition of phosphate in Hazara and its implication on the collision boundary. Abstract Volume, First Pakistan Geological Congress, Lahore, p.76.

The descriptive similarities of Hazara phosphate deposits with those of Tien Shan geosyncline of neighbouring Russia and China are remarkable. The Hazara phosphate as well as lien Shan geosynclinal phosphate deposition both are associated with Late Precambrian glacial tillites, manganiferous and volcanic sediments, and occupy an identical distribution with the same rock types in their regional stratigraphic column. They were effected by the same tectonic event-the Baikalian orogeny. All these similarities in the environment and the tectonics and their present-day proximity point out that Hazara phosphate as well as lien Shan geosynclinal phosphate were deposited in one and the same geosynclinal basin. It is most logical that these deposits have continuously occupied their position unchanged. As unchanged position of Hazara deposits with respect to contemporaneous phosphate deposits of lien Shan imply that Hazara is part of Eurasia continent rather than of the Indian subcontinent.

Key words: Phosphate, Hazara, tectonics, Himalayan collision,

B/176. Bhatti, N.A. & Alam, A., 1989. Heavy mineral analysis of stream sand samples from Gilgit Agency. Geological Survey of Pakistan. Information Release, 336, 11p.

Stream sand sampling was carried out in the report area of Gilgit Agency under the Mineral Exploration program of the Geological Survey of Pakistan. 34 samples were collected by panning the detrital sands from the tributaries of the Gilgit River covering a drainage area of about 2,500 sq .miles. Heavy mineral concentrates from these samples were examined for the identification of their mineral constituents and their percentage composition. This report provides the locations of these samples and their percentage of mineral constituents. Some anomalous values of certain minerals have been noted and as such, their pertinent areas of occurrence are recommended to be of consideration for further exploration work in the area .

Key words: Heavy minerals, Gilgit.

B/177. Bhatti, N.A. & Ghaznavi, M.I., 1984. A modification of Precambrian phosphogenic model. Abstract Volume, First Pakistan Geological Congress, Lahore, 76-77.

The study concerns regional deposition of phosphates and draws inferences regarding Precambrian plate tectonics.

Key words: Phosphates, tectonics, Precambrian.

B/178. Bhatti, N.A., Hasan, M.T. & Hussain, M., 1972. Phosphate deposits of Kakul Mirpur area, Hazara District, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 51, 31p.

The phosphate deposits of the Hazara area have been studied by many workers because of their economic potential. This stud gives details of the occurrence and reserve evaluation of the deposits of Kakul-Mirpur area near Abbottabad.

Key words: Phosphates, Abbottabad, Hazara.

B/179. Bhatti, N.A. & Khan, A.M., 1992. Status of gemstone in North-West Frontier Province, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 7-8.

The gem resources of North West Frontier Province of Pakistan comprises of variety of gemstones that are being processed and sold worldwide as Pakistani gems. These include exquisite deep green to bluish green emeralds from district Swat, rare variety of topaz in natural pink color from district Mardan and sky blue color of aquamarine from district Chitral. All form highly prized rough and cut gemstones as well as mineral specimen.

Detailed exploration in the remote areas of the province has also revealed occurrences of emerald or green beryl, garnet, jade and epidote from Mohmand and Bajaur agencies, rosy quartz, bicolor tourmaline, garnet and beryl from

Chitral and Corundum, and aquamarine and garnet from Dir area. These gem deposits could not be mined or developed either due to their poor quality and grade or due to their hostile location in the tribal agencies.

All the above mentioned gemstones are the result of the processes that were generated due to complex tectonic activities and are associated with pegmatites, hydrothermal veins and ophiolitic mélange.

Key words: Gemstone, NWFP.

B/180. Bhatti, N.A., Rashid, A.Z. & Quraishi, I.H., 1967. Beneficiation of low grade lead ore. Pakistan Journal of Scientific and Industrial Research 10, 112-115.

Key words: Lead, beneficiation.

B/181. Bhatti, T.H., 2000. Seismic reflection data interpretation of Mianwali East, Pakistan. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 34p.

A Seismic line oriented in SE-NW direction covering 32.35 km area was provided for interpretation by OGDCL. The seismic line 904 -MwI-009 is acquired in Mianwali (East) area (Pakistan). Out of total length, 15.3 km VP-1.1.0- to-VP 450 is studied in this dissertation. The average velocity contour map of the study area shows the lateral as well as vertical velocity variations where the lateral velocity variations are due to structural changes and vertical variations are due to change in lithology. Three reflectors have been marked and their depth is calculated using Dix average velocity and mean average line velocity method by using given RMS and interval velocity.

Key words: Seismic reflection, Mianwali.

B/182. Bhatti, M.J., Khan, J., Ahmed, J. & Karimullah, 1966. A survey of potash resources in West Pakistan. Science and Industry, Karachi 4(1), 21-24.

Key words: Mineral deposits, potash, West Pakistan.

B/183. Bhuiyan, K., Sualeheen, M. & Qurashi, M.M., 1963. A brief report on the current status of the collaborative investigation on some important iron ore deposits of Pakistan. Pakistan Journal of Scientific and Industrial Research 1, p. 87.

Key words: Economic geology, iron ore.

B/184. Bhutta, A.A., Siddiqui, S. & Butt, M.Q., 1987. Fossils of Leguminaeaceae from Nagri of Salt Range, Punjab. Palaeobotany, Palynology Club, Pakistan, Bulletin. 1, 49-54.

The fossils of Leguminaeaceae are described from the Nagri Formation of the Siwalik Mollase in the Salt Range.

Key words: Palaeontology, siwaliks, Salt Range.

B/185. Bignold, S.M. & Treloar, P.J., 1998. The Kohistan island arc, N. Pakistan: A geochemical perspective on arc stratigraphy. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 38-39.

The Kohistan terrane represents a Cretaceous arc initiated offshore of Asia as an intraoceanic arc. At ca 100Ma it was accreted to the southern margin of Asia, and subsequently behaved as a continental margin volcanic arc until being underplated by continental India at the initiation of the India-Asia collision.

Three main volcanic sequences have now been recognized in the arc: from the south, these are the Kamila Amphibolites, the Jaglot Group and the Chalt Volcanic Group. On geochemical criteria, Treloar et al., (1996) argued that the Kamila Amphibolites can be divided into two suites: one which predated the arc and has a chemistry typical of ocean plateaux, and one which relates to the erection of a supra-subduction fore-arc on the ocean plateau sequence. They argued that subduction was to the north, and that the bimodal Chalt Volcanic Group, which contains

deformed, pillowed lavas, some of which have basaltic komatiite-high Mg basalt to high-Mg andesite and boninite chemistry, was extruded into a back-arc basin. In contrast, (Khan et al., 1997) proposed that the direction of subduction was southwards, and that the Chalt Volcanic Group represents a fore-arc sequence, the Kamila Amphibolites forming a back-arc basin. In an attempt to resolve this difference, we present new geochemical data from both the Chalt Volcanic Group and Kamila Amphibolite sequences, as well as the first full data set for the Jaglot Group. Preliminary interpretation of these data shows a clear geochemical transition from the rocks of the Kamila Amphibolites to those of the Jaglot Group. This is consistent with the field evidence that the Jaglot Group rocks overlie the Kamila Amphibolites with a consistent northward dip.

Although all rock units have clear subduction-related chemical signatures, those of the Chalt Volcanic Group are distinctly different from the others. The boninitic geochemistry of some of these rocks, and in particular the rare earth element pattern, bears a close similarity to the boninites from the Eocene Zambales Ophiolite in the Philippines (Yumul, 1996) and the Group III lavas from the Limassol Forest Complex, Cyprus (Rogers, et al., 1989), which are characteristic of a supra-subduction zone setting in a primitive intraoceanic arc or incipient back-arc or marginal basin. Ongoing geochemical, isotope and modeling programmes should enable the erection of a model for the initiation of subduction, the evolution of magma source regions and the role of crustal contamination in magma evolution.

Key words: Geochemistry, stratigraphy, Kohistan arc.

B/186. Bignold, S.M., Treloar, P.J. & Petford, N., 1999. The Kohistan island arc, N. Pakistan: Identification of changing magma sources during intra-oceanic evolution. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop Kloster Ettal, Germany, 15.

The Kohistan arc terrane was initiated offshore of Asia during the mid-Cretaceous as an intraoceanic island during the mid-Cretaceous as an intraoceanic island arc above the subducting Tethyan oceanic slab. At ca. 100 Ma it was accreted to the south margin of Asia, and subsequently behaved as a continental margin volcanic arc until being underplated by continental India in the early Tertiary.

Three main volcanic and volcano-sedimentary sequences are recognised from the intraoceanic stage of arc evolution. Modelling of geochemical differences from basaltic rocks from these sequences illustrates significant changes in magma source regions during arc evolution. The oldest sequence, the Kamila Amphibolites, are tholeiitic to calc-alkali basalts, erupted on to thickened, plateau-like oceanic crust. Trace element and REE chemistry have clear arc signatures. Modelling shows the basalts were derived by up to 16% melting of spinel lherzolite at between 30 and 80 km. Field and geochemical data demonstrate an apparent upward transition from this sequence into the Jaglot Group. Jaglot Group basalts are also tholeiitic to calc-alkali, but are interbedded with turbiditic volcanoclastic sediments, the proportion of sediment to volcanic rocks increasing eastward. Basalts in the west are chemically similar to those in the Kamila sequence. Those from the eastern part of the sequence are more enriched in the REE than in the west although both have similar patterns. Modelling shows these basalts were derived by high (>80-km) pressure melting of garnet lherzolite, differences in REE chemistries being consistent with lower percent melting in the west (8%) than in the east (12%). Basalts from the Chalt Volcanic Group in the north of the arc, which include tholeiitic, pillowed, high-Mg basalts and high-Mg andesites and boninites, have significantly different geochemical signatures from basalts of the other sequences. In contrast to those, the Chalt basalts are H, REE-enriched relative to the LREE. Modelling suggests derivation through 10% melting of a cpx-depleted spinel-rich mantle at shallow depths, probably during back-arc rifting, above a north-dipping subduction zone.

On the basis of geochemistry and modelling there is no evidence for significant metasomatism of the mantle wedge in the source region. It is hence likely that differences in basalt chemistry reflect differences in depth of melting and of melt percentage, both of which can be related to either magmatic thickening of the arc or to extensional thinning.

Key words: Mid-Cretaceous, Kohistan arc.

B/187. Bignold, S.M., Treloar, P.J. & Petterson, M.G., 2001. The Chalt Volcanic Group, Kohistan, N. Pakistan: Formation of a small back-arc basin. *Journal of Asian Earth Sciences* 19, p.4.

The Chalt volcanic have passed through low-grade metamorphism and commonly display pillow structure. They are a prominent feature of the northern part of the Kohistan magmatic arc. They have been variously interpreted in term

of tectonic locale. This paper gives geochemical details in support of a small back-arc basin in which the Chalt volcanic originated.

Key words: Volcanics, Kohistan, Chalt.

B/188. Bilgrami, S.A., 1982. Mineral Industry of Pakistan. Resources for the Twenty-first Century, Resource Development Corporation, Karachi1, 68-178. US GS professional Paper 1193, 168-180.

Key words: Mineral resources.

B/189. Bilgrami, S.A., 1989. Far East: Pakistan, a review of mineral deposits; exploration, production and commercial aspects. Mining Journal Annual Review 103.

This account deals with the exploration, production and commercial aspects of the mineral deposits of Pakistan. Most of the commercially exploited minerals have been discussed.

Key words: Mineral deposits, exploration.

B/190. Bilgrami, S.A. & Farah, A., 1986. Plate tectonics and mineral potential of Pakistan. Die Naturwissenschaften in Pakistan, Deutsch-Pakistanisches Forum, 239-257.

It has now been agreed that plate tectonics have a bearing on the mineral deposits. In this document, with two figures and two tables, the authors describe in detail plate tectonics and mineral potential of Pakistan.

Key words: Tectonics, mineral deposits.

B/191. Bilham, R., Panth, G.B. & Jacoby, G.C., 1984. A preliminary study of ancient trees in the Hunza valley, and their dendroclimatic potential. In: Miller, K.J., The International Karakoram Project, Volume 2. Cambridge University Press.

Trees of great age are found on the high mountain slopes bordering the Hunza Valley and tributary valleys in the Karakoram Mountains. The survival of ancient trees is partly attributable to the enlightened local practice of culling branches for fuel rather than felling entire trees. We have subjected two specimens of juniper found at elevations of 3,800 m and 4,150m to ring analysis and determined maximum ring counts of 1200 and 479, respectively. The detection of incomplete rings in different radial sections from both specimens suggests that some rings may be missing and that the age of the trees may be more than their ring counts indicate. The lower and older of the two specimens consisted of a dead stump of unknown absolute age and an attempt to crossdate the specimen with the higher, living specimen was unsuccessful.

The two specimens are unlikely to be the oldest or most climatically sensitive trees in the region. We conclude that there is a strong possibility for deriving climatic information for the last several centuries from the ancient trees of the region. A knowledge of past climate has Important consequences in the study of glacial movements, erosion, and agriculture in the Hunza Valley.

Key words: Paleobotany, climate, Hunza valley.

B/192. Bilham, R. & Simpson, D., 1984. Indo-Asian convergence and the 1913 survey line connecting the Indian and Russian triangular surveys. In: Miller, K.J., The International Karakoram Project, Volume 1. Cambridge University Press.

In 1913 a 480-km long north-south triangulation survey was conducted across the Karakoram and Pamirs near the 73rd meridian. It spans more than one third of the zone of convergence characterizing the collision of the Eurasian and Indo-Australian plates and its remeasurement after more than 65 years is expected to reveal considerable crustal deformation.

This article discusses the errors associated with the 1913 survey and attempts to predict the magnitude and style of deformation that may have occurred since then. It is known that the original survey accuracy is associated with errors greater than $\pm 10^{-6}$ strain and that, unless a convergence rate of more than 6 cm/year has occurred, uniform compression of the survey line will be undetectable. At 73° E the Indo-Asia convergence is expected to be 4 cm/year. However, it is clear from historical and continuing seismicity that the convergence is not uniform and that locally large deformations may have occurred. Two areas appear particularly promising. These are the area just north of Gilgit and the area north of Lake Karakul in the Soviet Pamirs.

Key words: Neotectonics, geodetic survey, Karakoram

B/193. Billington, S., Isacks, B. & Barazangi, M., 1977. Spatial distribution and focal mechanisms of mantle earthquakes in the Hindu Kush-Pamir region: a contorted Benioff Zone. *Geology* 5, 699-704.

Seismological evidence based on the spatial distribution and focal mechanism solutions of mantle earthquakes in the Hindu Kush-Pamir region supports a model in which suboceanic lithosphere that existed between the converging Eurasian and Indian continents is subducted into the upper mantle. Two lines of evidence support this model. First, a careful selection of well-defined hypocenters in the region from 1950 through 1973 defines a thin (about 25 km thick) contorted Benioff zone within the upper mantle. The zone dips steeply (about 70°) toward the north in the western part of the region and has a shallower dip (about 50°) toward the southeast in the eastern part of the region. Second, focal mechanism solutions of intermediate-depth earthquakes have extensional (T) axes oriented parallel to the dip of the Benioff zone. The thin slab-like distribution of hypocenters and the downdip extensional stress are similar to features found in many other more typical regions of active lithospheric subduction. In addition, comparison of the focal mechanism solutions and the spatial distribution of earthquakes demonstrates the presence of a fault plane at about 200 km depth within the western part of the subducted lithosphere. Similar fault planes have also been observed in other areas of subduction. Comparison of the seismicity of the Hindu Kush-Pamir region with the apparent lack of mantle earthquakes along the main Himalayan arc suggests that the region is the site of the final stage of subduction of suboceanic lithosphere along the collision boundary between the Indian and Eurasian plates.

Key words: Earthquakes, seismology, Hindukush, Pamir.

B/194. Bilqees, R., 1995. Petrological studies of some phosphorite deposits of Hazara, Pakistan and their Economic importance. M.Phil. Thesis, University of Peshawar, 65p.

For details see the following account.

Key words: Petrology, phosphorite, Hazara.

B/195. Bilqees, R., Tanoli, S.K. & Hussain, V., 1995. Petrological studies of some phosphorite deposits of Hazara, Pakistan and their Economic importance. Abstracts, International Symposium and Field Workshop on Phosphorites and other Industrial Minerals, Abbottabad, 35-36.

Phosphorites occurring in Hazara are the only commercially workable deposits in Pakistan. These phosphorites are of sedimentary origin belonging to Cambrian age occurring in a number of localities in the area. The rock phosphate in Kakul area occurs in a folded and faulted sequence of Cambrian to Jurassic sediments. The geology of the area has been complicated by thrusts which have divided the phosphate bearing strata into a number of discrete thrust sheets. There are two phosphatic horizons in this area. The main occurrence is in the Abbottabad Formation where it is associated with chert and dolomite while, in Hazira it is associated with siltstone. Present studies are based on the phosphorite deposits of Kakul and Lambidogi belonging to Abbottabad Formation. Field and laboratory studies reveal that these phosphorites were formed by the upwelling currents in the shelf environments. Later, when high energy conditions prevailed, this authigenically formed phosphate mud was reworked and pellets were formed. The associated dolomite is of secondary origin which probably was formed by the alteration of limestone, whereas chert was formed by the incorporation of silica. Hazara phosphorites are of good quality and the estimated reserves are about 20 million tones which are sufficient to fulfil the requirements of our phosphatic fertilizers in Pakistan. Despite known large resources of phosphorite in Hazara, its annual production is about 40,000 tones. The selective mining of rock phosphate is being done at Kakul thus leaving huge quantities of low grade ore as dump. There is a

need to undertake beneficiation and direct application studies for utilizing rock phosphate resources of the country more judiciously. Further, these deposits should be exploited at a faster pace and efforts should also be made to explore the new ones in this district. Encouraging results in these directions can be obtained when the provincial and federal governments provide or facilitate the necessary technical and financial Inputs to this phosphorite project, as has been done in case of Saindak metallic project in Balochistan.

Key words: Petrology, phosphorite, Hazara.

B/196. Bird, P., 1978. Initiation of intracontinental subduction in the Himalaya. *Journal of Geophysical Research* 83, 4975-4987.

Independent arguments based on topographic stress and crustal strength give upper limits of 200 bars and 300 bars, respectively, for the average shear stress on the intracontinental thrust fault that formed the Himalaya. According to either a one-dimensional or a two-dimensional fault model, such stresses could not have produced the Himalayan granites by friction, unless overthrusting velocity exceeded 30 cm/yr. More probably, Himalayan metamorphism was caused by exposure of continental crust to hot asthenosphere prior to the formation of the intracontinental thrust. Crust was exposed by peeling away of Indian subcrustal lithosphere in response to the force and moment exerted by the Tethyan slab. This detachment of buoyant crust from dense lithosphere better explains the metamorphic pattern and also explains why the distributed crustal shortening at the beginning of the collision orogeny was replaced by localized thrusting or intracontinental subduction.

Key words: Tectonics, subduction, Himalaya.

B/197. Bishop, M.P. & Shroder, J.F.Jr., 2000. Remote sensing and geomorphometric assessment of topographic complexity and erosion dynamics in the Nanga Parbat massif. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 181-200.

The dynamic mountains of the western Himalaya are the result of complex interactions involving tectonic, structural, lithological, climatic and surface processes. The multi-scale dynamics of surface processes in this region are largely unknown. This paper assesses the spatial complexities of the topography at Nanga Parbat, as we seek to understand erosion dynamics, differential denudation and the geodynamics of uplift and denudation. Spatial analysis of a high resolution digital elevation model and three-dimensional terrain simulation using satellite imagery indicate that the topographic complexity of Nanga Parbat is highly scale-dependent and exhibits a hierarchical order that is reflective of erosion dynamics. Observations and analyses reinforce prior understandings of rapid rates of uplift and high rates of surficial denudation. Results indicate that climate controls the topographic complexity of the massif although a tectonic influence is present and is largely masked by the overprinting of surface processes with time. Consequently, Nanga Parbat is seen to owe its origin to erosionally induced tectonic uplift and rapid surficial denudation. Rapid uplift altered erosion dynamics and further accelerated erosion resulting in extreme relief. Nonetheless, the differential denudation resulting from erosion dynamics does not appear to be in spatial balance with the regional scale tectonic mass flux. Systematic integration of dynamic models that account for the scale-dependencies of subsurface and surface processes are required to study the nature of this complex system and explain topographic evolution.

Key words: Remote sensing, geomorphology, Nanga Parbat.

B/198. Bishop, M.P., Shroder, J.F.Jr., Hickman, B.L. & Copland, L., 1998a. Scale-dependent analysis of satellite imagery for characterization of glacier surfaces in Karakoram Himalaya. *Geomorphology*, 21, 217-232.

Information regarding process-structure relationships and change in the Karakoram Himalaya is of great importance in studying glacier hydrology, mass balance, and dynamic environmental change. Such information is not readily available. Detailed spatio-temporal assessment requires field investigation coupled with quantitative remote sensing studies. We conducted an investigation of the large Batura Glacier in Pakistan to determine if spectral variability can be quantified and used to characterize glacier surfaces. Specifically, SPOT Panchromatic satellite data were evaluated for differentiating features of glacier structure resulting from ice movement, ablation, and supraglacial

fluvial action. Image semivariogram analysis was conducted for assessing spectral variability patterns and fractal analysis was used to examine scale-dependent variation in the data. Results indicate that spectral variability from fields of ice seracs can exhibit fractal characteristics, although most surface features on the glacier exhibit a change in the fractal dimension over different ranges in scale. The fractal dimension was found to be useful for differentiating between glacier surfaces such as white ice and debris-covered ice. Characteristics of the debris-load and the scale-dependent nature of calculating the fractal dimension ultimately determined the potential of class separability.

Key words: Remote sensing, geomorphology, glaciology, Karakoram, Himalaya.

B/199. Bishop, M.P., Shroder, J.F.Jr., Sloan, V.F., Copland, L. & Colby, J.D., 1998b. Remote sensing and GIS technology for studying lithospheric processes in a mountain environment. *Geocarto International* 13, 75-87.

Analysis of relationships between uplift and denudation in complex mountain environments requires integrated approaches using remote sensing and geographic information systems (GIS) analyses in combination with field investigations. We present multidisciplinary research focusing on the Nanga Parbat Himalaya of northern Pakistan. Remote sensing of the subsurface includes radio-echo sounding to investigate glaciers, magnetotelluric sounding, and seismic tomography to investigate shallow to deep aspects of the lithosphere. Remote sensing of the landscape includes satellite image acquisition, multispectral analysis, geomorphometric analysis of a satellite-derived digital elevation model (DEM), and the application of GIS and pattern recognition procedures to analyze topographic complexity and the geomorphology of the mountain massif. Detailed mapping requires topographic normalization of satellite imagery using the non-Lambertian model. Radar measurement of thicknesses of glacier ice, coupled with assessment of satellite imagery and field data, have enabled calculation of ice and sediment discharge. Collectively, scientific observations reinforce prior understandings of rapid rates of uplift and high rates of surficial denudation. The integration of data has thus enabled a systematic approach to study localized coupling between tectonic and surface processes. In future studies of this kind, it will become ever more important for geoscientists to integrate quantitative remote sensing and GIS into a standard analytical framework in order to solve complex problems.

Key words: Remote sensing, GIS, Nanga Parbat, Himalaya.

B/200. Bishop, M.P., Shroder, J.F.Jr. & Ward, J.L., 1995. SPOT multispectral analysis for producing supraglacial debris-load estimates for Batura Glacier. *Geocarto International*, 10, 81-90.

SPOT multispectral and panchromatic data were evaluated to determine their utility to detect debris-load characteristics of the Batura Glacier located in the Karakoram Himalaya. Debris-depth measurements, surface samples, and ground photography were obtained and used with satellite-derived information to produce supraglacial debris-load and discharge estimates. Visual analysis of panchromatic data indicated that structural characteristics of the glacier exhibited unique textures associated with surface structure characteristics. Multispectral analysis revealed that stratified unsupervised classification of principal components can be used to produce classifications depicting supraglacial lithology and shallow debris-load variability. Debris-load discharge estimates ranged from 48-97 x 10³ m³ yr⁻¹. These results indicate that SPOT multispectral data may be used to produce reasonable quantitative estimates of debris-load characteristics for glacier mass balance and regional denudation studies.

Key words: Remote sensing, glaciology, Batura, Himalaya.

B/201. Blandel, F. & Marivier, L., 1952. Note on iron ores in Pakistan. 9th International Geological Congress, Algeria. Symposium on Iron Ore 1, p. 381.

The iron ores of Pakistan, including those from the Northern part, are described.

Key words: Iron ore.

B/202. Blasi, A., Brajkovic, A., De Pol Blasi, C., Forcella, F. & Martin, R.F., 1980. Contrasting feldspar mineralogy, textures and composition of Tertiary anorogenic and orogenic granites, Gilgit area, northwestern Pakistan. *Neues Jahrbuch fur Mineralogie, Abhandlungen* 140, 1-16.

Key words: Mineralogy, texture, granites, feldspar, Gilgit.

B/203. Blauwet, D., Smith, B. & Smith, C., 1997. A guide to the mineral localities of the northern areas, Pakistan. *Mineralogical Record* 28, 183-200.

Key words: Mineral guide.

B/204. Blisniuk, P.M., 1996. Tectonic evolution of the NW-Himalayan thrust front: Implications from sediment characteristics in the Trans-Indus Ranges, Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy 13-14.

This paper presents the results of sedimentological, magnetostratigraphic and structural work constraining the latest Miocene to recent tectonic evolution in the area of the present-day NW-Himalayan thrust front. In the Trans-Indus Ranges of northern Pakistan, forming the western part of the NW-Himalayan thrust front, unconformities, changes in paleocurrent directions and locally derived conglomerates contained in syn-orogenic foreland basin deposits provide evidence for local deformation between ≥ 3.5 and ≥ 3 Ma. The tectonic history of the Trans-Indus Ranges has previously been described in terms of a well-documented single episode of major thrusting starting at ~ 1 Ma [e.g., Khan et al., 1998], thus the work presented here implies, instead, that there were two distinct phases of local deformation, at ~ 6 to 5 Ma and ≤ 2.5 Ma to present [e.g., Burbank and Beck, 1989], this study demonstrates that the presence of two phases of deformation during latest Miocene to recent time is a regional-scale phenomenon, and these two phases are probably correlative along the present-day NW-Himalayan thrust front.

In the Salt Range, the earlier deformation can variously be interpreted as either initial thrusting along the Salt Range Thrust [e.g., Burbank and Beck, 1989], or normal faulting in the foreland basin [e.g., Lillie et al., 1987]. However, in the Trans-Indus Ranges, the reconstruction of possible source areas for the locally derived conglomerates shows that the earlier deformation is much more likely related to normal faulting than to thrusting. In combination with other workers' flexural and gravity modeling [Duroy et al., 1989], the results present here suggest that the tectonic evolution in the area of the present-day thrust front is characterized by: 1) latest Miocene to early Pliocene north-dipping normal faulting in the footwall of the frontal thrust system related to flexure of the Indian plate in response to topographic loads emplaced to the north on older NW-Himalayan thrust, and 2) subsequent south-directed thrusting along the present-day thrust front, related to outward growth of the NW-Himalayan thrust wedge since the latest Pliocene. The geometry of the present-day thrust front appears to be largely controlled by normal faults and monoclines formed during the earlier deformation and acting as thrust ramps during the still active younger deformation.

This mechanism may not only be responsible for the basement offsets observed in the subsurface of the thrust front, but also for others that appears to have controlled the location of several other major structures underneath the NW-Himalayan foreland fold-and-thrust belt, e.g. the Northern Potwar Deformed Zone [Leathers, 1987], and structures on the Kohat Plateau [Pivnik and Sercombe, 1994]. Basement normal faults acting as structural ramps have also been observed in other areas along the Himalayan thrust front [Talkadar and Sudhakar, 1972] as well as in other orogens such as the Western Alps [Butler, 1989] and Ouachita Mountains in Arkansas and Oklahoma [e.g., Briggs and Roeder, 1975]. Therefore, the interplay between thrust stacking above basal detachment of fold-and-thrust belts and syn-orogenic flexural deformation beneath the detachment may be a more significant component of collision-related deformation than previously recognized.

Key words: Tectonics, sedimentology, Trans-Indus Ranges, Himalaya.

B/205. Blisniuk, P.M. & Saheed, G., 1993. The Tectonic evolution of fault systems with strong lateral variations in tectonic style: The Trans-Indus Ranges (Northern Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 62-63.

The main focus of this ongoing study is the structural evolution of fault systems with lateral variations in tectonic style between compression and transpression. Such fault systems have been recognized in many mountain belts. However, due to the complex pattern of deformation their formation is still poorly understood, and the tectonic interpretation of regions affected by this kind of deformation is difficult. The Trans-Indus Ranges are part of the

young and still active frontal thrust system of the NW-Himalayan foreland fold-and-thrust belt which is characterized by the occurrence of several pronounced structural re-entrants and promontories. Studies of such structurally complex fault systems in actively deforming regions are important because they can provide information that is usually not available in older mountain belts but necessary to understand the mechanics of their formation. A particularly attractive aspect of the ongoing project is the young age of deformation in the study area (< 1 Ma ?), which allows a very precise quantitative assessment of the rates of deformation. Furthermore, thermal and tectonic overprinting which has occurred in many older mountain belts is absent, and exposure is excellent in most of the region.

Preliminary results of a first field season in the Trans-Indus region (11/91 to 1/92) indicate that the emergence of the Trans-Indus Ranges was controlled by a system of frontal ramps that form the centers of re-entrants and promontories, and lateral or oblique ramps that form their edges. The Construction of balanced cross-sections shows that the total shortening along the frontal ramp segment represented by the western Khisor Range is on the order of at least 10 km. This suggests that the deformation along the lateral and oblique ramps is characterized by a strike-slip Component of similar magnitude. Pronounced bends of structures in the Khisor Range near the transition zones to adjacent regions of transpressive deformation suggest that vertical axis rotations occur in these areas. Structures show an apparent clockwise rotation near the western end of the Khisor Range, which is truncated by a right-lateral strike-slip fault, and an apparent counterclockwise rotation near its eastern end, which seems to be truncated by a left-lateral strike-slip fault. The sense of the apparent rotations is therefore compatible with the assumed relative motions along the lateral terminations of the Khisor Range. Alternatively, the observed bends could simply reflect a complex ramping geometry, in which case vertical axis rotations would not have occurred at all. Present fieldwork (12/92 to 3/93) therefore includes sampling for a paleomagnetic investigation to test these hypotheses.

With the exception of the results of our previous investigations in the Trans-Indus Ranges, quantitative data on the deformation in that region are not yet available. The main goal of our study therefore is a qualitative analysis of the structural style of deformation, and a quantitative assessment of the total deformation.

The area presently represented by the Trans-Indus Ranges was part of the Himalayan foreland basin and received synorogenic deposits during Late Neogene folding and thrusting further north, and was subsequently deformed as part of the hanging wall of the younger frontal thrust system in the south. The onset of deformation in the Trans-Indus region should be reflected by decreasing sedimentation rates of the more distal facies with a source area further north, and subsequent nondeposition and erosion, or deposition of proximal deposits that have the Trans-Indus Ranges as source area. Ongoing research therefore integrates sedimentological and chronostratigraphic studies of the synorogenic deposits with structural investigations in this area.

The structural portion of this work includes detailed field mapping to provide constraints on the style of deformation. This mapping also is the basis for the construction of balanced cross-sections that are needed to quantify the total amount of shortening along the Trans-Indus Ranges. The chronostratigraphic studies will include paleomagnetic age determinations of young synorogenic molasse deposits, and fission track dating of volcanic ashes within that sequence. These studies will provide information on the age ranges and deposition rates of syntectonic sediments. Together with sedimentological mapping of syndeformational unconformities, facies changes and paleocurrent analyses these results will constrain the temporal and spatial character of deformation in the NW-Himalayan foreland.

Key words: Tectonics, structural geology, Trans-Indus Ranges, Himalaya.

B/206. Bloemendaal, S. (Ed.), 1983. Technical report on ground water resources in Kohat Plain, Kohat District, North West Frontier Province. Pak-Dutch Programme for Water Investigation in North West Frontier Province. Hydrogeology Directorate, Water and Power Development Authority, Report No. III-1, 57p.

Key words: Groundwater, Kohat.

B/207. Bloemendaal, S. & Vanenk, D., 1982. A computer model for safe yield assessment of the Talash Valley, North West Frontier Province, Pakistan. Hydrogeology Directorate Water and Power Development Authority.

Key words: Hydrogeology, Dir.

B/208. Bloemendaal, S. & Sadiq, M. (Eds.), 1985. Technical report on groundwater resources in Maira area, Mardan and Peshawar districts-NWFP. Report IX-I. Hydrogeology Directorate, WAPDA-Peshawar, Pakistan & Institute of Applied Geoscience, TNO-DGV, DELFT-The Netherlands.

The report comprises nine chapters, 11 tables, nine figures, five plates and five appendices.

Key words: Hydrogeology, Groundwater, Mardan.

B/209. Blum, J.D., Gazis, C.A., Jacobson, A.D. & Chamberlain, C.P., 1998. Carbonate versus silicate weathering in the Raikhot watershed within the High Himalayan Crystalline Series. *Geology* 26, 411-414.

The major element and Sr isotope geochemistry of surface waters, bedrock, and river sands was investigated in the Raikhot watershed within the Himalayan Crystalline Series (HHCS) in northern Pakistan. Mass-balance calculations of mineral-weathering contributions to the dissolved flux of ions from the watershed indicate that 82% of the HCO₃⁻ flux is derived from the weathering of carbonate minerals and only 18% is derived from silicate weathering, even though the bedrock is predominantly quartzofeldspathic gneiss and granite with only 1% carbonate in the watershed. This study demonstrates the importance of rare amounts of bedrock carbonate in controlling the water chemistry of glacial watersheds. We suggest that the flux of Sr with a high ⁸⁷Sr/⁸⁶Sr ratio in the major Himalayan river may be derived in large part from weathering of trace amounts of clacite within the largely silicate HHCS. Models that use the flux of radiogenic Sr from the Himalayas as a proxy for silicate weathering rates may, therefore, overestimate the amount of CO₂ consumption due to silicate weathering in the Himalaya.

Key word: Isotope geochemistry, weathering, Raikhot, Himalaya.

B/210. Blume, H., 1962. Pakistan, a geographical summary. *Zeitschrift für Kulturaustausch* 18; Stuttgart.

Key words: Geography.

B/211. Bogue, R.G., 1962. Chromite deposits near Hari Chand, Peshawar Division, West Pakistan. Geological Survey of Pakistan, Mineral Information Circular 20.

Key words: Chromite, Hari Chand, ultramafic rocks, Peshawar.

B/212. Bogue, R.G. & Schmidt, R.G., 1961. Bentonite deposits near Padhrar, Rawalpindi Division, West Pakistan. Geological Survey of Pakistan, Mineral Information Circular 3, 24p.

Key words: Bentonite, Rawalpindi.

B/213. Bohlin, B. & Norin, E., 1960. Zentralasiatische gebirgszusammenhänge. *Geologische Rundschau* 50, 325-334.

This account summarizes the orogenic relationship of the central Asian mountain ranges.

Key words: Tectonics, Central Asia.

B/214. Bokhari, S.A.A., 1999. Potential of export of gems & jewelry from Pakistan. In: Brochure "Pakistan Gems & Mineral Show '99". Export Promotion Bureau, Government of Pakistan, 31-39.

This article gives a brief account of the commercial data on gem stones of Pakistan with information on occurrence and other aspects of jade, fluorite, tourmaline, ruby, lapis-lazuli, kunzite, garnet, emerald, topaz, aquamarine and peridot.

Key words: Gems, jewelry.

B/215. Bonis, N.R., 1985. Paleocurrent analysis of Siwalik strata in the Trans-Indus region, north-western Pakistan. B.Sc. thesis, Dartmouth College.

Key words: Paleocurrents, siwaliks, Trans-Indus region.

B/216. Bonney, T.G. & Raisin, C.A., 1894a. On rocks and minerals collected by Mr. W.M. Conway in the Karakorum-Himalayas. *Proceedings of the Royal Society* 55, 468-487.

During his journey in the Karakoram Himalayas, Mr. W. M. Conway collected more than 300 specimens of rocks and minerals, which, however, were generally rather small. These were sent to us for examination at University College, London. Thin slices have been prepared of the specimens which promised to be the more interesting. Of the rest, the mineral composition was verified in cases of doubt by examining pulverised fragments under the microscope. Since the detailed results of our examination, which practically form an annotated catalogue of the specimens, will be printed as an appendix to Mr. Conway's forthcoming volume, we restrict ourselves in this paper to a summary of our work, and to a notice of a few specimens which appear to be of more than local interest.

Key words: Rocks, minerals, Karakoram, Himalaya.

B/217. Bonney, T.G. & Raisin, C.A., 1894b. Notes on Mr. W.M. Conway's collection of rock specimens from the Karakoram Himalayas. In: Conway, II: 41-73.

Some details are given in the preceding account.

Key words: Rocks, minerals, Karakoram, Himalaya.

B/218. Boota, M., 1978-80. Geology, Petrology and Geochemistry of Chalt-Hini Area, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore, 179p.

The project area (Chalt-Hini) lies in the Hunza Valley District Gilgit at (E) $74^{\circ} 35'$ to $74^{\circ} 18'$ latitude (N) $36^{\circ} 19'$ to $36^{\circ} 13'$ and has been mapped on tectonically. The area is located in the center of the Karakoram Mountain and represent a part of a cross section through this mighty range. Area is intensely disturbed tectonically being involved in Himalayan Orogeny, which is evident from the strained, crushed and deformed lamellae of the minerals in the rock.

Structures found in the area are orthotectonic; the most important are Sikandarabad anticline, Chalt Fault, Boudalus Fault and Hini Fault. The project area is composed mainly of metamorphic and igneous rocks.

The metamorphic rocks are sedimentary in origin. Rocks were originally deposited in eugeosynclinal conditions as argillaceous sediments and afterward these were regionally metamorphosed and uplifted due to stress during Himalayan Orogeny. These are of Permo-Carboniferous or Cretaceous to Eocene in age, and grade from chlorite to garnet. Lithologically metasediments units include Khizarabad Slate, Calcareous Quartzite, Chlorite Mica Schist, Biotite Schist and Garnet Mica Schists. Igneous rocks in the area are, Karakoram Axial Granodiorite which is acidic plutonic rock of Tertiary age Greenstone which is a basic volcanic rock of Pre-Carboniferous age. Mineralogical description and petrographic analysis of these rock units are reported in detail. An attempt is made to interpret the petrogenesis of rock type. Detailed geochemical study of rocks has been described. Study also covers the ore microscopic deposits, which show the presence of ore minerals such as magnetite, hematite, pyrite etc. Orogenesis is discussed in detail. Economic mineral found in area is also described.

Key words: Petrology, geochemistry, Chalt-Hini, Gilgit.

B/219. Bordet, P., 1978. The Western border of the Indian Plate; Implication for Himalayan geology. *Tectonophysics* 51, 171-176.

The study of regions situated beyond the western margin of the present-day Indian plate (Afghanistan principally) point to the following facts:

(1) During the Late Precambrian—Early Paleozoic, stratigraphical continuity existed between western and central Iran, Central Afghanistan, Salt Range and western Pakistan. (2) During the Paleozoic a similar epicontinental cover existed in central Afghanistan, Kashmir and Tibet, with Gondwana tillites and associated cold fauna, such as in India (Umaria); however, a so-called Hercynian zone exists also in northern Iran—Hindu Kush and northern Pamir: it exhibits a Middle Paleozoic unconformity (Upper Devonian Carboniferous) on metamorphic Early Paleozoic. (3) The end of the Paleozoic, is marked by: a fracturation of the basement of the Hercynian zone, with powerful volcanic eruptions at the northern part of Hindu Kush, Kashmir (Panjal trap) and also Nepal (Nar valley) the formation of a geosynclinal zone at the southern part of Hercynian zone (Turkman, Penjaw). (4) During the Jurassic: the geosynclinal evolution of the Turkman—Penjaw furrow accelerated, with the accumulation of flysch, radiolarites, ophiolites, olistolites and incipient HP metamorphism. A general subduction took place followed by a Neocimmerian orogenic phase with overthrusting of the central Afghanistan ranges on the scar of the geosynclinal furrows. (5) During the Cretaceous: the geosynclinal evolution ended: Lower Cretaceous lies unconformably on the folded Jurassic flysch. In eastern Afghanistan and northern Pakistan, during the Middle (?) or Upper Cretaceous, a new geosynclinal zone was created. (6) During the Cenozoic, central Afghanistan was emerged; northwards, sedimentary basins were created along the Herat fault, with volcanic and magmatic activity. A southeastern geosynclinal furrow evolved with accumulation of flysch, ophiolites and finally molasse deposits (Katawas—Soleimans). Its western border began overthrusting, but this movement changed into a left lateral fault i.e., the presentday Chaman Arghandeh fault.

Conclusion: Two major phases of dislocation took place during the geological history of Gondwana: the first one began during the Permian and ended in the Jurassic; the second one began during the Cretaceous and is still active. The important Eocimmerian orogenic phenomena, existing in the Central Afghanistan and northern Pakistan, took place at the edge of a Gondwana continental fragment, which was larger than the presentday Indian plate. Coeval phenomena may exist in the Himalayan region and perhaps in one of the ophiolitic sutures of Tibet.

Key words: Indian Plate, tectonic history, Himalaya.

B/220. Bose, S.C., 1968. Lacustrine basins in the Himalaya. *Geological Review, India* 30(4), 25-32.

Deals with the formation and sediments of lacustrine basins of the Himalaya. Details not available, but might have descriptions covering northern Pakistan.

Key words: Lacustrine basin, Himalaya.

B/221. Bossart, P., 1986. Fine neue interpretation der tectonic der Hazara-Kashmir syntaxis (Pakistan). Doctoral Dissertation, ETH, Zurich.

The contents of this thesis have been reproduced in the following papers by Bossart and others.

Key words: Tectonics, structural geology, Hazara-Kashmir Syntaxis.

B/222. Bossart, P., Chaudhry, M.N., Dietrich, D., Ghazanfar, M., Greco, A., Meier, A., Ottiger, R., Papriz, K., Ramsay, J.G., Rey, R., Spencer, D.A. & Wahrenberger, Ch., 1992. A review of the geology of the northern Indian plate, Kaghan valley, NE Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 6-7.

A review is presented of the regional significance of the tectonic and metamorphic structure of the northern part of the Indian plate lying beneath the Main Mantle Thrust (MMT) of the Himalayas. The region in and around the Kaghan Valley is especially relevant in that it displays what is probably the best exposed and most easily accessible cross section of the overthrust nappes of the Himalayas in Pakistan.

From south to north the section passes from the northern Foreland of the Indian plate, with its sedimentary cover of Cambrian, Paleocene and Eocene (Murree) formations, which is overthrust along the Main Boundary Thrust (MBT)

by Precambrian rocks of the Lesser Himalayas and which are themselves overthrust along the Main Central Thrust (MCT) by the metamorphic rocks of the Higher Himalayan units. All these structural thrust slices lie beneath the Kohistan Island arc volcanics and their basement of granulite facies basic rocks and separated by the Main Mantle Thrust (MMT) from these overlying units.

Much of the displacement along the main thrust planes which demarcate the main structural units was accomplished after the main Himalayan high temperature (and high pressure) metamorphism. There is always a metamorphic jump across the major thrust surfaces such that higher grade (pressure P and temperature T) rocks always lie structurally above units with lower P-T conditions. However, within each overthrust slice there is a general systematic increase in P and T from south to north. Beneath the MBT the rocks show little or no metamorphism. In the units between the MBT and MCT metamorphic grades range from greenschist to low amphibolite facies and in the Higher Himalayan structural unit between the MCT and MMT the dominant metamorphism is of middle to high amphibolite facies. However, in the Higher Himalayas the Himalayan metamorphism is complicated in that there appears to have been an early high pressure-medium temperature phase, with local production of eclogites, followed by an overprint of amphibolite grade and later greenschist facies minerals. We have found no evidence to suggest the existence of abrupt metamorphic discontinuities of Himalayan age within the main structural units. However, within the formations making up the Higher Himalayan unit, there are preserved certain lithological and metamorphic characteristics which appear to predate the Himalayan overprint and which suggest that pre-Himalayan metamorphic and structural features are preserved: features which can be used to separate rock groups into 1) a pre-Himalayan metamorphic "crystalline" basement (Precambrian ?) and two overlying sequences of cover rocks predominantly of sedimentary aspect, a lower 2) Naran Formation of pelitic and greywacke-like sediments of late Precambrian or early Paleozoic age (?) and an upper 3) Burawai Formation of calc-pelites and interbedded basic lavas (Panjal Traps?) of Tethyan aspect possibly of late Paleozoic and Mesozoic age (?). Although all these rocks have suffered a strong Himalayan metamorphic overprint, there are locally preserved sedimentation structures (graded bedding in the Naran Formation and syn-sedimentary extensional faults and stromatolitic fossils in the Burawai Formation).

The structural styles seen in the various thrust slices are complex and are interpreted as being the result of superposed deformations with differing regional shortening directions. In the Foreland region and Lesser Himalayan Unit markers are available to determine local

and regional variations in the finite strain states and to give some indication of the progressive strain history. In the Higher Himalayas such markers are rarely identifiable but, where present, indicate that the strain states are often lower than that seen at the unit contacts. Strain markers along the locations of the MBT, MCT and MMT indicate extremely high deformations with the formation of shear zones and ductile mylonites. In the Lesser and Higher Himalayan Units the earliest deformations of Himalayan age appear to be broadly syn-metamorphic and appear to have developed large scale fold nappes, with isoclinal anticlinal folds cored with pre-Himalayan basement gneisses and granitoids. These structures were later refolded and now the geometry appears to be the result of complex fold interference patterns. In the Lesser Himalayas an early low amphibolite or greenschist fades (syn-nappe formation) shows late developed retrogression associated with the late fold superposition. In the Higher Himalayas an early eclogite facies (early subduction effect?) is locally very well preserved but, in general, the high pressure mineralogy is overprinted by amphibolite or greenschist metamorphic minerals and fabrics. In many regions this overprint is more or less complete and only traces of symplectite textures and abundance of rutile fingerprint, albeit imperfectly, the earlier high-pressure metamorphism.

The Kaghan cross-section appears to record the earliest subduction of the Indian plate beneath the Asian plate and the development of high pressure-medium temperature metamorphism (Eclogite facies). The stacking of large fold (and thrust?) nappes was followed by a thermal rise, development of further shortening and superposed folding and thrusting of individual regional units, uplift and erosion. The sediment debris was eroded from the uplifted collision zone and transported southwards to be deposited in an embryonic, low topographic, shallow marine foreland basin (the Murree Formation of the Foreland) in Paleocene to early Eocene time, and these foreland sediments were themselves involved in the late stage compressions, and overthrust by the more internal tectonic units along the Main Boundary Thrust.

Key words: Structural geology, tectonics, Kaghan, Indian Plate.

B/223. Bossart, P., Dietrich, D., Greco, A., Ottiger, R. & Ramsay, J.G., 1984. A New structural interpretation of the Hazara Kashmir Syntaxis southern Himalayas, Pakistan. *Kashmir Journal of Geology* 2, 19-36.

The stratigraphic and structural features of the Hazara Syntaxis are described. The principal lithological features of the geological formations are reviewed and special type of rhythmic sedimentation which characterises the structurally lowest Murree formation is described in detail. The region is one of overthrust and shear zone tectonics associated with the development of at least two superimposed sets of major folds and associated minor structures (Microfolds, cleavage, vein systems and various types of lineations related to rock strain or intersection of planar structures). It is concluded that the syntaxis results from an early set of nappe units developed by southwestward overthrusting of a previously metamorphosed (Himalayan) rocks followed by the formation of a large shear zone structure and finally by the transport of overthrust units from northwest to southeast.

Key words: Structural geology, Hazara-Kashmir Syntaxis, Himalaya.

B/224. Bossart, P., Dietrich, D., Greco, A., Ottiger, R. & Ramsay, J.G., 1985. A new structural interpretation of the Hazara Syntaxis, NE Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The stratigraphic and structural features of the Hazara Syntaxis have been remapped by a research team from the ETH. The region has been shown to contain overthrust and shear zone tectonics associated with the development of two sets of major folds and their attendant small scale structures (microfolds, cleavages, vein systems and various types of lineations related to total rock strain or to the intersection of differently oriented planar structures). Evidence will be presented that the syntaxis has been developed first by southwestward overthrusting of a series of metamorphic nappes over the Murree (Tertiary age) Formation. This thrusting event was followed by the formation of a large, steeply inclined shear zone structure and finally by the transport of overthrust nappes from the northwest to the southeast.

Key words: Structural geology, Hazara-Kashmir Syntaxis, Himalaya.

B/225. Bossart, P., Dietrich, D., Greco, A., Ottiger, R. & Ramsay, J.G., 1988. The tectonic structure of the Hazara-Kashmir syntaxis, southern Himalayas, Pakistan. *Tectonics* 7, 273-297.

The stratigraphic and structural features of the Hazara syntaxis are described. A special aim of this work was to integrate modern approaches to rock deformation with the regional tectonics. The region is one of overthrust and shear zone tectonics associated with the development of at least two superimposed sets of major folds and associated minor structures (microfolds, cleavage, vein systems and various types of lineations related to rock strain or intersections of planar structures). It is concluded that the syntaxis results from an early set of nappe units developed by southwestward overthrusting of previously metamorphosed (Himalayan) rocks followed by the formation of a large shear zone structure and finally by the transport of overthrust units from northwest to southeast.

Key words: Structure, Hazara-Kashmir Syntaxis, Himalaya.

B/226. Bossart, P. & Ottiger, R., 1989. Rocks of the Murree Formation in northern Pakistan: indicators of a descending foreland basin of Late Paleocene to Middle Eocene age. *Eclogae Geologicae Helveticae* 82, 133-165.

The red clastic sand and shale deposits of the Murree formation have been regarded as continental deposits of Miocene age. A new and more detailed sedimentological and micropaleontological survey on a profile of about eight kilometers in length, in the apex region of the Hazara-Kashmir Syntaxis in Northern Pakistan, has shown that these rocks were deposited in a very shallow marine, tidally influenced environment. This hypothesis is based on the recognition and interpretation of the cyclic sedimentation seen in these rocks. One can interpret a single cycle as the product of meandering tidal channels in a continuously subsiding foreland basin. Each cycle starts with typical channel fill deposits (microconglomerates, crossbedded sandstones) and passes upwards into tidal flat deposits (laminated and strongly bioturbated sand and siltstones). The uppermost part of a cycle is composed of red clayey silt with local horizons containing calcareous concretions which are interpreted as a type of fossil Caliche. Chrome-spinels out of coarse grained sandstones from the base of the Murree formation, near Balakot, indicate the Kohistan complex as a possible source area. It therefore seems likely that the Murrees are derived from the North and not from the South as previously presumed. Age determination based on syndepositional nummulites and assilines indicate an age of late Iberan (latest Paleocene) at the base of the Murree formation and late middle Lutetian at a

position some into thirds from the base of the profile. In the North, the Murree formation is therefore much older than it is in the South (Kohat, Potwar) where data suggests an early Miocene age. This age discrepancy is explained by a southwestward migration of the Himalayan thrust front that led to a southwestward migration of the Himalayan foreland basin and the Murree facies belt. As a consequence the Murree deposits prograded on to progressively younger shallow marine deposits. The introduction of a new formation for the marine part of the Murree formation is recommended to the Stratigraphical Committee of Pakistan.

Key words: Foreland basin, Murree Formation, Paleocene, Eocene.

B/227. Bossart, P., Ottiger, R. & Heller, F., 1988. Paleomagnetism in the Hazara-Kashmir syntaxis, Northern Pakistan. Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.9.

Consult the following, essentially similar, account.

Key words: Paleomagnetism, Hazara-Kashmir Syntaxis.

B/228. Bossart, P., Ottiger, R. & Heller, F., 1990. Rock magnetic properties and structural development in the core of the Hazara-Kashmir syntaxis, NE Pakistan. *Tectonics* 9, 103-121.

Paleomagnetic and structural analyses have been conducted on three well-exposed sections through a 6–8 km thick pile of molassic red beds (Murree formation) in the lowermost tectonic unit of the Hazara-Kashmir Syntaxis. Micropaleontological age determinations of the lowermost Murree sediments indicate Late Paleocene deposition (55 m.y.). From south to north, the sections are situated in the Jhelum, Neelum (both in Azad Kashmir), and Kaghan (northeastern Pakistan) valleys. Thermal demagnetization experiments suggest that haematite with high unblocking temperatures carries stable characteristic remanence directions. The relationship between finite strain and magnetic fabric was established by mapping deformed reduction spot strain markers and by measuring the anisotropy of magnetic susceptibility (AMS). For the Jhelum valley the weakly tectonized Murree beds are characterized by flattened AMS ellipsoids resulting from diagenetic compaction. Inclination values suggest that the Murree foreland basin started to develop at about 8°N during the early suturing of India and the development of island arcs to the north. India has moved northward by at least 2600 km since collision with Eurasia in the Paleocene. Declination values suggest 45° of clockwise rotation of the block supporting the Murree formation relative to the Indian craton. For the Neelum and Kaghan valleys, quantitative strain mapping shows a progressive increase of deformation northward. NRM directions rotate passively toward the cleavage plane which parallels the foliation of the AMS ellipsoids. NRM directions and AMS ellipsoids are deformed because of superposition of tectonic strain on a primary compactional strain. The AMS pattern is interpreted in light of this superposition, and a regional deformation path from south to north is suggested. A tectonic rotation model is proposed which is consistent with the transport directions around the Hazara-Kashmir Syntaxis and the rotation of thrust sheets indicated by the NRM data. This model relates the convergent transport directions with the mean indentation direction of India into Asia.

Key words: Structural geology, paleomagnetism, Hazara-Kashmir Syntaxis, Himalaya.

B/229. Boulin, J., 1981. Afghanistan structure, greater India concept and eastern Tethys evolution. *Tectonophysics* 72, 261-287.

The large and complex area between Central Asia and the Arabia-India block includes, from north to south, the Tien Shan and Hindu Kush-Kun Lun Hercynian belts, the Turkman-Farah Rud and Tanghla Shan Neokimmerian belt, the Zagros-Makran-Baluch-Himalayan Alpine belt and relics of corresponding oceanic spaces. The Angarian or Gondwanian affinities of the different blocks separated by these successive peri-Indian belts are discussed. An interpretation is proposed for the paleogeographic and structural evolution of this area, from Early Paleozoic to Present. This interpretation is based on geologic and paleomagnetic data and on global tectonic considerations. The Hindu Kush-Kun Lun pre-Hercynian ocean probably separated Laurasia from Gondwanaland. It was an Early Paleozoic Tethys (Tethys 1). The Tien Shan ocean may have been a marginal basin for the Hindu Kush-Kun Lun ocean. The Turkman-Farah Rud-Tanghla Shan pre-Neokimmerian ocean resulted from the break-up of the Gondwanaland margin. Its opening seems to have been related to the pre-Hercynian ocean closure resulting in the formation of a new Tethys (Tethys 2). Its subsequent closure may also have been related to the opening of the

Zagros-Baluch-Indus-Tsang Po pre-Alpine ocean (Tethys 3). According to this interpretation, Eurasia appears to have increased from Early Paleozoic to Cenozoic by successive accretion of cratonic blocks which came from the south through the Tethys. This evolution can be compared to the similar Mediterranean evolution. This interpretation is in agreement with the Greater India concept. However, the northern border of Greater India differs according to the stage of the Gondwanaland evolution which is considered. Actually, Greatest India extended north to the Caledonian belt and consequently has recorded the whole history of the Eastern Tethys.

Key words: Regional tectonics, Tethys, Afghanistan, Central Asia, India,

B/230. Boulin, J., 1988. Hercynian and Eocimmerian events in Afghanistan and adjoining regions. *Tectonophysics* 148, 253-278.

The area centered around Afghanistan is a collage of continental blocks derived from Gondwanaland. This collage comprises, among others:

(1) a Hercynian orogenic belt widely represented in Afghanistan and also by some sparse outcrops in the northern Iran; it is a subduction-type orogen constructed at the margin between the Paleotethys and the Turan-Turkestan-Tarim block;

(2) a northern Eocimmerian orogenic belt, widely represented in Afghanistan and the north of Iran; it is a collision-type orogen constructed in the same place as the Hercynian orogenic belt and resulted from the closure of the Paleotethys and the collision of the central Iran and central Afghanistan blocks with the Turan-Turkestan-Tarim block;

(3) a southern Eocimmerian orogenic belt of which outcrops are now confined to southern Iran but which may project beneath the Neogene and Quaternary formations of southern Afghanistan; it is a subduction-type orogen constructed at the margin between the Neotethys and the central Iran-central Afghanistan block, which itself was at that time subjected to regional extension; this belt is now incorporated in the Alpine-Himalayan orogen. The geology of these belts suggests that the opening of the Neotethys became effective only from the Permian or Triassic, and was in a Red Sea-type phase during the Upper Devonian. Its initial rifting possibly occurred during the Lower Paleozoic, much like the Paleotethys, in which initial rifting also occurred in Lower Paleozoic time and whose opening became effective from the Ordovician. Thus, each of the oceanic realms in this region appears to have possibly resulted from the same extension of Gondwanaland during the Lower Paleozoic after which they followed more or less different paths of evolution. Moreover, the proposed geodynamic interpretation implies that during the Permian and Triassic there was in this region a certain coexistence of the vanishing Paleotethys with the relatively young Neotethys, which was beginning to subduct.

Key words: Regional tectonics, Tethys, Hercynian, Eocimmerian, Afghanistan.

B/231. Bowersox, G.W. & Anwar, J., 1989. The Gujar Killi emerald deposit, Northwest Frontier Province, Pakistan. *Gems and Gemology* 25, 16-24.

Over the last decade, Pakistan has developed into an important source for many gem materials. A number of localities have been identified for emeralds in particular. This article reports on the emerald deposits in the valley of Gujar Killi, located in the Northwest Frontier Province. The occurrence, mining, and gemological properties are described. Reserves appear to be good, and increased mining activity suggests stronger production for the near future.

Key words: Gemstone, emerald, Gujar Killi, NWFP.

B/232. Bradshaw, E.J. & Crookshank, H., 1950. Search for oil in Pakistan. *Geological Survey of Pakistan, Quetta, Record* 2.

Key words: Hydrocarbons, oil, Pakistan.

B/233. Branson, C.C., 1935. A labyrinthodont from the Lower Gondwana of Kashmir and new edestid from the Permian of the Salt Range. *Connecticut Academy of Arts and Sciences, Memoirs*, 9, 19-26.

Key words: Palaeontology, Gondwana, Permian, Kashmir, Salt Range.

B/234. Bridge, J.S., 1996. Architecture of Miocene overbank deposits in northern Pakistan-Discussion. *Journal of Sedimentary Research*, Section B, 65, 401-403.

Willis and Behrensmeyer (1994) have presented a remarkably detailed description and analysis of the architecture of ancient overbank deposits from the Miocene Chinji Formation of northern Pakistan (see also Behrensmeyer 1987, Willis 1993a). They described meters-thick paleosols bounded sequences that are defined by an alternation of relatively mature paleosols and stratified deposits with a lesser degree of pedogenesis. They asserted that the mature paleosols represent relatively long periods of very low deposition rate, whereas the stratified deposits represent relatively short periods of high deposition rate. They proposed and evaluated five end-member hypotheses for the origin of the paleosol-bounded sequences. They concluded that the stratified deposits were formed by local rapid filling of low areas on the floodplain, independently of the position of major channels: such filling may have been a more or less continuous process, or may have been a short-lived event associated with river-channel avulsion. They specifically dismissed the possibility that the nature of the stratified deposits was related to the proximity of major channels and the growth of alluvial ridges. They also dismissed the possibility that paleosol-bounded sequences could have been related to regional variations in sediment supply and deposition rate, or to valley incision and filling. In my view, these far-reaching conclusions are flawed, for three main reasons: (1) whether or not the overbank sediment bodies appear to fill topographic lows in the paleo-floodplain depends critically on the way the stratigraphic cross sections were constructed, which was not justified adequately; (2) the hypotheses for the origin of the stratified deposits are misleading; and (3) the sections studied do not extend sufficiently in a direction normal to paleoflow direction to test adequately the hypotheses presented. I will expand upon these points in turn.

Key words: Miocene, paleosol, Chinji Formation, Siwaliks.

B/235. Bridge, J.S., Behrensmeyer, A.K., Khan, I.A., Willis, B.J. & Zaleha, M.J., 1997. Evolution of Miocene fluvial environments in northern Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 20-23.

Fluvial deposits of the Miocene Siwalik Group (Chinji, Nagri, and Dhok Pathan Formations; age from 15 to 7 Ma), Potwar Plateau, Northern Pakistan were studied in order to: (1) reconstruct the nature and evolution of paleoenvironments across part of the ancient Himalayan foredeep; (2) assess depositional controls such as river diversions, tectonism, climate and base-level change, and; (3) examine the relationship between changing paleoenvironments and faunal evolution. Kilometers-long sedimentologic-paleomagnetic logs were constructed in three separate areas of the Potwar Plateau (near the towns of Chinji, Khaur, and Dma). Detailed sedimentological cross sections (up to 100 m thick and 4 km across), spanning different stratigraphic intervals in each area, were constructed using photomosaics and closely spaced vertical logs. Litho- and chrono-stratigraphic correlation of the strata between the three study areas was attempted.

The strata comprise relatively thick (100 to 101 m) sandstone bodies and mudstones that contain thinner sandstone bodies (101 to 100m) and paleosols. Thick sandstone bodies are km to tens of km wide normal to paleoflow, and are composed of large-scale stratsets (storeys) stacked laterally and vertically adjacent to each other. These sandstone bodies are single or superimposed channel belts of major braided (mainly) and meandering rivers, and large-scale strata sets represent channel bars and fills. Channel belts were km wide, had bankfull river discharges on the order of 103 - 104 cumecs and braiding parameter upto to about 3. Individual channel segments had bankfull widths, maximum depths and slopes on the order of 102 in, 101 m and 104, respectively, and sinuositities around 1.1. Rivers of the Nagri Formation are 2 to 3 times wider and deeper than those of the Chinji and Dhok Pathan Formation. The rivers generally flowed to the southeast. Flow was perennial with seasonal flooding. These rivers are comparable to many of those flowing over the megafans of the modern Indo-Gangetic basin, and a similar depositional setting is likely.

Thin sandstone bodies within mudstone sequences extend laterally for on the order of 102 m and have lobe, wedge, sheet and channel-form geometries; they represent crevasse splays, levees, single sheet-flood deposits and floodplain channels. Mudstones are laminated and variably bioturbated/disrupted and represent mainly floodbasin and lacustrine deposits. Floodplain lakes were both ephemeral and perennial, were up to a few tens of km across and probably less than 10 m deep. Extremely disrupted strata with m-thick horizons with pedogenic features are 'mature'

paleosols that extend laterally for tens of km. Many paleosols have a nodular calcite horizon overlain by a noncalcareous horizon, and were generally formed under relatively well-drained conditions. Other paleosols have matrix calcite and lack such distinct horizons, and formed in relatively poorly drained topographic lows. All mature paleosols indicate extended periods of slow deposition. A variety of features indicate episodic wetting and drying as water tables fluctuated seasonally. Paleosols are similar to modern alluvial soils of the Indo-Gangetic basin, which is consistent with interpretation of a monsoonal paleoclimate. Paleosol-bounded sequences are m to 1Gm thick, km to 10 km wide lenses of stratified, moderately disrupted overbank deposits bounded by mature paleosols. They are interpreted to represent periods of relatively rapid deposition, associated with progradation of crevasse sills-levees into low area of the floodplain, alternating with long periods (103 - 104 years) of very low deposition rate.

Trace fossils and body fossils within all rock types indicate the former existence of terrestrial and aquatic vertebrates, molluscs (bivalves and gastropods), arthropods (including insects), worms, trees, bushes, grasses, and aquatic flora. Vertebrate remains are particularly common, invertebrate (mollusc) remains are uncommon, and plant fossils (including pollen and spores) are rare. Plant macrofossils occur as impressions in crevasse-splay mudstones, and tree-trunk casts in channel fills and upper portions of major channel fills, less common in other floodplain deposits, and relatively uncommon in major channel sandstones. Vertebrate fossils are, thus, more abundant in the Chinji and Dhok Pathan Formations than in the Nagri Formation, with the exception of Nagri locality Y311, that represents an unusual, fine-grained fill of a large-scale abandoned channel.

The proportion of sandstone bodies varies vertically on three scales in all study areas. Relatively small-scale variations are tens-of-in-thick alterations of thick sandstone bodies (major channel deposits) and mudstone-sandstone strata (overbank deposits), or paleosol-bounded sequences, that represent on the order of 103 - 104 years. These can be explained by repeated river avulsions that may be autocycle and/or triggered by tectonic activity. However, some paleosol-bounded sequences may result from local shifts in deposition of crevasse splay-levees without major-channel avulsion.

At an intermediate-scale are 100 m-scale variations in the proportion and thickness of thick sandstone bodies (representing on the order of 104 - 105 years).

Such variations are due to either changes in the thickness of channel-bar deposits or in the degree of superposition of channel belts. They can only be traced laterally for up to tens of km. Theoretical modeling indicates that increases in the proportion and thickness of major channel sandstone bodies can be explained by increasing channel-belt sizes (mainly), average deposition rate and avulsion frequency on a megafan comparable in size to modern examples. 100 in-scale variations could thus result from regional shifts in the position of major channels on a megafan, or temporal changes in sediment input and/or basin subsidence resulting in progradation and retrogradation of individual megafans.

The largest scale variations define Formations (i.e. 102 to 103 m thick, representing on the order of 105 -106 years). The Nagri Formation has more abundant and thicker and coarser grained sandstone bodies than the Chinji and Dhok Pathan Formations. This increase in thickness and abundance of sandstone bodies is due mainly to increase in thickness of channel-bar deposits (i.e. channel size), but also to increasing superposition of channel belts. As proportion of sandstone bodies increases, deposition rates increase and paleosols are less well developed. Formations can be correlated across the Potwar Plateau for at least 100 km, although they may be diachronous by on the order of a million years. Formation boundaries in the Potwar Plateau decrease in age towards the west.

Formations and 100 in-scale stratal variations may be associated with regional changes in tectonic uplift, climate sediment supply and basin subsidence. The Nagri Formation possibly resulted from diversion of a relatively large river and its associated megafan to the Potwar Plateau area. River diversion or piracy was possibly associated with spatially variable increases in uplift and subsidence rates, and probably took place in the mountain belt. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (but possibly also linked to tectonic uplift). The deposits generally yield no direct evidence for climate change in the sedimentary basin: however, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods (e.g. around 10.8 Ma, corresponding to base of Nagri Formation), fluctuations in the degree of glaciation of the higher Himalayas may have resulted in varying sediment supply to megafans on time scales of 104 to 106 years. Eustatic sea-level changes are associated with global climatic change: however, they are not directly related to Siwalik stratigraphic changes because the Potwar Plateau was 1000 km from the Miocene shoreline. There is a period of vertebrate faunal extinctions between 13 and 12 Ma that may be correlated with global cooling, and a faunal turnover near the base of the Nagri Formation may be related to faunal immigration during a sea-level low stand.

Stable carbon and oxygen isotopes in pedogenic carbonate nodules indicate a marked shift in vegetation and climate from 8 to 6 Ma. The shift from C3 and C4-dominated vegetation recorded in the carbon isotope shift, and the increase in soil evaporation inferred from the oxygen isotope shift, indicate intensification of the regional monsoon

and increased seasonality (warmer dry periods and more pronounced wet seasons). This climate change is not reflected in the alluvial architecture of the Dhok Pathan Formation, although there are some changes in paleosols that may be linked to the climate shift. However, the vertebrate fauna shows a prolonged period of turnover associated with this change, with declining species diversity and extinction of some notable taxa such as *Sivapithecus*. This is consistent with the replacement of woodlands and forest with drier, more open habitats. Thus, it appears that the history of the Siwalik biota was tied to climatic changes in the depositional basin and faunal migrations from other regions, and not to changes in the Siwalik fluvial systems that were more strongly linked to the tectonics and climate of the Himalayan source areas. Identification of specific controls on depositional environments, alluvial architecture and faunal change will require more sedimentologic-paleomagnetic studies from other parts of the basin.

Key words: Fluvial environments, Miocene, siwaliks.

B/236. Bridges, H.F., 1906. Hunza and Nagir glaciers. Geological Survey of India Records, 37(2), 221p.

Key words: Glaciers, Hunza, Nagir.

B/237. Bridges, H.F., 1930. Himalayan notes. Geographical Journal 75, 166-172.

Key words: Himalaya.

B/238. Brinckmann, R. & Rafiq, M., 1971. Landforms and soil parent materials in West Pakistan. Soil Survey of Pakistan, Lahore-Decca.

Key words: Geomorphology.

B/239. Brookfield, M.E., 1977. The emplacement of giant ophiolite nappes, 1, Mesozoic-Cenozoic examples. Tectonophysics 37, 247-303.

The occurrence of ophiolite nappes has been considered evidence for the siting of ancient subduction zones. A study of the detailed stratigraphy and plate motions associated with Upper Mesozoic to Pliocene ophiolite nappes of the Pacific, Indian and Mediterranean shows that transcurrent faulting during changes in relative plate motions is the major cause of initial ophiolite nappe emplacement. Giant ophiolite nappes are not related to subduction zones or island arcs.

Key words: Ophiolite, nappes, Mesozoic, Cenozoic.

B/240. Brookfield, M.E., 1980a. Reconnaissance geology of the Hushe and Saltoro-Kondus river valleys, Karakorum Mountains, Kashmir, Pakistan. Academia Nazionale dei Lincei 69, 248-253.

Key words: Reconnaissance, Kashmir, Karakoram.

B/241. Brookfield, M.E., 1980b. New radiometric dates (U/Pb, Rb/Sr, $\text{Ar}^{40}/\text{Ar}^{39}$) from Kashmir (Northern India and Pakistan) and their bearing on the evolution of the Indus and Shyok suture zones. 24th International Geological Congress, Montreal.

Key words: Radiometric dating, Indus suture, Shyok suture, tectonics.

B/242. Brookfield, M.E., 1981. Metamorphic distributions and events in the Ladakh range, Indus suture zone and Karakorum Mountains. In: Saklani, P.S. (Ed.), Metamorphic Tectonites of the Himalaya. Today and Tomorrow's Publisher, New Delhi, 1-14.

In terms of simple metamorphic facies scheme and sketch map, the paper summarizes the metamorphic events and history of the hitherto little known areas of northwestern India and Pakistan (north of the main Himalayan ranges). The evidences suggest following four main phases of metamorphism:

(1) Mid-Cretaceous metamorphism was associated with the development of an island arc along the Indus suture zone. The volcanic arc core is represented by transitional low-intermediate pressure regional metamorphism, while in the south the fore-arc region represented by sedimentary and ophiolitic *mélange* contains fragmentary glaucophane schists.

(2) Late Eocene to Oligocene metamorphism was associated with the development of an Andean-type magmatic arc on the northern edge of the Indian plate (the Ladakh batholith complex). This consists of medium-pressure Barrovian regional metamorphism towards the east. At higher level, lower pressure metamorphism towards the west is observed.

(3) Miocene metamorphism was associated with the development of the Andean-type Karakorum magmatic arc on the southern edge of the 'Tibetan' plate. This has a relatively high pressure metamorphic belt in the south (the Shyok *mélange*) with a Barrovian medium-pressure belt in the north (Karakorum batholiths).

(4) Post-Miocene low-pressure regional metamorphism was associated with the late stage anatectic granites of the Karakorum mountains.

Key words: Metamorphism, Ladakh, Indus suture zone, Karakoram.

B/243. Brookfield, M.E., 1982. The sedimentology of Indus flysch and molasses, it's bearing on the evolution of the collision zones between India and Asia, and a comparison with the classic Swiss flysch and molasses. 11th Congress on Sedimentology, Hamilton (Canada), 37p.

Key words: Sedimentology, molasse, collision zones, India, Asia, Swiss.

B/244. Brookfield, M.E., 1993a. Paleodrainage patterns and basin evolution of the NW Himalaya. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 7.

During the late Tertiary the NW Himalaya rose rapidly due to crustal shortening, thickening and differential erosion. At the same time adjacent basins subsided accumulating thick prisms of sediments, which were continually compressed, uplifted and eroded as thrust sheets migrated over them. The interplay of tectonism with erosion by changing river systems is particularly apparent in the Pamir arc, which indented Asia only within the last 20 ma, involving almost 1000 km northward thrusting of already assembled collision belts over the Tadjik marginal basin.

The age and nature of the foredeep sediments of the Tarim and Tadjik basins have been used to infer pulses of contemporary tectonism in the mountains. Net rates of erosion derived from radiometric and fission track dating, sediment budgets and river drainages can be compared with GROSS rates of uplift derived from fossil faunas and floras. These studies show that each range has an independent history of uplift and erosion within the framework of generally increasing late Tertiary uplift. And so has each basin. Deposition in basins is determined by the courses of the major rivers, which have not remained constant. The thickness of sediment accumulating in marginal basins and the isostatic uplift of ranges depends on when rivers changed their courses, on when and how much temporary storage occurred within intermontane basins, and the time at which the intermontane barriers were breached and their sediments eroded.

Establishing the Cenozoic courses of the major rivers of Central and Southeast Asia shows that coarse clastic sediment pulses cannot be used to infer increased tectonism in adjacent ranges, they may simply reflect river capture. Though this places constraints on the tectonic history of collision, it also provides an opportunity to reconstruct the landscape as well as orogenic evolution of the mountain belt.

Key words: Paleodrainage, basin evolution, Himalayan orogeny.

B/245. Brookfield, M.E., 1993b. The interrelations of post-collision tectonism and sedimentation in Central Asia. International Association of Sedimentologists, Special Publication 20, 13-35.

During the Late Tertiary the northwest Himalaya and adjacent ranges underwent progressively increasing uplift associated with crustal thickening and differential erosion. At the same time the adjacent Tarim and Tadjik basins

and the Himalayan foredeeps subsided accumulating thick piles of clastic sediments. The ages of these accumulations have been used to infer contemporary tectonism in the mountains. Radiometric and fission track dating together with faunal and floral studies and sediment budget and river drainage studies allow gross rates of uplift and subsidence to be compared with net rates for different areas. These studies show that the bulk of the derived clastics were eroded from the fronts of the Karakorum, Himalayan and Pamir allochthons during progressively increasing rates of uplift and thrusting from Early Miocene times onwards. Nevertheless, cooling Cenozoic climates, partly driven by uplift, have also contributed to increasing physical erosion and coarsening of the deposited sediments through time. Furthermore, each range shows an independent history of uplift and erosion within the framework of generally increasing uplift and erosion in Late Tertiary times. Contemporary deposition in adjacent basins is partly dependent on the timing of adjacent uplifts. But uplift and deposition also depend on erosion and deposition along the courses of major rivers which have not remained constant. The thickness of sediment accumulating in marginal basins and the isostatic uplift of ranges depend on when the river changed its course, on when and how much temporary storage occurred within intermontane basins, and the time at which the intermontane barriers were breached and their sediments eroded. In some cases, e.g. the Indus, Tsangpo, Salween and Mekong, the rivers have even switched into different major oceans or basins. Coarse clastic sediment pulses cannot be used to infer increased tectonism in adjacent ranges.

Key words: Tectonics, sedimentology.

B/246. Brookfield, M.E., 1993c. The Himalayan passive margin from Precambrian to Cretaceous times. *Sedimentary Geology* 84, 1-35.

The Himalaya passive margin should be separated into the Indian Himalaya and the Pakistan Himalaya, divided by the Nanga Parbat-Haramosh basement uplift in the northwestern syntaxes. The Indian passive margin shows a complex history involving splitting of microcontinents off the northern Gondwana margin from early Paleozoic times until the Jurassic. In contrast, the Pakistan Himalaya formed part of the stable Indian shelf until separation from Africa started in the Jurassic. Each margin has a distinct stratigraphic history until the mid-Mesozoic after which they show similar histories until the Tertiary.

The Himalaya mountains in India consist of three distinct tectonic units juxtaposed during the Neogene by southward thrusting of the northern Indian Precambrian to Mesozoic passive margin. The Lesser Himalaya on the south forms a late Precambrian passive margin usually directly overlain by late Cretaceous to Tertiary clastics: its stratigraphy is closest to that of the Indian Shield. In contrast, the High Himalaya has a thin Ordovician to Carboniferous shelf sequence deposited after early Ordovician deformation and granite intrusion. Above this, thick Permian and Mesozoic shelf sequences mark the separation of continental blocks off the northern Indian margin and the opening of the Neotethys ocean. The North Himalaya formed the slope and basin of this ocean and consists of reactivated Paleozoic gneiss domes overlain by thick Mesozoic sediments which pass, in the northeastern Himalaya, into an enormously thick sedimentary sequence resting on oceanic crust.

Paleomagnetic and structural evidence indicates at least 500 km of southward thrusting along the Main Central Thrust between the Lesser and High Himalaya. This thrusting, together with a further 250 km of erosion at the front of the nappes, has removed the entire inner shelf of the Himalaya passive margin and can explain the startling contrast between the High and Lesser Himalaya stratigraphic sequences. But there are still discrepancies, particularly in the eastern Himalaya, where Precambrian basement is juxtaposed with the North Himalaya Mesozoic slope. These discrepancies can be partly resolved by strike-slip movements roughly parallel to the Himalaya which have removed parts of the northern Indian passive margin. Such faults of the requisite orientation, displacement and age occur in southeast Asia where their cumulative displacements can add up to several thousand kilometres. Similar faults, of undoubted pre-Tertiary age, occur in the Pakistan Himalaya. Here, the passive margin shows a much simpler history of Jurassic to Miocene subsidence.

Key words: Precambrian, Cretaceous, tectonics, crustal shortening, Himalaya.

B/247. Brookfield, M.E., 1998. The evolution of the great rivers systems of southern Asia during the Cenozoic India-Asia collision: rivers draining southwards. *Geomorphology* 22, 285-312.

During uplift of the Tibetan plateau and surrounding ranges, tectonic processes have interacted with climatic change and with local random effects (such as landslides) to determine the development of the major river systems of Asia. Rivers draining southward have three distinctive patterns that are controlled by different tectonic and climatic

regimes. In central and southern Afghanistan, the rivers have moderate gradients and fan out from northeastern sources to disappear into arid depressions. Anti-clockwise rotation of southern Afghanistan, caused by differential compression and right-lateral shear, cut the rivers on the north, while increasingly arid conditions developed on the south as arc accretion in the Makran separated sources from the coastal rains. In Tibet and southeast Asia, the rivers are widely separated and have low gradients on the Tibetan plateau, higher gradients as they turn southwards into close and parallel gorges, before they fan out southeast to enter different seas. Differential shear and clockwise rotation between the compressing Tibetan plateau and Southeast Asia determined the great sigmoidal bends of this river system which was accompanied by increasing aridity, with truncation of river systems in the north and river capture in the south. In the Himalaya and southern Tibet, the main rivers have steep gradients where they cut across the Himalayan range and occasionally truncate former rivers with low gradients on the Tibetan plateau to the north. Southward thrusting and massive frontal erosion of the Himalaya caused progressive truncation of longitudinal rivers on the plateau, accompanied by river capture, and glacial and landslide diversions on the south. The drainage history of southern Asia can be reconstructed by restoring the gross movements of the plates and the tectonic displacement, uplift, and erosion of individual tectonic units. Most important changes in drainage took place in Pliocene to Quaternary times.

Key words: River systems, drainage evolution, collision, Cenozoic, India, Asia,

B/248. Brookfield, M.E. & Gupta, J., 1984. Permian fossils from the Shyok mélange, near Shigar, Baltistan, Pakistan. *Bulletin of Indian Geologists Association* 17, 39-44.

Key words: Palaeontology, Shyok, mélange, Shigar, Baltistan.

B/249. Brookfield, M.E. & Reynolds, P.H., 1981. Late Cretaceous emplacement of the Indus Suture Zone ophiolitic mélange and an Eocene-Oligocene magmatic arc on the northern edge of the Indian Plate. *Earth and Planetary Science Letters* 55, 157-162.

We report three $^{40}\text{Ar}/^{39}\text{Ar}$ dates (on stratigraphically located samples) of 82 ± 6 Ma from a syenite cutting the Indus suture zone ophiolitic mélange and about 39 and about 45 Ma from granodiorite intrusions north of the suture zone. Sedimentological observations indicate Eocene to Miocene deposition of coarse clastics by very large braided and meandering streams in a continental back-arc setting. These observations suggest that the ophiolitic mélanges of the Indus suture zone were emplaced in the late Cretaceous, shortly after a major change in plate motions in the Indian Ocean: they further suggest that an Andean-type magmatic arc developed on the northern edge of the Indian plate during the Eocene and Oligocene.

Key words: Ophiolites, Indus Suture Zone, mélange, magmatic arc, Indian Plate, Late Cretaceous collision.

B/250. Brookfield, M.E. & Reynolds, P.H., 1990. Miocene $^{40}\text{Ar}/^{39}\text{Ar}$ ages from the Karakoram Batholith and Shyok Mélange, northern Pakistan, indicate Late Tertiary uplift and southward displacement. *Tectonophysics* 172, 155-167.

The magmatic arc of the Karakorum Mountains is separated from the Cretaceous-Tertiary Kohistan arc sequence by an ophiolitic mélange-the Shyok Mélange. Two views of the age of the Shyok Mélange and Karakorum arc are: (a) that they represent a mid-Mesozoic arc-trench complex which collided with the Kohistan arc in the Cretaceous before the closure of the main Tethys ocean to the south; and (b) that they represent a late Tertiary arc-trench complex which closed in the late Miocene, representing final subduction of Tethyan sea-floor. Whether final destruction of ocean crust took place in the Mesozoic or Tertiary has important implications for current models of the development of the Indian-Asian collision zone. Here are reported ages of between 20 and 8 Ma, suggesting that final assembly and uplift did not occur until the late Tertiary; and that the Shyok Mélange is the structural equivalent of the Main Central Thrust of the Himalaya to the east. Like the Main Central Thrust, the Shyok Mélange appears to mark intraplate continental subduction which is mainly responsible for Tertiary granitoid intrusion, deformation and uplift in the High Himalaya and Karakorum to the north.

Key words: Karakoram batholith, geochronology, Shyok mélange, tectonics.

B/251. Broughton, R.D. & Windley, B.F., 1988. The Central Himalayan gneisses in northern Pakistan. *Journal of Geological Society of India*, 31, 185-196.

Key words: Gneiss, Himalaya.

B/252. Broughton, R.D., Windley, B.F. & Jan, M.Q., 1984. Reaction isogrades and P–T estimates in metasediments on the edge of the Karakorum plate, Hunza, N. Pakistan. *Abstracts, First Geological Congress, Lahore*, p.58.

The Hunza area of North Pakistan contains a metasedimentary sequence on the southern margin of the Karakorum Plate. The sequence is largely pelitic with carbonate layers, cut by amphibolite and granitic sheets, and is bounded to the N E by the Karakorum batholith, and to the S W by the Northern Suture at Chalt. The grade of metamorphism increases from S W to N E and this is marked by variation in mineral chemistry, and changes in mineral assemblages at a series of reaction isograds, which separate zones in which stable mineral pairs are; garnet - chlorite, chloritoid-biotite, staurolite-biotite, kyanite - biotite and sillimanite-biotite from S W to N E respectively. A reaction isograd marked by the paragenesis; forsterite-diopside-calcite-dolomite occurs in the siliceous dolomites. The northeasterly dip of the isograds indicates that the zones are inverted. At Hunza, maximum metamorphic conditions given by pelitic rocks are 632° C and 5.5 kb. The temperature obtained from calc-silicate rocks is 669°C at 5.5 kb, with CO₂, F1 0.66. The inversion of the metamorphic zones was associated with major southward thrusting during collision of the Karakorum Plate with the Kohistan Arc.

Key words: Isogrades, P-T estimates, metasediments, Karakoram, Hunza.

B/253. Broughton, R.D., Windley, B.F. & Jan, M.Q., 1985. Reaction isogrades and P–T estimates in metasediments on the edge of the Karakorum plate, Hunza, N. Pakistan. *Geological Bulletin University of Peshawar* 18, 119-136.

The Hunza area of N. Pakistan contains a metasedimentary sequence on the southern margin of the Karakorum Plate. The sequence is largely pelitic with carbonate layers, cut by amphibolite and granite sheets, and is bounded to the N. E. by the Karakorum Batholith, and to the S. W. by the Northern Suture at Chalt.

The grade of metamorphism increases from S. W. to N. E., and this is marked by variation in mineral chemistry, and changes in mineral assemblages at a series of reaction isograds, which separate zones in which stable mineral pairs are: garnet-chlorite, chloritoid-biotite, staurolite-biotite, kyanite-biotite and sillimanite-biotite from S. W. to N. E. respectively. A reaction isograd marked by the paragenesis, forsterite-diopside-calcite-dolomite occurs in the siliceous dolomites, and the northeasterly dip of the isograd indicates that the zones are inverted.

At Hunza, maximum metamorphic conditions given by pelitic rocks are 669 °C and 5.5 kb, with XCO₂, F1=0.66. The inversion of the metamorphic zones was associated with major southward thrusting during collision of the Karakorum Plate with the Kohistan Arc.

Key words: Isogrades, P-T estimates, metasediments, Karakoram, Hunza.

B/254. Brown, H.C., 1936. *India's mineral wealth: A guide to the occurrences and economics of the useful minerals of the Indian Empire. With a Geological Map, Scale 1:45,000,000*, Oxford University Press, London, 335p.

This is a pre-partition map of the Indian empire including the areas of the current day Pakistan. This might be one of the earlier accounts of the economic minerals found in this part of the subcontinent.

Key words: Economic minerals, Indian empire.

B/255. Brown, J.C. & Dey, A.K., 1955. *India's Mineral Wealth; A guide to the occurrence and economics of the useful minerals of India, Pakistan and Burma*. 3rd Edition 761p. Oxford University Press.

This is the 3rd edition of the manuscript of the same title, first published by J.C., Brown in 1936 for the Indian Empire. It gives brief information on some of the minerals of northern Pakistan.

Key words: Economic minerals, Indian empire.

B/256. Brozovic, N., Burbank, D.W. & Meigs, A.J., 1997. Climatic limits on landscape development in the northwestern Himalaya. *Science* 276, 571-574.

The interaction between tectonism and erosion produces rugged landscapes in actively deforming regions. In the northwestern Himalaya, the form of the landscape was found to be largely independent of exhumation rates, but regional trends in mean and modal elevations, hypsometry (frequency distribution of altitude), and slope distributions were correlated with the extent of glaciation. These observations imply that in mountain belts that intersect the snowline, glacial and periglacial processes place an upper limit on altitude, relief, and the development of topography irrespective of the rate of tectonic processes operating.

Key words: Deformation, tectonics, NW Himalaya.

B/257. Brunet, M. & Heintz, E., 1983. Comparison between Late Miocene Mammalian faunas from Afghanistan and Indo-Pak Sub-continent: Paleo-biogeographic implications. *Geological Bulletin University of Punjab* 18, 3-8.

Localities of Tertiary fossils from Afghanistan have been placed in a biochronological sequence and correlation has been attempted with those of Greece, Turkey, Iran and Pakistan. It is concluded that faunas of Afghanistan and Pakistan were distinct about 8 Ma ago although geographically these were less than 300 km apart. Explanation is given of the differences.

Key words: Palaeontology, mammals, Miocene, siwaliks, Afghanistan, Pakistan.

B/258. Brunet, M., Heintz, E. & Battail, B., 1984. Molayan (Afghanistan) and the Khaur Siwaliks of Pakistan: An example of biogeographic isolation of Late Miocene mammalian faunas. *Geologie en Mijnbouw* 63, 31-38.

Refer to Brunet & Heins 1983 in the preceding account.

Key words: Biogeography, Miocene, mammals, siwalik, Afghanistan, Pakistan.

B/259. Brunschweiler, R.O., 1951. Lower Cretaceous fossils of the Yasin Group, Gilgit Agency. *Geological Survey of Pakistan, Records* 8 (2), p.27 (Appendix-C of Ivanac, Traves & King (196)).

This is a paleontological study of the fossiliferous Yasin Group. The occurrence of the Lower Cretaceous corals from the area was first recorded by the author. He identified *Eugyra* cf. *neocomiensis* de FROMENTEL; *Calamophyllia* cf. *racilis* BLAINVILLE; *Thecosmilia* sp.; *Isastrea* cf. *regularis* de FROMENTAL; and *Montastrea* sp. The geological age of the Yasin Group is considered Barremian-Aptian, as supported by the presence of a species of rudiste, *Horiopleura* cf. *lamberti* (MUN.-CHAT), common in the Lower Cretaceous of the Pyrenees.

Key words: Paleontology, Yasin Group, Gilgit, Hindu Kush, Karakoram.

B/260. Brunschweiler, R.O., 1956. Lower Cretaceous fossils of the Yasin Group, Gilgit Agency. *Geological Survey of Pakistan, Records* 8, 27p.

Key words: Fossils, Cretaceous, Yasin group, Gilgit.

B/261. Brunsden, D., 1984. The geomorphology of high magnitude-low frequency events in the Karakoram mountains. In: Miller, K.J. (Ed.), *The International Karakoram Project*, 1, 383-398, Cambridge University Press.

The conceptual basis of high magnitude-low frequency event studies in high mountains is describes and the use of a Transient Form Ratio to isolate the stability state of the landform evolution pattern is proposed. Methods of study and the use of the Karakoram Project (1980) for Hazard surveys are outlined.

Key words: Geomorphology, Karakoram.

B/262. Brunsten, D., Jones, D.K.C. & Goudie, A.S., 1984. Particle size distribution in debris slopes of the Hunza Valley. In: Miller, K.J. (Eds.), *The International Karakoram Project 2*, 536-580. Cambridge University Press.

The rock fall secree slope model in which there is a size difference down slope on sacress formed by rock fall processes was shown to apply to Karakoram screes. These simple relationships were shown to be disturbed by subsequent mass movement processes to produce distinctive patterns of stripes, festoons and scallops. The patterns are described for large and small screes and scallops. The patterns are described for large and small screes and various processes. Considerable differences in grain size are caused by dry grain flow, shallow sliding and mudflow or debris avalanche.

Key words: Debris slopes deposits, Hunza, Karakoram.

B/263. Brunsten, D., Jones, D.K.C., Whalley, W.B. & Goudie, A.S., 1984. Debris flows of the Karakoram mountains. In: Miller, K.J. (Eds.), *The International Karakoram Project Proceedings*, Cambridge University Press.

Key words: Debris flow, Karakoram.

B/264. Buchroithner, M.F., 1980. An outline of the geology of the Afghan Pamirs. *Tectonophysics* 62, 13-35.

In the Great Afghan Pamir (Pamir-e Kaland) the following formations can be distinguished, from bottom to top: Wakhan Fm. (3000–4000 m thick anchimetamorphic slates and sandstones with frequent intercalations of quartzites and rare beds of crystalline limestones; conodonts of Lower Triassic); Qala-e Panja Tonalite (epimetamorphic, cataclastic); Qal'a-e Ust Gneiss (meta- and orthogneisses); Issik Granodiorite (batholite of the Afghan Pamirs, equivalent to Baba Tangi-Lunkho Granodiorite; xenoliths, flow structures and diaphtoritic portions; Upper Jurassic to Eocene). The tectonics are determined by the Peripheric Southern Fault of the Pamirs and the Wakhan Fault, showing vertical dislocation up to 1000 m and sinistral thrusting in connection with the Western Himalayan Syntaxis. Late Variscan and Alpine deformations and an intensive middle Alpine metamorphism can be observed. Interpretations of satellite pictures lead to an insertion of the regional tectonic features into the model of plate tectonics of the Himalayan arc. The paper is of interest for those working in Chitral because some of the Pamir rocks extend there through Wakhan.

Key words: Tectonics, Afghanistan, Pamir.

B/265. Buchroithner, M.F. (Ed.), 1998. Geological map of Chitral 1:100,000. Dresden University of Technology, Germany.

As the title indicates this is an updated compilation of the geology of Chitral and northern Pakistan. Formations are arranged and briefly described in stratigraphic orders. Major structures are also shown.

Key words: Mapping, Chitral.

B/266. Buchroithner, M.F. & Gamerith, H., 1985. On the geology of the Tirich Mir area, central Hindu Kush (Pakistan). *Jahrbuch der Geologischen Bundesanstalt (Wien)* 128, 367-381.

An outline of the geology of Central Chitral (Hindu Kush, Pakistan) with emphasis on the Tirich Mir Area is given. Descriptions of rock units and structure shall serve as explanatory notes on a new geological map 1:50.000 of the Tirich Mir Massif (enclosure).

Key words: Tectonics, Tirich Mir, Hindu Kush.

B/267. Buchroithner, M.F. & Kostka, R., 1986. Zur herstellung einer topographisch-thematischen karte des Tirich Mir-Gebietes (Hindukusch). Kartographische Nachrichten 36, 171-179.

Key words: Topography, mapping, Tirich Mir.

B/268. Buddruss, G., 1991. On artificial glaciers in the Gilgit Karakorum. Pakistan Archaeology 26, Silver Jubilee Number, Volume 1, 251-262. [Revised in: Studien zur indologie und Iranistik 18, 77-90, 1993, Reinbek].

Key words: Glaciers, Gilgit, Karakoram.

B/269. Buffetant, E., 1978. Crocodilian remains from the Eocene of Pakistan. Abstract, Nuncius Jahrbuch Geology Paleontologia 156, 262-283.

Key words: Palaeontology, Eocene.

B/270. Bughio, G.M. & Khan, N.A., 1970. Report on copper mineralization, Surgin glacier area, Gilgit Agency. West Pakistan Industrial Development Corporation, 34p.

Key words: Mineralization, copper, Surgin glacier, Gilgit.

B/271. Bukhari, K., Ahmad, N. & Sajjad, W., 1998. Effect of Mardan Scarp Project on ground water conditions in parts of Mardan and Charsadda District, N.W.F.P. M.Sc. Thesis, University of Peshawar, 47p.

Key words: Groundwater, scarp project, Mardan, Charsadda.

B/272. Buksh, M.N., 1962. Radioactivity of green sand from Chichali Pass area of Kalabagh, District Mianwali. Pakistan Journal of Scientific and Industrial Research 5, 48-49.

Key words: Radioactivity, Chichali pass, Kalabagh, Mianwali.

B/273. Buksh, M.N. & Mohammad, F., 1963. Preliminary survey and chemical investigation on iron ore of Khyber Agency. Pakistan Journal of Scientific and Industrial Research 6(1), 21-24.

Iron ore outcropping at several localities near Jamrud and elsewhere was found to be too siliceous for profitable beneficiation. The occurrences are briefly described, and the hematitic ore at Lashoora is described in greater detail because of its larger size and relatively high iron content.

Key words: Iron ore, Khyber Agency.

B/274. Bunch, T.E. & Okrusch, M., 1973. Al-rich paragasite. American Mineralogist 58, 721-726.

Two Al-rich amphiboles were found in a corundum- and spinel-bearing calcite marble together with minor phlogopite, margarite, anorthite, and sphe or rutile. Microprobe analyses give half their unit cell contents as:

Amphibole AA-5, $\text{Na}_{0.54} \text{K}_{0.16} \text{Ca}_{1.99} \text{Mg}_{3.35} \text{Fe}_{0.01} \text{Ti}_{0.16} \text{Al}^{\text{vi}}_{1.47} \text{Al}^{\text{iv}}_{2.26} \text{Si}_{5.74} \text{OH}_{1.4} \text{F}_{0.40} \text{Cl}_{0.07}$;

Amphibole HA-1/2, $\text{Na}_{0.67} \text{K}_{0.17} \text{Ca}_{1.99} \text{Mg}_{3.62} \text{Fe}_{0.07} \text{Ti}_{0.27} \text{Al}^{\text{vi}}_{1.12} \text{Al}^{\text{iv}}_{2.25} \text{Si}_{5.75} \text{OH}_{1.05} \text{F}_{0.55} \text{Cl}_{0.02}$.

Amphibole AA-5 is the most aluminous yet found in nature (22.6 wt percent Al_2O_3) and contains essentially no Fe (total iron as FeO : 0.05 wt percent).

Both amphiboles are too rich in Al^{iv} (viz, high Al_2O_3 , combined with low SiO_2) to consider them as mixed crystals strictly intermediate between pure pargasite and pure tschermakite. Al-rich pargasite appears to be a suitable name for amphiboles of this composition, owing to the fact that more than 50 percent of their structural formulae can be recalculated in terms of a hypothetical end-member molecule Al-pargasite, $(\text{Na},\text{K})\text{Ca}_2\text{Mg}_3\text{Al}^{\text{vi}}_2 \text{Al}^{\text{iv}}_3 \text{Si}_5\text{O}_{22}(\text{OH},\text{F})_2$, which conforms to the limiting $\text{Al}^{\text{iv}}/\text{Al}^{\text{vi}}$ ratio of Ca-amphiboles statistically evaluated by Leake (1965, 1971).

The water determination and X-ray powder data are given for one of the amphiboles but not for the other owing to insufficient material. Conditions for the crystallization of the Al-rich amphiboles are briefly discussed.

Key words: Mineralogy, amphiboles, Hunza.

B/275. Bundschun, J., 1992. Hydrochemical and hydrogeological studies of groundwater in Peshawar Valley, Pakistan. Geological Bulletin, University of Peshawar 25, 23-37.

In September 1988 a comprehensive three months program for hydrogeochemical groundwater investigations in Peshawar Valley in the North West Frontier Province (NWFP) of Pakistan was carried out. Its main aim was to classify the groundwater chemically in order to limelight the regional differences and highlight problems related to drinking and irrigation water in the region. About 100 water samples were collected from wells and analyzed. The elevation of the groundwater table in Peshawar Valley is < 5 m deep, except in areas near the mountains and in the southeast where it ranges from 5 to > 30 m. There is a general groundwater flow towards the center of the basin from where the discharge is towards the Indus Valley. It has been noticed that the electrical conductivity (EC-values) increases from < 800 S/cm near the mountains to a maximum of 7800 S/cm in the center of the basin. Similar is the case of mineralization.

The groundwater has been classified according to PIPER. In Peshawar Basin predominantly low mineralized groundwaters of the type "normal alkaline earth freshwater prevailing hydrogencarbonatic" and "normal alkaline earth freshwater with higher contents of alkalies prevailing hydrogencarbonatic" are present. These groundwaters are of good quality. Only in its central part highly mineralized groundwater of the type "alkaline freshwater either hydrogencarbonatic or sulfatic-chlorotic" are found. This high mineralization in combination with the low depth of the groundwater table causes salification of the soils in the center of Peshawar Basin, i.e. Risalpur and its surroundings. It is concluded that the use of such highly mineralized drinking and irrigation water should be abandoned as soon as possible because of the expected hazards to human health and irrigation. It is highly recommended that deeper wells should be drilled to find low mineralization groundwater in this area.

Key words: Hydrochemistry, hydrogeology, groundwater, Peshawar Valley.

B/276. Burbank, D.W., 1982. The chronologic and stratigraphic evolution of the Kashmir and Peshawar intermontane basin, Northwestern Himalaya. Ph.D. Thesis, Dartmouth College, Hanover, New Hampshire, USA, 291p.

Consult the following account for further information.

Key words: Chronology, stratigraphy, intermontane basin, Kashmir, Peshawar, Himalaya.

B/277. Burbank, D.W., 1983a. The chronology of intermontane-basin development in the northwestern Himalaya and the evolution of the northwest syntaxis. Earth and Planetary Science Letters 64, 77-92.

The Northwest Syntaxis delineates a complex zone where the northwesterly trending Himalayan Ranges meet the northeasterly trending Hindu Kush and Indus Kohistan Ranges. The southern margin of the Hindu Kush-Himalayan collisional belt is delineated by a series of imbricate thrusts that transect the northern edge of the modern Indo-

Gangetic foredeep. The Kashmir and Peshawar Basins are embedded in this still-developing thrust belt and are symmetrically oriented about the Northwest Syntaxis.

Consideration of chronologic, stratigraphic, structural, and geophysical data from the syntaxial zone permits the construction of a model for intermontane-basin development and the evolution of the Northwest Syntaxis during the Late Cenozoic. The formation of the Kashmir and Peshawar Basins results from the transfer from the north of the locus of thrusting and uplift to the southern margins of the basins. During the Pliocene, the morphotectonic emergence of the ancestral Pir Panjal and Attock Ranges along the southern margins of the two basins coincides with changes in the patterns of sedimentation and deformation both within the basins and in the bounding foredeep to the south. Contrasting styles of tectonic deformation on opposite sides of the Syntaxis are interpreted as a response to differences in the strength of sediment-basement coupling across the Syntaxis.

Key words: Chronology, intermontane basin, Himalaya.

B/278. Burbank, D.W., 1983b. Multiple episodes of catastrophic flooding in the Peshawar basin during the past 700, 000 years. *Geological Bulletin, University of Peshawar* 16, 43-49.

At least 40 catastrophic floods inundated the Peshawar Basin in prehistoric times. A sequence of graded beds up to 25m thick near Paran records these flood events. These older floods resulted from significantly higher flows than those of the well-documented floods of 1800's. Such floods can be a real threat to the safety of Tarbela Dam and a careful monitoring of the Indus and its major tributaries is required and suggested.

Key words: Floods, Peshawar Basin, Himalaya.

B/279. Burbank, D.W., 1984. A brief normal-polarity magnetozone in the post-olduvai sediments of northern Pakistan. *EOS* 65, p.864.

Key words: Magnetism, polarity, sediments.

B/280. Burbank, D.W., 1991. Models of aggradation versus progradation in the Himalayan Foredeep. *Geological Society of America, Special Paper* 232, 113-128.

A frequent goal of decompaction analysis is to reconstruct histories of basin subsidence and tectonic loading. In marine environments, eustatic and paleobathymetric uncertainties limit the resolution of these reconstructions. Whereas in the terrestrial basins, these ambiguities are absent, it is still necessary to account for depositional slopes between localities in order to analyze three-dimensional patterns of subsidence. We define two end-members for depositional surfaces: aggradation and progradation. The relative importance of either end-member is a function of the interplay between the rate of net sediment accumulation and the rate of basin subsidence. The models predict the patterns of major drainages (transverse versus longitudinal) and the way in which provenance should be reflected within different portions of a basin. Consequently, paleocurrent and provenance data from the ancient stratigraphic record can be used to distinguish between these endmembers. The subhorizontal depositional surfaces that dominate during times of aggradation provide a well-defined reference frame for regional analysis of decompacted stratigraphies and related subsidence. Depositional slopes during progradation cannot be as precisely specified, and consequently yield greater uncertainties in reconstructions of subsidence. These models are applied to the Mio-Pliocene foreland basin of the northwestern Himalaya, where sequences of isochronous strata have been analyzed throughout the basin. These time-controlled data delineate a distinctive evolution from largely aggradational to largely progradational depositional geometries as deformation progressively encroaches on the foreland. Such a reconstruction of past depositional surfaces provides a well constrained reference frame for subsequent integration of subsidence histories from throughout the foreland.

Key words: Aggradation, progradation, foredeep, Himalaya.

B/281. Burbank, D.W. & Beck, R.A., 1989a. Synchronous sediment accumulation, decompaction and subsidence in the Miocene foreland basin of northern Pakistan. *Geological Bulletin University of Peshawar* 22, 11-24.

Previous magnetostratigraphic studies in northern Pakistan provide a tightly constrained temporal framework within which to analyze the sediment accumulation history of the northwestern Himalayan foreland basin. Paleocurrent and provenance data indicate that a longitudinal drainage system flowing to the ESE persisted through much of the middle and late Miocene deposition. The subhorizontal cross-sectional surfaces defined by the paleodrainage configurations provide a reference frame for analyzing subsidence histories. Six magnetic sections in the Potwar Plateau have been decompacted as a function of burial depth and lithology to provide both accumulation and subsidence records. These records demonstrate consistently higher amounts of accumulation and subsidence in the northern portions of the basin, but also indicate that events of tectonic loading were experienced synchronously across the basin. Inflections in the curves of tectonically induced subsidence suggest that an important interval of thrust loading began ~ 11.5 Ma and terminated ~8 Ma.

Key words: Magnetostratigraphy, sediments, Himalayan Foreland Basin, siwaliks.

B/282. Burbank, D.W. & Beck, R.A., 1989b. Early Pliocene uplift of the Salt Range; Temporal constraints on thrust wedge development, northwest Himalaya, Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), *Tectonics of the Western Himalayas*. Geological Society of America, Special Paper 232, 113-128.

Recent chronologic and stratigraphic studies in the northwestern Himalayan foreland basin have led to better constrained deformational and depositional histories. In order to test the hypothesis that considerable pre-Pleistocene uplift occurred in the Salt Range of northern Pakistan, the stratigraphic record adjacent to the central and eastern Salt Range has been examined. Unconformities, paleomagnetically documented tectonic rotations across these unconformities, and changes in the paleocurrent directions, provenance, and rates of sediment accumulation serve to delineate an interval of early Pliocene uplift of the Salt Range, as well as several late Pliocene-Pleistocene uplift events in thin range and adjacent structures. Stratigraphic, reflection seismic, and structural data indicate that these uplift events resulted from thrusting related to the salt- lubricated Potwar detachment. When considered in conjunction with the chronology of deformation in other parts of the foreland, these data clearly indicate that out-of-sequence thrusting has occurred on a large scale (>100 km) during the past 6 m.y. This pattern of deformation supports the concept that an irregular spatial and temporal distribution of shortening should be expected to occur within an advancing thrust wedge.

Key words: Structure, Pliocene, Salt Range.

B/283. Burbank, D.W., Beck, R.A. & Mulder, T., 1996. The Himalayan foreland basin. In: Yin, A. & Harrison M. (Eds.), *The Tectonic Evolution of Asia*, Cambridge University Press, 149-189.

Tectonic loading during the Cenozoic growth of the Himalaya created the Indo-Gangetic foreland basin, a flexural depression that is the largest terrestrial foreland basin on the earth's surface. Stratigraphic, chronologic, petrographic, sedimentological and structural data from across the foreland are synthesized here to produce an overview of the Cenozoic evolution of this basin. Within the foreland, variations in crustal rigidity along the strike and the presence of long-lived basement faults have modulated its width and large-scale subsidence patterns. During most of the Cenozoic, the rates of migration of the distal basin pinch-out and of the foreland depocenter suggest that about 20% of the Indo-Asian convergence has been accommodated by thin-skinned thrusting within the foreland, often related to detachments localized at the top of the basement or in incompetent foreland strata, and by thrusts with hanging walls more than 4-10-km thick along its proximal margin. Episodic southward relocation of these basin-margin thrusts has served to define large intermontane basins.

Although the early foreland deposition is poorly documented, ≥8-km of Paleogene strata have accumulated in proximal locations and show clear Himalayan derivation. Neogene deposition encompasses the Siwalik Group strata of Miocene and younger age. In northwestern Pakistan and parts of India and Nepal, excellent time controls derived from magnetostratigraphic studies permit detailed correlations, analyses of accumulation and subsidence patterns, and delineation of the interrelationships between deformation and deposition. During early and middle Miocene times, axial rivers, fed by numerous oblique tributaries, appear to have followed southeastward from northwestern Pakistan into the Ganges drainage. In northwestern Pakistan, a major stratigraphic change occurred at about 11 Ma: Accumulation rates increased 30-200%, sandstone abundances doubled, fluvial discharges increased fivefold and a major influx of detritus occurred, attributed to unroofing of the Kohistan island-arc. Upward coarsening and accelerated accumulation also prevailed in India and Nepal. Those changes are interpreted as having resulted from

initial motion and loading by the Main Boundary Thrust at about 11 Ma, approximately 5 m.y. earlier than previously documented.

Proximal portions of the foreland are more abundantly represented within the preserved Upper Neogene strata. As deformation encroached on the foreland, depositional environments and regimes of accumulation and erosion became increasingly heterogeneous. On the basis of scale, petrology, and dispersal patterns, often four river systems can be delineated within the foreland as it became structurally disrupted: an axial river, large transverse rivers with hinterland catchments, and rivers sourced on newly created intra-foreland uplifts. Late Miocene-Pliocene growth of the Salt Range at the southern limit of a 100-km wide salt-lubricated detachment in northwestern Pakistan initially created a large piggyback basin that localized the ancestral Indus River. Continued shortening caused diversion of the Indus to the southwest, coinciding with rapid accumulation and southward pinch-out migration in the Trans-Indus region. Large-scale out-of-sequence thrusting occurred in northwestern Pakistan between 6 Ma and 1 Ma, coeval with deposition Plio-Pleistocene intermontane basins ponded behind major basin-bounding thrusts. Across the foreland, records of initial conglomeratic strata indicate highly diachronous progradation (ranging from >8 to <1 Ma) that was strongly influenced by fluvial interactions with local folds and thrusts. Whereas tectonic loading appears to continue to control depositional patterns in the Indus foreland, changes in the position of the axial river and in cross-sectional stratal geometries suggest that erosional unloading during the past 4-5 m.y. has become increasingly important in the Himalaya adjacent to the Gangetic foreland. This may be a response to expanding glacial climates. In contrast, the inferred strengthening of the Asian monsoon at about 7-8 Ma does not appear to have led to an increased detrital-sediment flux to the foreland.

Major unresolved problems in the Himalayan foreland included the following: our poor understanding of its Paleogene history; sparse reliable chronologic control in the central and eastern foreland; absence of clear “fingerprinting” that could tie foreland strata to specific hinterland source areas; inadequate seismic analysis of foreland structure; poorly understood climatic influences on deposition and erosion; and uncertainties regarding strain partitioning and its variation along strike within the foreland.

Key words: Tectonics, Foreland Basin, siwaliks, Himalaya.

B/284. Burbank, D.W., Beck, R.A., Raynolds, R.G.H., Hobbs, R. & Tahirkheli, R.A.K., 1988. Thrust and gravel progradation in foreland basins: A test of post-thrusting gravel dispersal. *Geology* 16, 1143-1146.

The use of gravels as syntectonic indicators of thrusting has recently been questioned by foreland-basin models that assign gravels to a post-thrusting interval of progradation, except in very proximal areas. On the basis of precise temporal control provided by magnetostratigraphically dated sections, the history of gravel progradation after a major thrusting and uplift event in the northwestern Himalaya is shown to be a virtually syntectonic phenomenon. Despite considerable crustal subsidence driven by a thick-skinned thrust, gravels prograded ~ 70 km during a 1.5-m.y.-long thrusting event. By 3 m.y. after the start of thrusting, gravels extended more than 110 km into the basin. Although delayed gravel progradation appears appropriate for many Rocky Mountain foreland basins, it is clearly not valid for the Himalaya. We attribute the difference in depositional response between these basins to differences in the quantity of sediment supplied to them (sediment starved vs. overfilled), the availability of resistates in the source area, and the size of the antecedent drainage.

Key words: Tectonics, structure, Foreland Basin, siwaliks, Himalaya.

B/285. Burbank, D.W. & Johnson, G.D., 1982. Intermontane-basin development in the past 4 Myr in the north-west Himalaya. *Nature* 298, 432-436.

Through the combined use of magnetic-polarity stratigraphy with fission-track dating of volcanic ashes, a new chronology, spanning 4 Myr, has been developed for the intermontane basin of Kashmir in the northwestern Himalaya. Additional information on the basins' configuration can be seen above in Burbank 1983.

Key words: Tectonics, Intermontane basin, Himalaya.

B/286. Burbank, D.W. & Johnson, G.D., 1983. The Late Cenozoic chronologic and stratigraphic development of the Kashmir intermontane basin, northwestern Himalaya. *Palaeogeography, Palaeoclimatology Palaeoecology* 43, 205-235.

The intermontane basin of Kashmir developed within the thrust-faulted, southern margin of the Himalayan Range. Detailed lithostratigraphies, magnetic-polarity stratigraphies, and fission-track dates on enclosed volcanic ashes were determined at four separate localities in order to develop a chronology of the Late Cenozoic evolution of the Kashmir Basin.

The results indicate that sedimentation had commenced by about 4 m.y. ago. Since then, over 1300 m of sediments have aggraded at inferred average rates varying from 16 to 64 cm per 1000 yr. Lacustrine and deltaic sediments dominate the Kashmiri sequences and appear to respond sensitively to tectonic events along the basin margins. Conglomerates shed from the faulted basin margins at about 1.7, 2.1, 2.7, and 3.0–3.5 m.y. ago punctuate the predominantly low-energy, fluviolacustrine depositional record. Paleocurrent analyses indicate a switch from northeasterly derived conglomeratic facies to southwesterly derived ones about 1.7 m.y. ago. This transition reflects enhanced activity along the Main Boundary Thrust complex to the southwest and an apparent diminution of faulting along the northeastern margin of the basin. In the Pir Panjal Range, 1400–3000 m of uplift at inferred rates of up to 10 mm yr⁻¹ have terminated widespread sedimentation within the Kashmir Basin since the middle Pleistocene.

Key words: Chronology, stratigraphy, Late Cenozoic, Kashmir.

B/287. Burbank, D.W., Leland, J., Fielding, E., Anderson, R.S., Brozovic, N., Reid, M.R. & Duncan, C., 1996. Bedrock incision, rock uplift and threshold hillslopes in the northwestern Himalayas. *Nature* 379, 505-510.

The topography of tectonically active mountain ranges reflects a poorly understood competition between bedrock uplift and erosion. Dating of abandoned river-cut surfaces in the northwestern Himalayas reveals that the Indus river incises through the bedrock at extremely high rates (2–12 mm yr⁻¹). In the surrounding mountains, the average angles of hillslopes are steep and essentially independent of erosion rate, suggesting control by a common threshold process. In this rapidly deforming region, an equilibrium is maintained between bedrock uplift and river incision, with landsliding allowing hillslopes to adjust efficiently to rapid river down-cutting.

Key words: Topography, uplift, erosion, Indus, Himalaya.

B/288. Burbank, D.W. & Raynolds, R.G.H., 1984. Sequential Late Cenozoic structural disruption of the northern Himalayan foredeep. *Nature* 311, 114-118.

Chronologies for the Siwalik molasse and intermontane basins along the southern margin of the Himalaya and Hindu Kush Ranges constrain the timing and pattern of facies migration and structural disruption of the Indo-Gangetic foredeep. This synthesis indicates that quiescent intervals are punctuated by pulses of rapid deformation as thrusting migrates in a stepwise fashion across the foredeep.

Key words: Structure, tectonics, foredeep, siwaliks, Himalaya.

B/289. Burbank, D.W. & Raynolds, R.G.H., 1988. Stratigraphic keys to the timing of thrusting in terrestrial foreland basins: Applications to the northwestern Himalayan. In: Kleinspehn, K.L. & Paola, C., (eds.) *New perspectives in basin analysis*. Springer Verlage, New York, 331-351.

Key words: Stratigraphy, tectonics, Himalaya.

B/290. Burbank, D.W., Raynolds, R.G.H. & Johnson, G.D., 1986. Late Cenozoic tectonics and sedimentation in the north-western Himalayan foredeep: II. Eastern limb of the Northwest Syntaxis and regional synthesis. In: Allen, P.A. & Homewood, P. (Eds.), *Foreland Basins*. Special Publication of the International Association of Sedimentologists, Special Publication 8, 293-306.

Key words: Cenozoic tectonics, sedimentation, Himalaya.

B/291. Burbank, D.W. & Tahirkheli, R.A.K., 1985. The magnetostratigraphy, fission-track dating, and stratigraphic evolution of Peshawar intermontane basin, northern Pakistan. Geological Society of America, Bulletin 96, 539-552.

The Peshawar basin is situated along the junction of the northern margin of the Indo-Gangetic foredeep and the southern margin of the Hindu Kush-Himalayan Ranges. During the late Cenozoic, southward encroachment of tectonic disruption into the foredeep terminated molasse deposition and delineated the Peshawar intermontane basin through uplift of the Attock Range along the southern margin of the basin. In this study, magnetostratigraphy, fission-track dates on volcanic ashes, and stratigraphic data are used to define the chronologic and stratigraphic evolution of the basin.

Following a late Miocene to Pliocene interval of folding and thrusting of the preexisting molasse sediments, deposition began in the Peshawar basin by at least 2.8 m.y. ago. Subsequently, >300 m of basin-filling sediments accumulated at rates averaging 15 cm/1,000 yr. Northward progradation of alluvial-fan deposits from the uplifted basin margin had begun by 2.6 m.y. ago and continued at an inferred rate of 2 cm/yr. Proximal to the Attock Range in the south, alluvial-fan facies persisted until 0.6 m.y. ago. Contemporaneous sediments closer to the basin center demonstrate the presence of rapid facies transitions to extensive floodplain and shallow-lacustrine depositional environments. Widespread intermontane-basin sedimentation was terminated by accelerated uplift of the Attock Range after ~0.6 m.y. ago. Subsequently, during the Brunhes chron, catastrophic floods have periodically inundated the Peshawar basin. Continuing tectonic deformation of the basin is indicated by uplifted flood deposits, offset terraces, and modern seismicity.

Key words: Chronology, magnetostratigraphy, Peshawar basin.

B/292. Burchfield, B.C. & Royden, L.H., 1985. North-South extension within the convergent Himalayan region. *Geology* 13, 679-682.

Recent work by Burg et al. (1984) indicates the presence of east-west-striking, gently north-dipping normal faults in the Higher Himalayas and southern Tibet that formed during postcollisional convergence of India and Tibet. These faults extend for at least 800 km along strike. We interpret these normal faults as probable late(?) Miocene extensional features with perhaps several tens of kilometres of down-to-the-north displacement. A simple elastic model suggests that these normal faults may have formed during gravitational collapse of the Miocene topographic front between India and Tibet. In this interpretation, gravitational collapse occurred by southward motion, relative to India and Tibet, of a wedge of crustal rocks bounded above by gently north-dipping normal faults and below by thrust faults that probably dip north. North-south extension produced in this way is probably confined to upper crustal levels only and does not reflect regional extension of the entire lithosphere.

Key words: Structure, collision, Tibet, Himalaya.

B/293. Burg, J.P., Bodnier, J.L., Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1998. Intra-arc mantle-crust transition and intra-arc mantle diapirs in the Kohistan Complex (Pakistan Himalaya). *Petro-structural evidence. Terra Nova* 10, 74-80.

The Jijal and Chilas complexes have been interpreted previously as the lower level of the layered Kohistan Island Arc, in Pakistan. We provide petro-structural evidence for melt-consuming reactions between mantle rocks and infiltrated, volatile-rich magmas in both complexes. Precipitate minerals in Jijal and Chilas suggest that melt-rock reaction occurred at higher pressure in Jijal than in Chilas. The early appearance of orthopyroxene in Chilas and the spatial relationship of the ultramafics rocks with quartz-bearing norites indicate that the reactant melt was more silicic. We argue that the Jijal complex includes the intra-arc crust/mantle boundary and that ultramafics associations of the Chilas complex are apices of possibly younger, intra-arc mantle diapirs.

Key words: Petrology, mantle, Jijal, Chilas, Kohistan complex.

B/294. Burg, J.P., Bodinier, J.L., Chaudhry, M.N., Hussain, S.S., Dawood, H. & Garrido, C.J., 1999. Mantle-crust and mantle diapirs in the Kohistan arc complex (Pakistani Himalaya). Petro-structural evidence. J. Conference Abstract 4. European Union of Geology Meeting, Strausbourg, p.396.

Consult the preceding account for further information

Key words: Petrology, mantle, Jijal, Chilas, Kohistan complex.

B/295. Burg, J.P., Bodinier, J.L., Chaudhry, N., Hussain, S.S., Dawood, H. & Garrido, C.J., 1999. Mantle-crust transitions in the Kohistan Arc Complex (Pakistani Himalaya). Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 16-18.

The Kohistan complex is an island arc obducted during the Mesozoic onto India along the Indus Suture. We have recognized two units containing ultramafic rocks in this complex: (1) the Jijal unit, which is the lowermost part of the exposed arc and (2) the Chilas unit, which configures the core of the arc. Our observations indicate that the ultramafic rocks are exhumed mantle rocks that record distinct evolution and different depths of equilibration. The Jijal unit includes the arc crust-mantle boundary and contains mantle rocks equilibrated in the Arieigite subfacies. The Chilas ultramafic associations are apexes of intra-arc mantle diapirs with ultramafic rocks equilibrated in the plagioclase peridotite facies.

The lower part of the Jijal section ('the mantle section') is dominated by dunites and wehrlites interlayered with subordinate pyroxenites. The presence of harzburgites, with a high-temperature tectonite microstructure, indicates that peridotites were part of a residual 'arc mantle'. Flames of dunite in websterites indicate that these rocks have replaced peridotites through magma-consuming melt-rock reactions, at P-T conditions close to the peridotite solidus. The proportion of mafic rocks (websterite and minor hornblendites and garnetites) increases up-section, up to a sharp intrusive contact between ultramafic rocks and overlying garnet granulites. The latter facies is derived from garnet gabbro. The contact dips gently to the north, parallel to the pyroxenite-peridotite layering. We interpret this boundary as the exhumed petrological arc-'Moho'.

The Chilas section includes a series of ultramafic bodies and gabbro norites. Gabbro-norites display magmatic/cumulitic textures. Ultramafic rocks, however, show microstructure typical of mantle rocks, notably, porphyroclastic textures in wehrlites and harzburgites and coarse-grain textures in plagioclase-bearing dunites. The contact between ultramafic rocks and gabbro-norites is steep and underlined by strongly metasomatised rocks, such as hornblende and/or plagioclase pyroxenites. This metasomatic aureole is indicative of extensive reaction between peridotites and infiltrated melt, implying that the mantle rocks were intruded at high, near-solidus conditions within partially consolidated norites. Interstitial plagioclase and diffuse impregnations of gabbro-norite are further indications of magma percolation in peridotites. Thereafter, upon cooling, the peridotites were fractured, intruded by magma dikes and eventually brecciated and finely dispersed in the gabbro-norite. These final evolutionary stages are exemplified by the occurrence of steeply dipping, intrusive gabbro-norite layers in peridotites, blocks of peridotites in gabbro-norites and olivine xenocrysts in graded cumulate layers. These cumulate layers describe a large antiform. To integrate small (reactional and intrusive contacts) and large (antiformal) scale observations, we interpret the Chilas ultramafic bodies as pieces of intra-arc mantle diapirs. These mantle diapirs indicate rifting of the Kohistan arc during a major tectonic event that should be considered in any collisional model of the area.

Key words: Indus suture, Jijal, Chilas, Mesozoic, Kohistan complex.

B/296. Burg, J.P., Chaudhry, M.N., Ghazanfar, M., Anczkiewicz, R. & Spencer, D.A., 1996. Structural evidence for backsliding of the Kohistan arc in the collisional system of NW Pakistan. *Geology* 24, 739-742.

In the Naran region of the Pakistan Himalayas, a regionally distributed second generation of folds results from northward-directed shear deformation. These folds are collapse structures associated with back sliding of the hanging wall, namely the Kohistan paleo-island arc. They are explained by a geometrical model that combines coeval vertical and horizontal shortening. Accordingly, they are synconvergence collapse features that indicate at

least 5-km of vertical shortening of the imbricate thrust slices derived from the Indian continent in the northwest Himalayas.

Key words: Tectonics, extensional faults, Kohistan, Himalaya.

B/297. Burg, J.P. & Podladchikov, Y., 1998. Bending of syntaxes: consequences. In: Hamidullah, S., Lawrence, R.D. & Jan, M.Q. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 39-41.

Syntaxis areas where orogenic structures seem strongly bent around a vertical axis are fundamental features of modern collisional orogens. The still active Himalayan mountain belt is one example that terminates at both ends into nearly transverse syntaxes. The West and East Himalayan syntaxes (named after the Nanga Parbat and Namche Barwa, respectively) are crustal antiforms in which granitic and migmatitic rocks yield Cenozoic to very recent apparent ages.

The first part of this talk will emphasise that both syntaxes present remarkably similar thermo-mechanical evolution of basement rocks overprinted by Himalayan metamorphism and Pliocene-Pleistocene high-grade metamorphism and anatexis. Both straddle the same Neogene time span and have undergone rapid denudation, which links their still going growth to the uplift that produced Tibet in the last few million years. A rise of the Moho level is recorded under the Nanga Parbat. No information on the topic seems available beneath the Namche Barwa. In Pakistan, the Hazara-Kashmir Syntaxis is the southern continuation of the Nanga Parbat Syntaxis. In the Arunachal Himalaya, the Siang antiform appears as the southwestern continuation of the Namche Barwa syntaxis. All interpretations point to crustal scale folding as the driving mechanism that has produced these orogenic structures.

Folding and buckling instabilities as a response to layer parallel shortening are well-investigated features in geodynamics. Classical theories are restricted to initial stages of the instability development and to linear viscous, elastic and visco-elastic rheologies. Recent theoretical developments extend to waning stages of folding and to non-linear visco-plastic rheologies. However, gravity plays a fundamental role at a crustal or lithospheric scale, which means that new methods are needed to model folding of the oceanic and continental lithospheres. We employ 2-Dimension FEM modelling to study shortening of the continental lithosphere driven by far field motions of relatively rigid plates over an inviscid substratum (asthenosphere). Features of the model are:

Visco-elasto-plastic rheology. Viscous deformation is power law creep. Plastic yielding is according to Mohr-Coulomb plasticity.

There are three compositional layers, upper felsic crust 25 km, lower mafic crust 15 km, subcrustal olivine lithosphere 70-140 km. Boundary conditions are free surface, erosion and zero temperature at the top; zero differential stresses and fixed temperature at the bottom, compressional velocity and no heat flux at the lateral boundaries. Erosion is modelled according to linear diffusion equation.

Second order implicit FEM is used to discretise the momentum and heat transfer equations. Because of the number of parameters controlling the style of folding we do not attempt any systematic study. We restrict ourselves to a particular example of continental shortening - the West and East Himalayan "syntaxes".

Modelling yields the following results:

Only cold (strong) lithospheres exhibit buckling with a wavelength of ca. 200-km. Significant amplification is achieved in the overall strain range of 10-25%.

Topography due to buckling is up to 5-10 km. Exhumation is limited by fold locking and the typical amount is ca. 20 km.

After locking up the first anticline, lateral fold propagation occurs.

The Moho is uplifted beneath crustal antiforms and one can define several Mohos at strongly deformed stages.

High heat fluxes are detected within the antiforms whilst tectonic overpressure as high as twice of the lithostatic value may build in limb areas.

There are broad small amplitude depressions around the growing anticline.

We extend point 6 to discuss the development of synformal basins on both sides of crustal antiforms. We propose that the Peshawar and Kashmir basins are such structural depressions. The synclinal Peshawar basin to the west is readily seen on any geological map as a structural analogue of the synclinal Kashmir basin to the east of the Hazara-Kashmir Syntaxis. This relationship and the possible correlation between these two synformal depressions were noted by. Like the Karewas of Kashmir, the Peshawar basin has a thick Plio-Pleistocene to recent fill of alluvial sediments that began around 4 My. ago. We note that both basins have the same beginning age as the syntaxis and that sedimentation developed in both basins, although their bulk history is that of surface uplift. Our interpretation explains the location of both basins, which a ramping interpretation does not.

The kinematic model involving crustal folding to explain the Himalayan syntaxes is verified by our FEM dynamic modelling. In addition, first order features of the "cold model" of lithospheric folding fit well geological observation. We conclude that buckling is a basic response of the continental lithosphere to shortening. We emphasise that dominant geological and physiographic features of Northern Pakistan formed during the last 4 Ma have been controlled by the growth of the Nanga Parbat syntaxis. This is true also for the less known eastern Himalayan Syntaxis.

Key words: Orogeny, structural geology, Himalayan Syntaxis.

B/298. Burg, J.P. & Podladchikov, Y., 2000. From buckling to asymmetric folding of the continental lithosphere: numerical modeling and application to the Himalayan syntaxes. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 219-236.

The eastern and western Himalayan syntaxes are large-scale, coeval antiforms developed late in the history of India-Asia collision. We use two-dimensional finite element models of lithospheric folding to develop a mechanically plausible structural interpretation. The models mimic the coeval development of adjacent synformal basins, analogous to the Peshawar and Kashmir basins on either side of and adjacent to the western syntaxis. Pure-shear thickening and symmetric buckling accommodate shortening until, at a certain strain, an asymmetric thrust-like flow pattern occurs on a crustal to lithospheric scale. Similarities between geological data and calculated models suggest that lithospheric buckling is a basic response to large-scale continental shortening. To generalize these results, we suggest that a typical shortening history would include: (1) locking of an early thrust system in hinterland regions, followed by (2) pure shear shortening and symmetric buckling of the shortened lithosphere, and (3) loss of symmetry leading to the formation of an asymmetric fold in which a new thrust system will nucleate.

Key words: Tectonics, crustal shortening, Himalaya.

B/299. Burgisser, H.M., Gansser, A. & Pika, J., 1982. Late glacial lake sediments of the Indus Valley area, north western Himalayas. *Ecologiae Geologiae Helvetiae* 75, 51-63.

Key words: Glaciers, sediments, Indus Valley, Himalaya.

B/300. Buri, C.Z., 1965. A new Permian *Epimastopora* (calcareous alga) from Hunza Valley (Western Karakorum). In: *Italian Expeditions to the Karakorum (K2) and Hindu Kush*, (A. Desio leader), *Scientific Reports IV* (1), 79-88. Paleontology-Zoology-Botany. Brill, Leiden.

This paper reports on a new species of *Epimastopora* alga of Permian age from Hunza.

Key words: Palaeontology, Permian, Hunza, Karakoram.

B/301. Burnes, A., 1833a. On geology of the transect from NW India to Caspian. Geological Society of London, *Transaction Series* 2-3.

Key words: Geology, India, Caspian.

B/302. Burnes, A., 1833b. Substance of a geographical memoir on the Indus. *Royal Geographic Society Journal* 3.

Key words: Geography, Indus.

B/303. Burrard, S.G., 1915. On the Origin of the Indo-Gangetic Trough, commonly called the Himalayan Foredeep. *Proceedings of the Royal Society*, 91A, 220-238.

1. The Question under Discussion.

The plains of Northern India consist of alluvial deposits brought down by the Rivers Indus and Ganges. These plains conceal from our view a deep trough that has been formed in the solid rock of the Earth's crust. The trough is bounded on the north by mountains of the tertiary age and on the south by an ancient pre-tertiary tableland. North of the trough the Earth's crust has undergone continual compression, disturbance, and uplift since the beginning of the tertiary age ; south of the trough it has remained undisturbed since the close of the paleozoic era. On Fig. 1 are shown the Indo-Gangetic trough, the mountainous area on its north, and the tableland on its south.

From the writings of Suess, the Indo-Gangetic trough has come to be called the Himalayan foredeep. In this paper is proposed to consider one question only, namely, the origin of the Himalayan foredeep

2. The Zone of Low Density in the Crust,

In 1912 I published a paper in which I endeavoured to show that a zone of low density underlies the Indo-Gangetic alluvium and skirts the southern foot of the Himalaya Mountains. The existence of this line of low density in the crust has not been disputed. Its significance lies in the fact that it furnishes an argument against Prof. Suess's theory of Himalayan formation. Prof. Suess held that the mountains of Tibet and Persia are advancing southwards in a great series of folds. Mr. Hayden, Director of the Geological Survey of India, writes that the great series of folds in Central Asia are supposed to have been caused by a horizontal thrust from the north.⁵

Key words: Tectonics, Himalayan Foredeep.

B/304. Burrard, S.G., 1930. The Himalayan ranges and Godwin Austen's map. *Geographical Journal* 75, 35-37.

There were one or two points in your article on the Indian Border, G.J., September, p. 274, which were not quite fair to the Survey of India. You are quite mistaken in thinking that the ideas of Godwin Austen have dominated the survey for fifty years or that our maps are dependent on geology. I have never seen that map in any Indian drawing-office, I have never heard it quoted, and have never used it myself. The reason that the successive maps of Tibet from Walker's downwards all resemble one another is that they are all based on the same topographical data, the later maps having additional data. All our maps of Tibet are purely topographical; geology does not enter; there have been no geological surveys, and if there had been, we never use geology in topographical maps.

In all branches of knowledge generalization is necessary and difficult. Geographers are obliged to generalize, and to produce diagrammatic maps of complicated mountain systems. These diagrams are required as index maps, and for bird's-eye views. If we plot all the known peaks above 16,000 feet, the points on our charts arrange themselves in curvilinear alignments. I am no advocate of "ranges"; as a geologist Hayden was opposed to long ranges, because the eastern part of the Himalayan range was of a different age from the western. But Hayden, like myself, could not but see that the high points of Tibet insisted on grouping themselves in curvilinear arrangements, and a "range" is merely an abbreviation for curvilinear arrangement. We have to keep quite separate the question of the continuity of ranges from east to west, and the continuity of their names throughout their lengths. As to the continuity of ranges the topographical data lead to the idea that the plateau of Tibet is traversed from west to east by long continuous ranges. If a range does sink into the plateau here and there, it seems to reappear on the same alignment a little farther on. Between the ranges the plateau seems to consist of level strips. There has been no topographical survey; but there have been scattered surveys from east to west and from north to south, and they all confirm the view of parallel ranges.

As to continuity of names across the plateau, everyone would like to find Tibetan names. No one wants to extend the name Karakoram east of the Karakoram region: it would be a mistake. The Map of Tibet, 1914, which you quote, had a very unfortunate error, which was not noticed by the scrutineer; the drawing-office was short-handed, and this mistake crept in. The draughts-man entered the name Karakoram too far east. This was a mere slip; there was nothing intentional about it. I have never heard any surveyor advocate the extension of the name Karakoram east of the Shyok basin. The name has not been limited in area with the same definite precision as a state boundary. But just as the name of this range is automatically changed to Hindu Kush, as it proceeds westwards into Afghanistan, so we may hope that it will one day take on a Tibetan name as it proceeds eastwards.

With regard to your remark about the Ladakh and Kailas ranges extending eastwards to 920, there is no doubt that these two ranges are very long alignments of elevated points. The apparent breaks in their continuity are mentioned on pp. 93 and 95, Part II (Burrard and Hayden's sketch). These breaks are probably only dips of the alignment below the high level of the plateau. The difficulties of naming these long ranges, when there are no Tibetan names, were painfully present to Hayden and myself in 1907. Our critics may say, "How absurd to extend the names Ladakh and

Kailas through so many degrees of longitude!" The names affixed to these two ranges were given in 1852-53 by Cunningham, a careful, scientific and erudite explorer; we followed Cunningham, and in the absence of Tibetan names we continued Cunningham's names throughout the eastern prolongations of his range- alignments. In taking this step and in avoiding inventions of new names, we were only actuated by the wish to leave the whole question open for final consideration when the time had become ripe. We thus saved our successors from the complications of having new names started which might prove unsuitable. I may say that in 1907 we consulted every known authority about these ranges, and we received the universal advice: "the time is not ripe; leave the question alone."

The ranges of Tibet seem to open like a fan, and to be squeezed together at the north-western end. But the same elevated alignments seem to persist even when squeezed and pushed north-west.

Key words: Godwin Austen, Karakoram, Hindu Kush, Himalaya.

B/305. Burrard, S.G. & Hayden, H.H., 1933-34. A sketch of the geography and geology of the Himalayan Mountains and Tibet. Four volumes (2nd Edition. Revised by S. Burrard and A.M. Heron.) New Delhi.

This is a reproduction of a book published before 1923. This book may have occasional imperfections such as missing or blurred pages, poor pictures, errant marks, etc. that were either part of the original artifact, or were introduced by the scanning process. We believe this work is culturally important, and despite the imperfections, have elected to bring it back into print as part of our continuing commitment to the preservation of printed works worldwide. We appreciate your understanding of the imperfections in the preservation process, and hope you enjoy this valuable book.

Key words: Geology, geography, Himalaya, Tibet.

B/306. Burtman, V.S., 1983b. Development of the Pamir–Punjab syntaxis. *Geotectonics*, 16, 385–393.

Key words: Syntaxis, Pamir, Punjab.

B/307. Butler, B.C.M., 1963a. An occurrence of nephrite jade in West Pakistan. *Mineralogical Magazine* 33, 385-393.

Two pebbles of good quality nephrite jade from the riverbed of the Teritoi, Kohat District, West Pakistan, are described. One pebble is pale greenish white and has specific gravity 2.954, and the other is spinach green with specific gravity 3.021. Under the microscope both consist of sub-parallel bundles of tremolite fibers. The discovery is of significance in relation to the problem of the origin of the raw material of Indian carved jade. The pebbles are thought to be derived from the Siwalik sediments.

Key words: Jade, Kohat, siwaliks.

B/308. Butler, B.C.M., 1963b. Nephrite jade in West Pakistan. *Journal of the Royal Asiatic Society*, (3 &4), 130-139.

Consult the preceeding account for further information.

Key words: Jade, Kohat, siwaliks.

B/309. Butler, B.C.M., 1965. Epidiorite-limestone contact relations at Burawai, Hazara district, West Pakistan. *Mineralogical Magazine* 34, 82-91, 2 Pl.

Mineral assemblages in calcareous rocks upto 6 ft from the contact of an epidiorite sill are interpreted as a result of regional metamorphism superimposed on an earlier thermal metamorphism in which potassium metasomatism occurred. The sill, originally a dolerite, is 70-100 ft thick and now consists of green amphibole, oligoclase, and sphene. The rocks 6 ft from the contact are impure calcareous rocks with microcline, epidote and zoisite, oligoclase,

pale green pyroxene, actinolite amphibole, and quartz. At 4 ft from the contact calcite, microcline, Ca-rich garnet (n 1.760), zoisite epidote, and pyroxene are the chief components. Nearer to the contact the abundance of garnet increases, but in the last foot of the contact garnet is absent and the assemblage is epidote-amphibole-calcite-quartz. Numerous model analyses are given.

Key words: Petrology, metamorphism, Hazara.

B/310. Butler, R., 1995. When did India hit Asia? *Nature* 373, 20-21.

Key words: Tectonics, India, Asia.

B/311. Butler, R., Jones, C., Treloar, P. & Wheeler, J., 1991. Tectonic evolution of the Nanga Parbat massif insights from the central-southern segment. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 23.

The Nanga Parbat massif represents the northern-most continuous outcrop of the Indian continent within the Himalayan collision belt, exhumed from beneath the overriding Kohistan arc terrane by young thrust activity. Recent work has concentrated on the uplift neotectonics, effect which are concentrated on the western margin of the massif.

The internal structure of the Nanga Parbat massif is schematically represented as antiformal, with the early high strain contact between Kohistan-Ladakh and Indian continental material (a possible MMT analogue) defining this structure. However, recent studies of the internal structure of the massif (Wheeler, Potts and Treloar) along the accessible Indus transect suggest otherwise. This work defined two major antiformal structures in foliation of the Nanga Parbat basement. In this contribution we present new results arising from two expeditions into the Nanga Parbat massif, both of necessarily of a reconnaissance nature: the Durham University geological expedition in 1998 and a NERC-funded trip in 1990.

Our studies in the heart of the massif to the south attempted to trace the composite antiformal structure determined on the Indus section. Our more recent work suggests a rather more complex arrangement. Foliation on the western side of the massif is concordant to the early high strain contact with Kohistan (subtracting the affects of local neotectonic faulting), consistent with the antiformal model. However, work along the Astor valley transect did not reveal a major antiformal closure. Rather the structure is of an asymmetric west-gaping synform with foliation on the eastern margin dipping steeply east, beneath Kohistan (Ladakh). The penetrative stretching lineation plunges N in the E and NE in the W with a gradual change in trend. Further insights from the Rupal transect allows a second major south-gaping closure to be mapped, with an apparently high strain upper limb (outcropping on the Rupal face and summit of Nanga Parbat). The lower, south-dipping limb, while also high strain, contains a south-plunge stretching lineation. We discuss the interpretation of these unexpected structures, specifically the relationship between position on large-scale folds, shear criteria and orientation of lineations. However, the age of some fabrics in the massif, despite the "Himalayan" trend of stretching lineations, is not necessarily Tertiary. A suit of biotite granite bodies, mineralogically distinct to the late two-mica leucogranite veins of the massif, crosscut fabric. Therefore we also discuss the problems of identifying Himalayan deformation from much earlier tectonics within basement of the Indian continent. Work is underway investigating these topics.

Key words: Tectonics, MMT, Nanga Parbat, Kohistan.

B/312. Butler, R.W.H., 1985. Relationships between crustal scale thrusting, subduction and lithospheric flexure on the NW margin of the Indian Continent. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

Data from magnetic anomaly stripes on the floor of the Indian Ocean suggest that 1500-2500 km of relative convergence has occurred between Indian and stable Asia since the abutment of the two continental masses in the middle Eocene. This has been accommodated by southward directed thrusting within the Indian crust together with other shortening processes in the Himalayan hinterland. To the west, oceanic subduction has continued throughout this period beneath the Makran forearc. This contribution explores the ways in which crust and mantle stacking varies within the Himalayan belt and links through the Makran region, together with the control these geometries on patterns of flexural basin development on the Indian Continent.

This study is underpinned by a balanced cross-section, constructed from the Punjab foreland to the main Mantle thrust in northern Pakistan. This restores upper crustal thrust systems to a width in excess of 720-km with an implicit shortening of at least 470-km. A further 150-km displacement on MMT, amounting to simple subduction of Indian lithosphere, preceded this shortening. Indian lower crust of the western Himalayas has been stacked beneath the Asian hinterland, possibly as far north as the Pamirs while in the central Himalayas whole crustal stacking occurs directly beneath the thrust belt. This has resulted in a greater topographic elevation in the central Himalayas and gravity modeling has suggested that this topographic load account entirely for the flexural depression of the adjacent foreland. However, in western Pakistan the lower Indus basin has a similar width (c. 300-km) and inner depth (c. 7-km) as the main Punjab-Gangetic foreland basin. Yet in these western regions the orogenic belt has a relatively low topographic elevation (average less than 2-km) so that an extra, subsurface load is required to drive the flexural basin. This can be provided by the adjacent oceanic lithosphere which has been subducted below the Peshawar basin which overlies thrust systems in northern Pakistan. These interpretations suggest that load stresses in the subducted oceanic lithosphere can be transmitted across the adjacent continental lithosphere, which must be coupled at depth. This argues against the concept of India behaving as a rigid indenter with respect to Asia but supports models of thrust continuity within the convergent plate system.

Key words: Tectonics, structural geology, Indian plate.

B/313. Butler, R.W.H., 1986. Thrust tectonics, deep structure and crustal subduction in the Alps and Himalayas. *Journal of the Geological Society of London* 143, 857-873.

The structural restoration of collision orogenic belts onto crustal templates provides important insights into the tectonic evolution, deep structure and amounts of plate convergence after the initial contact between two continental masses. Balanced cross-sections have been constructed, parallel to the local displacement directions, across the western Alps and western Himalayas and demonstrate very large amounts of crustal shortening above intra-crustal detachments. To achieve a balance, substantial volumes of lower crust must have been subducted beneath the two tectonic hinterlands. A model of eclogite metamorphism is invoked to facilitate this subduction and to explain the varying isostatic responses of the Alpine and Himalayan hinterlands. Patterns of eclogite metamorphism are controlled by the geometry of thrust profiles on a lithospheric scale: the development of crust-mantle detachments being of crucial importance. Such a profile is proposed for the Himalayas, suggesting that relatively small volumes of the footwall crust succumbed to eclogite metamorphism. In the Alps however, a steeper thrust profile apparently developed, emplacing mantle onto crust, causing wholesale eclogite metamorphism in the underlying Franco-Swiss crust. The resultant density increase would provide a mechanism of isostatic collapse and flexural subsidence in the Po plain region.

Key words: Tectonics, structure, subduction, Alps, Himalaya.

B/314. Butler, R.W.H., 2000. Structural evolution of the western margin of the Nanga Parbat massif, Pakistan Himalaya: insights from the Raikhot-Liachar area. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 51-75.

There are several competing interpretations of the structure of the margins of the Nanga Parbat massif: that the massif is bounded by original suture between the Indian continent and the Kohistan-Ladakh island arc-the Main Mantle Thrust; that the massif is entirely bounded by neotectonic faults; that it is bounded by a combination of early and late faults and shear zones. If the marginal structures of the massif are to be related to local and regional geotectonic evolution then their correct characterization is critical. The Raikhot Bridge area on the western margin of the massif is useful in this regard, as it provides accessible and near-continuous outcrops. This contact, sometimes called the Raikhot Fault, is composite. Sheared metagabbros of the Kohistan arc are juxtaposed tectonically against metasediments and orthogneisses of the Nanga Parbat massif along an early ductile shear contact, developed under amphibolite facies conditions. In this regard it may be a preserved segment of the Main Mantle Thrust. However, this ductile shear zone has been strongly modified, flattened and rotated, and is cut by younger shears and faults. The original kinematics of the shear zone has been largely overprinted by these subsequent deformations. The younger structures include NE-SW striking, dextral strike-slip faults and a major top-to-NW thrust and shear zone. A sequence of metamorphism, deformation and igneous emplacement may be used to study the history of structural evolution within the massif. The use of a single name (e.g. Raikhot Fault) for the present-day map contact between

the Nanga Parbat massif and neighboring Kohistan is misleading. The early contact (termed here the Phusparash Shear Zone, possibly the northeastern continuity of the Main Mantle Thrust) is modified by the Buldar Fault Zone (dextral strike-slip) and the Liachar Thrust Zone (top-to NW carriage of the Nanga Parbat massif across the Phusparash Shear Zone and onto Kohistan). The activity of the Buldar Fault and Liachar Thrust Zone continued during exhumation of the massif, through amphibolite facies to the Earth's surface. The interaction between these structures is at present unknown. However, establishing these and similar interactions within the Nanga Parbat area remain central to establishing the role of regional NE-SW dextral transpression in the modern structure of the massif.

Key words: Structure, Raikhot-Liachar, Nanga Parbat, Himalaya.

B/315. Butler, R.W.H. & Coward, M.P., 1989. Crustal scale thrusting and continental subduction during Himalayan collision tectonics on the NW Indian plate. In: Burchfiel, B.C. & Sengor, A.M.C. (Ed.), *Tectonic evolution of Tethyan Regions Proceedings*. NATO ASI, Kluwer, Dordrecht C259, 387-413.

Following the subduction of Tethyan oceanic lithosphere beneath Asia and Kohistan the continued convergence between the upper plate and the Indian continent led to thrust stacking of Indian crust to form the Himalayas. This lasted from Oligocene to Recent times and in an attempt to evaluate displacements, a series of balanced cross-sections have been constructed across the belt. In Pakistan these illustrate that over 600km of relative convergence between India and the Kohistan complex north of the Eocene suture zone has occurred by SSE-directed thrusting. This deformation only involves Indian upper crust at present outcrop levels so that the lower crust and remaining lithosphere must have been subducted beneath Kohistan and Tibet. The northern edge of the Indian lower crust may lie beneath the Pamirs. Similarly large amounts of shortening (several hundred kilometres) are implied by other balanced crustal sections through the central Himalayas and western Pakistan. The continuity of thrust systems around the NW margin of the Indian continent is proposed so that thrusts which stack continental crust step off into oceanic lithosphere in the west. This thrusting mechanism accounts for a substantial fraction of the total, 1200–2000km relative convergence between stable India and Asia. Further shortening in the Tibetan region which developed after the Eocene continent-continent collision must be added to the displacements on thrusts which stack Indian lithosphere. Deformation within the entire collision zone approximates more closely to an essentially vertical plane strain model rather than to a process of lateral expulsion of Tibet towards the east.

Key words: Tectonics, subduction, Indian Plate, Himalayan collision.

B/316. Butler, R.W.H., Coward, M.P., Harwood, G.M. & Knipe, R.J., 1987. Salt control on thrust geometry, structural style and gravitational collapse along the Himalayan mountain front in the Salt Range of northern Pakistan. In: Lerche, I. & O'Brien, J.J. (Eds.), *Dynamic Geology of Salt and related Structures*. Academy Press, Orlando, FL, United States, 339-418.

Key words: Salt, thrust geometry, Salt Range, Himalaya.

B/317. Butler, R.W.H., George, M., Harris, N.B.W., Jones, C., Prior, D.J., Treloar, P.J. & Wheeler, J., 1992. Geology of the northern part of the Nanga Parbat massif, northern Pakistan and its implications for Himalayan tectonics. *Journal of Geological Society of London*, 149, 557–567.

The northern outcrop termination of Indian continental crust lies at the Nanga Parbat massif, from where this contribution presents new field data. The tectonic contact with the structurally overlying Kohistan island arc is concordant and ductile, is associated with interleaving of Nanga Parbat and Kohistan lithologies, and may be correlated with the Main Mantle thrust found elsewhere in the NW Himalayas. This ductile shear zone is locally overprinted by cataclastic faults associated with exhumation of the massif but overall, the northern outcrop termination of the massif is controlled by erosion through a gently, northward-plunging antiformal structure. This folds both the Main Mantle thrust and the underlying, concordant 'Layered Unit' of the Nanga Parbat basement. Thus there is no indication that the massif acted as a promontory to the Indian continent during collision nor that it is a structure entirely bound by neotectonic faults. Ductile shear fabrics associated with the 'Main Mantle thrust' are

cross-cut by leucogranite sheets and pegmatites. These may represent the stockwork to a significant crustal-melt granite body described here in the northern massif. This Jutial granite shows many geochemical characteristics in common with similar bodies in the High Himalayas which are consistent with anatexis of the buried Indian continental basement rocks. However, the granite is enriched in heat producing elements (particularly Th: 22 ppm) and shows extremely high $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (>0.88). The high concentrations of radiogenic Sr are also an attribute of a suite of hitherto enigmatic leucogranitic pegmatites that laces the Nanga Parbat massif, suggesting that these may represent a stockwork to a largely buried body of which the Jutial granite is a small exposure. The enrichment in heat-producing elements within the granite may reflect similarly high heat production in the source Indian continental crust requiring in turn a fundamental re-examination of the thermal evolution of this crust during Himalayan metamorphism and exhumation.

Key words: Tectonics, MMT, Nanga Parbat, Himalaya.

B/318. Butler, R.W.H. & Harris, N.B.W., 1990. The Himalayas. The Open University, Milton Keynes, UK, 59p.

Key words: Himalaya.

B/319. Butler, R.W.H., Harris, N.B.W. & Whittington, A.G., 1997. Interactions between deformation, magmatism, and hydrothermal activity during active crustal thickening: A field example from Nanga Parbat, Pakistan Himalayas. *Mineralogical Magazine*, 61, 37–52.

The Nanga Parbat massif is a rapidly eroding, thrust-related antiform that is distinct from other regions of the Himalayan orogen in being both intruded by Late Miocene-Pliocene anatectic granites and permeated by a vigorous hydrothermal system. Exhumation is achieved by erosion during thrusting along the Liachar thrust in the apparent absence of extensional tectonics. At depths in excess of 20 km, small batches of leucogranitic melt have been generated by fluid-absent breakdown of muscovite from metapelitic lithologies. These melts ascend several kilometres prior to emplacement, aided by low geothermal gradients at depth and by interaction with meteoric water as they reach shallow levels. At intermediate depths (approximately 15 km) limited fluid infiltration is restricted to shear zones resulting in localised anatexis. Within the upper 8 km of crust, magmatic and meteoric fluid fluxes are channelised by active structures providing a feedback mechanism for focusing deformation. Leucogranite sheets show a range of pre-full crystallization and high-temperature crystal-plastic textures indicative of strain localisation onto these sheets and away from the country rocks. At subsolidus temperatures meteoric fluids promote strain localisation and may trigger cataclastic deformation. Since near-surface geothermal gradients are unusually steep, the macroscopic transition between distributed shearing and substantial, but localised, cataclastic deformation occurred at amphibolite-facies conditions (approximately 600 degrees C). Even with the greatest topographic relief in the world, the meteoric system of Nanga Parbat is effectively restricted to the upper 8 km of the crust, strongly controlled by active structures.

Key words: Deformation, magmatism, crustal thickening, Nanga Parbat, Himalaya.

B/320. Butler, R.W.H., Owen, L.A. & Prior, D.J., 1988. Flash floods, earthquakes and uplift in the Pakistan Himalayas. *Geology Today*, 4, 197–201.

Catastrophic flooding of parts of the frontal plains of the Pakistan Himalayas has occurred throughout the historical past. The largest recorded flood (1841) originated from an earthquake triggered landslide from the flanks of Nanga Parbat, which blocked the Indus river for six months. The earthquake probably occurred on the Liachar thrust, which has been responsible for uplifting the amphibolite facies Nanga Parbat gneisses to the Earth's surface in the last 10 million years. These movements raise serious problems for hydroelectric engineering project in this and other active mountain belts.

Key words: Natural hazards, floods, earthquake, uplift, Himalaya.

B/321. Butler, R.W.H. & Prior, D.J., 1988a. Tectonic control on the uplift of the Nanga Parbat Massif, Pakistan Himalayas. *Nature* 333, 247-250.

Cenozoic mountain belts like the Himalayas contain regions that experienced rapid uplift in comparison with the areas around them. Whether this uplift occurred by buoyant rebound of previously thickened crust or during the crustal thickening process itself is uncertain. Here we show, however, that the 7 mm yr⁻¹ Recent uplift of the Nanga Parbat massif, Pakistan Himalayas, was accomplished during NW-directed thrusting located along its western margin. This 3-km-wide Liachar thrust zone operated from amphibolite facies to the present topographic surface and accommodates substantial crustal shortening. The adjacent Indus river valley, itself cut by seismogenic faulting, completely transects the massif, showing that erosion keeps pace with geologically rapid thrust uplift.

Key words: Tectonics, uplift, Nanga Parbat.

B/322. Butler, R.W.H. & Prior, D.J., 1988b. Anatomy of a continental subduction zone: the Main Mantle thrust in Northern Pakistan. *Geologische Rundschau* 77, 239-255.

Key words: Tectonics, subduction, MMT.

B/323. Butler, R.W.H., Prior, D.J. & Knipe, R.J., 1989. Neotectonics of the Nanga Parbat Syntaxis, Pakistan, and crustal stacking in the northwest Himalayas. *Earth and Planetary Science Letters* 94, 329-343.

The northwest termination of the Himalayan arc is marked by two large antiformal structures, termed syntaxes, and a NW-SE zone of intermediate depth earthquakes which have yielded both strike-slip and thrust-sense fault-plane solutions. This contribution presents new structural data from the Nanga Parbat area, the northern syntaxis, one of the fastest rising portions of the orogen (7 mm yr⁻¹). Our studies show uplift related to syntaxis growth to be accommodated by structures located along its western margin. Fault kinematics in the southern part of the margin indicate NW-directed thrusting along a shear zone and high level cataclastic faults, termed the Liachar thrust zone. This carries amphibolite facies basement rocks out onto Quaternary sediments. Further north along the western margin active faults are dominantly dextral strike-slip, oriented north-south (e.g. the Shahbatot fault). Overprinting relationships suggest that the strike-slip fault zone has migrated southwards into the NW-directed thrust zone. These relationships are consistent with the northwest termination of the arcuate Himalayan thrust belt at a lateral tip generating folding and radial thrust directions. Faulting patterns at Nanga Parbat suggest that this tip zone has migrated southwards. Active faulting is now concentrated in the northwest continuation of the Hazara (southern) syntaxis, along a seismogenic strike-slip and thrust zone. These deep level tips lie on the crustal stacking thrusts which cut through the higher level, SSE-directed thrusts of Pakistan.

Key words: Neotectonics, crustal thickening, Nanga Parbat.

B/324. Butler, R.W.H., Wheeler, J., Treloar, P.J. & Jones, C., 2000. Geological structure of the southern part of the Nanga Parbat massif, Pakistan Himalaya, and its tectonic implications. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 123-136.

The Nanga Parbat massif lies in the core of the major north-south trending, broadly upright antiform that marks the NW syntaxis of the Himalayan arc. However, this antiformal structure is not evident in the trend of foliation and banding within the central and southern parts of the massif. Reconnaissance field studies in this region (Astor, Rama and Rupal areas) have delineated an important shear zone with top-to-the-south overthrust kinematics. This Rupal Shear Zone carries the migmatitic core of the massif onto non-migmatitic metasediments locally termed the Tarshing Group. The shear zone traces north into a broad high strain zone of steep foliation with gently plunging mineral elongation lineations with no consistent sense of shear. A tentative model is proposed whereby top-to-the-south overshear in the Rupal area passes northwards into a steep belt of apparently constrictional N-S elongation. This type of large-scale transpression may record the early growth of the syntaxis. However, relating these structures to Himalayan orogenesis and the amplification of the NW syntaxis is problematic. The Nanga Parbat massif displays a long and complex history of polyphase deformation, metamorphism and magmatism, as might be expected of a terrane derived from the basement of the Indian sub-continent. Although at least the alter part of the constrictional

steep belt developed with syn-kinematic leucogranite intrusions (<10 Ma), the old age limit on the Rupal Shear Zone remains unconstrained.

Key words: Structure, Nanga Parbat massif, Himalaya.

B/325. Butt, A.A., 1962. Remarks on the proposed "Abbottabad Group" of Gardezi and Ghazanfar. Geological Bulletin, Punjab University 7, 69-80.

Key words: Stratigraphy, Abbottabad, Hazara.

B/326. Butt, A.A., 1969. A note on the Cretaceous Tertiary boundary in Hazara, West Pakistan. Geological Bulletin, Punjab University 8, 73-78.

Middlemiss (1896, pp. 39-40) described grey limestone (proposed as Kawahgar Formation by the Stratigraphic Committee of Pakistan, 1969), of doubtful age, which underlies the Paleogene formations in the Hazara District of West Pakistan. Latif (1962, p. 57) pointed out that the limestone belongs to the Upper Cretaceous age because of the presence of foraminifera Globotruncana, Heterohelix, Rugoglobigerina and Pseudotextularia, which he identified by examining thin sections of the rock from certain localities, namely, Darband, Dungagali and Khan.

If we consider the lithological characteristics of the Kawahgar Formation in the district, we find that the formation is present, as a hard and very fine-grained, well-bedded, light grey limestone for which reasons the foraminifera can only be examined under thin sections. However, at some localities, for example at Changlagali (1" 43 G/5) along the Murree-Nathiagali road, which is regarded here as one of the reference sections; nearly 13 miles east of the Jabri Forest Rest House along the Lora-Maqsood road (1" 43 G/1), this formation is predominantly represented by very thinly-bedded pale weathering marls which, on treatment with peroxide, yield loose fossil specimens. It is from the latter locality that the foraminifera, because of their better preservation, mentioned below are discussed and illustrated (Coll. Aftab, 1966, sample 9125) for the first time.

The boundary between the Kawahgar Formation and the overlying dense grey, nodular limestone, the Lockhart Limestone (name proposed by the Stratigraphic Committee of Pakistan, 1969) is marked by a laterite band of few feet in thickness. This band is very conspicuous in the field and can be used as a marker bed for the purpose of mapping.

The sampling from the marls of the Kawahgar Formation from the above mentioned localities, has shown the presence of well-preserved globotruncanids. The species/subspecies encountered are Globotruncana limelano, G. fornicata, G. ventricosa and G. concavata carinata. Moreover, Heterohelix globulosa, H. reussi and Rugoglobigerina rugosa also form part of the planktonic association. Rugoglobigerina rugosa, recorded here as few specimens, however, has not been illustrated. This assemblage suggests that the Kawahgar Formation ranges from Coniacian up to the Campanian.

Reviewing the Cretaceous-Tertiary succession in Hazara, we find that the Kawahgar Formation marks the end of the Cretaceous period. The Paleocene begins with a new transgressive phase which is represented by nodular limestone, the Lockhart Limestone that overlies the Kawahgar Formation. The Lockhart Limestone shows an abrupt change in lithology as well as in the faunal composition. The pelagic foraminiferal association of the Kawahgar Formation is entirely absent and the fauna is now composed of the benthonic larger foraminiferal species such as Lockhartia haemei, Miscellanea miscella, Ranikothalia soldadensis (= R. sirdensis), Daviesina khatiyohi and Discocyclina ranikotensis suggesting an Upper Paleocene age. At this stratigraphic level, similar lithologic as well as paleontologic changes have been observed by the author in the Kala Chitta and the Samana Ranges pointing towards a similar stratigraphic break. Further research is, however, in progress to discuss, in detail, the foraminiferal assemblages of these regions and their stratigraphic implications.

Key words: Stratigraphy, Cretaceous, Tertiary, Hazara.

B/327. Butt, A.A., 1970. The Cretaceous Tertiary boundary in Hazara, West Pakistan. Abstracts, 21st /22nd All Pakistan Science Conference, Rajshahi, p. H3.

Key words: Stratigraphy, Cretaceous, Tertiary, Hazara.

B/328. Butt, A.A., 1972. Problems of stratigraphic nomenclature in the Hazara District, NWFP, Pakistan. *Geological Bulletin, University of Punjab* 9, 65-69.

Three formations, Hazara Formation, Abbottabad Formation and Kihal Formation, the last two with five and two members respectively, are recommended for the unfossiliferous sequence of the (?) Paleozoic of Hazara stratigraphy, as opposed to Hazara Group and Abbottabad Group of Latif (1970).

Key words: Stratigraphy, Hazara.

B/329. Butt, A.A., 1973. The Kawagarh Formation in Kala Chitta. Abstracts, 24th Pakistan Science Conference, Islamabad, p.H-4.

Key words: Stratigraphy, Kawagarh Formation, Kala Chitta.

B/330. Butt, A.A., 1986. The Concept of Unconformity in the Geological Record. *Kashmir Journal of Geology* 4, 155-158.

The stratigraphic concept of the residual deposit – the laterite is believed to form basis for recognition of the Paleocene succession of the Kohat-Potwar-Hazara province of northern Pakistan and thus enables to decipher the presence or absence of the Hangu Formation, the oldest formation of the Paleocene.

Key words: Stratigraphy, unconformity, Potwar, Kohat, Hazara.

B/331. Butt, A.A., 1987a. The Paleogene stratigraphy of the Kala Chitta Range, Northern Pakistan. *Acta Mineralogica Pakistanica* 3, 97-110.

The geology of the Kala Chitta Range is an integral part of the structural units of the Kohat-Hazara region, northern Pakistan. The sedimentary geology of the Kala Chitta Range has similarities with the adjoining areas. However, there are certain differences in the stratigraphy and the geology history. The structural evolution of the Kala Chitta Range began in the Mesozoic time and attained its maximum by the end of the Eocene time. The deposition of the Upper Cretaceous (Coniacian-Campanian) Kawagarh Formation in a narrow belt along the northern part of the Range, intergradation of the Upper Paleocene (Thanetian) sedimentary facies, the continuity of the stratigraphic and the paleogeographic pattern from north to south by a southward trend of younging of strata, especially during the Middle Eocene, are some of the salient geological features of this structural entity. First major stratigraphic break between the Upper Cretaceous Kawagarh Formation (Coniacian-Campanian) and the Upper Paleocene (Thanetian) Lockhart Limestone is marked by a ferruginous pisolite. The second major break between the Middle Eocene Kohat Formation and the Miocene Murree Formation is marked by a pebbly deposit-the Fatehjang Member. An attempt is made to review the stratigraphic, biostratigraphic as well as the paleogeographic setting of the region in the context of basin analysis framework.

Key words: Stratigraphy, paleogene, Kala Chitta.

B/332. Butt, A.A., 1987b. The Ranikothalia Sindensis zone in Late Paleocene Biostratigraphy. *Acta Mineralogica Pakistanica* 3, 111-115.

The foraminiferal genus *Ranikothalia* characterizes the Upper Paleocene (Thanetian) succession of Pakistan and elsewhere in the world, but does extend rarely into Lower Eocene. A closer examination of several Upper Paleocene species from various world localities demonstrates that the open spiral complanate forms may be identified as *Ranikothalia sindensis* (Davies), which has been illustrated here from the Upper Paleocene Lockhart Limestone of the Kala Chitta Range, northern Pakistan. In view of its stratigraphic value, it is strongly advocated that the *Ranikothalia sindensis* Zone be incorporated within the Upper Paleocene (Thanetian) in the Paleogene stratigraphic correlation scale of Cavelier and Pomerol (1983). This would be one step forward towards refinement of the Paleogene biostratigraphy on the basis of benthonic larger foraminifera.

Key words: Stratigraphy, biostratigraphy, *Ranikothalia*, Late Paleocene.

B/333. Butt, A.A., 1988a. Upper Cretaceous foraminiferal biostratigraphy of Pakistan. *Acta Mineralogica Pakistanica* 4, 90-95.

The Upper Cretaceous succession of Pakistan covers a time interval from Cenomanian to Turonian but largely, Coniacian to Campanian and a Maastrichtian interval. Deposition of the Kawagarh Formation in northern Pakistan and correspondingly the Parh Limestone in southern Pakistan (Coniacian to Campanian in age) is the result of a major transgression along the north-western margin of the Indian Plate, whereas the Maastrichtian interval records a major regression, marked either by the complete absence of the Maastrichtian deposits in northern Pakistan or by the development of a regional blanket of regressive facies of the shallow-water Pab Sandstone in southern Pakistan. Uninterrupted succession argillaceous deposits, the Korara Shale, across the Cretaceous-Tertiary boundary in the Kirthar Range (Gaj River section) containing Maastrichtian and Danian planktonic foraminifera in continued sedimentary environments, is among the very few world-wide examples of continuous section across the boundary.

Key words: Biostratigraphy, Cretaceous, foraminifera.

B/334. Butt, A.A., 1988b. Some geological aspects of the Hazara arc, Northern Pakistan. *Acta Mineralogica Pakistanica* 4, 147-150.

For details consult Butt, 1992 below.

Key words: Structure, Hazara Arc.

B/335. Butt, A.A., 1991. Plate tectonics and the upper Cretaceous stratigraphy of Pakistan along the northwestern margin of the Indian Plate. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, 13-14.

In terms of sedimentary geology, global marine transgression (sea-level rise) has been expressed as an episode of active plate movement, drowning the margins and many inland depressions of the world continents with shallow epicontinental seas. This significantly expanded the world oceanic environments favourable for flourishing of marine organisms, whereas global marine regression is an episode of slow plate movement causing major lowering of the sea-level. It means that the epicontinental seas and much of the continental shelf areas were periodically drained, thereby reducing world oceanic environments considerably. The shrinking of world oceanic environments caused extinction of marine organisms.

The Upper Cretaceous stratigraphy of Pakistan is interpreted to fit into this concept along the northwestern margin of the Indian Plate. The deposition of the Upper Cretaceous (Coniacian-Campanian) Kawagarh Formation in northern Pakistan and correspondingly Parh Limestone in southern Pakistan, has been interpreted as a result of active plate movement causing major regional flooding (marine transgression) along the northwestern margin of the Indian

Plate, thus causing expansion of marine environments favourable for the flourishing of the marine organisms. This is manifested by the presence of varied age-diagnostic globotruncanid fauna in these stratigraphic units.

The Maastrichtian time interval envisages a major episode of "draining off" regression the northwestern margin of the Indian Plate - a period of destruction of marine environments creating limited shallow-water living space, which amounts to a major extinction of the marine organisms.

The reduced marine environments in northern Pakistan are, therefore, refloated by the complete absence of the Maastrichtian sediments (total "drain off" of the shelf areas), while there is a development of regional blanket of regressive clastic facies in southern Pakistan --- the shallow-water Pab Sandstone resulting from the lowering of sea-level. This created a sedimentary facies almost barren of marine organisms except for a very rare reported occurrence of a Maastrichtian orbitoidal foraminifer *Lepidobitoides minor* (Vredenburg, 1908). The rare occurrence, however, is in harmony with respect to the shrinking environments

Key words: Plate tectonics, stratigraphy, Cretaceous, Indian Plate.

B/336. Butt, A.A., 1992. Geological framework of the Hazara arc. Abstracts, First South Asia Geological Congress, Islamabad, p.8.

The Hazara Arc forms part of the western limb of the Hazara-Kashmir Syntaxis and the closely situated geological segment of the Azad Kashmir from the towns Balakot to Muzaffarabad appears to form an integral part of the Hazara Arc. This interpretation gains support on the basis of following criteria: 1. The structural configuration of the Hazara Arc and, in its immediate neighborhood, the presence of dislocated lobe shaped geological segment of Azad Kashmir between the towns Balakot and Muzaffarabad. The dislocated junction between the geological segment of Azad Kashmir and the Hazara Arc can be visualised as a result of structural complexities caused by the Nathiagali Thrust merging further into the Main Boundary Thrust.

2. The extension of the stratigraphic units of the Hazara Arc into the neighbouring geology of Azad Kashmir, 3. The location of the town Balakot at the northern tip of the Hazara Arc.

Our interpretation based upon the structural setting, stratigraphic framework and the geographical location appears most appropriate for the definition of the Hazara Arc. Major geological events which occurred in the Hazara Arc can be summarized as follows: 1. A major Paleozoic stratigraphic gap crossing over to the Triassic. 2. Cretaceous-Tertiary unconformity (Maastrichtian-Danian interval) marked by residual deposits. 3. Marked southward depositional shift during the Middle Eocene Kuldana Formation towards the adjoining Potwar Basin. 4. A major depositional break from Upper Eocene to Oligocene which marked an end to the maximum stratigraphic and structural evolution in the Hazara Arc. 5. Creation of the Hazara arc as a hinterland to the adjoining actively subsiding Potwar Basin during the Miocene. This structural framework brought prominence to the Miocene sedimentation (Murree Formation) to the actively subsiding Potwar Basin, while it formed a southernmost bordering belt of the Hazara Arc.

Key words: Balakot, Muzaffarabad, Hazara Arc.

B/337. Butt, A.A., 1992-93. Plate tectonics and the upper Cretaceous stratigraphy of Pakistan along the northwestern margin of the Indian Plate. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 43-44.

Key words: Plate tectonics, stratigraphy, Cretaceous, Indian Plate.

B/338. Butt, A.A. & Malik, M.H., 1973. Revised geological map of south east Hazara - Evaluation as a field guide. Abstracts, 24th Pakistan Science Conference, Islamabad, H-4 - H-5.

Key words: Geological map, Hazara.

B/339. Butt, G.D., 1993-95. Study of Geo-aspects of barrage and its related structures of Ghazi Barotha Hydropower Project. M.Sc. Thesis, Punjab University, Lahore, 81p.

Ghazi Barotha Hydropower project is named after the village Ghazi near Tarbela and near Attock. It is basically a hydropower project which consists of second biggest channel of the world. This project was started in 1989. It is eight year project, and was expected to complete in 1997 to 1998. Due to some financial constraints and political problems for land acquisition, the project is delayed by 4-5 years. The project is a joint venture of five different companies in which two of these are national and three companies are international named as:

- * Pakistan Hydro Consultants (P.H.C.)
- * National Engineering Services of Pakistan (NESPAK) (Pvt.) Ltd.
- * Associated Consulting Engineers (A.C.E.) (Pvt.) Ltd.
- * Binnie and Partners (Overseas) Ltd.
- * Ghazi Barotha Contractors (G.B.C.)
- * Ewbank Preece Ltd.
- * Harza Engineering Company International. ,

The project is started on the idea that the overflow water from Tarbela should be reused for electricity. A concrete line channel is proposed on the left side of the area, 7 km down stream of Tarbela. It follows a gentle slope up to Attock and then a sharp head difference of about 250 feet is available at Barotha providing a suitable head for hydropower generation.

Key words: Engineering geology, Ghazi Barotha, Hydropower, Hazara.

B/340. Butt, I.H., 1997-98. Geological mapping of Rawalakot Area with special emphasis on engineering characteristics of soils. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 40p.

A number of static and dynamic tests have been performed in order to investigate the basic nature of the natural soils during testing. The samples tested cover a large variation in composition and dynamic behaviour. The test enables to study how the tests can be applied for land use. Void ratio, laboratory consolidation history settlement history can be established.

Clays, silty clays and inhomogeneous soils including consolidated soft clays, a slightly overconsolidated silty clays and a stiff overconsolidated clays were tested. The results indicate that the bearing capacity directly depends on the load. For foundations on clay soils the pore pressure is a good parameter, for the pore pressure dissipation and redistribution can easily be measured. The liquid limit, plastic limit, compaction and grain size distribution are within the ASTM specifications. The results indicate that most of the soils are firm and are good for sale construction of local purposes. The key parameters in the stress-strain relationship is the shear stress and the effective stress which are still to be investigated.

Key words: Soil, engineering geology, Rawlakot, Kashmir.

B/341. Butt, K.A., 1981a. Hydrothermal phenomenon associated with Lahor pegmatoid granite complex, Kohistan. Geological Bulletin, University of Peshawar 14, 85-93.

Pb-Zn-Mo and uranium mineralization spatially associated with Lahor pegmatite / granite complex and enclosing metasediments is examined in the light of new data on ore minerals. Several ore paragenetic associations are described and it is concluded that polyphase mineralization processes are responsible for the ore associations described.

Key words: Hydrothermal process, mineralization, granite, pegmatoid, Besham.

B/342. Butt, K.A., 1981b. Pyrochlore group minerals in carbonatites from Loe-Shilman, Khyber Agency, NWFP, Pakistan. Geological Bulletin University of Peshawar 14, 111-122.

Metamict, partially metamict and non metamict species of pyrochlore group minerals have been identified from a sheet like carbonatite complex in Loe-Shilman, Khyber Agency. Microscopy, X – ray diffractometry and partial chemical analyses are reported which indicate a chemical and structural variability between various species of pyrochlore. A multiplicity of intrusive activity is considered to be responsible for the variations described.

Key words: Mineralogy, carbonatite, Loe-Shilman, Khyber Agency.

B/343. Butt, K.A., 1983a. Komatiitic Affinities of Ultramafic Rocks, Serpentinites and ultramafic amphibolites in the amphibolite belt of Northern Pakistan. Kashmir Journal of Geology 1, 43-48.

A review of komatiites is presented and the existing chemical and petrographic data on amphibolites of Dir, Swat, Kohistan, Thak Valley, Nanga Parbat and Astor is re-evaluated. This study suggest that the association of amphibolites, ultramafic rocks, serpentinites, talc-carbonate rocks with occasional occurrence of pillow structures and ultrabasic volcanic breccias, all suggest komatiitic to tholeiitic affinities. Much of the ultrabasic material occurring within the amphibolite belt is interpreted to be submarine ultramafic to high MgO basaltic volcanic flows and minor intrusions. An oceanic crustal model proposed for this belt (Butt et al. 1979) is therefore further substantiated.

Key words: Petrography, komatiite, amphibolite belt, Kohistan.

B/344. Butt, K.A., 1983b. Tectonic environments for Ni and Pt group elements sulphide deposits in northern Pakistan. 2nd National Seminar on Development on Mineral Resources, Peshawar, 1, 21–24 May, 8p.

Nickel mineralization reported from Swat and Dir Districts are described with reference to their immediate geological and tectonic environments. Two types of environment of the ultramafic rocks hosting Ni mineralization have been distinguished; Synvolcanic and Alpine type. The significance of these environments with respect to their potential as hosts for sizable Ni and platinum group element sulphide deposits is discussed.

Key words: Ni-Pt group sulphides, tectonics, Swat, Dir.

B/345. Butt, K.A., 1983c. Petrology and geochemical evolution of Lahor pegmatoid/granite complex, northern Pakistan, and genesis of associated Pb-Zn-Mo and U mineralization. In: Shams, F.A. (Ed.), *Granites of Himalayas, Karakorum and Hindu Kush*. Institute of Geology, Punjab University, Lahore, 309-326.

The study describes a detailed account of the geology of Lahor pegmatite-granite complex. Field relations, texture, major and trace element chemistry are used to arrive at conclusion that the complex formed by in situ melting of pre-existing metamorphites. Metallic mineralization associated with the complex is interpreted to have been mobilized by hot fluids produced during anatexis but the source of metals probably lay in the metamorphites. Lahor pegmatoid complex is correlated with the Nanga Parbat-Haramosh migmatites and their significance at the plate-scale is discussed.

Key words: Hydrothermal process, granite, pegmatoid, Lahor.

B/346. Butt, K.A., 1988. Geology of Koh-i-Sufaid Mountain, north of Parachinar and its correlation with other areas of comparable geology and mineralization. *Geological Bulletin*, University of Peshawar 21, 57-69.

Geology of Koh-i-Sufaid imbricate zone, North of Parachinar is described and compared with similar occurrences in Thakot-Besham and Nanga Parbat-Haramosh area. Ductile deformation exposed in the migmatitic rocks of these areas is interpreted to be due to structurally up thrown block of deep seated rocks along the older strike slip faults which have developed a significant vertical component during their re-activation under the influence of Himalayan orogeny.

Key words: Tectonics, structure, Koh-i-Sufaid, Parachinar.

B/347. Butt, K.A., 1989a. Uranium occurrences in magmatic and metamorphic rocks of northern Pakistan. In: *Uranium Deposits in Magmatic and Metamorphic Rocks*. Proceedings of the Technical Committee Meeting, Salamanca 29, 1986. IAEA, Vienna, Austria, 131-154.

Key words: Radioactive minerals, uranium, metamorphic rocks.

B/348. Butt, K.A., 1989b. Release of uranium through cataclastic deformation of Mansehra granite gneiss and its precipitation in the overlying montane basin in northern Pakistan. In: *Uranium Deposits in Magmatic and Metamorphic Rocks*. Proceedings of the Technical Committee Meeting, Salamanca 29, 1986. IAEA, Vienna, Austria, 155-166.

The Mansehra pluton belongs to a discontinuous belt of two mica granites of the Lesser Himalayas. The Mansehra granite is generally foliated except in the area around Mansehra. Several phases of granitic activity have been reported from the Mansehra complex. Shams and Rahman have demonstrated that the younger phases tend to be enriched in Na₂O. The northern edge of this sheet-like granitic mass has undergone extensive cataclastic deformation, resulting in the formation of shear zones, mylonites and cataclasites. A chemical comparison of crushed granite with granite outside the shear zone suggest little chemical reconstitution in terms of major elements during cataclastic deformation. A huge shear zone in albited granite gneiss has yielded secondary uranium minerals at water seepage, suggesting a liberation of uranium. Hydrogeochemical survey of the crushed granite and adjoining areas suggest that uranium from crushed granite was easily leachable in comparison with rocks outside the

shear zone. The uranium thus liberated was trapped in a Pleistocene sequence of clays and unsorted fluvial sand overlying the granite and country rock metamorphics.

Key words: Economic geology, uranium mineralization, cataclastic deformation, Mansehra Granite.

B/349. Butt, K.A., 1990. Ultrapotassic hypabyssal rocks from Khyber Agency. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.23.

Ultrapotassic rocks of a possible subvolcanic hypabyssal environments are described from Khyber Agency. These rocks contain sanidine as a major rock forming mineral. Other minerals include calcite, phlogopite, sodalite, fluorite, zircon and zeolites. Textural data suggest that these rocks crystallized under high-T conditions characteristic of high level subvolcanic environments. A predominance of K₂O over Na₂O is characteristic of these rocks. On the basis of chemical data presented, these rocks have been classified as LAMPROITE of "GROUP III" (Foley et al. 1987). Petrogenetic models for the origin of these rocks are discussed.

Key words: Ultrapotassic rocks, petrography, Khyber Agency.

B/350. Butt, K.A., 1994. Evidence of Pleistocene thrusting in Ahl area, Mansehra, Pakistan. Pakistan Journal of Geology 2 & 3, 73-77.

Key words: Structural geology, Pleistocene, Ahl, Mansehra.

B/351. Butt, K.A., 1995. Lithium mineralization in gem bearing complex pegmatites in Nanga Parbat Haramosh massif and Asiatic mass, N. Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.16.

Pegmatite rocks associated with Oligocene two-mica granites of the Asian plate as well as pre-Cambrian granites of the Nanga Parbat Haramosh Massif on the Indo-Pak plate have been investigated for their Li content. The pegmatites are of two distinct metaklogenic types, one showing enrichment towards lithium and the other to REE.

Key words: Lithium mineralization, pegmatites, Nanga Parbat-Haramosh.

B/352. Butt, K.A., 1997. An assessment of uranium favourability of granitic rocks of Indo-Pak plate in northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

An assessment of the granitic rocks of Indo-Pakistan plate for their favourability to host uranium deposits is presented. Mathews (1978) arrived at a set of recognition criteria including tectonic setting, host rock lithology, host rock texture, mineralogy, chemistry, alteration, geometry of mineralization and rock associations. Comprehensively compatible data on all these aspects of granitic rocks of Indo-Pakistan plate is not available. This paper, however, is an attempt to present a compilation of the available geological data along with more than 400 new chemical and petrographic analyses in order to arrive at a preliminary assessment of favourability of the granitic rocks of Indo-Pak plate.

Three groups of granitic rocks have been identified from the Indo-Pak plate in North Pakistan. Only one group has been interpreted to be favourable for hosting uranium deposits. This assessment would result in a substantial reduction in the size of the target area for uranium exploration in these granitic environments.

Key words: Uranium, granite, Indo-Pak plate.

B/353. Butt, K.A., 1997. Ruby mineralization at Nangi-Mali upper Neelum valley, Azad Jammu and Kashmir. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

Regional geological set-up and detailed local geology of Nangi-Mali ruby occurrence is described. Based on geology petrography and mineralogy of the occurrence a genetic model for the mineralization is proposed potential of this model's applicability in prospection of ruby in the higher Himalayan region of Pakistan is discussed.

Key words: Gems, ruby, petrography, Neelum valley.

B/354. Butt, K.A., Arif, A.Z., Ahmed, J., Ahmed, A. & Qadir, A., 1989. Chemistry and petrography of the Sillai Patti carbonatite complex, north Pakistan. *Geological Bulletin, University of Peshawar* 22, 197-215.

Detailed geology, petrography and chemistry of Sillai Patti sheeted carbonatite complex is presented. The complex is an anastomosing set of dykes intruding metamorphics of possible Proterozoic age. The complex is interpreted to be a product of multiple intrusions. The early phase of the intrusion is represented by peralkaline ultrabasic rocks (pyroxenites). This was followed by the intrusion of carbonatites and its attendant fenitization. There is a considerable petrographic and chemical variability in the complex, which is considered to be a function of varying degree of fenitization and hybridization of the earlier ultrabasic rocks by the carbonatite dykes.

Key words: Geochemistry, petrography, carbonatite, Sillai Patti, Malakand Agency.

B/355. Butt, K.A., Chaudhry, M.N. & Ashraf, M., 1980. An interpretation of Petrotectonic Assemblage West of Western Himalayan Syntaxis in Dir District and adjoining areas in Northern Pakistan. *Geological Bulletin, University of Peshawar* 13, 79-86.

A review of the geology of areas west of western syntaxial bend of Himalayas in Dir district and adjoining areas of northern Pakistan is presented. Several geotectonic regimes have been recognized and it is proposed that the well-known Indus ophiolite suture in this area is represented by amphibolite/ophiolite belt of Dir. These ophiolites are thought to have generated in an ocean and that their emplacement involved initially an ocean-continent type of plate interaction followed much later by continent-continent collision.

Key words: Tectonics, petrology, amphibolite, ophiolite, Dir, Himalaya.

B/356. Butt, K.A., Chaudhry, M.N. & Ashraf, M., 1985. Evidence of an incipient Palaeozoic ocean in Kashmir, Pakistan. *Kashmir Journal of Geology* 3, 87-102.

The Himalayas are interpreted to have formed by continent-continent collision between Indo-Pak plate and Asia. This event has been dated to be Eocene. Prior to the collision however, tectonics of the passive northern margin of the Indian plate has rarely been examined although these older rocks constitute a significant part of the Himalayan region especially the southern Kohistan ranges of Yeats & Lawrence (1984). Geochemistry of the Panjal volcanics is used to demonstrate that these represent an incipient ocean floor which lay between the Gondwana and Kashmir-Hazara microcontinent prior to the break-up of India from Gondwana.

Key words: Paleozoic, oceanic rocks, Panjal volcanic, tectonics, Kashmir.

B/357. Butt, K.A., Chaudhry, M.N. & Ashraf, M., 1987. Evidence of an incipient Paleozoic ocean in Kashmir, Pakistan- A reply. *Kashmir Journal of Geology* 5, 127-132.

Geochemical data presented in the paper Butt et al. (1985) is shown to be comparable to the data published by other authors on Panjal volcanics. Repeat analysis of 40 rock samples (to be published elsewhere) confirm high Al_2O_3 and low to moderate TiO_2 and low MnO_2 values.

The treatment certainly does not prove that Panjal basalt are MORB and the same was never claimed. Similarly the problem of these rocks being tholeiitic, alkaline or otherwise is also apparent from data of Gupta et al (1983) and Pareek (1983). Instead a transitional nature of these basalts was suggested which may have formed in an incipient ocean. The first stage in the evolution of an ocean is widely accepted to be an "Intracontinental rift" and successive developmental stages from a rift to an oceanic environment must involve an evolutionary process of development of oceanic crust between these two end members. The transitional nature of these basalts was proposed in this study.

Key words: Paleozoic, oceanic rocks, Panjal volcanic, tectonics, Kashmir.

B/358. Butt, K.A. & Khalid, M.M., 2001. Interpretation of satellite image to delineate the lineaments and natural drainage in and around Islamabad and their impact on environment. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.42.

Islamabad capital city of Pakistan is situated at the foothills of Margalla, which are considered to be in close proximity of Main Boundary Thrust (MBT).

Satellite image interpretation reveals that a number of lineaments abutting with MBT pass through the well-planned city of Islamabad. Most of the civil structures have been made in close proximity to these lineaments without any consideration for a special foundation design due to which cracks have been reported to develop in these buildings.

The streams originating from the hills surrounding Islamabad have also been blocked by manmade structures, which obstruct the natural seepage during rainfall and cause maximum surface runoff. This tremendously increased in the runoff input of water to Nala Lai. Due to this fact intensity of flood in Lai Nala has been increased in recent years.

Key words: Remote sensing, drainage, Islamabad.

B/359. Butt, K.A. & Khan, T.M., 1992. Uraniferous black shales of Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.8.

The graphitic-metapelites of NW Pakistan and Azad Kashmir are exposed in a zone of thrust tectonics, and are scattered in the form of continuous beds and lenses in various nappes. These are highly radioactive at places but the equivalent chemical uranium is found to be lower than its radiometric equivalents. Based on petrography and X-Ray diffraction studies a classification of black shales of Pakistan is presented. The chemical composition of the graphitic-metapelites indicates that the rocks from Tarbela area are more siliceous and contain more organic C compared to the rest of the exposures of the graphitic-metapelites. Due to their fine-grain-size, dark colour and Fe oxidation along fractures the rock types are classified as black shales. According to this classification the graphitic-metapelites from Tarbela area are siliceous and the graphitic-metapelites from other areas are dominantly argillaceous-siliceous with high normative quartz. Uranium and other associated elements are concentrated in the upper parts of the graphitic-metapelites. Compared to the metal rich black shale deposits elsewhere in the world, these rocks are enriched in U, V, Ba and Pb. Precipitation of these elements from saline waters is suggested rather than normal seawater. However, sulphidization of Fe by hydrogen sulphide has played some role in the concentration of elements from saline waters. Precipitation of the elements has taken place in oxygenated waters in a transitional environment close to the continent. The black shales were deposited in multiple basins characterized by different sources of supply of the elements to these basins.

Key words: Mineral exploration, petrography, XRD, black shale, uranium, Kashmir, Thakot, Tarbela..

B/360. Butt, K.A. & Mahmood, K., 1983. Munirite, naturally occurring sodium vanadium oxide hydrate, a new mineral. *Mineralogical Magazine* 47, 391-392.

Munirite was found in the sandstones of Siwaliks formation of mid-Miocene to Pleistocene age. It occurs as small globular clusters of acicular crystals (2 to 3 mm long). Analysis gave V₂O₅ 67.46, N₂O 22.91, and H₂O 10.26%. The X-ray powder diffraction pattern shows remarkable similarity to a synthetic compound NaV₃O₁₀ · 1.9H₂O (Lukacs and Strausievici, 1962). The new mineral was collected from Siwalik sandstones in Bhimber area, Azad Kashmir, Pakistan.

It crystallizes as radiating fibrous aggregates on outcrops as well as on the walls of exploratory trenches. The new mineral has been named after Mr Munir Ahmad Khan, Chairman of the Pakistan Atomic Energy Commission, who instituted the Mineral Research Laboratories in the Commission. The name and data have been approved prior to publication by the Commission on New Minerals and Mineral Names, IMA. Type material has been deposited with the Hard rock Division, Atomic Energy Minerals Centre, PO Box 734, Peshawar, Pakistan, and the British Museum (Natural History).

Key words: New mineral, sandstone, siwaliks, Azad Kashmir.

B/361. Butt, K.A. & Mahmood, K., 1986. Unit cell dimensions of uraninites from various geological environments in Pakistan. *Acta Mineralogica Pakistanica* 2, 47-52.

Key words: X-ray crystallography, uraninite.

B/362. Butt, K.A., Malik, R.H. & Khan, A., 1997. Geology of gem bearing complex pegmatites from upper Neelum Valley Azad Kashmir. Geological Bulletin, Punjab University 31 & 32, 127-132.

Geology of Janawai-Folowai area in upper reaches of Neelum valley, Azad Kashmir is presented. The geology of the area is divided into two units. A migmatitic basement complex consisting of high grade pelitic gneisses, migmatites and sheet granites thrust on to the high grade dominantly calcareous metasediments. This area is the host of a number of lithium and rare earth enriched complex pegmatites. These pegmatites have been reported to contain gem bearing cavities. This study suggests a tectonic classification of the pegmatites of this area and it is proposed that this classification has a potential in discriminating between Li, rare metal and Gem producing pegmatites from barren pegmatites.

Key words: Gems, pegmatites, Neelum valley, Azad Kashmir.

B/363. Butt, K.A. & Qadir, A., 1987. Discovery of lepidolite from Shengus area, Gilgit, Pakistan. Geological Bulletin, Punjab University 22, p.153.

Several pegmatite localities in Gilgit and Chitral were sampled in a bid to investigate their Lithium content.

There are a few unpublished previous reports about pink micas from northern area i.e. Ruby mines of Hunza area etc. Some of these samples were analysed and were found to be rose muscovite (Nawaz, Personal Comm.). Kazmi et-al. (1985) reported an occurrence of lepidolite from Bulechi area in Gilgit. However they did not produce supporting mineralogical or chemical data.

Mica samples of various colours were collected from Chitral areas and analysed for Lithium. It has been observed that pink, greenish, smoky and colourless micas from these pegmatites contain anomalously high Lithium but do not approach the Li_2O concentration to be classified as Lepidolite.

Garam Chashma area in Chitral contains micas with highly anomalous Li_2O content of the order of 0.45% Li_2O . Associated white micas within a single body of pegmatite clearly fall in two categories in terms of their Lithium content.

(i) Lithium rich micas, 0.45% Li_2O

(ii) Lithium poor micas, 0.008% Li_2O

None of the muscovite analysed from this area approached lepidolite.

Similar sampling was carried out in Shingus (Gilgit) area. Once again associated micas gave two populations:

1. Lithium rich micas 4.24% Li_2O

2. Lithium poor micas. 0.05% Li_2O

Lithium rich micas of shingus area can be classified as Lepidolite. Considering the similarity of Lithium distribution patterns in the two areas, it is concluded that the complex pegmatites in Chitral also hold a good potential for the discovery of Lithium minerals. It may be added that this is the first report in Pakistan wherein the occurrence of Lepidolite has been confirmed on the basis of chemical data.

Key words: Lepidolite, Shengus, Gilgit.

B/364. Butt, K.A. & Shah, Z., 1985. Discovery of blue beryl from Ilum granite and its implications on the genesis of emerald mineralization in Swat District. Geological Bulletin, University of Peshawar 18, 75-81.

Geological mapping of toposheet 43 B/6 in Buner Valley, District Swat is presented. Petrographic and mineralogical data on veins associated with Ilum granite have revealed a complex assemblage produced by multiphase hydrothermal activity. Some of these veins have been cataclastically deformed along with the granite body, whereas others show minor or no cataclasis and are hosted in post-cataclasis joints.

A genetic relationship between the granite and associated veins is proposed from field criteria. Hydrothermal veins associated with Ilum granite contain blue beryl. A granitic source forms the beryl and possibly for spatially associated emerald mineralization is postulated.

Key words: Gemstones, beryl, emerald, granite, Ilum, Swat.

B/365. Butt, K.A., Zafar-ul-Islam, Chaudhry, M.I. & Khan, J.A., 1994. Discovery of early Permian carbonatic to melilititic/nephelinite glassy flows in eastern Salt Range, Pakistan: Kashmir Journal of Geology, 11-12, 105-112.

Key words: Salt Range, Permian.

B/366. Butt, K.A. & Zaidi, M.M.S., 1969. Petrology of Thak Valley igneous complex. M.Sc. Thesis, Punjab University.

Thak valley comprises a variety of plutonic and volcanic rocks, including large quantities of gabbroic rocks, and diorites. These rocks show local deformation and metamorphism. The work involved mapping and sampling, and gives details of the petrography of various rock-types.

Key words: Petrology, Chilas.

B/367. Butt, M.H., 1972. Magnetic survey in upper Kurram Agency, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 45, 9p.

Key words: Geophysics, magnetic survey, Kurram Agency.

B/368. Butt, M.H., 1976. Gravity survey for Lead–Antimony Ore in Shoghor area, Chitral, Pakistan. Geological Survey of Pakistan. Information Release. 96, 10p.

This is a report to check the presence of Lead-Antimony mineralization along the fault contact between Marble and black Phyllite. Gravity measurement techniques are used. The anomalous area is recommended for more study.

Key words: Geophysics, gravity, lead-antimony, mineralization, Chitral

B/369. Butt, M.H., 1989. Resistivity measurement along the proposed 500 km transmission line from Kushab to Tarbela, Pakistan. Geological Survey of Pakistan, Information Release 416.

Key words: Geophysics, resistivity, Khushab, Tarbela.

B/370. Butt, M.H. & Latif, A., 1992. Production of major minerals of Pakistan 1947-1989. Geological Survey of Pakistan, Information Release 512, 28p.

The term mineral is used for any of the large group of natural inorganic substance having homogeneous structure, a specific chemical composition, uniform physical characteristics and usually a definite form of crystal. In broader terms it refer to all products (solid or liquids) derived from the mineral kingdom including energy raw materials.

It is felt generally by all those concerned with and interested in mineral development that essential information regarding the minerals sector is not accessible easily, hence the pace of mineral development is restricted, which is extremely important for industrial development of the country. As a result, if on one hand exploitation of indigenous mineral resources has not expanded rapidly, on the other hand extent of their industrial utilization has remained rather restricted, so this foreign exchange deficient country is importing a lot of common mineral based commercial products, which can easily be available to the consumer in the coal currency.

Geological Survey of Pakistan (GSP), an attached department of the Federal Ministry of Petroleum and Natural Resources, is also aware of this situation and since its establishment (i.e. 1947), it has tried to find the new minerals by the application of most modern techniques and knowledge. A lot of new discoveries have been made by this organization, starting from Coal Copper, fluxes, Fertilizer, China clay, Silica Sand, Bauxite, Lead zinc, Manganese, Uranium to the latest discovery of high grade iron ore in Chiniot-Sargodha area.

It is the joint effort of private and public mineral enterprises, supplemented by the mineral-surveying national organization that the mineral sector share in the Gross National Product of Pakistan rose from Rs. 793 million in

1947 to Rs. 14767 million in 1987-88, a nineteen fold increase in real terms and in percentage share to GNP, it rose from 0.75% in 1947 to 2.27% in 1987-88, a threefold increase.

The aim of present report is to highlight the production of major minerals of Pakistan from 1947-1989 and represent these figures in the form of graph to tell the reader at a glance about the ups and downs of a particular commodity. For interested readers it also gives the physical properties, diagnostic features, occurrence and uses on the opposite page.

Key words: Minerals, economic geology.

B/371. Butt, S., 1987. Crustal thickness and basement depth mapping using integrated gravity and magnetic surveys and geological sampling along Gayal-Thakot section of the Karakoram Highway 1986-87. M.Sc. Thesis, Quaid-i-Azam University, Islamabad, 88p.

Key words: Geophysics, gravity, magnetic, crustal thickness, KKH.

B/372. Butt, Z.H., 1988-90. Petrology of the Jijal and Pattan complexes between Gantar and Baleja (N.W.F.P.) with special emphasis on petrogenesis of the Pattan complex. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 69p.

A geological map is presented at a scale of 1:25000 covered by topo sheet No. 43 F/1 issued by the Survey of Pakistan. The rock sequence in the project area is the part of eastern Jijal and Pattan Complexes. The Jijal Complex in the project area is thinned out due to the intersection of MMT and Pattan faults as compared with the western part of the Jijal Complex. It is relatively fresh and massive on the KKH section, but in our project area the Jijal Complex has imprints of metamorphism but is the least metamorphosed among series of meta-plutonic complexes. The Pattan Complex (lowest part of the so called Kamila amphibolites) is considered here as a metamorphosed basic plutonic complex. The rocks of the complex exhibit relic igneous textures, at places but the mineral assemblages correspond to the low pressure metamorphic assemblages from green schist to granulite facies. Field and petrographic studies show that the Jijal Complex is formed within a separate magma chamber and is predominantly igneous in nature. The Jijal rocks are considered younger than overlying metamorphosed series of plutonic complexes (earlier known as Kamila amphibolites). The plutonic complexes have been metamorphosed under low pressure dynamothermal metamorphism during the development of northern suture (MKT).

Key words: Petrology, ultramafics, Jijal, Pattan, Kohistan arc.

C/1. Cai, Xiangxing, Li, Nienjie, & Li, J., 1980. The mudrock flows in the vicinity of the Batura Glacier. Professional Papers on the Batura Glacier, Karakoram Mountains, Science Press, Beijing, China, 146–152.

Key words: Glaciers, mudrock, Batura, Karakoram.

C/2. Calciati, C., 1910. Les fronts des glaciers de Yengutsa et d'Hispar. *La Geographie* 22, 241-246.

This paper reports the fronts of the great Hispar glacier and the Yengutsa glacier. The Hispar is one of the longest glaciers outside the polar region.

Key words: Glaciers, Hispar, Central Karakoram.

C/3. Calciati, C., 1914. Esplorazione delle valle Kondus e Hushee nel Caracorum sub-orientale. *Bollettino delle Reale Societa Geograpica Italiana* 51(9), 995-1014 & 51(10), 1076-1093.

Key words: Karakoram.

C/4. Calciati, C., 1923. Il piu grande ghiacciaio delle terra. Il Siascen nel Caracorum. *Emporium* 58, 105-115.

This is a report on the Siachin glaciers, one of the greatest glaciers of the world, in central Karakoram. It gives some details of the geography and geology of the area.

Key words: Glaciers, Siachin, Karakoram.

C/5. Calciati, C., 1928. Il Karakorum secondo le ultime esplorazioni con special riguardo al contributo degli italiani. Istituto Geografico Militare, Firenze.

This is a map of the Karakorum according to the latest explorations with special regard to the contribution of Italian workers.

Key words: Italian expedition, Karakoram.

C/6. Calciati, C., 1928-29. Nel Caracorum. L'assalto alle piu alte vette del mondo. *Le Vie d'Italia*, 1928: 976-987; 1929: 57-64, Milano.

Key words: Karakoram.

C/7. Calciati, C., 1930. Al Caracorum. Diario di due esplorazioni. Bemporad, Firenze.

Key words: Glaciers, Siachin, Karakoram.

C/8. Calciati, C. & Koncza, M., 1910. The basin of the Hispar Glacier. In: Workman, W.H. (Ed.), *The call of the snowy Hispar*. Appendix 1. Constable, London, 245-282.

Key words: Glaciers, Hispar, Karakoram.

C/9. Caldeira, K. & Kerrick, D.M., 1995. Uplift and chemical weathering in south-central Asia, the carbon cycle and Cenozoic climate. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

It has been proposed that the general cooling trend through the Cenozoic has been largely due to the enhancement of silicate-rock weathering rates associated with continental uplift in south-central Asia (i.e., the Himalayan and related orogens, and the Tibetan Plateau). One of the primary pieces of evidence cited to support this proposal is the Cenozoic strontium isotope curve, which has been interpreted as indicating progressively increasing silicate-rock weathering rates associated with continental uplift in this region.

Uplift, by increasing the exposed surface area of fresh rock exposed to chemical weathering, may enhance the ease with which rock is weathered, and hence may have an impact on atmospheric CO₂ content and climate. However, if this mechanically weathered rock is rapidly transported to and buried in river deltas, enhanced mechanical erosion need not induce enhanced chemical weathering. Enhanced silicate-rock weathering on a global scale requires an enhanced supply of CO₂, else the atmospheric and oceanic reservoirs of CO₂ would be rapidly depleted. We have constructed a preliminary carbon budget for the Cenozoic, and have shown that the interpretation of the strontium isotope curve in terms of enhanced chemical weathering rates is inconsistent with both inferred rates of CO₂ degassing from the solid Earth and the inferred timing of uplift in Tibet, Himalayas and related orogens. Furthermore, the strontium in rivers draining the Tibetan plateau and the Himalayas is insufficient to account for the observed Cenozoic change in oceanic ⁸⁷Sr/⁸⁶Sr ratios.

Furthermore, we have conducted a preliminary field study examining the Himalayan and Karakorum orogens as a potential metamorphic CO₂ source to the atmosphere. Our initial results indicate that metamorphic CO₂ releases associated with the India-Asia collision would not have been sufficient to supply the CO₂ required to account for proposed increases in chemical weathering rates.

Key words: Weathering, climate, carbon cycle, uplift, Asia.

C/10. Calkins, J.A., 1966. The geology of the western limb of the Hazara-Kashmir Syntaxis, West Pakistan and Kashmir. Ph.D. Thesis, University of Massachusetts.

The Hazara-Kashmir Syntaxis is one of the most prominent structural features of the Himalayan Range. Forming a hair-pin bend, this structure has been studied in detail in this work. Some of the information from the thesis was published in several papers by Calkins and his co-authors.

Key words: Hazara-Kashmir Syntaxes, Himalaya.

C/11. Calkins, J.A. & Ahmad, M., 1969. Geology of the Tarbela damsite area, Peshawar Division, West Pakistan. USGS/GSP, Information Release PK-47, 17p.

About 80 square miles in the vicinity of the Tarbela damsite was mapped in order to relate the geology of the damsite proper to larger regional geologic features. The rocks in the area are chlorite-mica-quartz schist, marble and calcareous schists, and calcareous graphite schists of the Salkhala Formation (Precambrian); slate and phyllite schists of the Hazara Formation (Precambrian to Early Paleozoic); quartzite of the Tanawal Formation (Silurian or Devonian); dolomite of the Abbottabad Formation (Carboniferous to Permian); and small intrusive bodies of Tertiary age. Unconsolidated surficial deposits include reworked loess, river alluvium, and terrace deposits.

The main structural feature is a strike-slip fault, called the Darband fault, which passes down the Indus River through the damsite, and separates the Salkhala and Tanawal Formation on the west bank from Hazara and younger formations on the east bank. East of the Darband fault large northeast-trending folds plunge northeast. On the west bank, west of the Darband fault, large folds are not evident in the Salkhala Formation, but most small-scale folds are parallel to the large folds east of the fault.

In the northern part of the mapped area quartzite of the Tanawal Formation forms a large east-trending anticline overturned to the south. The southern overturned limb has moved relatively southward over the Salkhala rocks along a north-dipping thrust fault. The geological feature of greatest potential concern relative to the Tarbela dam is the Darband fault, which passes through the damsite. This fault is considered to be inactive, however, and may be too deeply buried by river alluvium to promote leakage. The schistose rocks in the west abutment area are weak, permeable, and cut by numerous shear zones.

The dolomite rocks of the Abbottabad Formation in the east abutment area, although much jointed. Are rigid and relatively impermeable in comparison with the rocks in the west abutment area.

Key words: Dams, Tarbela, Peshawar

C/12. Calkins, J.A., Ali, S.T. & Offield, T.W., 1967. Soapstone deposits of the Sherwan area, Hazara District, West Pakistan. USGS/GSP. Information Release PK-25, 13p.

Key words: Economic geology, soapstone, Sherwan, Hazara.

C/13. Calkins, J.A., Jamiluddin, S., Bhuiyan, K. & Hussain, A., 1981. Geology and mineral resources of the Chitral-Partsan area, Hindukush Range, northern Pakistan. USGS Professional Paper 716-G, 33p.

This report is based upon field investigations covering an area of about 1,400 square miles (3,626 sq km) in the Hindu Kush Mountains of Chitral State in northern Pakistan and also includes a discussion of geological questions relating to an area of about 8,000 square miles (20, 720 sq km) in the Chitral-Gilgit area. The area is extremely rugged; local relief is more than 8,000 feet (2,438 meters) over most of the area and commonly reaches 10,000 feet (3,048 meters). Many peaks are higher than 17,000 feet (5,182 meters), and Tirich Mir, 8 miles (12.9 km) north of the mapped area, is 25,263 feet (7,700 meters) high. The mapped area includes the following units: Devonian unit; Sarikol Shale (Devonian to Carboniferous); a broad belt of metamorphic rocks of Devonian to Jurassic age; Reshun Formation, a volcanic greenstone unit, a limestone and phyllite unit, a greenschist unit, and the Chitral Slate-all of Cretaceous age. Elongate bodies of granite (Cretaceous) underlie large parts of the area. Of stratigraphic interest are (1) the lateral facies change of the Reshun Formation from fossiliferous conglomeratic red shale and phyllite at Reshun, to marble in the Kafiristan area, and (2) the determination of a Cretaceous age for the Chitral Slate, which formerly was considered to be of Paleozoic age.

Structurally, the mapped area is characterized by a system of folds overturned toward the east and south. This fold pattern marks the regional trend of the Hindu Kush Range, from north in the southwestern part of the area to east-northeast in the eastern part. Several reverse and thrust faults separate belts of rocks of Cretaceous age from belts of older rocks. Metallic deposits in the area include (1) veins containing antimony, lead, and copper with associated gold, silver, and tin; (2) copper localities in mafic rocks and greenschist; and (3) miscellaneous showings, mainly of copper. Antimony has been mined on a small scale at Krinj since 1939. The places of high mineral potential are the vein-type deposits along the fault zones in the Awireth Gol-Shoghot-Madashil area, the Krinj mine area, and in the Shishi Valley area. Along these faults the largest showings of copper, lead, and antimony are found, and in the Awireth Gol locality the lead ore contains large amounts of gold and silver.

Nonmetallic mineral deposits include limestone, marble, dolomite, granite, pegmatite, and talc. No commercial limestone industry exists in the Chitral area. However, limestone and marble are used locally for building stone. Granite is also used locally for building stone. Mica and beryl are mined on a small scale from pegmatites 15 miles (24 km) northwest of the mapped area.

The work also includes a geological map of the area at a scale of 1:96000 along with two cross-sections, a regional geological map of the Gilgit-Chitral area at a scale 1:250,000 scale and a table of chemical analyses for metallic minerals.

Key words: Mineral resources, Chitral, Hindukush.

C/14. Calkins, J.A. & Matin, A.S.A., 1968. The geology and mineral resources of the Garhi Habibullah quadrangle and Kakul area, Hazara district, West Pakistan. Geological Survey of Pakistan/USGS Project Report, Information Release PK 38, 55p.

The mapped area occupies about 250 square miles in the southern Himalayas of northern Pakistan and western Kashmir, rugged mountainous country characterizes the area; maximum topographic relief is about 7500 feet between Lachi Khan (9473 ft) and the lowest elevation of 2000 feet.

The oldest rocks are the slates and phyllites of the Hazara Formation, considered to be of Precambrian (?) age. Quartzose schists of the Tanawal Formation (Silurian? Or Devonian?) overlies the Hazara Formation. Succeeding rock units in the area include: dolomite of the Abbottabad Formation (Carboniferous to Permian), red shales of the

Galadanian Formation (early Jurassic), Daulatmar Limestone (Jurassic), Spiti shale and Glumal sandstone (Upper Jurassic and lower Cretaceous), Sattu Limestone (Upper Cretaceous), chhalpani Formation (Paleocene and Eocene), and the Murree Formation (Miocene). Correlation of the Carboniferous to Eocene sequence of rocks in this area has been established with rocks of the Kala Chitta hills west of Rawalpindi, and with rocks of the Kohat area south of Peshawar.

Key words: Mineral resources, Hazara.

C/15. Calkins, J.A., Offield, T.W., Abdullah, S.K.M. & Ali, S.T., 1969. Geology and mineral resources of southern Hazara District, West Pakistan and parts of western Azad Kashmir. USGS Project Report, Information Release PK-43, 92p.

Key words: Mineral resources, Hazara.

C/16. Calkins, J.A., Offield, T.W., Abdullah, S.K.M. & Ali, S.T., 1975. Geology of the southern Himalaya in Hazara, Pakistan and adjacent areas. USGS Professional Paper 716-C, 29p.

Geologic mapping and mineral investigations were conducted from 1961 to 1965 by the Geological Survey of Pakistan and the U.S. Geological Survey in the Hazara district, Pakistan, and part of western Kashmir, as part of a cooperative mineral exploration and development program. The area covers 2,000 square miles in the southern foothills of the Himalaya between the Jhelum River on the east and the Indus River on the west. Rugged mountains and deep canyons characterize most of the area. Altitudes range from 1,100 feet on the Indus River near Tarbela to more than 16,000 feet on the Kashmir divide; the Indus, Siran, Kunhar, Kishanganga, and Jhelum Rivers all flow in deep gorges through the area. The geologic formations range in age from Precambrian to Quaternary and include sedimentary, igneous, and metamorphic rocks and unconsolidated material. The oldest rocks belong to the Salkhala Formation of Precambrian age. Above it are the Hazara Formation (Precambrian(?)) and possibly lower Paleozoic, Tanawal Formation (Upper Ordovician(?) to Devonian (?)), Panjal and Kingriali Formations and "Agglomeratic Slate" (Carboniferous to Triassic), Datta Formation (Lower Jurassic), Samana Suk Limestone (Jurassic), Chichali Formation (Upper Jurassic), Lumshiwal Sandstone (Upper Jurassic to Lower Cretaceous), Kawagarh Limestone (Upper Cretaceous), Kala Chitta Group (Paleocene to Eocene), and the Murree Formation (Oligocene(?) to Miocene). The Mansehra Granite was intruded in Late Cretaceous to early Tertiary time, apparently in the form of one or more sheetlike bodies. Contact-metamorphic effects around the granite generally are not pronounced; however, wollastonite occurs at one locality. Regional metamorphism and accompanying penetrative deformation increase in intensity northward. The regional metamorphism was synchronous with or postdates the granite, because the granite itself is involved in the deformation. The structural pattern in the mapped area consists of two northward-projecting loops or reentrants the larger Hazara-Kashmir syntaxis and the smaller Indus reentrant connected by a broad arcuate belt, called the western arc. The Hazara- Kashmir syntaxis, which is the pivot point of the great regional arc of the northwest Himalaya, is oriented slightly west of north and contains younger rocks in its core or axial zone; successively older rocks wrap around the periphery. A system of boundary faults also wraps around the syntaxis and helps to define it. The southern part of the western limb of the syntaxis is divided into three structural blocks separated by major faults which show combined strike-slip and vertical displacement.

The structural development of the Hazara-Kashmir syntaxis is believed to be related to the great regional arc of the Himalaya 150 miles to the north. Southward tectonic transport moving perpendicular to this great arc would converge on the axial zone of the Hazara-Kashmir syntaxis, which is at the pivot point of the arc. The present syntaxial structure would be the natural result of such movement. Late-stage westward countermovement of the rocks in the axial zone resulted in the present westward overturning of the folds along the southern segment of the western limb of the syntaxis.

The Indus reentrant, as with the Hazara-Kashmir syntaxis, also is interpreted to be the result of smaller scale tectonic convergence towards its present axial zone. Between the Hazara-Kashmir syntaxis and the Indus reentrant, the rocks moved south to form the southward bulge of the western arc. In terms of large-scale tectonics the Himalayan mountain system has southward asymmetry, which has been interpreted in two ways: (1) radial spreading out southward of middle Asia and (2) continental drift of India against Asia. The latter view has gained credibility recently as a result of new data and ideas on global tectonics. The earliest known indications of the Himalayan

orogeny are found at Hindubagh, near Quetta, where ultramafic rocks were emplaced after Cretaceous but before Eocene time. The widespread episode of folding and mountain building began in Miocene time in the mapped area.

Key words: Mapping, Hazara, Himalaya.

C/17. Callegari, E. & Zanettin, B., 1960. Chimismo di rocce vulcaniche plutoniche del Karakorum centro meridionale. Memoir Institute of Geology and Mineralogy, University of Padova, Mem., vol. xxi, 38p.

The Karakoram Range contains large number of plutonic rocks, as well as volcanic rocks along its southern margin. This is a report of the geochemistry of the rocks collected during the Italian expeditions led by Ardito Desio.

Key words: Geochemistry, volcanic, plutonic rocks, Central Karakoram

C/18. Campbell, E., 1917. Notes on the rock specimens collected by the Bullock Workman Expedition 1911–12 in the Bilaphond and Kondus basins, and on the Khondokoto and Masherbrum Glaciers. Appendix. In: Two Summers in the Ice–Wilds of Eastern Karakorum. Workman, F. Bullol and Workman, W.H. (Eds.), Fisher Unwin, London.

Three specimens were collected in the Ghyari nala below the Bilaphond glacier: two of these are white crystalline limestone containing a little tremolite; the third is a serpentine (chrysotile). These were the only specimens actually collected. Dr. Longstaff had previously recorded granite as abundant in the moraines.

Some interesting material was collected at the head of the Dong-Dong glacier. One is a coarse white crystalline limestone like those collected in the Ghyari nala. Another is a fairly coarse-grained white biotite-granite, with garnets reaching 4 mm in diameter; it is very poor in ferromagnesian minerals, containing only a little biotite and a trace of muscovite. Quite the most interesting specimen from this locality is a fragment showing large plates of pale green actinolite: some of these show rough crystal outlines, the outer zone of the crystal being brown. They are associated with portions of finer grain consisting of diopside and tremolite, and some fragments of aplite are also adhering to the specimen. This rock is evidently a product of contact metamorphism due to a granitic intrusion.

Several specimens were collected on the central moraine of the north-east branch of the Kaberi glacier. Here occurred white, pink, and purple limestones similar in texture to those of the Siachen; while a light coloured moraine at the head of the glacier yielded abundant slabs of white marble similar to that collected on the Tarim Shehr.

With the limestones of the central moraine occur masses of tetrahedrite, with malachite and azurite, and a curious mass of black pisolitic concretions cemented and impregnated with pyrites and apparently passing into a kind of pisolitic ironstone.

The east wall of the Khondokoro glacier yielded a fine-grained hornblende-biotite-gneiss and also a typical felspar-amphibolite. From the moraines of the same glacier came a muscovite-biotite-granite containing small garnets and showing a tendency towards granulitic structure. This rock occurs as a fine-grained granite, but in some specimens the plates of muscovite may measure half an inch across. The garnets never seem to exceed 1 mm. in diameter. This type was also found by Sir Martin Conway in the Astor valley.

The Masherbrum glacier yielded four specimens: two are white fine-grained dolomite, one is serpentine, the other is an augen of quartz, apparently from a chlorite schist. An interesting rock was collected at the junction of the Khondokoro and Masherbrum nalas. It is a fine-grained granite-gneiss consisting of quartz, stained yellowish brown, oligoclase and some microcline, with fairly abundant patches of biotite. Sphene and epidote occur as accessories. The oligoclase frequently shows patches of inclusions of biotite and sphene, and also a secondary development of muscovite and epidote. There is some micrographic intergrowth with quartz at the borders of the felspar crystals, and in places a marked tendency towards granulitic structure.

Key words: Glaciers, Masherbrum, Karakoram.

C/19. Campbell, J.F., 1877. On Himalayan glaciations. Journal of the Asiatic Society of Bengal 46.

Key words: Glaciation, Himalaya.

C/20. Caporali, A., 1992. Recent gravity measurements in Karakoram. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 11.

Two new gravimetric profiles have been observed in Karakorum as part of the activities of the Ev K2 CNR Project led by prof. Ardito Desio. One profile, established in 1988, starts from Bazar Dara (China), north of the Aghil range, and covers the portion of the Shaksgam valley between the confluence of the Urdok-Gasherbrum glaciers to the SE and, along the Shaksgam River, Tek ri-Sughet Jangal to the NW. The second profile, done in 1990, starts from Skardu and ends in Gilgit via the Biafo Hispar glaciers. During both expeditions we established a number of astrogeodetic stations for the measurement of the deflection of the vertical, using the satellites of the Global Positioning System to determine reference geodetic coordinates. Two astronomic stations were done in 1988 and fourteen in 1990,

The geographic location and overall quality of the observations indicate that they provide an interesting addition to the collected by Marussi and coworkers from 1964 to 1979. In the course of our surveys a number of the Marussi points were checked to ensure consistency.

The paper contains a preliminary analysis of the Marussi plus our 1988-1990 data. To remove low frequency trends in the anomalous gravity field we make use of predictions based on the spherical harmonics expansion of the global earth gravity field produced by the Ohio State University (model OSU91A). This representation is complete to degree and order 360 and is particularly interesting as it includes for the first time Chinese gravimetry.

Key words: Geophysics, gravity, GPS, Karakoram.

C/21. Caporali, A., 1993. Recent gravity measurements in the Karakoram. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society of London, Special Publication 74, 9-20.

Two new gravimetric profiles have been obtained in the Karakoram as part of the activities of the Ev-K2-CNR Project. One profile, established in 1988, starts from Bazar Dara (China), north of the Aghil range, and covers the portion of the Shaksgam valley between the confluence of the Urdok-Gasherbrum glaciers to the SE and, along the Shaksgam river, Tek ri-Sughet Jangal to the NW. The second profile, carried out in 1990, starts from Skardu and ends in Gilgit via the Biafo Hispar glaciers. During both expeditions a number of astrogeodetic stations were established for the measurement of the deflection of the vertical, using the satellites of the Global Positioning System (GPS) to determine geodetic reference coordinates. Two astronomic stations were established in 1988 and fourteen in 1990. The new data, when added to those collected by Marussi and co-workers from 1954 to 1979, improve the coverage north of the Main Karakoram Thrust, where the Bouguer anomalies attain their largest negative values. For all available data Bouguer and Airy isostatic corrections have been computed using the ETOPO5 height grid. A mean crust density of 2.85 g cm^{-3} , a density contrast of 0.3 g cm^{-3} and a normal thickness $T = 30 \text{ km}$ have been assumed, so that the surface of isostatic compensation locally best fits the Moho. Two profiles have been selected, one continuing northward of the Nanga Parbat - Haramosh massif the deep seismic sounding profiles done in the 1970s. The other is such that it crosses the Indus Suture Zone, the Main Karakoram Thrust and the Karakoram Fault nearly at right angles. In both profiles, from Pakistan to China, the horizontal gradients of the Bouguer anomalies are in the interval -1.5 to -2 mgal km^{-1} , comparable to gradients found in the region between the Indo-Gangetic Plains and the Himalaya. A marked steepening of the Moho is implied here with increased detail. Isostatic anomalies underneath the Karakoram are found to be more negative than those computed in the earlier work of Marussi, who made different assumptions of density and density contrast. Clearly the new data do not uniquely constrain the local structure of the lithosphere but may be of help in better understanding non-negligible deviations from isostatic equilibrium.

Key words: Geophysics, gravity, GPS, Karakoram.

C/22. Caporali, A., 1995. Gravity anomalies and the flexure of the lithosphere in the Karakoram, Pakistan. *Journal of Geophysical Research* 100 B(8), 15075-15085.

The negative correlation between gravity anomalies in mountain regions and the topographic height implies a mass deficiency beneath the range and adjacent regions. Classical compensation schemes in which roots of constant

density form at a depth proportional to the topographic height (Airy scheme) or individual columns of laterally variable density develop to a constant depth (Pratt scheme) enable only part of the anomalies to be modeled and provide a “static” description of the structure of the crust and upper mantle, regardless of the vertical and horizontal motions associated with the origin and evolution of mountain belts. Early studies of isostatic anomalies across the Karakoram range, in northern Pakistan, have shown that the region is not in isostatic equilibrium in the Airy sense and have pointed to the need of a more refined model of the forces and stresses shaping the lithosphere than classical isostasy. The concept that the lithosphere should respond by flexure to applied loads as a thin, elastic, semi-infinite plate buoyant on a denser, inviscid fluid is used here as the basis to compute model Bouguer anomalies, estimate by least squares the deformation of the plate, and constrain some of the plate's elastic parameters. It is assumed that the forces responsible for the deformation are the topographic load, the hydrostatic response, and the elastic stresses within the plate. The plate itself is assumed to be separated into an Indian and an Asian portion, each with its own equivalent elastic thickness. At the border between the two portions an empirical infracrustal point load is assumed to act vertically. Gravity anomalies are then computed along five profiles crossing the range, as a function of the abscissa of the border point, the load acting at this point, the elastic thicknesses of the Indian and Asian portions of the plate, and the density contrast across the median section of the plate. The corresponding numerical values and associated formal uncertainties are determined by a least squares fit of the model anomalies to the observed Bouguer anomalies, along each of the five independent profiles. The postfit residuals are found to have essentially zero mean and an rms (root mean square) dispersion of the order of 20 mGal, which is consistent with the expected overall accuracy of the “observed” Bouguer anomalies interpolated to the profiles. The distribution of the post fit residuals still shows systematic components at the level of a few tens of mGal, that are likely to be caused by local, shallow geological structures. Overall the peak-to-peak excursion of the residual anomalies is considerably smaller than the classical isostatic anomalies for the same region. It is found that (1) the line connecting the estimated abscissas of the border points on each profile follows closely suture lines which have been independently identified from geological data and could be associated with the center of mass of the Kohistan-Ladakh island arc considered as a buried load; (2) for all profiles the elastic thickness of the Indian plate is systematically less than for the Asian plate, typically 80–100 km for India and 100–120 km for Asia; (3) there is a tendency of the elastic thickness of both portions to increase moving NW, towards the Pamirs. The gravity data are thus consistent with a relatively rigid Asian plate in the Tarim basin, unlike the Central Himalaya where Tibet, being indented by India, has zero strength.

Key words: Topography, gravity, lithosphere, Karakoram.

C/23. Caporali, A., 2000. The gravity field of the Karakoram Mountain Range and surrounding areas. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society of London, Special Publication 170, 7-23.

A ‘blank on the map’ only 60 year ago, the Karakoram Range has been explored and surveyed with greater difficulty than the Himalaya and Tibet due to its rugged terrain and extensive glaciation. In the past ten years we have succeeded in doubling the number of gravity stations. A substantial improvement in coverage and overall quality was obtained by concentrating on previously unsurveyed areas and by validating older data with more accurate measurements. Our data were merged with earlier data, converted to full Bouguer anomalies and gridded. The resulting Bouguer anomaly map defines very precisely the gravimetric low associated with the Nanga Parbat-Haramosh Syntaxis, and the huge negative values are now visible also in the Ghujerab-Khunjerab areas. Correlation of the topography and Bouguer anomaly shows that a plate of flexural rigidity with $D=2 \times 10^{21}$ Nm fits the coherence data in the Karakoram at all but two distinct frequency ranges centered at wavelengths of 80 and 300 km. In a rheologically layered lithosphere developing a buckling instability under horizontal compression, the observed spectral features of the topography and Bouguer gravity anomalies constrain the depth of the competent layers to be in the range 13-20 km and 50-75 km respectively.

Key words: Geophysics, gravity, Karakoram,

C/24. Caporali, A., Marzari, F. & Palmieri, F., 1991. Geodetic and geophysical report. In: *Geodesy, Geophysics and Geology of the Upper Shaksagam Valley, North East Karakoram and South Sinkiang*. Scientific Report of the Italian Expedition to Karakoram 1988 (A. Desio leader). Consiglio Nazionale delle Ricerche-Milano, 11-92.

Key words: Geophysics, geodesy, Karakoram.

C/25. Caputo, M., 1958a. La profondita del Ghiacciaio Baltoro ad Urdukas determinata con metodo gravimetrico, e per mezzo della sua velocita superficiale metodo di 50 migli, Geofisica e Meteorologia, Geneva, 6(3-4). Lst. Topografia Geodesia Univ. Trieste; publication series A-39.

This account describes the details of the work conducted by the authors around Baltoro glacier. The depth of the Baltoro Glacier to Urdukas was determined by gravimetric method, and by means of its surface speed of 50 nautical miles, using geodetic and geophysical methods.

Key words: Glaciers, gravimetry, Baltoro.

C/26. Caputo, M., 1958b. Ein graphisches verfahren fur die berechnung der vertikalen komponente der anziehungskraft zylindrischer korper unter dessen anwendung fur die bestimmung der gestalt von gletscherbetten. Zeitschrift fur Geophysik 24.

Key words: Glaciers, geophysics.

C/27. Caputo, M., 1964. Glaciology. In: Geophysics of the Karakoram, Italian Expeditions to the Karakoram (K2) and Hindu Kush (Prof. A. Desio leader), II-Geophysics, 1, 147-162. Brill, Leiden.

Key words: Glaciology, geophysics.

C/28. Carpena, J., 1988. Traces de fission au sommet du K2 (8611 metres). Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.14.

Consult the following account for additional information.

Key words: Dating, fission track, Karakoram.

C/29. Carpena, J. & Rutkiewicz, W., 1989. Ages traces de fission des apatites et des zircons du sommet du K2 (8611 m), Pakistan. Eclogae Geologicae Helveticae 82, 735-742.

A paragneiss from the top of K2 (8611 m) in Karakoram chain (Pakistan) yields apatites and zircons. Fission Track dating of zircons indicates an age of 63.6 ± 6.0 Myrs (Paleocene). Apatites, a more sensitive Fission Track chronometer, give an age of 8.8 ± 1.0 Myrs (Upper Miocene). These ages let us constrain the thermal history of the K2 massif.

Key words: Dating, fission track, Karakoram.

C/30. Carrel, R.P., 1974. Les pierres precieuses du Pakistan. Bulletin Association France Gemmologie 41, p7.

This account gives details of the gemstones of Pakistan till the date of publication.

Key words: Gems, Pakistan.

C/31. Carter, S., 1983. Petrology and structure of the Swat granite gneisses near Manglaur, southern Swat, Pakistan. M.S. Thesis. Geology Department, Oregon State University, Corvallis, U.S.A.

The granite gneiss at Manglaur to the north of Mingora is one of a series of granitic intrusions in Swat. This biotite granite is quite fresh and contains large crystals of alkali feldspar. Much of the rocks is sheared and strongly gneissose with porphyroclasts of the feldspar in medium-grained matrix, but some parts are not so deformed.

Key words: Petrology, structure, granite, gneiss, Swat.

C/32. Casati, P., Spadia, P., et al., 1980. Studi geologici idrologici e floristico vegetazionali nel buchino del Ghiacciaio Biafo e nella valle del F. Brauldu (Karakorum occidental, Pakistan). *Natura* 71, 121-164, Milano.

This is a multi-disciplinary study of the Biafo Glacier and Brauldu valley in the eastern Karakorum. It relates geology and hydrology of the area with flora and vegetation.

Key words: Geology, hydrology, vegetation, Biafo Glacier, Brauldu valley, Karakorum.

C/33. Casnedi, R., 1976a. Geological reconnaissance in the Yasin valley, NW Pakistan. *Rend. Accademy Nazionale Lincei, Series 8*, 59, 792-799.

Key words: Reconnaissance geology, Yasin valley.

C/34. Casnedi, R., 1976b. Geological notes on the junction between the Haramosh–Nanga Parbat structure and the Karakoram Range. *Rendiconti Accad. Accademy Nazionale Lincei* 16, 631–633.

Key words: Structure, tectonics, Nanga Parbat, Haramosh, Karakoram.

C/35. Casnedi, R., 1976c. The ophiolites of the Indus suture line Dras and Astor zones-Kashmir. *Ophioliti* 1, 365-371.

The ophiolites of the Dras zone outcropping along the Suture between Indian and Eurasian continents are mostly made-up of lherzolite, gabbro and basalt. These are associated with Jurassic-Cretaceous sedimentary rocks (jaspers-radiolarite-shales-breccias), with the northern fault covering (Deosai plateau) and southern tectonic overthrust of the Tethyan calcareous dolomitic Triassic series. Amphibolitic prasinitic formations influenced by the Nanga Parbat Massif metamorphism and basic igneous masses developed near Astore on the western slope Deosai. They could represent the northern continuation of this Suture line. The ophiolitiferous series and the metabasites are briefly described, and hypotheses as to their origin are presented.

Key words: Ophiolites, Indus Suture, Astor, Kashmir.

C/36. Casnedi, R., 1979. Stratigraphic outline of the area between Karakorum and Hindu Kush with probable occurrence of Hercynian geosynclinal stage. *Memoir Society Geologia Italia*. 20, 277–287

Key words: Stratigraphy, structure, Hindukush, Karakoram.

C/37. Casnedi, R., 1981. Geological reconnaissance in the Ishkuman and Karambar valleys, northern Pakistan. *Geological Bulletin, Punjab University* 16, 66-70.

The formations crossed on a route travelled in the Ishkuman and Karambar valleys, along the profile of the Karakorum Geophysical project, are described. The section includes a plutonic core of granodioritic compositions surrounded by metamorphic rocks. In this body two batholiths can be identified, the northern one of which seems to constitute the axial batholith of the Karakorum. To the S of this structure there is development of metasedimentary and igneous rocks divided into two complexes; the greenstone complex with slates, phyllites, marbles, intrusives and middle-basic volcanics, and the clastic metasedimentary succession of turbiditic origin. To the N a thick sedimentary

sequence was observed, consisting of sandstones, limestones, dolomites, argillites, marls and conglomerates comprising terms from the Permian to the Cretaceous, never reported before.

Key words: Reconnaissance geology, granites, volcanics, low-grade metasediments, Ishkuman, Karambar.

C/38. Casnedi, R., 1983. Tentative interpretation of the geological structure of the Western Karakorum on the basis of surface and subsurface data at plate scale. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 365-373.

Key words: Structure, tectonics, Karakoram.

C/39. Casnedi, R., 1984. Geological Reconnaissance in the Ishkuman and Karambar valleys (Northern Pakistan). *Atti Soc. Ital. Sci. Nat.*, 125, 132-138.

For further details consult Casnedi 1981.

Key words: Reconnaissance, granites, volcanics, low-grade metasediments, Ishkuman, Karambar.

C/40. Casnedi, R., Desio, A., Forcella, F., Nicoletti, M. & Petrucciani, C., 1978. Absolute age of some granitoid rocks between Hindu Raj and Gilgit River (Western Karakorum). *Accademia Nazionale dei Lincei, Series 8*, 64, 204-210.

Key words: Granitoid, radiometric ages, Karakoram.

C/41. Casnedi, R. & Ebblin, C., 1977. Geological notes on the area between Astor and Skardu, Kashmir. *Rendiconti Accademia Nazionale Lincei, Series 8*, 61, 662-668.

Key words: Geology, Astor, Skardu.

C/42. Casnedi, R. & Mosna, S., 1979a. Upper Paleozoic and Mesozoic rocks in the Upper Karambar Valley (Pakistan-Afghanistan border). *Revista Italiana Paleontologia e Stratigrafia* 85, 1-12.

Key words: Paleontology, Karambar valley, western Karakoram.

C/43. Casnedi, R. & Mosna, S., 1979b. Upper Palaeozoic and Mesozoic sedimentary rocks in the Karambar valley (Pakistan Afghan border). *Revista Italiana di Palaeontologia Stratigraphia* 85, 285-295.

Key words: Sedimentary, Paleozoic, Mesozoic, Karambar.

C/44. Casnedi, R. & Nicora, A., 1985. Short notes on the Shimshal valley geology (Western Karakorum–Pakistan). *Rivista Italiana di Palaeontologia i Stratigrafia* 90, 463–480.

Key words: Geology, Shimshal, Karakoram.

C/45. Cervený, P.F., Johnson, N.M., Tahirkheli, R.A.K. & Bons, N.R., 1989. Tectonic and geomorphic implications of Siwalik Group heavy minerals, Potwar Plateau, Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), *Tectonics of the Western Himalayas*. Geological Society of America Special Papers 232, 129-136.

Heavy mineral and paleocurrent direction data suggest that the ancestral Indus is an analog of the modern Indus River (Pakistan). During the past 18 m.y., the Indus has maintained a relatively stationary outlet position along the Himalayan Front. Sandstones from three sections of Siwalik strata have been sampled and their heavy mineral suites analyzed. These stratigraphic sections cover some 200 km in an east-west direction in the Potwar Plateau area. In the western and central Potwar Plateau sections, blue-green hornblende makes a conspicuous first appearance at 11 Ma, the boundary between the Chinji and Nagri Formations. Above this boundary, blue-green hornblende dominates the heavy mineral assemblage of Siwalik sand. In the Upper Siwalik beds the heavy mineral suite contains as much as 75 percent blue-green hornblende. Unroofing of the Kohistan Arc terrane is the most likely explanation for this detrital hornblende. In marked contrast, the eastern Potwar region does not show the same abundance of blue-green hornblende. Significantly, the modern river~ of the eastern Potwar do not carry abundant blue-green hornblende either; only the Indus River does. Paleocurrent measurements taken in the Chinji Village section near the center of the Potwar Plateau indicate a northwest-to-southeast flow direction, whereas those in the Trans-Indus 120 km west of Chinji Village indicate a northeast-to-southwest flow direction. These data indicate that the Siwalik sequence of northern Pakistan is configured as a large-scale alluvial fan with the ancestral Indus shifting course back and forth across the Potwar Plateau region with a frequency of 10^4 to 10^5 yr/cycle. River sinuosity varied systematically from side to side of this fan, with minimum sinuosity attained along a north-south axis. As indicated by the absence of blue-green hornblende, the ancestral Indus did not reach the eastern Potwar Plateau (Kotal Kund area, 100 km east of Chinji) during the past 11 m.y.

Key words: Tectonics, geomorphology, heavy minerals, Potwar Plateau, Siwaliks.

C/46. Cervený, P.F., Naeser, C.W., Keleman, P.B., Lieberman, J.E. & Zeitler, P.K., 1989. Zircon fission-track ages from the Gasherbrum diorite, Karakoram Range, Northern Pakistan. *Geology* 17(11), 1044-1048.

The Gasherbrum Peaks, in the Himalaya of Pakistan, reach elevations of >8000 m. The relief between the peaks and the adjacent valley (Baltoro Glacier) is in excess of 3000 m. Eight samples of the Early Cretaceous Gasherbrum Diorite at elevations between 4880 and 7165 m on Gasherbrum IV were collected for fission-track dating. Zircon fission-track ages from the Gasherbrum Diorite vary from Early Cretaceous to middle Tertiary in age. There is no consistent pattern between age and elevation. The Cretaceous ages indicate that these rocks were never deeply buried, i.e., heated to temperatures in excess of 175°C, to reset the zircons during Cenozoic time. These results also indicate that the uplift of this part of the Himalaya has been either very rapid and recent, or very slow since Early Cretaceous time. This latter possibility is not consistent with the high relief at Gasherbrum and what is known about regional tectonics. Gasherbrum IV zircons, currently at ~4880 m, have never been at depths greater than 6 km, and less than 3 km of material has been removed from the top of the range by erosion since the Early Cretaceous. Rapid uplift has occurred very recently, and erosion rates have not been able to keep pace with this uplift.

Key words: Fission-track ages, diorite, Gasherbrum, Karakoram.

C/47. Cervený, P.F., Naeser, N.D., Zeitler, P.K., Naeser, C.W. & Johnson, N.M., 1988. History and relief of the Himalaya during the past 18 million years: Evidence from fission-track ages of detrital zircons from sandstones of Siwalik Group. In: Kleinspehn, K.L. & Paola, C. (Eds.), *New Perspectives in Basin Analysis*. Springer-Verlag, Berlin, 43-61.

Fission-track dating of individual detrital zircon grains can be used to characterize both ancient and modern sedimentary provenance. Ages of zircons in the modern Indus River drainage system of northern Pakistan are controlled dominantly by uplift rates of the source rocks in the Himalaya. Young detrital zircons come from rapidly rising terrain, whereas old zircon ages imply slow or negligible uplift. Modern Indus River sands contain a distinctive population of young, 1 to 5 Ma, zircons that are derived from the Nanga Parbat-Haramosh Massif, an area of rapid uplift ($5 \text{ m}/10^3 \text{ yr}$). Sandstones of the Siwalik Group deposited by the ancestral Indus River over the past 18 million years contain zircons that are only 1 to 5 million years older than the depositional age of the sandstones. Therefore, young zircons have been a consistent component of Himalayan surface rocks for the past 18 million years. These ages imply that a series of uplifted blocks or "massifs," analogous to the contemporary Nanga Parbat area, have been continually present in the Himalaya since 18 Ma, and that over that time the elevation and relief of the Himalaya, on a broad scale, have been essentially constant.

Key words: Fission track ages, sandstone, siwaliks, Himalaya.

C/48. Cervený, P.F., Tahirkheli, R.A.K., Johnson, N.M. & Bonis, N.R., 1986. Position and source area of the ancestral Indus River during the past 18 million years. Abstracts with Programs, Geological Society of America 18.

Key words: Indus River.

C/49. Chakravarti, D.K., 1935. On the generic reference of a doubtful Rynchorostrine bunomastodontid from Chinji in the Salt Range. Abstracts, Proceedings 22nd Indian Science Congress, 209-210.

Key words: Paleontology, siwaliks, Salt Range.

C/50. Chamberlain, C.P., Jan, M.Q. & Zeitler, P.K., 1989. A petrologic record of the collision between the Kohistan Island Arc and Indian Plate, northwest Himalaya. In: Malinconico, L.L. & Lillie, R.J. (Eds.), Tectonics of the Western Himalaya. Geological Society of America Special Paper 232, 23-32.

Pressure-temperature (P-T) paths observed in pelitic schists on either side of the Main Mantle Thrust in northern Pakistan record the dynamics of the collision between the Kohistan Island-Arc and Indian plate. Geothermometry studies, mineral reaction textures, and thermodynamic modeling of zoned garnets suggest that the rocks in the Kohistan Arc and the Nanga Parbat-Haramosh Massif experienced different pressure-temperature histories as a result of imbrication of these two terranes during thrusting. Rocks in the Kohistan Arc followed decreasing pressure-temperature paths, with early garnet growth occurring at high pressures (9.5 kbar) and later garnet growth at lower pressures (8.5 kbar). Conversely, rocks in the Nanga Parbat-Haramosh Massif record an increasing P-T path history. The early P-T history within the massif was at low pressures (4.0 kbar) and low temperatures (450°C). Later, both pressure and temperature increased to a maximum of 7.5 kbar and 580°C. The contrasting P-T paths observed within these two terranes provide evidence for overthrusting of the Kohistan Arc over the Nanga Parbat-Haramosh Massif along the Main Mantle Thrust.

Key words: Petrology, collision, Kohistan Island Arc, Indian Plate, Himalaya.

C/51. Chamberlain, C.P., Kraw, D., Koons, P.O., Winslow, D. & Zeitler, P.K., 1993. Coupled compression and extension in the NW Himalaya. Proceedings, Conference on Late Orogenic Extension in Mountain Belts (Montpellier, France), BGRM Document no. 219, p.42.

Further information is not available to the authors.

Key words: Tectonics, structure, Himalaya.

C/52. Chamberlain, C.P. & Zeitler, P.K., 1996. Assembly of the crystalline terranes of the northwestern Himalaya and Karakoram, northwestern Pakistan. In: Yin, A. & Harrison M. (Eds.), The Tectonic Evolution of Asia. Cambridge University Press, 138-148.

In northern Pakistan, the collision of three terranes proceeded sequentially, with an initial collision of the Asian plate with Kohistan at 70-100 Ma (Coward et al., 1986; Treloar et al., 1989a), followed by a later collision of Kohistan with the Indian plate at about 50 Ma (Klootwijk et al., 1991). The P-T-t data show that the assembly of these crystalline terranes was a complicated process. The collision of the Asian plate and Kohistan began with initial tectonic thickening and high-pressure, high-temperature metamorphism, followed by post-metamorphic southward-directed thrusting as rocks of the Asian plate were thrust over Kohistan. The timing of these events is poorly constrained, but they must have occurred before 37 Ma (Searle, 1991) and, most likely, during the early stages of collision in the middle to late Cretaceous.

The timing of events related to the collision between the Asian Plate/Kohistan terranes and the Indian plate is much better constrained. We know from U-Pb ages of syn-metamorphic granites (Zeitler and Chamberlain, 1991; Smith, 1993;) and Nd-Sm ages of eclogites (Tonarini et al., 1993) that at about 50 Ma the northern margin of the Indian plate underwent initial tectonic thickening and relatively high pressure metamorphism. Following metamorphism, in the interval from 45 Ma to 25 Ma the northern margin of the Indian plate underwent a period of rapid exhumation and uplift. We (Chamberlain et al., 1991) and others (Treloar, Rex, and Williams, 1991) have tentatively suggested that the rapid cooling was a result of extension of Kohistan slid northward along normal faults.

By 20 Ma, movement along the Main Mantle Thrust had ceased, and the Indian plate and Kohistan were locked into place, with much northern Pakistan subsequently undergoing simple post-orogenic uplift and erosion. However, we have discovered that some areas of northern Pakistan are presently undergoing extraordinarily rapid exhumation: the Nanga Parbat-Haramosh massif has experienced long-term denudation rates on the order of 1-km/m.y. over the past 10 m.y., and rates as high as 5-km/m.y. over the past 3m.y. During the recent exhumation, Indian-plate gneisses have undergone granulite-grade metamorphism, intrusion by abundant leucogranites, and intense hydrothermal activity. The cause of this most recent phase of active Himalayan tectonism is unknown.

Key words: Tectonics, continental collision, Himalaya, Karakoram.

C/53. Chamberlain, C.P., Zeitler, P.K., Barnett, D.E., Winslow, D., Poulson, S.R., Leahy, T. & Hammer, J.E., 1995. Active hydrothermal systems during the Recent uplift of Nanga Parbat, Pakistan Himalaya. *Journal of Geophysical Research* 100, 439-453.

During the last 10 m.y., the Nanga Parbat Haramosh Massif in the northwestern Himalaya has been intruded by granitic magmas, has undergone high-grade metamorphism and anatexis, and has been rapidly uplifted and denuded. As part of an ongoing project to understand the relationship between tectonism and petrologic processes, we have undertaken an isotopic study of the massif to determine the importance of hydrothermal activity during this recent metamorphism. Our studies show that both meteoric and magmatic hydrothermal systems have been active over the last 10 m.y. We suggest that the rapid uplift of the massif created a dual hydrothermal system, consisting of a near-surface flow system dominated by meteoric water and a flow regime at deeper levels dominated by magmatic/metamorphic volatiles. Meteoric fluids derived from glaciers near the summit of Nanga Parbat were driven deep into the massif along the transpressional faults causing $\delta^{18}\text{O}$ and δD depletions in the gneisses and marked oxygen isotopic disequilibrium between mineral pairs from the fault zones. The discharge of these meteoric fluids occurs in active hot springs that are found along the steep faults that border the massif. At deeper levels within the massif, infiltration of low $\delta^{18}\text{O}$ magmatic fluids caused $\delta^{18}\text{O}$ depletions in the gneisses within the migmatite zone. These low $\delta^{18}\text{O}$ fluids were derived from the young (<4 Ma), relatively low $\delta^{18}\text{O}$ granites (~8‰) that are found within the core of the massif. Geochronological evidence in the form of fission track and $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages and U/Pb ages on accessory minerals from the granites and gneisses provide a constraint on the timing of fluid flow in the surface outcrops we examined. Fluid infiltration in the migmatite zone rocks located along the Tato traverse was coeval with metamorphism, granite emplacement, and rapid denudation, in the interval 0.8–3.3 Ma. Finally, we infer from the presence of active hot springs that significant flow systems continue to be active at depth within the central portion of the Nanga Parbat-Haramosh Massif.

Key words: NPHM, metamorphism, hydrothermal system, Himalaya.

C/54. Chamberlain, C.P., Zeitler, P.K. & Erickson, E., 1991. Constraints on the tectonic evolution of the northwestern Himalaya from geochronologic and petrologic studies of Babusar Pass, Pakistan. *Journal of Geology* 99, 829-849.

Key words: Tectonic evolution, geochronology, petrology, Babusar, Himalaya.

C/55. Chamberlain, C.P., Zeitler, P.K. & Jan, M.Q., 1986. Pressure-temperature-time paths in the Nanga Parbat massif: Constraints on the tectonic development of northwest Himalayas. *Abstracts with Programs, Geological Society of America* 18, p.561.

Consult the following account for further details.

Key words: Kohistan island arc, Nanga Parbat-Haramosh Massif, P-T-t paths.

C/56. Chamberlain, C.P., Zeitler, P.K. & Jan, M.Q., 1989. The dynamics of a crustal suture in the Pakistan Himalaya. *Journal of Metamorphic Geology* 7, 135-149.

The pressure-temperature and temperature-time paths derived for rocks in the Kohistan arc and adjacent Nanga Parbat-Haramosh massif record the dynamics of the collision between the island arc and the Indian plate. Studies of P-T-t paths show that the Kohistan arc was thrust over the Nanga Parbat-Haramosh massif at least 25 Ma ago, but not more than 30–35 Ma ago. Rocks in the Kohistan arc followed decreasing pressure paths, with the early metamorphism beginning at high pressures (9.5 kbar) and later metamorphism occurring at 8.0 kbar. In contrast, rocks in the Nanga Parbat-Haramosh massif (Indian plate) experienced increasing pressure and temperature paths. Prior to thrusting, the massif was at low pressures (4.0 kbar) and low temperatures (450°C). Later, the pressure and temperature increased to 8 kbar and 580°C. The authors interpret the convergence (to approximately the same pressure and temperature) of the P-T paths in the two terranes as being the result of thrusting and thermal equilibration between the thrust sheets. $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages of hornblendes and other geochronological data suggest that the time of peak metamorphism and hence the completion of thickening was approximately 30–35 Ma ago. Temperature-time paths show that after thrusting, during the period 25–10 Ma, the Kohistan arc and Nanga Parbat-Haramosh massif were uplifted at similar rates (0.5 km Ma). However, in the past 10 Ma the Nanga Parbat-Haramosh massif has been uplifted more rapidly than the adjacent Kohistan arc. Rapid uplift has been accommodated by late faults along the edge of the massif.

Keywords: P-T-t paths, Kohistan island arc, Nanga Parbat-Haramosh massif.

C/57. Chamberlain, C.P., Zeitler, P.K. & Winslow, D., 1992. Metamorphic hydrothermal systems associated with the rapid denudation of the Pakistan Himalaya. *Abstracts with Programs, Geological Society of America* 24, A112.

Keywords: Metamorphic, hydrothermal, denudation, Himalaya.

C/58. Chambers, A., 1991. The effect of stratigraphic variation on structural style: examples from the western limb of the Hazara-Kashmir Syntaxis, N. Pakistan. *Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop*, Auris, France, 27-28.

An attempt is made to integrate stratigraphic and structural data in order to generate an evolutionary model of the Lesser Himalaya and Sub Himalaya of N. Pakistan. Field outcrops in the Potwar Plateau and Murree Hills and well data and seismic profiles from the Potwar Plateau constrain the stratigraphy. The regional stratigraphic variations are telescoped by Himalayan shortening, which exceeds 200-km in the external zones of Pakistani Himalaya. The true regional stratigraphic is evident only after the restoration of Himalayan structures.

Three stratigraphic cover series separated by major unconformities of base Permian and base Paleocene age is represented in the Potwar region. The crystalline basement is overlain by a series of Eocambrian-Cambrian age that comprises the basal Salt Range Formation and the Jhelum Group clastics and carbonates. The Permian-Cretaceous series represent an essentially shallow marine shelf environment, although the cycles of sandstone, carbonate and occasional laterite indicate transgressive pulses throughout this period. Flexure and erosion is associated with the widespread basal Paleocene unconformity. Erosion increases towards the southeast such that the Paleocene overlies the Cambrian in the eastern Salt Range whilst in the north the unconformity is negligible. Shelf conditions were reestablished in the lower Tertiary before molasse deposition commenced in Miocene times. The thick, but poorly-consolidated, alternating sands and shales of the Rawalpindi and Siwalik Groups form the youngest stratigraphic series.

These stratigraphic series have distinct rheological properties. The weak evaporitic Salt Range Formation forms a major basement-cover decollement throughout the Potwar Plateau. The Permian-lower Tertiary carbonate carapace acts as a rheologically competent unit that deforms brittly. Where it is thick the carapace forms large thrust sheets. However, the action of the Paleocene unconformity reduces the carbonate carapace to approximately 100m thickness, effectively juxtaposing the Eocambrian salt and the Tertiary molasse. The molasse behaves incompetently and collapses to form a series of pop-ups, boxfolds and breaching thrusts above the salt decollement. The western

and eastern Potwar therefore show different structural styles, the former being controlled by the carbonate carapace and the latter by the molasse.

During the south-southeastward propagation of the Pakistani thrust wedge two to major detachments have been exploited, the Hazara Detachment (or MBT) and the Salt Range Detachment (or MFT). The strongly deformed strata of the Murree Hills lie in the hangingwall of the Hazara Detachment. This thrust has been carried more than 80-km across the molasse basin, a process assisted by the presence of talcs and evaporites in the Hazara Slate Formation. Further displacement occurred by duplexing in the footwall of the Hazara Detachment, the floorthrust following the basement-cover contact until the Salt Range Formation was encountered. This decollement is still active today.

The timing of deformation can be dated using palaeomagnetic reversal methods in the molasse sediments of the Potwar Plateau. Dating of events in the Murree Hills is more loosely constrained by metamorphic cooling ages in the internal zones and thrust interference with the southwest-directed Kashmir thrust wedge.

Keywords: Stratigraphy, structure, Hazara Kashmir syntaxis, Himalaya.

C/59. Chambers, A. & Izatt, C., 1992. The evolution of the external Himalayas, N Pakistan: The Galiat and Eastern Potwar, Punjab. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 13.

During the last 10 Ma, the Miocene-Recent molasse series of the external Pakistan Himalayas and its sedimentary substratum has been shortened by over 200-km. This progressive shortening, which was concurrent with the rapid subsidence in the Potwar Basin, can be divided into four phases:

The imbrication of the hangingwall to the Hazara Detachment (or MBT).

Ramping of the MBT from the basement-cover contact (Hazara Formation) to an intramolasse (Murree Formation) and translation of the MBT thrust wedge across the molasse basin by over 80-km.

Collapse of the MBT footwall ramp to produce a duplex at depth. Initially displacement was transferred from the floorthrust within the Hazara Formation to the foreland-wedge MBT. As the duplex propagated southward the roofthrust became hinterland-vergent due to the loss of the competent MBT overburden. This is expressed by backfolding in the Hill Ranges and Northern Potwar, the duplex tip being marked by a frontal monocline.

Deformation of the Southern Potwar in the hangingwall of a salt detachment, the Potwar-Salt Range Detachment (SRT). An abrupt change in structural style is observed as the Himalayan sole thrust encounters the Hazara Formation-Salt Range Formation facies change from intertidal clastics to evaporites.

In this presentation the role of inherited pre-Himalayan stratigraphic variations upon the structural style of Himalayan deformation is emphasised-with particular reference to the evolution of the Potwar Plateau during the Pliocene. A combination of field and seismic data is used to demonstrate the relative control exerted by the three major lithostratigraphic series (Eocambrian evaporites series, the Cambrian-Eocene pre-orogenic "shell" series and the syn-orogenic molasse series) upon structural style in the Potwar Plateau.

It is concluded that, in addition to halotectonics and basement topography, the presence or absence of the Cambrian-Eocene carbonate carapace is paramount in controlling structural style in the Potwar Plateau.

Keywords: Sedimentary, Hazara, Potwar, Himalaya.

C/60. Chandra, U., 1976. Fault plane solution and tectonic implications of the Pattan Pakistan earth quake of December 28, 1974. *Tectonophysics* 28, T1-T24.

A large destructive earthquake occurred on December 28, 1974 on the western bank of the Indus River near the village of Pattan. The earthquake reportedly killed 5,300 persons, injured 17,000 and left 60,000 people homeless. A seismicity map of the region is presented for the period January, 1963, to March, 1974 on a Mercator projection. Two main linear trends are recognized on the epicenter map. The northwest trend, beginning at 32.3°N, 76.6°E terminates at the southwest alignment of epicenters beginning at 36.0°N, 73.5°E and ending at 33.0°N, 71.0°E. The Pattan earthquake occurred near the junction of the two linear trends. A fault-plane solution for this earthquake has been determined from an analysis of teleseismic P-wave first-motion and S-wave polarization data. The strike and dip of the two nodal planes are N65°E, 68°SE and N50°E, 23°NW, respectively. The solution is compatible with and indicates underthrusting of the Indian plate in this region in the NNW direction along a thrust zone striking northeast.

Keywords: Earthquakes, hazards, tectonics, Pattan, Himalaya.

C/61. Chandra, U., 1978. Seismicity, earthquake mechanisms and tectonics along the Himalayan mountain range and vicinity. *Physics of the Earth and Planetary Interiors* 16, 109-131.

The historical as well as recent seismicity data and the focal mechanism solutions for 48 earthquakes determined from the observations of world-wide standardized stations network (WWSSN) records, were used to investigate the tectonics of the Himalayan mountain system and vicinity. Seismicity maps of the region showing large earthquakes (magnitude 7.0 and above, and damaging earthquakes that caused fatalities) from the earliest time through 1976, and instrumentally located earthquakes for the period January 1963–March 1974 are presented. Eleven of these earthquakes are estimated to be of magnitude 8.0 and above. The earthquake epicenters generally follow the trend of the mountains with greatest concentrations of seismic activity occurring along the Hindu Kush and Pamir mountain ranges, and near the Quetta, Kashmir and Assam syntaxes. Throughout Tibet, however, the distribution of epicenters is rather irregular and no clear trends are apparent. Two aseismic lineaments, one west of the Sulaiman Range and the other in the Assam Valley, are identified. Also, seismic activity in the vicinity of the Counter Thrust (Indus-Tsangpo suture zone) is rather small. Based on the identification of these aseismic lineaments and from a consideration of the geometry and kinematics of the continental collision model, a hypothesis for the origin of the Himalayan syntaxes is presented.

Focal mechanism solutions confirm northward underthrusting of the Indian Plate along the Main Boundary Thrust and Main Central Thrust system, and eastward underthrusting along the Burmese Arc. Fault-plane solutions indicate left-lateral motion along the Kirthar-Sulaiman Range, right-lateral motion along the Karakoram Fault, left-lateral motion along the eastern extremity of the Himalayan flank of the Assam syntaxis, and right-lateral motion along the northern part of the Naga Hill flank of the syntaxis. These observations are in agreement with the expected sense of lateral (parallel to the collision boundary) mass movement for the continental collision model. Focal mechanism solutions for three earthquakes in east Afghanistan show NW-SE compression. A near-vertical orientation of the axes of tension in the solutions for two earthquakes in the Hindu Kush region is consistent with the sinking of a remnant slab of oceanic lithosphere. Normal fault-plane solutions showing NW-SE extension for two events near Gatok, Tibet, and for the recent Kinnaur earthquake are interpreted to indicate a possible subsurface northern continuation of the Aravalli Range of Peninsular India, and its involvement in the tectonic framework of the region. Focal mechanism solutions of three earthquakes near the southern edge of the Shillong Plateau suggest block uplift of the plateau as a horst along the Dauki Fault. The solution for one earthquake near the Yunnan Graben shows NE-SW extension.

Keywords: Seismology, earthquakes, tectonics, Himalaya.

C/62. Charles, C., 1981. Hommes et glaciers de la vallee de la Hunza (Karakorum-Pakistan). *Revue de Geographie Alpine* 69, 607-615.

Hunza valley *sensu lato* is the abode of a large number of glaciers, including some of the longest ones outside the polar region. Baltoro, Hispar, Minapin, Passu, are only some. This paper describes many of the glaciers of Hunza Karakoram.

Keywords: Glaciers, Hunza, Karakoram.

C/63. Charles, C., 1985. La vallee de Hunza, Karakorum-Pakistan: Milieu naturelle, a menagement traditionnel et mutations recentes de une vallee aride du Nord-Ouest de l'ensemble Himalayen. Ph.D. Thesis, Universite de Grenoble.

Keywords: Geography, glaciers, Hunza, Karakoram.

C/64. Chatelian, J.L., Roecker, S.W., Hatzfeld, D. & Molnar, P., 1980. Microearthquake seismicity and fault plain solutions in the Hindu Kush region and their tectonic implications. *Journal of Geophysical Research* 85, 1365-1387.

The nature of the Hindu Kush intermediate seismic zone was studied in two microearthquake investigations in 1976 and 1977. By testing several sources of uncertainty the precision of about 600 earthquake locations was estimated to be about 5 km in epicenter and 10 km in depth. Projections of the earthquake locations from several perspectives reveal several regions of aseismicity as well as a highly contorted nature of the active regions. Very little seismicity was recorded in the crust from 0- to 70-km depth. The part of the zone southwest of about 37°N, 71.5°E and shallower than about 160 km is broad and seems to dip north at progressively steeper angles from west to east. Fault plane solutions for this region do not reveal a simple consistent pattern. This region is separated from another active region to the northeast by a curved gap that is nearly 50 km wide. Northeast of this gap the zone dips to the southeast. In the western portion there is an aseismic region around 160-km depth that separates the contorted shallower zone from a narrow (15–20 km wide), consistently steep, deeper zone. As in island arcs, the fault plane solutions for the deeper events show T axes generally lying within the plane of seismicity and P axes perpendicular to the plane. In contrast to island arcs the T axes in general are not parallel to the dip direction, and there seems to be greater variation in the orientation of these axes. The entire western zone plunges to the west at about 20°, and most of the T axes plunge steeply to the west. In detail, the earthquakes tend to occur in clusters that leave aseismic gaps between the clusters. There is a distinct gap of about 15-km width near 70.7°E. This gap seems to separate events with fault planes solutions that in the west have westward plunging T axes and in the east have eastward or vertically plunging T axes. Although many of these features were not detected in previous studies of this region, the data from those studies are consistent with the dips, changes in dip, gaps, and breadth of the seismic zone. Both the variations in dip and breadth of the active zones and, for one gap, the difference in fault plane solutions of earthquakes on either side of it, make the role of the gaps as boundaries clear and suggest their long-term existence. We infer that the configuration of the Hindu Kush seismic zone could possibly be the result of the subduction of oceanic lithosphere from two separate, small basins in opposite directions. The age of the subducted lithosphere is probably greater than 70 m.y., and subduction probably has occurred over a relatively short duration. The rate of subduction probably has been between 20 mm/yr and 48 mm/yr. Correlations of seismic trends with surficial features suggest that in the south the Hindu Kush suture zone lies along or somewhere between the Panjer and Kunar faults and that in the north the Pamir suture zone lies near the Darvaz-Karakul fault. Finally, it seems that the protrusion of India into Eurasia has been a major factor in developing the present configuration of the zone.

Keywords: Seismology, earthquakes, tectonics, Hindukush.

C/65. Chaudhry, A.G., 1970. Geology of Khagram area, Dir district. M.Sc. Thesis, Punjab University, Lahore, 84p.

Keywords: Geology, petrology, Dir.

C/66. Chaudhry, J.A. & Latif, S., 1981. Geology and petrology of Malam Jaba -Yakh Tangai area, District Swat, NWFP. M.Sc. Thesis, Punjab University, Lahore.

Keywords: Petrology, Malam Jaba, Swat.

C/67. Chaudhry, J.I., 1985-87. Stratigraphic Studies of Area around Dhamtaur-Baghseri District, Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 96p.

The present report is a geological study of nearly 30-miles² (Dhamtaur and Baghseri area) in southeastern direction of Abbottabad. The study includes a geological map on the scale 1:12500 (1cm=125m) and the stratigraphy of the area, from Precambrian to Upper Paleocene (Thanetian). The geological history of the Hazara Trough and the environmental deposition of the formation are reviewed. Structurally, the area is very complicated within which a generally complex folding and faulting predominates.

Keywords: Stratigraphy, structure, sedimentology, Abbottabad.

C/68. Chaudhry, M.A., 1981-83. Geological mapping with special studies on discontinuities in rocks and their effect on the rockmass strength at Kalabagh Damsite. M.Sc. Thesis, Punjab University, Lahore, 30p.

Keywords: Structure, geotechnical, mapping, Kalabagh damsite.

C/69. Chaudhry, M.A., Farooq, I. & Arshad, M., 1977. Mineralogy and petrology of Shangla Par area, District Swat, NWFP, Pakistan. M.Sc. Thesis, Punjab University, Lahore.

Keywords: Mineralogy, petrology, ultramafics, Shangla, Swat.

C/70. Chaudhry, M.I.R., 1999. Electrical resistivity survey for ground water exploration in Zulmkot Area, District Malakand, N.W.F.P., Pakistan. M.Sc. Thesis, Punjab University, Lahore, 160p.

Keywords: Geophysics, electric resistivity, groundwater, Malakand.

C/71. Chaudhary, M.M., 1986. Nanga Parbat: A study of geographic influence. Geological Bulletin, Punjab University 21, 95-103.

Nanga Parbat is under active investigations in the field of geology. On the other hand there does not exist any notable geographical investigation to elaborate the geographical factors of the area. Here an attempt has been made to elaborate geographical factors at work and their associations. Here a probe has been made to ascertain the commanding position of Nanga Parbat and its influence in shaping the regional geomorphology and the resultant topography.

Key words: Geography, Nanga Parbat, Himalaya.

C/72. Chaudhry, M.N., 1982. Lead and zinc mineralization associated with Lahor granite, Kohistan. The Pakistan Metallurgist 3.

Keywords: Granite, Lead-zinc mineralization, Besham, Kohistan.

C/73. Chaudhry, M.N., Ahmed, R., Mahmood, T. & Ghazanfar, M., 1992. A reconnaissance microfacies study of Kawagarh Formation near Giah, Abbottabad-Nathiagali road, Hazara, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 57-58.

Keywords: Reconnaissance, microfacies, Kawagarh Formation, Nathiagali, Abbottabad.

C/74. Chaudhry, M.N. & Ahsan, N., 1999a. Reservoir potential of Datta Formation Hazara Basin, Pakistan. Pakistan Journal of Hydrocarbon Research 11, 1-13.

Keywords: Reservoir potential, hydrocarbons, Datta Formation, Hazara.

C/75. Chaudhry, M.N. & Ahsan, N., 1999b. Sedimentological constraints on India-Asia collision. Abstract Volume, 14th Himalayan-Karakoram-Tibet International Workshop, Terra Nostra 99.

Keywords: Sedimentology, Asia, India, Collision.

C/76. Chaudhry, M.N., Ahsan, N. & Ahmed, F., 2001. Petrography and environment of deposition of Lumshiwal Formation, Karlan Bazar, Nathiagali-Abbottabad Road, Hazara basin, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 25-26.

The studied section of the Lumshiwal Formation (Shah, 1977) is located near Karlan Bazar. It is composed of quartz arenites that are cemented by quartz, glauconite, clay, iron oxides and calcite. The amount of cements and their proportions to one or other vary considerably. These arenites are generally off-white, medium grey, yellowish grey to greenish grey in colour.

The quartz is the main detrital constituent of the Lumshiwal Formation (Chaudhry et al., 1998). The arenites are compositionally mature and texturally sub mature to super mature. The maximum development of glauconite is in the middle and upper part of the formation. The glauconite appears to have developed from clay therefore glauconite rich arenites might have initially been deposited as wackes (Ahsan and Chaudhry, 1999).

The grains of tourmaline, zircon and rutile within the arenites indicate a granitic/gneissic composition of the source rock. Microcrystalline quartz indicates derivation from the textured siliceous rocks. The heavy minerals such as tourmaline, sphene, epidote and zircon also occur as inclusions and their occurrence is restricted. The suite of heavy minerals indicates the S-type granitic or gneissic provenance. The other common accessory minerals are magnetite, haematite and limonite.

The formation contains belemnites, brachiopods, pelecypodes and rare ammonites. This formation overlies the Chichali Formation, which was deposited in reducing conditions (Chaudhry et al., 1998). The lower contact of the Lumshiwal Formation is transitional. The Lumshiwal Formation was deposited in marine subtidal conditions. The presence of relict haematite and films of pyrolusite strongly suggest halmyrolysis in the presence of O_2 and CO_2 . The evidence of progressive deepening in the upper part of the Lumshiwal Formation resulted in the deposition of the pelagic shelf sea, Kawagarh Formation (Ahsan and Chaudhry, 1998). The upper contact of the formation with the Kawagarh Formation is transitional.

Key words: Sedimentology, Lumshiwal Formation, Abbottabad, Hazara basin.

C/77. Chaudhry, M.N., Ahsan, N., Ahmad, N. & Ahmed, F., 2000. Petrography of Lumshiwal Formation, Karlan Bazar, Nathiagali-Abbottabad Road, Hazara Basin, Pakistan. *Pakistan Journal of Geology* 12 & 13, 1-12.

Consult the following account for further details.

Keywords: Petrography, Lumshiwal Formation, Abbottabad, Hazara basin.

C/78. Chaudhry, M.N., Ahsan, N., Chaudhary, M.M. & Gondal, M.M.I., 2001a. Chilas sand--fine aggregate for Bhasha Dam. Abstracts, 4th Pakistan Geological Congress, Islamabad, 42-43.

Bhasha Dam with a rated hydroelectric potential of 4500 MW and a storage capacity of millions of acre feet of water is proposed to be build near Bhasha about 40 km downstream of Chilas. This dam is very important for national economy since it will cater the needs of water and power requirements of the country.

Huge amount of coarse aggregate is available in the area. However, there is no mineable fine aggregate deposit around the site proposed for the dam. Our studies show that the nearest source of fine aggregate for the proposed Bhasha Dam is Chilas sand deposit. It was deposited on the Chilas norites. There is no interbedded component of glacial deposits. These sands are overlain by a thick sequence of well-rounded Indus gravel (Chaudhry et al., 1998) which in turn are overlain, at places, by glacial till. The beds of this deposit are nearly horizontal or gently dipping towards the Indus River and contain associated oversized material.

The coarse aggregate is composed of amphibolites (0.4% to 5.8%), diorite (8.5% to 41.2%), dunite (0-2. 1%), leucocratic fine-grained S-type granite (1.9% to 8. 1%), S-type granite mylonite (3.3% to 18.9%), pyroxenite (0-1.17%), greenstone (0-3.6%), norites (12.1% to 19.2%), S-type microgranite (14.7% to 35.6%) and vein quartz (0-1.2%).

The granite mylonite fraction of coarse aggregate is potentially deleterious and may cause Alkali Silica Reaction.

The sand component of this deposit is composed of diorite/tonalite/amphibolite (0.5% to 2.5%), dolerite (0.3% to 0.9%), granite/granitoids (5.8% to 36.5%), jasper* (0.2% to 0.3%), limestone (0-0.6%) schist/gneiss (8.6% to 42.7%), quartzite/polygrain quartz (2.7% to 5.2%), biotite/vermiculite (1.0% to 8.0%), epidote (0 to 2.1%), feldspar (3.8% to 8.7%), garnet (0 to 1.1%). These sands possess minor reactive rock fragments. However, a peculiar problem of Chilas sand is the presence of vermiculite that may expand in the cement concrete. The role of vermiculite as a deleterious constituent in the concrete is still debated. However, our observations of civil structures and rock exposures indicate that concrete structures subjected to hydraulic conditions and containing vermiculite may show expansion.

The engineering properties (BS.8 12, 1965) of Chilas sand are fairly good. It can be quarried and sieved to meet the desired gradation. However, some horizons are very fine grained but their gradation can be improved by adding manufactured fine aggregate. The mechanical and physical properties of the Chilas sand are comparable with Lawrencepur sand (Chaudhry et al., 1999), Ravi and Chenab sands (Ahsan et al., 1999) and Maira sand (Ahsan et al., 2000). The compressive strength of mortars is within the limits specified by CP-110.

Key words: Building material, aggregate, Bhasha dam, Chilas.

C/79. Chaudhry, M.N., Ahsan, N., Chaudhary, M.M. & Gondal, M.M.I., 2001b. Petrographic evaluation of Jalipur mollase as construction raw material. Abstracts, 4th Pakistan Geological Congress, Islamabad, 60-61.

The Jalipur valley fill is composed of glacial tillites mollassic sediments. The deposit is exposed along Karakoram Highway upstream of Chilas. It is a huge deposit with millions of cubic metres of reserves. The Jalipur mollase is older than 0.78 Ma but younger than 2 Ma (Oslo, 1982; Shroder, 1993). The lower tillite unit which is overlain by Jalipur mollase is indurated. The Jalipur mollase itself is indurated, folded and faulted. The mollase unit is overlain by younger tills. The Jalipur unit occurs only in valley sides and floor. Detailed petrographic studies of coarse as well as fine fraction of Jalipur unit clearly shows that no contribution was made to the Jalipur mollase by the Nanga Parbat gneisses. This indicates the fact that the Nanga Parbat —Haramosh massif was not uplifted at the time the Jalipur mollase was being deposited. This mollase had derived its components from Kohistan Island Arc. It represents a warm period during Shanoz Glaciation period (Shroder, 1993). Its thickness is more than 150m.

The Jalipur mollase was sampled near Jalipur and coarse and fine aggregates were evaluated petrographically. The mollase is cemented mainly by calcite.

The coarse aggregate was sieved through ASTM sieves 2 to No. 4. The retain of each sieve was analysed for rock types. The mollase is composed of amphibolite, diorite, granite, granite mylonite, mylonite, schist, vein quartz, tonalite, slate, quartzite, greenstone, rhyolite and siltstone (wacke). The percentage of rock types is given in Table 1.

The fine aggregate of Jalipur mollase was sieved through sieves of ASTM. The retain of sieve No. 8, 16, 30, 50 and 100 were analyzed under binocular microscope. It is composed of granite/granodiorite (1.1% to 24.6%), diorite/tonalite/amphibolite (0-32.8%), quartzite (8.1% to 21.8%), phyllite/slate (7.2% to 20.4%), greywacke group (0-0.4%), chert (0-0.8%), quartz mica schist (4.60/o to 8.50/o) and schist (0-7.1%). The mineral grains include quartz/polygrain quartz (22.1% to 53.6%), feldspar (4.4% to 8.3%) and amphibole (0.9% to 3.7%). The mineral grains include quartz/polygrain quartz (22.1% to 53.6%), feldspar (4.4% to 8.3%) and amphibole (0.9% to 3.7%). Biotite, muscovite, epidote, magnetite, garnet, tourmaline and zircon are the minor constituents.

The Jalipur coarse as well as fine aggregate contains unacceptable quantities of potentially deleterious reactive phases with Alkali Silica Reaction Potential if used in concrete with OPC. These phases are slate/phyllite, chert and greywacke. These aggregates may be used with low alkali cement or slag cement after testing. The aggregates may also be used with cement-pozzolana, cement-fly ash or cement-silica fume blends after testing.

Key words: Petrography, Jalipur Mollase, Kohistan.

C/80. Chaudhry, M.N. Ahsan, N. & Ghazanfar, M., 1998. A preliminary account of sedimentology of Hazara basin from Jurassic to Eocene. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 41-43.

The Mesozoic to Eocene Hazara Basin dominated by shelf carbonates is characterised by a distinct package of sediments punctuated by a number of diastems, hiatus and unconformities. The environment of deposition vary from supratidal to shelf edge (250m) and from open shelf to restricted circulation anoxic conditions as a consequence of plate movement. The average Rhified rates of sedimentation vary from 0.96mm to 83.30mm per 1000 years.

During upper Hettangian the Hazara landmass changed into a marine basin with the development of a transgressive shore line with the deposition of Datta Formation which overlies either Upper Proterozoic Hazara Formation or Cambrian Hazira Formation.

It was deposited during open marine, lower to upper shoreface, lagoonal to subareal regimes (Chaudhry et al., 1997; Chaudhry et al., 1996; Chaudhry et al., 1995). It is composed of lenses, sheets and layers of poorly sorted medium to coarse grained quartz arenites with rare grit and interlayers of carbonaceous shales, silty shales, marls and oolitic to

pelletoidal limestones. The average lithified rates of sedimentation were approximately 2mm/1000 years. Provenance studies show derivation from an igneous metamorphic sialic Indian plate. Source tong to the south.

The Samanasuk Formation represents an epicontinental intertidal environment with upper shelf ooidic-pelletoidat shoals deposited from Toarcian to Callovian. Cross bedding and burrows are frequent. The sediment are composed of ooidic-pelletoidal wackestones to grainstones, bioclastic limestones and dolomitic horizons. Rare caicirudites also occur. The oyster topped beds and hard grounds represent slow rates of deposition and subareal exposures. The average lithified rate of deposition was about 6mm/1000 years.

At the close of Callovian restricted anoxic environment prevailed and condensed pyrite rich and belemnite-bearing black shale-siltstone sequence represented by Chichali Formation of Oxfordian to Kimmeridgian age was deposited. The lithified sedimentation rates were about, 2.3mm/1000 years.

Strongly reducing conditions changed to mildly reducing conditions with better circulation in Tithonian during which the Lumshiwal Formation was deposited. It is mainly composed of glauconitic quartz arenites (Chaudhry et al., 1997, Chaudhry et al., 1994) with submarine hard grounds. These sediments are generally cemented with quartz, clay, Iron oxides or glauconite. The ubiquitous glauconite indicates slow rates of deposition in mildly reducing environments. The suite of heavy minerals once again indicates sialic igneous metamorphic provenance. The average lithified rates of sedimentation were about 0.96mm/1000 years.

In Cenomanian, the Hazara basin deepened (upto a maximum of 250m as shown by the presence of oligostigena (Ahsan et al., 1993, Ahsan et al. 1994, Chaudhry et al. 1992) during a major global transgression with deposition of Kawagarh Formation composed of. pelagic mudstones, wackestones and packstones. The upper beds (Maastrichtian in age) of Kawagarh Formation were exposed during a widespread regression due to initiate contact of the Indian with the Kohistan Arc at 67 ± 2 Ma prior to main India-Eurasia collision (Bard et al., 1979) at 50-55 ma. The average lithified rates of sedimentation of Kawagarh Formation have been estimated as 9mm/1000 years (Chaudhry et al., 1994).

The subareal exposure under subtropical conditions reworked the Maastrichtian sediments of the Kawagarh Formation into fire clay, pisolitic bauxite and laterite. The rate of accumulation of these residual sediments of Hangu Formation are about 1.77mm/1000 years.

The crustal bulge which developed due to initial Kohistan Arc-Indian Plate contact at 67 ± 2 ma (Bard et al. 179, Chaudhry et al., 1994) subsided by Thanetian and Hazara Basin once again changed into an open shelf to deposit nodular Lockhart Limestone in shallow shelf (subtidal) environments. The sediments of the Lockhart Limestone rich in benthic forams are composed of mudstones, wackestones and packstones. The average lithified sedimentation rates are worked out at about 30mm/1000 years.

The carbonate shelf developed into a siliciclastic basin with increased turbidity which suppressed deposition of carbonates and olive grey splintary shales of Patala Formation with occasional limestone bands were deposited. The average lithified rates of deposition of Patala Formation are about 30mm/1000years.

During Ypresian the siliciclastic basin developed into a carbonate platform and deposited the Margala Hill Limestone in upper subtidal to lower subtidal environments. It is composed of mudstones, wackestones and packstones with many intercalations. The average rates of sedimentation of the Margala Hill limestone are about 62.5mm/1000 years.

The Chorgali Formation is composed of shales, mudstones, wackestones and packstones. The same environment that deposited the Margala Hill limestone deposited the Chorgali Formation. The average lithified rates of sedimentation were about 83-3mm/1000 years.

At about 55-50 Ma main collision between India and Asia took place due to which during Lutetian the sea started retreating. In Hazara with brief episodes of transgression-The Kuldana Formation represents these changing conditions and is represented by red continental shale-siltstone beds with interactions of fossiliferous marine limestones. The average lithified rates of sedimentation of this unit are about 71.1mm/1000 years. Thereafter the Himalayas started rising with the deposition of continental Molasse represented by Murree Formation with a Himalayan rather than Indian Plate provenance.

The cement stratigraphy for carbonate sediments of Hazara Basin (except Samanasuk Formation) shows that non ferroan microcrystalline calcite was penecontemporaneous with deposition. The second stage involves that dolomitization of calcite and bioclasts. Replacement of dolomite and bioclasts by ferroan calcite is the third stage. The final stage is the silicification of groundmass, bioclasts and at places the dolomite rhombs. In Samanasuk Formation dolomite occurs as first stage supratidal cement and sparite as early burial cement.

In addition to submarine and very early calcite cement the following order in cement stratigraphy for the pre-Danian clastic units of the Hazara Basin has been worked out: i) thin rim early quartz cement, ii) kalonite cement, iii) early calcic cement, iv) dolomitic cement, v) ferroan calcite cement, vi) deep burial quartz cement and vii) lite diagenetic kaolinite cement.

Key words: Stratigraphy, sedimentology, Jurassic, Eocene, Hazara basin.

C/81. Chaudhry, M.N. Ahsan, N. & Majid, C.M., 1997. Engineering properties, mineralogy, alkali aggregate reaction potential and provenance of Lawrencepur sand Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Lawrencepur sand is one of the most popular fine aggregate deposits of Pakistan. Detailed analysis of engineering characteristics, mineralogical composition and Alkali Aggregate Reaction (AAR) potential as well as the provenance of this deposit has been studied in detail.

The bulk densities of this sand vary from 82 lbs/cft to 86 lbs/cft. Its grading generally corresponds to the zone 3 or 4 of BS 882/1965 and is therefore considered an excellent fine aggregate for mixing with cement individually or as an additive with other fine aggregates of Pakistan. However, some sand layers contain oversize particles or other sizes larger than permissible limits for fine aggregates and therefore require sonic processing to meet the desired gradings. The Lawrencepur sand was tested in accordance with USBR Designation 14 to determine the organic impurities. The colour of the sand in 3% solution of NaOH was found to be lighter than the standard colour solution. This sand therefore, is free from organic impurities. Soundness test was carried out in accordance with ASTM Designation C88-76. The weight percentage losses range from 0.5% to 1.50% after five cycles of immersion. These results are lower than the maximum allowable limit of 12% (by Na₂ SO₄).

The Lawrencepur sand was tested petrographically for AAR potential with ordinary portland cement (OPC). It did not show Alkali Carbonate Reaction (ACR) potential. However, petrographic tests show that Lawrencepur sand ranges from innocuous to deleteriously reactive with respect to its ASR potential. These tests were carried out in accordance with ASTM Designation C33-81 and ASTM Designation C289-81. The chemical reactivity tests were carried out in accordance with ASTM Designation C289-8 1. These results range from innocuous to mildly deleteriously reactive.

Mineralogically the coarse sand is composed of lithoclasts as well as mineral grains. the average results and model analysis of coarse Lawrencepur sand are as follows:

quartz/quartzite 33.9%. granite/granodiorite 20.20%. amphibolite/foliated diorite 10.70%, feldspar 10%. mica 5.80%. graywacke group* 5.30%. amphibolite 4.60%, schist 4.0%, phyllite/slate* 3.300 a. iron ore 1.30%. sphene 0.30%. chert.* 0.20%, tourmaline 0.20%, apatite 0.10% and zircon 0.1 0%. The deleterious constituents are marked with an asterisk(*). The coarse sands are therefore generally potentially reactive with ASR potential. Some parts of this sand deposit specially the medium grained varieties are low in lithoclasts and deleteriously reactive constituents and are therefore innocuous.

The sand has been derived mostly from the Kohistan island arc and the Indian plate constituting the Higher arid Lesser Himalayas. Contribution from the Gawachi back arc basin and the Asian plate is negligible as far as lithoclasts are concerned.

Key words: Engineering geology, alkali aggregates, sand, Lawrencepur.

C/82. Chaudhry, M.N. Ahsan, N. & Majid, C.M., 2000. Alkali aggregate reaction potential and engineering properties of Indus aggregate from Skardu to Thakot, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 146-148.

The River Indus plays an important role in the industrial and agricultural economy of Pakistan. A number of dams are proposed to be constructed for water storage and power generation. The construction of these dams at Shyok, up and down stream of Kachura near Skardu, Raikot, Bhasha, Dasu and Patan will require millions of cubic metre of concrete. The (Chaudhry et al., 1999; Ahsan et al., 1999) aggregates of the River Indus for the Civil Engineering Projects. These aggregates were physically and petrographically evaluated for Alkali Aggregate Reaction (AAR) potential.

In the past, deleterious aggregates have been used in Tarbela Dam (Chaudhry and Zaka, 1994) and Warsak Dam (Chaudhry and Zaka, 1998). The aggregates used in Terbela and Warsak dams were considered safe but later on their inservice behaviour proved them deleterious with Alkali Silica Reaction (ASR).

The coarse and fine aggregates of Indus River meet the engineering characteristics as specified by ASTM or BS. The Los Angeles Abrasion Values are between 5.6 to 20.0 %. Specific gravity is 2.5 to 2.9 and water absorption is very low i.e. from 0.5% to 0.8%. The loss after 5 cycles of immersion in sodium sulphate solution ranges from 0.5% to 0.98%. The gradation of coarse and fine aggregates generally corresponds to BS 812: 1967, but at places they are

gap graded. The coarse aggregate of nine terraces of the Indus River from the Shigar Bridge, north of Skardu to Thakot Bridge were evaluated for Alkali Silica Reaction potential. The coarse aggregates were sieved through BS 2" to 3/16" sieves and retained fractions were separated for identification of rock types.

The rock types include greenstone, quartzite, dunite, leucacmtic fine grained S-type granite porphyritic S-type granitic gneiss amphibolite. S-type granite mylonite, norite, pyroxenite, peridotite, granodiorite, diorite, S-type microgranite, vein quartz, I-type granite, dacite, mica gneisses, microdiorite, schist/gneiss, andesite, rhyolite, black basalt, hornblendite, chert, greywacke, slate, phyllites, dolerite, greenschist, marble, quartzofeldspathic psammite, serpentinite, weathered schist, dacite, porphyry andesite porphyry and rhyolite porphyry. All these rock types may or may not be present in one sample. Moreover they vary from 0010 to as much as 63% on different sieves. The fine aggregates associated with the coarse aggregates were sieved through ASTM # 4 to # 200 sieves and rock types and minerals of each fraction were identified under the microscope. They include granite, granodiorite, diorite, tonalite, amphibolite, quartzite, slate, phyllite, greywacke, greenstone, basalt, norite, dolerite, quartz mica schist, gneiss, hornfelse, friable sandstone microfractured quartz, mica, greenstone, greenschist, polygrain quartz, feldspar, biotite, epidote, magnetite, garnet, tourmaline, sphene, zircon, calcite, rutile, barite, albite, plagioclase, clay lumps, acid to intermediate volcanics and diorite. All of these constituents may or may not be present in each fraction or deposit. The rock types indicated by asterish (.) are potentially deleterious. The coarse and fine material of these terraces was considered safe in the past. Petrographic studies, mon.ar bar tests and deterioration of concrete containing the Indus aggregates clearly show the deleteriously reactive nature of the Indus aggregates if used with Ordinary Portland Cement. Studies carried out on aggregates using low alkali cements, slag cements and using methods. Ahsan et al., (1999) and Chaudhry et al., (1999) have used Ravi and Chenab sands dilutants to minimize the ASR in the Lawrencepur sands of the Indus River. Experimentation and further studies to control the reaction by using silica fumes and dilution with innocuous aggregates are being carried out.

Key words: Engineering geology, alkali aggregates, sand, Skardu, Thakot.

C/83. Chaudhry, M.N., Ahsan, N., Mahmood, T. & Masood, K.R., 2001. Sedimentology of Margala Hill limestone, Neelum valley, Azad Kashmir, NW Lesser Himalayas. Abstracts, 4th Pakistan Geological Congress, Islamabad, 59-60.

The Margala Hill Limestone (Latif, 1970) at Chahla Bandi, Azad Kashmir (Ghazanfar et al., 1987) is composed of light grey to dark grey limestone. The formation at the base is thinly bedded. It is overlain by calcirudite that contains abundant pelecypode shells. Some shells are reworked. Highly fissile dark grey shale that overlies the shelly beds and contains marcasite nodules. The shale is followed by highly nodular limestone. The nodules are upto 30 cm x 50 cm x 13 cm and contain very thin shale partings. This zone is 29m thick. It is very dark grey in colour and gives very strong fetid smell. An argillaceous marly limestone that is 28 metres thick overlies the dark grey limestone. It is overlain by medium bedded to highly nodular limestone towards the top of the formation. This zone is grey and weathers to light grey.

On the basis of petrographic and field observations, the formation is divided into six facies. These facies from bottom to top include: a) Poorly developed nodular limestone facies, b) Calcirudite facies, c) Biostromic limestone facies, d) Highly nodular limestone facies, e) Argillaceous limestone facies, and t) Massive to nodular limestone facies.

After the collision of India-Asia (Bard et al. 1979; Chaudhry et al. 1994) a ramp (Ahsan et al. 2000) developed that received the Eocene sediments in Azad Kashmir. The formation started deposition in the middle subtidal zone on siliciclastic sediments of Patala Formation. It was followed by reworking of the facies (a) sediments and a brief period of subtidal exposure. Then a rapid transgression deposited kiohermal limestone facies. The many limestone facies was deposited in a relatively calm conditions followed by the deposition of massive nodular limestone. The groundmass of the microfacies is non-ferroan calcite that at places has been neomorphosed. Rare dolomite is associated with some horizon. Evidences of physical and chemical compaction are well preserved.

Palynological contents of the samples included moderate population of Dinoflagellates, Mycorrhizal spores and Acritarchs. Pollen, spores and cuticular fragments were rare to very rare. Most conspicuous were Ptenidophytic spores (PunctatLsporites, Lacinitriletes and Acanthotriietes) and Ccilpate pollen (Tricolpites).

Key words: Limestone, sedimentology, Margala Hills Limestone, Azad Kashmir.

C/84. Chaudhry, M.N., Ahsan, N., Masood, K.R., Baloch, I.H. & Spencer, D.A., 1997. Facies, microfacies, paleontology, depositional environment and economic potential of Datta Formation

of Early Jurassic age from Attock Hazara Fold and Thrust Belt, Lesser Himalayas (Salt Range, Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 133-134.

The Datta Formation (Danilchick, 1961; Shah, 1977) of Early Jurassic age is an important and persistent lithostratigraphic unit exposed in the Upper Indus Basin and Attock Hazara Fold and Thrust Belt of Pakistan. Its lithologies, thickness and environment of deposition vary widely. In the Hazara area, it unconformably overlies the Hazara Formation of Precambrian age. Here its basal part is a gritty sublithic arenite (Chuhan et al., 1990). The clasts were derived from the underlying slates during an Early Jurassic transgression (Chaudhry et al., 1994). The overlying package is composed of lenses and sheets of calcite and/or quartz-cemented quartz arenites. These are fine to coarse grained, generally sub-angular to sub-rounded, poorly to very well sorted, texturally sub-mature to mature and compositionally mature. This dominantly quartzose package also contains a few lenses of oolitic and pelletoidal limestones, marls, carbonaceous and silty shales. Diastems, at few places in this unit, are marked by hard-grounds.

The following order of cementation of stratigraphy for the Hazara area has been worked out: early submarine and calcite cementation followed by thin rim early quartz cementation followed by thin rim early quartz cementation => Kaolinite cementation => early calcite cementation => dolomitic cementation => ferroan calcite cementation => deep burial quartz cementation => late diagenetic Kaolinite cementation. The diagenetic events of the rock package in the Hazara area will be discussed in relation to the burial and uplift history of the basin. Submarine, early calcite cementation was followed by Kaolinite and thin rim quartz cements at shallow depths in the domain of meteoric or mixed meteoric-marine water circulation. This was followed at greater depths (under alkaline and mildly reducing conditions), by the precipitation of ferroan calcite. Transformation of Kaolinite to illite probably started at around 1000-meter depth. Extensive quartz cementation, suturing and reduction in porosity started at greater depth and was completed at depths of 4,000-4,200 meters at which the main phase of oil and gas maturation was completed. The late stage Kaolinite cement was formed during final stages of uplift by the alteration of surviving K-feldspar in the domain of meteoric circulation.

Zircon, tourmaline, epidote, sphene and biotite represent the heavy mineral suite for the Datta Formation and indicate an ultimate igneous metamorphic sialic source with minor basic/met basic component. The overall composition of sandstone, textural and compositional maturity, the restricted suite of heavy minerals, and their amounts and shapes, indicate a recycled origin for the sandstones of the Datta Formation. The granitoid component was S-type. Lack of kyanite, sillimanite and garnet suggests that high-grade gneisses were not exposed in the source area. This fact is further supported by the presence of indicolite, which indicates allochthonous granitoid intrusions in the epizone with thermal aureoles.

The environment of deposition of the Datta Formation varies from open marine, lower to upper shore face, lagoonal to sub-aerial. It was deposited along the northern edge of the Indian Plate along a mixed siliciclastic-carbonate shoreline during an overall transgression in Early Jurassic.

However, minor phases of off-laps and on-laps have been identified. The Datta Formation in the Western Salt Range is composed of fining-upward clastic fluvial sequences. Each cycle is composed of coarse-grained (often pebbly) sandstone or conglomerate lying on a scoured surface. This unit is interpreted as a channel lag deposit, which is overlain by cross-stratified sandstone interpreted as a point bar. This, in turn, is topped by overbank silt and clay deposits. The sequence also contains palaeosol horizons. The Datta Formation in the Western Salt Range represents fluvial deposits laid down by small shallow meandering streams subject to intense periodic flooding.

In the Attock region, to the west of Hazara, the Datta Formation is composed of three main horizons: the basal part is a thin and often discontinuous laterite bed; the middle part contains bauxitic clays composed of variable quantities of Kaolinite, boehmite and diasporite (Baloch, 1986); while the top unit is composed of variegated sandstones and shale of continental to transitional marine origin. This unit also contains recoverable amounts of rutile and anatase. In this area, the Datta Formation is composed of a continental residual deposit while in Hazara the unit is predominantly marine in origin. In the Hazara area small quantities of silica sand have been mined for the glass and chemical industries. Large quantities of refractory clays, high alumina clays, silica sand and small quantities of ochre are being mined from Attock, as well as parts of Kala Chitta and Salt Range. Our recent studies on the fire clays and high alumina clays have yielded encouraging results for recovering rutile and anatase from fire clays and high alumina clays of Attock. It is an important reservoir rock for hydrocarbons in the Upper Indus Basin.

Since the Datta Formation lacks diagnostic fauna, detailed palynological study of samples from the Salt Range and Hazara were carried out in order to constrain the age of this formation. The Datta Formation contains well preserved rich and diverse palynoflora, dominated by torate and auriculate miospores of Gleichenioidites (Ross) Delcourt and Sprumont and Triquitrites (Wilson and Coe) Potonie and Kremp types, respectively. Bisaccates were totally absent.

Cuticular fragments with sunken stomata and papillate outgrowths indicating a xerophytic habitat were observed in most samples. Some other important genera include *Leiotriletes* Naumova ex Potonie and Kremp 1954, *Todisporites* Couper 1958, *Calamospora* (Loose) Schopf Wilson and Bentall 1944, *Cyathedites* Couper 1953, *Granulatisporites* Ibrahim 1933, *Concavisporites* (Leschik) Nilson 1958 and *Verrucosisporites* potonie and Kremp 1954. *Triquitrites* and *Gelicheniidites* represent approximately 45% of the total microflora. Although the auriculate group was the most numerous, simple trilete miospores (*Leiotrites*, *Punctatisporites*, *Todisporites*) contributed an average of 5%. The most outstanding feature of the palynoflora was the persistent occurrence in the lower half of the Formation of any Early Jurassic marker pollen *Classopollis classoides* (Pflug) Pocock and Jansonius 1961.

Key words: Microfacies, palaeontology, depositional environment, Datta Formation, Jurassic, Himalaya.

C/85. Chaudhry, M.N., Ahsan, N., Zaka, K.J. & Majid, C.M., 1997. Alkali aggregate reaction potential of Indus gravel and sand between Raikot Bridge and Kalabagh. Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Following River-Water Treaty with India. Pakistan lost rights over the waters of Sutluj and Ravi rivers. Therefore, the river Indus with its water and power potential is rightly regarded as the life line of Pakistan. A very large number of dams, barrages, bridges and other civil structures are likely to be built using sand and gravel of this river and its terraces. The amount of aggregate required is colossal. This warrants systematic studies of gravel and sand of the river Indus. A part of the work carried out on the Indus aggregates is presented in this paper.

The effects of deleterious alkali-aggregate reactions are often very profound and severely detrimental to concrete structures affecting their strength, stiffness, serviceability, safety and stability.

This paper for the first time, presents an overall preliminary evaluation of alkali-silica and alkali-carbonate reaction potential of coarse as well as fine aggregates of the Indus river between Raikot bridge and Kalabagh. Bulk aggregate samples were drawn from near Raikot bridge. Besham. Tarbela Dam. Attock. Lawrancepur. Harrow-Indus confluence and Kalabagh to study their deleterious alkali-aggregate reaction (AAR) potential as well as their physical and engineering characteristics.

In addition to petrographic evaluation of alkali-silica and alkali-carbonate reaction potential of these aggregates, their physical properties like water absorption (0.5 to 0.8%), bulk densities (80-90 Lbs/cft), specific gravities (2.60 to 2.85) and organic impurities for coarse and fine aggregates and mechanical properties such as aggregate crushing value (9% to 30%), aggregate impact value (6% to 25%), Los Angeles abrasion test (5 to 20%) and soundness test (1.50% to 10%) were also determined.

In addition to these, tests a detailed quantitative petrographic analyses of all the samples were carried out in order to determine their deleterious alkali-aggregate reaction potential. At many places these fine aggregates are gap graded. Metagraywackes, metasubgraywackes and metavolcanics were previously regarded as safe since they had undergone metamorphic reconstitution in low grade. We present theoretical bases for drawing a boundary line between reactive and non-reactive metagraywackes and acid to intermediate metavolcanics.

These studies show that while these aggregates possess excellent physical and engineering properties they show alkali-silica reaction potential. The reactive rock types identified are metagraywackes, metasubgreywackes, phyllites slates, acid to intermediate volcanics, granite mylonites and cherts. However, the reactive rock types and their amounts vary widely (Chaudhry et al. 1992; Zaka et al. 1995) between Raikot Bridge and Kalabagh. Not all the reactive rock types may be present at all these sites but nevertheless all these samples show deleterious alkali-aggregate reaction potential.

Chemical reactivity tests on these aggregates are inconclusive and molter bar tests over a period of six months to one year do not give unacceptable expansion. However extended mortar bar tests show unacceptable expansion. Inservice behaviour of Indus gravel and sand at Tarbela Dam and behaviour of similar aggregates in Warsak Dam has been found unsatisfactory. Evidence of alkali-silica reaction has been proved in these structures. Five possible preventive measures can be taken to avert alkali-silica reaction i.e. i) use of low alkali cement instead of ordinary portland cement. ii) use of silica fumes. iii) addition of fly ash, iv) use of slag cement and v) addition of pozzolana.

Since a large number of dams and other civil structures are planned to be built on the river Indus requiring huge quantities of cement, therefore on account of cost considerations, we do not recommend the use of low alkali cement. Silica fumes has a short history of application, therefore, its effectiveness in controlling alkali-carbonate reaction has not yet been proved under inservice conditions over extended period of time. At present we do not have large quantities of indigenous fly ash available. The use of this material therefore must wait till under-construction and planned coal fired power plants become operational. Slag cement can be usefully employed where settling time and quick attainment of peak strength is not required. The only other practical solution at the moment appears to be

manufacturing of pozzolana and producing suitably blended cements. We very strongly recommend this economical and effective solution where slag cement cannot be used.

Key words: Alkali aggregates, Indus gravel, Raikot, Kalabagh.

C/86. Chaudhry, M.N. & Ashraf, M., 1977. Petrology of the Karak bentonite-Kohat District, NWFP, Pakistan. Geological Bulletin, Punjab University 14, 1-26.

A detailed petrographic, chemical, mineralogical and statistical study of the Karak bentonite is being presented for the first time. A total of 46 petrographic analyses, 47 chemical analyses, 6 X-ray analyses, 11 D. T. A. analyses and 11 spectrographic analyses have been discussed. The study shows it to be a mixed layered montmorillonite-illite with MgO in excess of CaO. It is originally thought to have been deposited as a montmorillonite which on a depth of burial of about 10000 feet and in the presence of K⁺ ions has been converted to a mixed layer montmorillonite-illite. The clay is transported and well stratified. It was deposited in a shallow undulating evaporitic basin with water reduced to nearly 1/3 of its original volume and varying slightly on either side.

Key words: Petrology, mineralogy, bentonite, Karak.

C/87. Chaudhry, M.N. & Ashraf, M., 1980. The volcanic rocks of Poonch District, Azad Kashmir. Geological Bulletin, University of Peshawar 13, 121-128.

The volcanic rocks of the Poonch District are confined to the Pir Panjal Range of Upper Haveli, Poonch District. The volcanic rocks belong to two distinct ages. The Dogra Trap is basaltic and is confined within the Precambrian Dogra Slates. The Panjal Trap along with basal agglomeratic slates and Tuffs are Upper Carboniferous. The flows are mainly basaltic to andesitic. The pyroclasts occurring towards the top are intermediate to acidic in composition. The Panjal Trap is overlain by the 'Gondwana Group' of upper part of Upper Carboniferous to Permian.

This paper deals with the geology, petrography, chemistry and geochemistry of the Poonch volcanics. Map of the area on 1:50000 has been prepared. This is the first detailed petrological study of the Poonch Volcanics. A total of thirty nine petrographic analyses, thirty two chemical analyses and fifteen spectro-chemical analyses of the volcanics are presented.

Key words: Volcanics, slates, Pir Panjal Range, Poonch, Azad Kashmir.

C/88. Chaudhry, M.N. & Ashraf, M., 1981. Petrology of Middle Siwalik rocks of Kotri area, Azad Kashmir. Geological Bulletin University of Peshawar 14, 183-191.

Sandstones and shales of the Middle Siwalik of the Kotli area have been studied petrographically, chemically and spectrochemically. By comparing the overall compositions of these rocks and those of the rock fragments present in the constituent sandstones, it has been concluded that the Middle Siwalik rocks have been derived from igneous, metamorphic and sedimentary formations lying to the north and northeast of the area, towards the Pir Panjal Range.

Key words: Petrography, geochemistry, sandstone, siwaliks, Azad Kashmir.

C/89. Chaudhry, M.N. & Ashraf, M., 1984. Geology, petrography and spectrochemistry of Gondwana rocks of Poonch District, Azad Kashmir. Kashmir Journal of Geology 2, 11-18.

Geology, petrography and spectrochemistry of Gondwana metaconglomerates, quartzites and schists have been described and discussed. Ten modal analysis of Gondwana metaconglomerate bed, four modal analyses of Gondwana schists, five spectrochemical analysis of Gondwana metaconglomerate and two spectrochemical analysis of Gondwana schists are presented for the first time from Poonch. The geological and petrographic evidence supports the view (Wadia 1928) that the Gondwana Group of rocks were deposited under continental conditions. It has been further suggested that the environment of deposition varied from oxidizing to reducing. The upper Haveli Tehsil of Poonch with Agglomeritic slates and tuff, Panjal Trap and Gondwana Group rocks belongs to the Kashmir geologic province while the remaining part (with the Palaeozoic rocks missing) should be grouped with the Hazara province. The two contrasting provinces are separated by the great boundary fault.

Key words: Petrography, detrital sediments, Gondwana rocks, Azad Kashmir.

C/90. Chaudhry, M.N. & Ashraf, M., 1985. Petrology of Murree Formation of Poonch District, Azad Kashmir. *Kashmir Journal of Geology* 3, 13-36.

A detailed petrographic, chemical and spectrochemical study of Murree Formation from Poonch Distt. of Azad Jammu and Kashmir is being presented for the first time. This study includes petrographic analysis of 22 sandstones, 31 shales and 13 limestones; chemical analysis of 23 sandstone, 6 shales and 13 limestones, chemical analysis of 23 sandstones, 6 shales, and 3 limestones and spectrochemical analysis of 10 sandstones, 8 shales and 4 limestones.

A comparison of the Murree Formation and Siwaliks of Poonch is presented to show similarities between the two. It is shown that the two have been derived from the same source.

The view held so far (following Wadia, 1928) that the Murree Formation has been derived from Dharwar and Cuddapah rocks of Peninsular India is dispelled. Instead, it is clearly shown that the Murree Formation like the Siwalik (Chaudhry and Ashraf, 1981) have been derived from the rising Himalayas.

In Poonch area it is shown that the Murree Formation are marine, while the middle and upper Murrees are of continental origin with local lacustrine conditions.

Key words: Petrology, geochemistry, Murree Formation, Azad Kashmir.

C/91. Chaudhry, M.N. & Ashraf, M., 1986. Petrology of ultramafics from Shangla-Alpuri-Malam Jabba area, Swat. *Kashmir Journal of Geology* 4, 15-33.

Chromite and chrome spinel bearing metamorphosed ultramafics occur south of the MMT within a eugeosynclinal assemblage composed of green schist, slices of blue schist and mafic lavas. The rocks originally peridotites are now composed of serpentinites, serpentinitised peridotites and a varied assemblages of talc-carbonates. The mineral assemblages show that the main metamorphic phase took place between 325 °C and 500 °C. That would correspond to low to very low grades of metamorphism. This paper presents petrography, chemistry and metamorphism of these rocks.

Key words: Petrology, geochemistry, ultramafics, serpentinitization, Shangla, Alpuri, Swat.

C/92. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1979. Molybdenum mineralization associated with Igneous-metamorphic rocks in Kohistan and Swat districts along Karakoram Highway. *The Pakistan Metallurgist*, 1 & 2, and 1980, 2 (1&2), 11-12.

Key words: Igneous rocks, metamorphism, molybdenum mineralization, Kohistan, Swat.

C/93. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1980b. Preliminary study of Nickel mineralization in the Swat district, NWFP. *Contributions to Geology of Pakistan*, 1, 9-26.

Important areas of interest where significant reserves of Nickel ore may be expected are Shangla, Malam Jaba and Tutan Banda (Swat). Some minor occurrences are also found in Aspanr, Bar-Malakand and Ursak (Dir). Petrographically the nickel bearing rocks are ultramafics e.g. altered serpentinites (talc-carbonate rocks), sulphide bearing serpentinites and limonitic altered serpentinites, norites and allied rocks, studied so far by authors from the Swat-Dir areas, do not show nickel mineralization although these rocks deserve further study.

Chemical and spectrographic studies indicate higher values of nickel in the ultramafics than the background values (NiO in various rocks varies generally from 0.4 to 0.8% and the usual background value is less than 0.2%).

Key words: Nickel, mineralization, Swat.

C/94. Chaudhary, M.N., Ashraf, M. & Hussain, S.S., 1981. Petrology of Koga nepheline syenites and pegmatites of Swat District. *Geological Bulletin, Punjab University* 16, 83-97.

Detailed petrography, chemistry and petrogenesis of the Koga nepheline syenite intrusion is being described. A total of 70 petrographic modal analyses and 56 chemical analyses of various types of nepheline syenite and its associates were carried out. The data was processed on ISM 1130 computer using FORTRAN IV language, thus averages,

standard deviations and correlation co-efficients were worked out. The nepheline syenites show characteristics of miaskitic type. A generalised evolutionary sequence of the nepheline syenitic rocks is as follows; Pulaskite-nepheline syenite-foyaite-sodalite syenite-fenite-carbonatite.

The intrusion is a part of the alkaline province lying between Loe Shalman and Chamla. The province is composed of northern nepheline syenites, syenties and carbonatites and southern soda granites and soda porphyries. The extent of eastward extension of this province is not known. The province is associated with substantial dislocations.

Key words: Petrology, geochemistry, pegmatites, nepheline syenites, Buner.

C/95. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1983. Lead-zinc mineralization of lower Kohistan District, Hazara Division, NWFP, Province, Pakistan. *Kashmir Journal of Geology* 1, 31-42.

Lead and zinc mineralization of galensphalerite type was discovered for the first time from Besham are of Kohistan. The mineralization is mainly of hypothermal to mesothermal vein type. Economically important deposits occur as veins within the igneous metamorphic zones formed by the interaction of Lahor granite and pelitic-calcareous metamorphics. Disseminated lead-zinc mineralization also occurs in skarns, altered granites, silicified granites and quartz veins. Petrography, ore microscopy, and chemistry of the mineralized rocks is presented and related to the field evidence to draw conclusions about the nature and origin of mineralization.

Key words: Mineralization, Lead-Zinc, Besham, Kohistan.

C/96. Chaudhry, M.N., Ashraf, M. & Hussain, S.S., 1984. Lead-zinc mineralization of lower Kohistan District, Hazara Division, North West Frontier Province, Pakistan. Abstract, First Pakistan Geological Congress Lahore, 23-24.

Consult the preceding account for further information.

Key words: Mineralization, Lead-Zinc, Besham, Kohistan.

C/97. Chaudhry, M.N., Ashraf, M., Hussain, S.S. & Iqbal, M., 1976. Geology and petrology of Malakand and a part of Dir (Toposheet 38, N/14). *Geological Bulletin, Punjab University* 12, 17-39.

A geological map of a part of the Malakand Agency and of southern Dir district covered by the toposheet No. 38 N/14 is presented. Succession of rocks of the area has been worked out. Detailed petrography of all the major units of the area is described. Six modal analyses of the pelitic rocks, fifteen modal analyses of the calcareous rocks including marbles, six modal analyses of the amphibolites, thirteen modal analyses of the Malakand granite gneiss and twenty-seven modal analyses of the Malakand granite are presented. Twelve chemical analyses of the granite were done. Petrogenesis of the rocks of the area is presented.

Key words: Petrography, calcareous, marbles, amphibolite, granite, Malakand, Dir.

C/98. Chaudhry, M.N., Baloch, I.H., Ahsan, N. & Majid, C.M., 2000. Engineering properties, mineralogy, alkali aggregate reaction potential and provenance of Lawrencepur sand, Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), *Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad*, 241-253.

Key words: Mineralogy, engineering properties, alkali aggregates, Lawrencepur.

C/99. Chaudhry, M.N. & Chaudhry, A.G., 1974. Geology of Khagram area, Dir District. *Geological Bulletin, Punjab University* 11, 21-43.

A map of ninety square miles of the area is presented. Bojites, diorites, trondhjemite, norite, hypersthene gabbro, hypersthene diorite, pyroxenite, intermediate pegmatite and amphibolites occur in the area. Normal igneous

differentiation of two different magma types is postulated to be responsible for two different types of related rocks i.e., basaltic magma of andesite rhyolite association, which, resulted in the formation of bojite, diorite, tonalite and trondhjemite and the tholeiitic magma which gave rise to norite, hypersthene gabbro, hypersthene diorite and pyroxenite. The study suggests that the formation of complex progressed by independent intrusions of earlier basaltic magma of andesitic, rhyolitic association to latter of tholeiitic nature with subsequent differentiation.

Keywords: Geology, petrography, mafic and intermediate rocks, amphibolites, Dir.

C/100. Chaudhry, M.N., Chuhan, F.A. & Ghazanfar, M., 1994. Microfacies, diagenesis, environment of deposition and burial history of Datta Formation from Baraoter, District, Abbottabad. *Kashmir Journal of Geology* 11 & 12, 43-58.

Datta Formation of Early Jurassic age from Baraoter, Abbottabad-Nathiagali area, has been studied, for the first time from petrological/sedimentological point of view. The 11.37m thick section shows a marked vertical variation in lithology. The units included from bottom to top are medium grained kaolinite-illite and quartz cemented quartz arenite, fine grained glauconitic sandstone, medium to fine grained quartz and kaolinite-illite cemented quartz arenite, alternating bands of carbonate cemented medium to fine grained quartz arenite and oolitic pelletal limestone, medium grained ferruginous quartz arenite, coarse grained carbonate cemented quartz arenite, fine grained quartz and carbonate cemented quartz arenite, very fine grained arenaceous limestone, fine grained carbonate and quartz cemented quartz arenite, mudstone, and coarse grained arenaceous dolomite with streaks and layers of grit. There is a very restricted suite of heavy minerals, which include tourmaline, zircon, epidote and sphene. This suite indicates ultimate derivation from an igneous metamorphic sialic basement with subordinate basic/metabasic component. The granitic component was predominantly S-type. The diagenetic events have been interpreted with respect to the burial and uplift history. The maximum depth of burial is estimated at 4150m at which oil and gas maturation and reduction of primary porosity occurred. Kaolinite is the first cement to form followed by quartz and ferron carbonate cementation. At depth beyond 1000m, kaolinite transforms into illite. Kaolinite is early diagenetic as well as formed at the final stage. The environment of deposition is also highly variable from continental, subtidal, inter-tidal and supra tidal.

Keywords: Sedimentology, Datta Formation, Abbottabad.

C/101. Chaudhry, M.N. & Ghazanfar, M., 1983. A plate tectonic model for N.W. Himalayas, Pakistan. *Kashmir Journal of Geology* 1, 109-112.

For further information, consult Chaudhry, Ghazanfar and Ashraf, 1984.

Keywords: Plate tectonics, Himalaya.

C/102. Chaudhry, M.N. & Ghazanfar, M., 1986. Petrology of Panjal ophiolites. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 22-23.

Geological set-up, geochemistry, petrography, petrogenesis and petrotectonics of Panjal greenstones from middle Kaghan Valley is presented for the first time. These greenstone ophiolites are tholeiites, alkali basalts and spilites of oceanic character. The Panjal volcanics which show pillow structures at many places were once considered subareal. Petrological and field evidence will be presented to show that they are in fact oceanic in character.

The sequence Panjal volcanics-Agglomeritic slate-Tanols taken together may mark the opening and then closure of an ocean (proto-Tethys), which developed on the rifted continental margin, what is now the Indo-Pak plate.

It is shown that the Panjal lavas are primary in nature and have been derived through a high degree of partial melting of pyrolite.

Keywords: Geochemistry, petrology, Panjal ophiolites.

C/103. Chaudhry, M.N. & Ghazanfar, M., 1986. A third suture in northwest Himalayas. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 23-24.

The MKT and MMT are two sutures so far identified in NW Himalayas and Northern Areas. In the region of Kaghan and Neelum Valleys the Main Boundary Thrust (MBT) constitutes an older Upper Palaeozoic-Lower Mesozoic suture-The Panjal suture.

The Panjal Volcanics - Agglomeratic slate-Tanol sequence tectonically is very significant and interesting and needs to be studied in greater detail. The Tanols which in Kashmir have Middle Palaeozoic age appear to indicate that the landmass of Kashmir-Hazara was developing series of disconnected basins marking the beginning of a phase of continental rifting which later led to the development of an incipient sea the Panjal sea.

The agglomeratic slate is a complex lithologic unit indicating a variety of environments including glacial and also containing an acid to intermediate volcanic suite representing a cratonic rift assemblage and an island arc affinity.

The presence of marine intertrappean limestones, pillow structures in Kaghan Valley and their tholeiitic to alkaline affinity indicates a suboceanic character for Panjal Volcanics.

The Tanol-Agglomeratic slate-Panjal sequence in the Kaghan Valley is enclosed between two major faults, which, together with others in between, constitute the Main Boundary Thrust (MBT) in this area. The MBT in Kaghan and Neelum Valley, Azad Kashmir, has therefore, acted as a suture along which representatives of a Palaeozoic incipient ocean floor developed in a rifted continental margin and were thrust onto the rocks of continental marginal affinity.

Keywords: Structure, tectonics, suture, Azad Kashmir.

C/104. Chaudhry, M.N. & Ghazanfar, M., 1987. Geology, structure and geomorphology of upper Kaghan valley, Northwestern Himalaya, Pakistan. Geological Bulletin, Punjab University 22, 13-57.

The part of Kaghan valley between Batakundi and Babusar pass (nearly 900 sq. km has been geologically surveyed and mapped at 1 : 50,000 scale for the first time. Besides a detailed field description of rock units, brief petrographic description, comments on metamorphism, origin of migmatites, granite gneisses and granites of the area, description of structure and geomorphology are included. The Pre-cambrian metasediments of Sharda Group are mainly calc-pelites and marbles, with subordinate psammities and minor orthoquartzites. These rocks belong to the upper amphibolite facies of regional metamorphism. The associated syntectonically folded para-autochthonous garnet-tourmaline granite gneisses and migmatites are S-type and are formed due to high grade metamorphism and anatexis of pelites and psammities, feldspathic psammities and metatuffs (?) of Sharda Group. The minor undeformed Tertiary granites are from late-to post-tectonic S-type anatexites. The amphibolites are mainly mafic and pre-tectonic. Thin metasedimentary layers of amphibolite also occur associated with calc-pelites. Burawai Synform and Basal Antiform and Bela Synform are the major fold structures of the area. These have themselves been deformed further. These structures are large more like structural basins and elongated domes. Geomorphically the higher parts of the area close to Kaghan and Kohistan watersheds show Alpine sculpture with glacial troughs and associated cirques, lakes and moraines. Relatively infrequent and patchy signs of glaciation also persist along the trunk valley of River Kunhar down to Kaghan township.

Keywords: Structure, geomorphology, Kaghan valley, Himalaya.

C/105. Chaudhry, M.N. & Ghazanfar, M., 1990. Position of the Main Central Thrust in the tectonic framework of the western Himalaya. Tectonophysics 174, 321-329.

Investigation in the western part of Northwest Himalaya have indicated a marked contrast in the stratigraphy, metamorphism and tectonics of the rocks north and south of Batal in the Kaghan valley and Luat in the Neelum valley. It is proposed that the Batal-Luat line represents the trace of the Main Central Thrust (MCT).

Contains 3 tables and 2 figures.

Keywords: Tectonics, MCT, Himalaya.

C/106. Chaudhry, M.N. & Ghazanfar, M., 1993. Some tectono-stratigraphic observations on northwest Himalaya, Pakistan. Pakistan Journal of Geology 1 & 2, 1-19.

Keywords: Tectonics, stratigraphy, Himalaya.

C/107. Chaudhry, M.N. & Ghazanfar, M., 1995. Geology and tectonic of the Kaghan valley. Abstracts, 2nd South Asia Geological Congress, Columbo, 36-37.

For further information consult Chaudhry and Ghazanfar, 1987.

Keywords: Tectonics, Kaghan valley, Himalaya.

C/108. Chaudhry, M.N. Ghazanfar, M. & Ahsan, N., 1994. Rates of sedimentation of Kawagarh Formation at Giah, Abbottabad-Nathiagali road and timing of uplift at K-T boundary in Pakistan. Pakistan Journal of Geology 2 & 3, 29-32.

It is postulated that lithified rates of sedimentation of Kawagarh Formation at Giah were on the average about 9 mm/1000 years, although Maastrichtian is not present at Giah section yet a substantial part of Maastrichtian is suppose to have been deposited but was removed through the process of lateritization. It is postulated that the Hangu Formation formed in upper most Maastrichtian, may have extended to lowermost Danian. Therefore, the Lockhart Formation is Danian in Age. The rapid regression resulting in the formation of Hangu Laterite started due to initial contact of Indian Plate with Kohistan Arc 67 ± 2 Ma prior to main collision between Indian and Asian Plate completely sandwiching Kohistan Island Arc at 55 Ma.

Keywords: Sedimentation, Kawagarh Formation, collision, Nathiagali, Abbottabad.

C/109. Chaudhry, M.N., Ghazanfar, M., Ahsan, N. & Masood, K.R., 1997a. Age, stratigraphic position and provenance of Murree Formation from Murree Hills and the syntaxial region. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 9-10.

The red sandstone, siliciclastic molasse sequence of Murree Formation with subordinate rudites, rare mans and limestone horizons has for a long time been regarded as Miocene in age and derived from Cuddapah and Dharwar rocks of Indian Peninsula.

On the basis of plant and vertebrate fossils, Pilgrim (1910) assigned an to Middle Miocene age to this Formation in Kohat, Potwar and Salt Range. In the Syntaxial Region, Calkins et al., (1975) assigned a possible Oligocene age to the lower part of the Murree Formation on the basis of an apparent gradational contact with the underlying Eocene rocks of their "Kalachitta group".

However Bossart and Ottiger (1989) on the basis of larger benthic foraminifera studied from four richly fossiliferous marine calcareous zones from within the Murree Formation assigned a Late Paleocene to Middle Eocene age to the Murree Formation. Two of these four horizons have been shown as fault slices of "Kalachitta group" of Paleocene to Lower Eocene age by Calkins et al., (1975). Calkins et al. (1975) as well as Ghazanfar et al. (1986) have mapped and described Paleocene and Eocene formations lying stratigraphically below the same Murree Formation which has been assigned a Late Paleocene to Middle Eocene age by Bossart and Ottiger (1989).

We examined in detail these four richly fossiliferous marine calcareous horizons. They have distinctly sheared contacts, often with fault breccias and at places with tectonic melanges. Nowhere is there a transitional contact between these marine fossiliferous, calcareous and marly horizons and the enclosing maroon to deep red siliciclastic continental deposits. Around Chahla Bandi in Neelum Valley near Muzaffarabad part of the Syntaxial region, underlying the Murree Formation with a slight unconformity represented by calcirudites occurs a complete and well defined sequence of formations of Lower Paleocene to Middle Eocene age namely Lockhart Formation, Patala Formation, Margala Hill Formation, Chor Gali Formation and Kuldana Formation.

Near Kuldana village in Murree Hills as well as on Kummi Spur near Balakot in Kuldana Formation of Middle Eocene age grades upwards conformably into the Murree Formation. Therefore in this region we regard the Murree Formation as Upper Middle Eocene since the underlying beds of Kuldana Formation are Middle Eocene in age.

A preliminary palynological study of the Murree Formation carried out for this paper from the Syntaxial Region rules out a Paleocene to Lower Eocene age for the Murree Formation.

Prior to 1975, Murree Formation was supposed to have been derived from the Cuddapah and Dharwar rocks of Indian Peninsula (Wadia, 1926). However Calkins et al, (1975) were the first to suggest the possibility that the

Murree Formation of the Syntaxial Region was derived from the rising mountains to the North. Chaudhry and Ashraf (1985) on the basis of petrographic studies of Murree rocks with special emphasis on lithoclasts and heavy minerals from Poonch area of Azad Kashmir conclusively demonstrated a specifically Pin Panjal source region for these rocks. Bossart and Ottiger (1989) on the basis of microprobe analysis of spinals suggested "Kohistan Island Arc" as one of the source regions. Author on the basis of detailed petrographic studies on the lithic arenites of Murree Formation from Poonch, Kotli, Neelum and Murree areas furnished concrete evidence that Murrees were derived from the lower grade meta-sediments and allochthonous plutons to the north from rising Himalayas and Pin Panjal, but contribution of resistant heavy minerals including spinals from the Peninsular region is not ruled out.

Keywords: Stratigraphy, provenance, Murree Formation, Murree Hills.

C/110. Chaudhry, M.N., Ghazanfar, M., Ahsan, N. & Masood, K.R., 1997b. Age, stratigraphic position and provenance of Murree Formation of North West sub-Himalayas of Pakistan and Azad Kashmir. Proceedings of the third GEOSAS Workshop, GSP, 81-91.

The red shale, sandstone clastic sequence of Murree Formation with rare marls and limestone bands has for a long time been regarded as Miocene age and derived from Cuddapah and Dharwar rocks of Indian Peninsula. More recently age from Late Palaeocene to Middle Eocene have been proposed for the Murree Formation of Western Syntaxial region between Balakot and Kwat. It has also been proposed that the source area for the Murree Formation lay to the north in the rising Himalaya rather than to the south in the Indian Peninsula. On the basis of field studies and paleontological data, it is suggested that this time transgressive unit is neither Paleocene nor Lower Eocene in age anywhere in NW Himalayas in Pakistan and Azad Kashmir. Palynological studies of the Murree Formation from the Syntaxial region and Murree Hills clearly indicate an age from Eocene to Oligocene. We suggest that a complete sequence from Hangu Formation of Danian age to Kuldana Formation of Middle Eocene age are also present in the southern part of the western limb of the Hazara Kashmir Syntaxis. A Miocene age has been generally accepted for this formation in Kohat-Potwar region on the basis of fauna and flora. We therefore suggest that the overall age range for the Murree Formation is from Middle Eocene to Early Miocene. We provide further evidence to reinforce the proposition that the dominant source area lay to the north in the rising Himalayas but insist that subordinate contribution from the Indian Peninsula is not ruled out. The source area to the north was composed of a sedimentary to low-grade metamorphic cover with volcanic horizons (pierced by granitoids) and ophiolites.

Keywords: Stratigraphy, provenance, Murree Formation, Murree Hills.

C/111. Chaudhry, M.N., Ghazanfar, M. & Ashraf, M., 1984. A plate tectonic model for northwest Himalayas, Karakorum and Hindu Kush lying between and adjacent to MMT and MKT. Abstracts, First Pakistan Geological Congress, Lahore, 16-18.

A new plate tectonic model based on a petrotectonic approach is being presented for the first time.

Tahirkheli et al. (1979) and Bard et al. (1979) have expressed their thoughts on the sequence of tectonic events in the NW Himalayas in Pakistan. They have indicated an initial ocean - ocean collision leading to the formation of an island arc in the north of the Indo-Pak plate. Later, according to these authors, this area was sutured to the south with the Indo-Pak and to the north with the Asian continents, and that the sequence of rocks constituting this island arc system is now located between two thrusts, the Main Mantle Thrust (MMT) in the south, and the Main Karakorum Thrust (MKT) in the north. They have called it the Kohistan Island Arc sequence.

Field studies in the Section between Shewa and Chitral, however, revealed a different picture. The petrotectonic zones in the section between Shewa and Chitral and adjoining areas are more or less symmetrically disposed on either side of the central layered intrusions which represent oceanic lithosphere (and not granulites, as proposed by Jan et al. 1980) There are southern and northern melanges, southern and northern volcanic-sedimentary zones (arcs) and the trench zone (so far well established only on the southern side).

In other sections, due to extensive thrusting and transport of crustal chunks, the situation has become much more complicated. However, the identification of various petrotectonic elements and their interpretation shows that they represent elements of the above mentioned petrotectonic units plus chunks and protrusions of IndoPak and Asian masses. The present model is therefore considered applicable to NW Himalayas, Karakorum and Hindu Kush lying between and adjacent to the MMT and MKT.

Petrotectonic relations also indicate an initial subduction of Tethyan plate under the Indo-Pak continent. This is contrary to the currently postulated northwards subduction, only.

The central layered intrusions represent oceanic lithosphere as against the idea that they form lower part of the so-called Kohistan Island Arc sequence (or that they are granulites). This latter term i.e. Kohistan Island Arc' may be used only for a narrower zone south of the MMT. The huge succession that has been previously called the Kohistan Island arc actually comprises a number of distinct petrotectonic provinces viz, from south, southern island arc, southern mélange zone, central layered intrusions, northern mélange zone and the northern island arc of Asian plate affinity.

The presently mapped or postulated position of MKT also needs correction. It should be placed south of the northern island arc and not to its north. In this paper chunks of sheeted complex, pillow lava and the latest elements of Tethys's sediment in the area are related. Extrusive and intrusive elements on the Indo-Pak plate are identified. The existence of a tension related alkaline province on the Asian mass and a northern trench zone are predicted.

Keywords: Plate tectonics, MMT, MKT, Himalaya.

C/112. Chaudhry, M.N., Ghazanfar, M., Ashraf, M. & Baloch, I.H., 1989. Observation on Precambrian orogeny and the age of the metamorphism in Northwest Himalaya, Pakistan. *Kashmir Journal of Geology* 6 & 7, 19-22.

Presence of Tertiary granites in Himalayas has clouded the earlier metamorphic history of Northwest Himalaya. Evidence from the relationship of various rocks units throws fresh light on the chronology and intensity of older metamorphic events which go back to 1840 ma. In particular, a Late Precambrian event rose to amphibolite facies. A Permo-Trias event of much lower intensity is also indicated.

Keywords: Orogeny, Tertiary, metamorphism, Himalaya.

C/113. Chaudhry, M.N., Ghazanfar, M., Ashraf, M. & Hussain, S.S., 1984. Geology of the Shewa-Dir-Yasin area and its plate tectonic interpretation. *Kashmir Journal of Geology* 2, 53-63.

Regional Geology of a large area between Shewa, Malakand, Warsak in the south and Hunza, Yasin, Chitral in the north through the valleys of Dir and Swat has been broadly described. Petrography and Modal compositions of the principal petrologic units are presented. Chemistry of some of these rocks has also been discussed. Petrotectonic significance of the principal rocks units in the area is assessed. A number of linear petrotectonic belts have been established running approximately east west between Shewa in the south and Yasin in the north. It is suggested that the mass of rocks enclosed in the Kohistan area between the Indian and Asian plates is not a single island arc sequence but comprises on the other hand at least two and possibly three island arcs and associated trenches. The extensive amphibolite, and complex is separate and does not represent the lower part of a single Kohistan island arc sequence as suggested in the past but comprise at least three distinctive belts two belts of obducted melanges with a central belt consisting of a possibly trapped portion of the Tethy's oceanic crust. Finally a southward subduction of the Tethyan lithosphere is postulated under the Indo-Pak plate in contrast to north directed subduction of the Indian plate as suggested in the past. A sequence of different subduction zones is suggested.

Keywords: Petrology, tectonics, Malakand, Hunza, Chitral.

C/114. Chaudhry, M.N., Ghazanfar, M., Baloch, I.H., Adil, M., Ahsan, N. & Chauhan, F.A., 1995. Sedimentology, depositional environment and economic potential of Datta Formation of Early Jurassic age of Attock-Hazara fold and thrust belts. In *Abstracts first Nepal Geological Congress*, 15-16.

For further information, consult Chaudhry, Chauhan and Ghazanfar, 1994.

Keywords: Sedimentology, deposition environment, Jurassic, Datta Formation, Attock.

C/115. Chaudhry, M.N., Ghazanfar, M. & Hussain, M.S., 1989. Petrology, metamorphism and origin of agglomeratic slates in Kaghan, Mansehra District, Pakistan. *Punjab Bulletin, Punjab University* 24, 61-70.

The Agglomeratic Slate in Kaghan Valley is a lithologically heterogeneous unit. It is composed of graphitic schist, micaceous quartzite, feldspathic quartzite, pelitic schist, feldspathic chlorite calcite schist, marble and metaconglomerate. The graphitic schist and feldspathic quartzites contain volcanogenic material. In Kashmir it contains well defined volcanic horizons. The unit was deposited under varying environmental conditions, continental, lagoonal and marine in a deepening cratonic rift, and represents continuation and, at places a replacement of Tanawals of Kashmir.

Keywords: Petrology, metamorphism, slates, Kaghan, Mansehra.

C/116. Chaudhry, M.N., Ghazanfar, M., Hussain, S.S. & Dawood, H., 1995. Problems of petrotectonic modelling of suture zones in northern Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 12-15.

The southern suture in northern Pakistan, popularly known as the Main Mantle Thrust (Tahirkheli, 1979) is as a whole composed predominantly of partially to completely dismembered ophiolitic suite. This suture zone is the true equivalent of the Indus- Tsangpo suture zone. Suturing of the Kohistan Island Arc to Indo- Pak Plate along this zone occurred at around 65 ma (Spencer, 1993; Smith et al., 1994; Chaudhry et al., 1994) to 35 ma (Treloar et al., 1995). The lithologies exposed are harzburgite tectonites derived from depleted mantle, dunites, peridotites and wherlites derived from upper mantle cumulates, layered and isotropic gabbros, sheeted dykes, pillow lavas, ribbon cherts, pelagic clays as well as flyschoid sediments. Because of extensive dismemberment it is rare to find all these lithologies in a single section. This has led to divergent petroTECTONIC interpretations based heavily on geochemical consideration without regard to structural or geological constraints. The sections composed of plutonic ultramafic and mafic rocks have generally been interpreted as arc related and emplaced at the base of amphibolites. One or another part of a particular section on the basis of major or trace elements alone has been assumed are related without considering the entire section and structural relations of the internal units.

Keywords: Tectonics, petrology, suture zones, Pakistan.

C/117. Chaudhry, M.N., Ghazanfar, M., Hussain, S.S., Dawood, H. & Spencer, D.A., 1998. Location of the Main Central Thrust and the subdivision of the Indian plate Himalaya in the Lower Swat region and Malakand region, Northern Pakistan. Geological Bulletin, Punjab University 33.

Keywords: Indian plate, MCT, Swat, Himalaya.

C/118. Chaudhry, M.N. Ghazanfar, M., Meier, A., Ramsay, J.G., Spencer, D. & Wahrenberger, C., 1991. New stratigraphic and fossil finds in the Higher Himalayas of the upper Kaghan valley, NE Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 29.

A collaborative project between the EHT and Punjab University during the summer of 1990 has led to important new discoveries bearing on the stratigraphic and structural relationships of the various rock groups marking up the Higher Himalaya Unit of NE Pakistan.

A coherent three unit stratigraphic subdivision appears to hold over most of the region. A basement consists of granitic gneiss which is overlain by a group of meta-pelitic to semipelitic sediments of original greywacke aspect which, although strongly recrystallized and locally granitized, still show traces of graded bedding with consistent younging directions away from the granitic basement. Although the relationships between these units is clear, suggesting that the granitic gneisses were metamorphic basement to a regionally overlapping group of sediments, no clear angular discordance has yet been discovered on outcrop scale.

The two basement groups are overlain by a thick series of calcareous pelites lithologically similar to the "schists lustrés" of the European Alps, and interpreted as a sedimentary cover. These rocks locally contain good sedimentational "way up" structures, synsedimentary extension faults and fossils (stromatolites, trace fossils). Considering the amphibolites metamorphic grade of these rocks, the preservation of fossil is remarkable. The base of the cover succession is marked by extensive thick sheets of amphibolite locally showing deformed amygdalites

suggesting that they were initially basaltic lavas, and thinner sheets of amphibolite of similar petrographic aspect are found throughout the succession.

As yet no firm ages have been placed on these stratigraphic units. However, lithological correlations with rocks of Swat, the Srinagar Basin and Ladakh suggest that the granitic gneisses are probably of Pre-Cambrian age. The metapelites are of Lower Paleozoic age and the calc-schists and associated basaltic lavas may be correlated with various basic volcanic rocks of Paleozoic and younger age (perhaps some being equivalent to the Panjal Trap). The overall distribution of these three units is suggestive of the presence of large scale recumbent fold nappes, but this pattern is complicated by the intensive development of later superposed fold phases and the formation of regional tectonic dome and basin structures.

Keywords: Stratigraphy, metamorphic rocks, tectonics, palaeontology, Kaghan valley, Mansehra.

C/119. Chaudhry, M.N., Ghazanfar, M. & Mian, M.A., 1983a. A plate tectonic model for Northwest Himalayas. International Seminar on Stratigraphy of Pakistan, Lahore, 1-7.

See Chaudhry, Ghazanfar and Ashraf, 1984.

Keywords: Plate tectonics, Himalaya.

C/120. Chaudhry, M.N., Ghazanfar, M. & Mian, M.A., 1983b. A plate tectonic model for Northwest Himalayas. Kashmir Journal of Geology 1, 109-112.

See Chaudhry, Ghazanfar and Ashraf, 1984.

Keywords: Plate tectonics, Himalaya.

C/121. Chaudhry, M.N., Ghazanfar, M. & Qayyum, M., 1986. Metamorphism at the Indo-Pak plate margin, Kaghan valley, District Mansehra, Pakistan. Geological Bulletin, Punjab University 21, 62-86.

This paper presents for the first time mineral assemblages, textures, structures, index mineral zones, metamorphic facies and metamorphic grades of the rocks lying between Paras and Babusar Pass, Kaghan valley. The metamorphic rocks are regionally metamorphosed and belong to a medium pressure type metamorphic series. The rocks range from unmetamorphosed units to high-grade metamorphic units e.g. from greenschist facies to high amphibolite facies. In terms of index minerals, they range from biotite to sillimanite zones and in terms of metamorphic grades the rocks range from very low grade to high grade metamorphism.

Keywords: Plate tectonics, barrovian metamorphism, structure, Kaghan valley.

C/122. Chaudhry, M.N., Ghazanfar, M., Ramsay, J.G., Spencer, D.A. & Qayyum, M., 1992. Northwest Himalaya-A tectonic subdivision. Abstracts, First South Asia Geological Congress, Islamabad, p.9.

Keywords: Plate tectonics, Himalaya.

C/123. Chaudhry, M.N., Ghazanfar, M., Ramsay, J.G., Spencer, D.A. & Qayyum, M., 1994. Northwest Himalaya-A tectonic subdivision. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia-I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 175-184.

Detailed geological mapping of the valleys of Neelum, Kaghan, Indus, Swat and Dir has afforded numerous excellent sections across the Northwest Himalaya. It has now become possible to characterize the tectonostratigraphy in these areas and define the major thrusts bounding the main tectonic units. The location of the Main Central Thrust (MCT) near Naran in the Kaghan Valley and its extension into the Neelum (to the east) and Swat valley (to the west) as finally formalized the correlation and extension of the transverse subdivision of the

Himalayas from India and Kashmir into Pakistan. This paper presents a systematic account of the stratigraphy, metamorphism and tectonics of the Himalayan subdivisions in Pakistan. The four major zones of the Himalayas, the Tethyan or Tibetan Himalaya, the Higher Himalaya, the Lesser Himalayas and the Sub-Himalaya have now been followed from the Neelum Valley, Azad Kashmir, through the valleys of Kaghan and Swat into Dir. The presence and nature of the northernmost belt of the Tethyan Himalaya is also established. The separation of the various tectonic zones of the Himalaya paves the way for synthesis and correlation of local stratigraphic, metamorphic and structural studies along various sections and their correlation with researches in Kashmir, Kumaun, Nepal and further east.

Keywords: Plate tectonics, tectonostratigraphy, structure, Kaghan, Indus, Swat, Dir, Himalaya.

C/124. Chaudhry, M.N., Ghazanfar, M. & Spencer, D.A., 1996a. Main Central Thrust in northwest Himalaya, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 31-32.

The transverse subdivision of the Himalayas, established in Eastern and Central Himalaya in India and Nepal, could not be fully extended to Kashmir and adjoining Pakistan since these areas have remained unmapped until very recently. In addition, these areas constitute the Western Himalayan Syntaxial Region characterized by sharp bends in strike with extensive imbrication and strike slip faulting that results in the attenuation or even elimination of some units. This, coupled with lack of mapping until very recently, made it difficult to extend geologic or tectonic trends from India and Eastern Kashmir into Western Kashmir and Pakistan, which resulted in various workers trying to connect the MCT trend from India into Kashmir with Panjal Thrust (PT) or MBT (Gansser 1964; Sinha 1989). This view was generally accepted for over two decades. Acceptance of such a view would lead to combining together in one block of terranes, which have entirely different tectonostratigraphic, tectonometamorphic, tectonomagmatic and structural characteristics.

Yeats and Lawrence (1984) regarded the Raikot Fault on the western margin of the Nanga Parbat Haramosh Massif as a terminal tear fault of the Main Central Thrust. Tahirkheli (1992) demarcated a NE-SW Trending Shon argali Thrust as the "MCT" between Astor and Ratta. In our opinion Raikot and Shon argali faults run entirely within the HHC block (see Spencer, 1995 for full review problems of locating the MCT in Pakistan).

Heim and Gansser (1939), while working in Garhwal and Kumaun, defined a major thrust between the sedimentary formations and moderately metamorphosed rocks. This thrust was subsequently formalized as the Main Central Thrust (MCT). They also described the inverse metamorphism from these areas. However, they did not recognize tectonic break between Mesozonal and Katazonal rocks. Sinha (1989) has followed Gansser (1964) in defining the Main Central Thrust (MCT) in the Central Himalayas. Valdiya (1984) based on an abrupt break in the grade of metamorphism and on the change in petrological composition of the rocks of the central crystalline, defined a thrust plane (MCT) at an even higher stratigraphic level (at the base of kyanite-sillimanite bearing rocks) than the one defined by earlier workers. He named this thrust as the Vaikrita Thrust.

A large number of Himalayan workers now believe that the MCT is an intracontinental thrust which demarcates the boundary between the Lesser and Higher Himalayas that resulted in the considerably thickening of the continental crust. It is a north dipping generally 5 to 20 km thick low to high angle shear zone associated with mylonitisation, a strong stretching lineation and strong foliation. It is also marked by the inverse metamorphism and a sudden jump in metamorphic grade from greenschist to upper amphibolite facies with a differing tectonic style on either side of the shear zone (Brunel, 1986; Valdiya 1984; Ghazanfar and Chaudhry et al. 1994).

The Main Central Thrust first located in the Kaghan and Neelum Valleys (Ghazanfar and Chaudhry, 1986) now extended across the entire NW Himalayas of Pakistan is a 500k to 5km thick zone of ductile deformation with the development of a strong schistosity is oblique but is being rotated into the shear zone. The ductile shear zone develops in the turbidites of Kaghan, as well as in the Malakand area. In zones of strong deformation within the turbiditic sequence, bedding is replaced by a strong mylonitic fabric. Therefore S₀ and S₁ have both been rotated into parallelism with the shear zone deformation. The thicker arenaceous beds are by contrast more folded and boundinaged. The mineral stretching lineation is strong and parallels the shear zone. Sheath folds are also present with eye-like structures developed due to fold hinges, which are curved and rotated towards parallelism with the shear zones. All kinematic indicators suggest a top to the south sense of shear.

There is a significant PT break on either side of ductile deformation. Rocks to the south of MCT in the Malakand and Swat fall in lower greenschist facies while rocks in Kaghan and Western Kashmir fall in middle greenschist facies. The rocks lying to the north of the proposed MCT in Western Kashmir and Pakistan fall in upper amphibolite facies (kyanite-sillimanite grades) and local eclogite facies. The structure style on either side of MCT is also very

different. The rocks to the north (HHC) occur as elongated structural basins and domes with fold interference pattern (Types 1 and 3) with major axis trending from NNE to the east of Besham Syntaxis and NNW to the West of Besham Syntaxis. The deformation is ductile with hardly any apparent fault. The rocks to the south of MCT generally trend EW. The deformation is brittle and is comprised of tight folds and abundant thrust comprising a schuppen structure.

Based on this work, both the Lesser and Higher Himalaya are now therefore recognizable in the NW Himalaya and are continuations of the better known LH, MCT and HH last seen in India.

Keywords: Plate tectonics, MCT, MMT, MKT, Himalaya.

C/125. Chaudhry, M.N., Ghazanfar, M. & Spencer, D.A., 1996b. Evidence for Pre-Mesozoic affinity of the Karakoram Himalaya to the Indian Plate, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 33-34.

The Karakoram Himalaya form a distinctive topographic and mountainous range in Central Asia. Geologically, they are classified as part of the Eurasian Plate, a collage of terranes into which the Indian Plate collided to form the Himalayan mountain range at times estimated from 65 to 45 Ma.

Recent mapping and traverses of the Karakoram Himalaya lead us to suggest that there is distinctive stratigraphical correlation between the units of the Karakoram Himalaya (Eurasian Plate) and the Himalaya (Indian Plate). In fact, we suggest that these similarities are so strong that the likelihood should be considered that the Karakoram Himalaya and the Indian Plate were until the early Mesozoic, attached as part of the same block or plate. With the closure of Paleo-Tethys and the opening of Neo-Tethys, a rifted piece of the Indian Plate (Karakoram Himalaya) subsequently broke away from Gondwanaland (and the juvenile Indian Plate) and was subjected to a passive collision, with eventual suturing, to Eurasia. The fact that the pre-collisional history of the Karakoram Himalaya is known to be comparable to the Lhasa block of Southern Tibet in the east (Searle, 1991) and the Helmand Block of eastern Afghanistan to the west (Blaise et al., 1977; Stocklin, 1977; Wolfart and Wittekindt, 1980), suggests that a distinctive belt with a similar pre-Mesozoic stratigraphy can be traced, north of the Indus Suture, from west to east of the Karakoram Himalaya. Here we provide evidence of a north to south correlation with the Indian Plate. For discussion purposes, we also suggest a new terminology for the Karakoram Himalaya with the implications that this has for its tectonic history. The classification that we have used is based on that of the Himalayan subdivisions (i.e., Higher Himalaya and Lesser Himalaya). We suggest that in the Karakoram the distinctive units of the Higher Karakoram and Lesser Karakoram can be found and, more importantly, be correlated to their Indian Plate equivalent (Table 1 and 2).

Table 1: Stratigraphic Correlation between the Higher Himalaya (Swat-Besham, Kaghan- Azad Kashmir and the Higher Karakoram (Hunza).

Lower Swat & Besham		Kaghan & Azad Kashmir		Hunza Valley	
Alpurai Group	Tilgram Fm Calc-pelite & marble with minor pelite Salampur Fm Pelite-psammite Turbite with amphibolite sheets	Burawai Group	Bans Formation (Pelites) Seri Fm Thick sequence of calc-pelite & marble with amphibolites Old Battakundi Fm Pelites psammite Turbite with amphibolite sheets	Baltit Group	Ganesh Fm marble, calc-pelite and amphibolite
Pacha Group	Swat granite Manglaur Formation Pelite-psammite turbidites Migmatites, minor, marble, calc schist & graphitic schist Kolangi Formation	Purbinar Group	Saiful-Muluk Granite Lulu Sar Formation pelite-psammite minor marble & graphitic schist Gittidas Granite		Minapin Formation Pelitic-psammite with minor marble & graphitic schist. Hasanabad Granite-

	(migmatites)		Jalkhad Nar Formation migmatites & enclaves		migmatite with meta sedimentary enclaves & horizons
	Targhao Granite Gneiss (granite gneiss & migmatite)		Ratti Gali Granite Gneiss (granite gneiss & migmatite)		

Table 2: Stratigraphic Correlation between the Lesser Karakoram of western Pakistan and the Lesser Himalaya (Peshawar Basin)

Zait & Parpish Formations	Bampokha Formation
Dolomite limestone; limestone	Limestone/dolomite
Carboniferous/Triassic	Carboniferous/Triassic?
Lun shales	Jafar Kandao Formation
Shale, sandstone and limestone (Late Devonian)	Limestone, dolomite & quartzite (Devonian)
	Girarai Formation
	Pelite, calc-pelite & marble (Age unknown)
Broghil Formation	Panjpir Formation
Slate, limestone, dolomite, quartzite (Ordovician/ Silurian?)	Slate, limestone & dolomite (Silurian)
	Misri Banda Quartzites
	Ordovician/Cambrian (?) S
Chitral Slates	Attock Slates
Slate, wackes, quartzites and some marble beds.	Slates, wackes, quartzites and some marble beds
Pre-Cambrian	Pre-Cambrian

Keywords: Plate tectonics, Eurasian plate, stratigraphic correlation, Karakoram, Himalaya.

C/126. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A, Hussain, S.S. & Dawood, H., 1995a. Higher Himalaya of Pakistan- A tectonic stratigraphic review. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, Switzerland.

Mapping of extensive areas in Neelum, Kaghan, Besham, Lower Swat, Malakand and Dir has made it possible to delineate the Main Central Thrust, MCT, and define the area of the Higher Himalaya Crystalline, HHC, slab in Pakistan and Azad Kashmir. This paper presents a first time integrated account of the stratigraphy, metamorphism and deformation of this major division and hinterland area of the Northwest Himalaya. Between Indus Suture, or the MMT, to the north and MCT in the south the HHC slab, extends from Bajaur on the Pak-Afghan border in the west to across the Neelum Valley of Kashmir in the east. The slab has a variable width. It is widest in the area of Nanga Parbat Syntaxis and is attenuated in the area of Hazara Kashmir Syntaxis.

Stratigraphically the Higher Himalaya in Kaghan, Besham and Swat comprises the oldest exposed rocks of Pakistan. The basement is composed of a lower autochthonous to parautochthonous granitoid-migmatite complex with metasedimentary enclaves and abundant pegmatites, a middle pelite-psammite sequence with paragneiss horizons of garnetiferous quartzofeldspathic rocks, abundant pegmatites, intrusive bodies of granite and contact migmatites and an upper pelite-psammite package in kyanite-sillimanite grades with subordinate pegmatites and granites. Marble, amphibolite and graphitic pelite are minor lithologies. It is overlain by two unfossiliferous cover sequences. The First cover comprises a thick calcpelite, marble sequence with an overlying pelites unit in Upper Kaghan and an underlying turbidite unit with interbedded amphibolites in Lower Swat. The basic volcanics show a stratigraphic upward jump into the lowermost part of the overlying calcpelites in the area of Upper Kaghan. We suggest that the basement and the First Cover are Proterozoic in age although the age of the cover in Kaghan is debated and has also been suggested as late as Triassic. The Second Cover comprises low-grade graphitic pelites, calc pelites and marbles, which mainly crop out below the Indus Suture. On the basis of dates on cross cutting granite veins the Second Cover may also be Late Proterozoic or it may be Palaeozoic and are here interpreted as the Tibetan Tethyan sediments elsewhere lying unmetamorphosed to the north of the HHC. However, both the age and affinity of these Second Cover rocks is debated. The basement granitoids and the overlying First Cover rocks together form the crystalline HHC slab, and are both characterised by metamorphism in the upper amphibolite facies. The metamorphism shows

sudden downward jumps to greenschist facies both in the north across an extensional detachment (Trans-Himadri Fault, THF, or the Zaskar Shear Zone) into the Tethyan cover and in the south across MCT into the Lesser Himalaya. Eclogites have been reported from the Besal area of Upper Kaghan which indicate $T=650^{\circ}\text{C} \pm 50$ and $P=15$ to 16 Kbars corresponding to a depth of 55 to 60 km. Elsewhere although the temperature was about the same the indicated depth ranged between 35 to 45 km. Whereas the whole of the HHC slab is metamorphosed in the upper amphibolite facies the conditions tend to become more intense structurally downward and the cores of major domes such as Besal, Besham and Kolangi may exhibit ultrametamorphism with profuse migmatization and generation of anatectic granites. The common model based on cooling ages considers the dominant metamorphism Himalayan in age and explains the PT conditions by burial of the Indian Plate under Kohistan consequent upon collision between India and Kohistan ($\text{Ca } 50 \text{ Ma}$) and its subsequent imbrication. Extensive mapping in the field has however not revealed evidence of thrust imbrication in the terrain of Higher Himalaya. The model as it stands also fails to explain such features as greenschist facies metamorphism of Indus Suture mélange and of the underlying low grade Tethyan cover as well as preservation and age of blue schist and the short time interval between collision and exhumation. Numerous evidences have been cited to suggest that the Higher Himalaya slab suffered at least one pre-Himalayan metamorphism, here suggested to be upto the amphibolite facies upon which a variable Himalayan metamorphism has been imprinted. Deformation in the HHC slab is characterised by the north-south trending kilometric scale domes and basins and a ductile regime. These structures are unique to the Higher Himalaya being truncated by the MMT and MCT in north and south. The Kohistan area and the Lesser Himalaya (except for the HKS) in the south both show east-west trends and a schuppen structure under conditions of increasing brittle deformation.

Keywords: Tectonics, stratigraphy, MCT, Higher Himalayan crystallines, Himalaya.

C/127. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A., Hussain, S.S. & Dawood, H., 1995b. The division between Lesser and Higher Himalaya in Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 24-26.

Lack of mapping on the ground, presence of an island arc in this section, the presence of Nanga Parbat and Hazara Kashmir Syntaxis and the continuing Kashmir dispute had complicated the task of tectonic correlation between the Pakistani northwest Himalaya with the Himalaya to the east. With the mapping of Neelum, Kaghan and Swat areas the stage was set for the delineation of the MCT for the subdivision of the Lesser and Higher Himalaya in Pakistan and correlate it across Kashmir to Kumaun and Nepal Himalaya. The MCT has now been defined from Luat in Neelum Valley and Kashmir across Batal in Kaghan through Malakand and Swat to Dir and Bajaur in the extreme west of Pakistan the HHC and the Lesser Himalaya stand differentiated.

The MCT is Characterized by a kilometric zone of milonites in the greenschist facies with a general top to the south sense of thrusting, The Major Boundary Thrust (MBT) is distinguished by major difference in lithostratigraphic packages on both sides, a sudden jump in metamorphic grade and a marked difference in tectonic style.

The HHC slab extend from Neelum Valley to Bajaur is characterized by a turbiditic basement sequence extensively migmatized in the lower part and a calc-pelitic cover sequence. A second low grade sequence appears in synclinal inliers on the high rocks of HHC. It appears the same low grade rocks appear between the suture zones and the Indian Plate in upper Kaghan as well as Banna area of Allai.

Keywords: Lesser Himalaya, Higher Himalaya.

C/128. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A., Hussain, S.S. & Dawood, H., 1999. Evidence for Pre-Mesozoic affinity of the Karakoram Himalaya to the Indian plate, Northern Pakistan. Geological Bulletin, Punjab University 33 & 34, 1-7.

Consult the Chaudhry et al., 1996b above for further information.

Keywords: Plate tectonics, Eurasian plate, stratigraphy, Karakoram, Himalaya.

C/129. Chaudhry, M.N., Ghazanfar, M., Spencer, D.A., Hussain, S.S. & Dawood, H., 1997. The higher Himalaya in Pakistan-A tectonicstratigraphic synopsis. Geological Bulletin, Punjab University 31 & 32, 21-41.

Following the demarcation of the Main Central Thrust (MCT), the mapping and tectonostratigraphic characterisation of the Higher Himalaya across northern Pakistan and Azad Kashmir has been made for the first time. This slab has a variable width. It is widest in the area of the Nanga Parbat Syntaxis and is attenuated in the region of the Hazara-Kashmir Syntaxis. This paper presents an integrated account of the stratigraphy; deformation and metamorphism of this major tectonic division and hinterland area of the Northwest Himalaya. The Higher Himalaya is comprised of a lower basement and an upper cover unit. The basement is constituted predominantly of granitoids, migmatites, pelite schists and micaceous quartzites with minor calc-pelite gneisses, marbles and discordant amphibolites. The cover consists predominantly of calc-pelite gneisses, with subordinate marbles and pelite schists and extensive amphibolites at its base. The Higher Himalaya is characterised by the development of kilometric scale elongated structural basins and domes with a fold interference pattern (types I & 3) that trend either northeast-southwest (Kaghan), north-south (Besham) and north northwest-south southeast (Swat). These fold trends are truncated at a high angle to the south across the Main Central Thrust in the Lesser Himalaya and to the north by the Tethys and Indus Suture Zone rocks. The nature of deformation in the Higher Himalaya is ductile. The rocks of the Higher Himalaya have been metamorphosed to upper amphibolite facies or kyanite-sillimanite grade. However around Besal in Upper Kaghan and at places in Upper Neelum valley the rocks have suffered eclogite facies metamorphism. The Pressure-temperature estimates by various workers give generally upper amphibolite facies metamorphism which range from 600° to 700° C at 7-11 Kbars. However, the basement and cover lithologies of the Besal area in Upper Kaghan valley have undergone eclogite facies metamorphism at T=65±5°C and P=15-17 Kbars, corresponding to depths of 55 to 65 kilometers. To the south of the Higher Himalaya across the Main Central Thrust, the Lesser Himalayan rocks take a marked downward jump in metamorphic grade to greenschist facies. Similar observations also were found to the north in the Tethyan lithologies which overlie the HHC slab or occur as fault slivers close to the suture.

Keywords: Mapping, tectonics, stratigraphy, MCT, Higher Himalaya.

C/130. Chaudhry, M.N., Ghazanfar, M. & Walsh, J.N., 1993. The Panjal sea, Kashmir Hazara microcontinent and Hercynide geology of Northwest Himalaya. Abstract Volume, 8th Himalaya-Karakoram- Tibet Workshop, Vienna, 13.

This paper discusses the tectonic significance of the Permian Panjal Volcanics Kaghan Valley on the basis of an overview of geology, field relations and associated rocks. It is proposed that more than 400-km long rift related, generally terrestrial Panjal suite developed into an incipient ocean, the Panjal Sea with continental to oceanic transitional to oceanic crust in Kaghan area. Major element, trace element and R.E.E. characteristics appear to corroborate this conclusion.

North of this incipient ocean lay the Kashmir Hazara micro-continent. The Permian Panjal Sea which developed during rifting of Gondwanaland closed during Triassic when the overlying Malakand limestone was deposited and Neo Tethys started opening to the north of the Kashmir-Hazara microcontinent.

Keywords: Tectonics, Panjal volcanic, Kaghan, Himalaya.

C/131. Chaudhry, M.N., Ghazanfar, M., Walsh, J.N. & Hussain, M.S., 1992. The Panjal Sea, Kashmir-Hazara microcontinent and Hercynid geology of Northwest Himalaya in Pakistan. Pakistan Journal of Geology 1, 81-99.

Consult the previous paper for further information.

Keywords: Tectonics, Panjal volcanic, Kaghan, Himalaya.

C/132. Chaudhry, M.N., Ghazanfar, & Zaka, K.J., 1992. Petrology, economic geology and origin of Siwalik sandstone from Northern and Western Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p. 54.

Keywords: Petrology, sandstone, siwaliks.

C/133. Chaudhry, M.N., Hassan, G. & Zaka, K.J., 1992a. Researches into geotechnical, petrographic and chemical aspects of Indus gravel and sand as concrete aggregate. Abstracts, First South Asia Geological Congress, Islamabad, p.9.

River Indus, the life line of Pakistan, is the single most important and major potential source of water and power in the country. Most of the future high dams, barrages, thermal and nuclear plants and bridges will be located on Indus river. This will require billions of cubic meters of concrete. The value of aggregate alone will run in billions of rupees. Aggregate may limit the strength of concrete, its durability and structural performance. Aggregate has generally been considered as inert material. In actual place, aggregate is far from inert in its characteristics and exerts a profound influence on the performance and durability of concrete. Indus gravel have shown excellent physical characteristics and are designated as most suitable for concrete. However, in service behaviour and mortar bar tests over extended periods have shown the development of significant distress. The causes of distress have been identified as alkali silica and alkali silicate reaction (A.S.R, A.St.R) between meta wackes, metagreywackes, micro-fractured quartzite and meta volcanics and the high alkali cement. Notwithstanding such evidence the controversy still rages as to the actual and relative causes of deterioration between physical and environmental factors and reactivity of aggregate.

This paper is an outcome of researches to resolve this controversy and to present a proper evaluation of various geotechnical, petrographic, mineralogical and chemical characteristics of the Indus aggregate. In the opinion of the authors, the ILS.R. and A3t.R. potential of these aggregate is a significant factor to be considered for future projects and it is proposed that this aggregate may be used either with low alkali cement (total alkalis less than 0.5%) or with the addition of appropriate quantity of pozzolanous additive or slag cement.

Keywords: Aggregate, petrography, geotechnical, Indus gravel, sand.

C/134. Chaudhry, M.N., Hassan, G. & Zaka, K.J., 1992b. Researches into geotechnical petrographic and chemical aspects of Indus gravel and sand as concrete aggregate. Pakistan Journal of Geology 1, 1-14.

Consult the preceding account for details.

Keywords: Aggregate, petrography, geotechnical, Indus gravel, sand.

C/135. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1992a. The Lithostratigraphic framework of North-West Himalaya, south of the Main Mantel Thrust along Mingora-Daggar section, Swat, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.54.

Consult the following account.

Keywords: Stratigraphy, MMT, Mingora, Himalaya.

C/136. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1992b. The Lithostratigraphic framework of North West Himalaya, south of the Main Mantel Thrust along Mingora-Daggar section, Swat, Pakistan. Pakistan Journal of Geology 1, 29-41.

The Mingora-Daggar section constitutes the northern edge of the Indo-Pak plate west of Besham syntaxis. The rocks exposed in the area range in age from Precambrian to Eocene. Manglaur group is the oldest rock unit of the area and is divided into lower Pacha formation and an upper Ilam granite gneiss formation. Pacha formation is Precambrian in age, falls in upper amphibolite facies and is composed predominantly of psammite and pelite with smaller proportion of marble, calc-silicate marble, graphitic schist, amphibolite, migmatites and old basement non porphyritic garnet tourmaline granite gneisses outside the area. Ilam porphyroblastic granite gneiss intrudes Pacha Formation and is probably Precambrian in age. Other granitic rocks are syn to post tectonic and Tertiary in age. One of these syntectonic bodies mapped is Tertiary Amlukdarra tourmaline garnet microgranite gneiss. Alpurai group of Precambrian age overlies the porphyroblastic Ilam granite gneiss and is divided into lower Salampur formation composed of pelite psammite interbedded with abundant amphibolites and an upper Tilgram formation comprised basically of banded garnetiferous calc-pelite and marble with subordinate graphitic garnetiferous schist and

garnetiferous amphibolites. Dagar formation is comprised predominantly of low grade graphitic schist and phyllite with subordinate phyllitic pelite, marble, calc schist and green schist. Kazmi et al (1984) named this unit as Saidu schist and regarded its age as lying between Palaeozoic and Mesozoic. This formation is regarded here as Precambrian in age. Bampokha group is Lower to Middle Palaeozoic in age falls in greenschist facies of regional metamorphism and is divided into Girarai formation and Tursak formation. The Girarai formation is composed mainly of calc-pelites, light gray to gray marble and subordinate graphitic schist. The Tursak formation is composed dominantly of white and bicoloured white and gray marble with subordinate calc-pelites, pelites and graphitic schist/phyllite. The Cretaceous-Tertiary Mingora ophiolitic mélange comprises tectonic blocks of greenschist, greenstone, talc-carbonate, amphibolite, gabbro, serpentinite, peridotite, harzburgite, siliceous and graphitic metasediments and a few Assilina and Nummulite bearing (Eocene) carbonate slices.

Keywords: Stratigraphy, MMT, Mingora, Himalaya.

C/137. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1992c. Position of the Main Central Thrust and sub-division of Himalaya in Swat. *Pakistan Journal of Geology* 1, 59-65.

Geological investigations and large scale mapping in Swat area of Western Himalaya has now made it possible to precisely locate the position of the Main Central Thrust (MCT). There is a clear and well-marked contrast in the tectonic style and degree of metamorphism and gross stratigraphy to the north and south of this line. The delineation of the Main Central Thrust in the area under study now makes it possible to extend the tectonic zones of Himalaya in Neelum and Kaghan to the West of Indus River. See also the following one.

Keywords: Tectonics, MCT, Himalaya.

C/138. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1994. Position of the Main Central Thrust and subdivision of Himalayas in Swat, Pakistan. In: Ahmed, R. & Sheikh, A.M. (Eds.), *Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992*. Hydrocarbon Development Institute of Pakistan, Islamabad, 208-211.

Detailed fieldwork recently carried out in southern Swat and Malakand has made it possible to locate the position of the Main Central Thrust (MCT). Across this very important line there is a marked contrast in tectonic style, stratigraphy as well as metamorphism.

Between the Main Central Thrust (MMT) to the north and MCT to the south lies the Higher Himalayan crystalline block. This deep-seated block was rapidly uplifted between these two major thrusts due to collision between Indo-Pak plate and Asian plate thus exposing some of the deepest rocks of the Northwest Himalaya in Pakistan. On the basis of delineation of these major structural lines, the Himalaya in Swat has been subdivided into Kohistan Himalaya, Tethyan Himalaya, Higher Himalaya and Lesser Himalaya.

Keywords: Tectonics, MCT, Himalaya.

C/139. Chaudhry, M.N., Hussain, S.S. & Dawood, H., 1997. Massive sulphide and porphyry mineralization associated with Gawachi back arc basin, Chitral, Ishkuman, Chatorkhand, Gakuch, Yasin, Gilgit and lower Hunza valleys. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 3p.

Geology, petrology and mineralization of the MKTZ ophiolites. Rakaposhi volcanics and associated rocks of the Yasin Group have been studied in Shishi Gol. Drosh and Mirkhani areas of Chitral and Ishkuman. Chatorkhand-Gakuch. Yasin, Gilgit river valley and lower Hunza river valley. On the basis of tectonostratigraphic elements and tectonomagmatic characterisation of the mafic and ultramafic rocks and associated sediments, a back arc basin named here as the "Gawachi back arc basin", has been defined by us. This basin has previously been considered by many workers as simply top of the Kohistan island arc. The Gawachi back arc basin, is composed of Rakaposhi volcanic complex and Yasin Group of middle Jurassic to Cretaceous age. These rocks have been intruded by plutons of the Kohistan arc. These plutons are sodic deformed plutons, potassic deformed plutons and potassic undeformed plutons (Treloar et al. 1989. Bard 1983).

The Rakaposhi volcanics have been classified on the basis of field characteristics, petrography and geochemistry. Most of the rocks are either basalts or basaltic andesites. Hardly any proper rhyolite could be found. Subordinate

lithologies defined on the above basis are andesites and dacites. These finds are contrary to the general implicit belief expressed in many reports and publications that these greenstones are predominantly composed of andesites, dacites and rhyolites. Tectonomagmatic discrimination diagrams were used to characterise the tectonic setting. Bonanitic characteristics are shown by certain volcanic sections. Other sections show an arc type, ocean floor and even MORB characters. Tectonomagmatic signatures as well as the contents of immobile elements coupled with tectonostratigraphic set up strongly indicate a back arc basin environment. But of course, arc input in this zone is also recognised. The Yasin Group is composed of siliciclastic as well as calciturbidites flyschoid sediments and pelagic limestones topped by platform carbonate and siliciclastic sediments. The final fill of this back arc basin is comprised of molassic fill of Reshun Formation. However this paper deals mainly with the massive sulphide mineralization and also touches upon porphyry type mineral shows. Petrology and tectonostratigraphy of the region will be dealt with in a separate publication. Mineral models were worked out for extensive Cu-Pb-Zn-Ag mineralization in Kaldam Gol-Purgar Got area. This volcano-sediment hosted deposit occurs in the Chitral part of the Gawachi back arc basin and holds promise for Ag and Au anomalous zones as well.

Values of 1.0% Cu and Zn and upto 905 ppm Ag and 8.5 ppm Au have been found in samples of mineralized zone from Purgar Gol in Shishi area of Chitral. This zone is an extension of Kaldam Gol massive sulphide mineralization. Cu-Pb-Zn-Ag mineralization from Kaldam Gol and adjoining areas of Drosh in Chitral has been studied in detail for metal values, extent of mineralization and host rock alteration. Substantial anomalies of Au values are also being reported. This mineralization occurs in a sedimentary-volcanic zone associated with the back arc basin. It has all the characteristics of massive sulphide deposits. The genesis of this mineralization has been discussed. Our studies and modelling show that this area holds potential for Au and Ag mineralization as well. This mineralization is likely to be much more extensive than realised so far. These mineral shows have anomalous values of Cu and merit further exploration. Porphyry type Cu mineralization from Kaldam Gol and adjoining areas has also been reported by some workers. A volcano-sedimentary zone in the Reshun formation of Darn area, Shishi valley, Chitral, hosts Cu mineralization. Only a few exposures of this mineralization have been observed so far.

The mineralization in lower Hunza valley and Singal is associated with the Rakaposhi volcanics and the associated metasediments. The peak metamorphism occurred at about 80 ma. This metamorphism is associated with the closure of the back arc basin between Asian plate and the Kohistan island arc. The metallic sulphide mineralized zones have been deformed and metamorphosed during this event. Due to this metamorphism and subsequent alteration, the primary zones of alteration associated with mineralization are difficult to delineate properly. The Normal mineralized zone (Leghari et al. 1986) is again associated with Rakaposhi volcanics and shows anomalous values of Cu, Zn, Pb, Mo and Mn. This is a composite mineralized zone. Here massive sulphide mineralization has been superposed by porphyry type overprint.

The Garesh mineralized zone is pyrite rich and occurs intimately associated with Rakaposhi volcanics. Although this mineralization is of pyrite type yet it shows somewhat anomalous values of Cu, Pb, Zn and Au. The Jutial mineralized zone is in the nature of "massive pyrite deposit" and is associated with neoturbidites of flyschoid origin. The mineralization in the Singal area (Khan et al. 1987) is also intimately associated with the Rakaposhi volcanic complex. The metallic contents are somewhat anomalous with respect to Cu, Zn, Co, Mo, and Fe.

A substantial volcano-sedimentary sulphide mineralized zone of Gawachi back arc basin (1 50m x 300m) is being reported from Mayoona Nala, Ishkuman valley. The extension of this zone is covered by scree and talus. The actual zone of this massive sulphide deposit may be much bigger than the exposed area. The metal values of this zone are being studied. In Drosh area amphibolites of the mélange zone contain disseminated Cu mineralization. These are strongly metamorphosed massive sulphide deposits.

Sulphide mineralization associated with Rakaposhi volcanics as well as associated metasediments has been studied in detail. The modified and reconstituted sulphide alteration zones have been studied and reinterpreted in some detail. On the basis of these studies working mineral models for sulphide mineralization have been established. These mineral models can now be applied for the search and study of other comparable areas. Disseminated copper mineralization "shows" associated with Kohistan arc diorites and associated porphyries have been studied and interpreted in Ashret and Mirkhani areas of Chitral. Mineral models for these deposits have been worked out. The Ashret and Mirkhani mineralization is related to porphyry type mineralization.

Keywords: Mineralization, porphyry, sulphide, Gawachi back arc basin, Chitral, Ishkuman, Yasin, Gilgit, Hunza.

C/140. Chaudhry, M.N., Hussain, S.S., Qamar, N.A., Islam, Z., Akhtar, J. & Rehman, S., 1987. Geology and petrology of Barawal-Dir-Bibior area (toposheet No. 38 M/16), Dir District, N.W.F.P., Pakistan. Geological Bulletin, Punjab University 22, 143-153.

A consolidated map of about 250 sq. miles of Dir-Barawal-Bibior area is presented on a scale of 1"=1 mile. Out of this 100 sq. miles has been mapped by the authors for the first time, Geology, petrology and genesis of the igneous, metamorphic and sedimentary rocks of the area has been described. The amphibolites of the area represent an obducted subduction mélange which is a metamorphosed sequence originally composed of a variable admixture of submarine Lavas and an assortment of sediments of calcareous and siliceous marly nature and arc-derived detritus. Quartzites and calcareous schists have been derived mainly from the arc zone.

The quartzites are overlain by slightly metamorphosed marls, calcareous shales and limestone beds and bonds. The calcareous rocks contain Eocene foraminifera. Volcanic horizons containing flows as well as pyroclasts occur interbedded with metasediments. The arc-related acid to intermediate intrusives occur intruding the metamorphic sequence.

Keywords: Mapping, petrography, igneous-sedimentary-metamorphic rocks, Barawal, Dir.

C/141. Chaudhry, M.N., Iqbal, M.A. & Ahsan, N., 1994. Petrology of Lumshiwal Formation from Gulgaah Nala near Chinali Bridge, Abbottabad-Nathiagali Road, Hazara with special reference to Nandpur Gasfield, Punjab Platform. *Pakistan Journal of Hydrocarbon Research* 6, 41-52.

A detailed study of petrology of Lumshiwal Formation of Early Cretaceous age from Gulgaah has been carried out for the first time. The objective was to study the petrography, provenance, environment of deposition and diagenesis of the Formation and to compare it broadly with Nandpur gasfield section of Punjab Platform where it is a gas reservoir.

The section of Lumshiwal Formation from Gulgaah Nala near Chinall Bridge is medium to thick bedded glauconite sandstone with intercalations of shale. This is petrographically divisible into 8 internal units. The unit overlying Chichali Formation is clay and quartz cemented arenite. The other units are mainly quartz, glauconite and carbonate cemented, moderately well to well sorted, sub-mature to mature quartz arenites and shale. The maximum development of glauconite is in the central part. Since glauconite appears to have originated from clay, the glauconite rich arenites might have originally been wackes. Some horizons are selectively cemented with flint. However, intraclasts of quartz grains cemented with flint are also observed towards the top of the Formation.

Accessory tourmaline, zircon, epidote and sphene which may occur either as discrete grains or as inclusions within quartz grains suggest an ultimate derivation from sialic igneous metamorphic basement with minor contribution from basic source. Granitoids were mainly S-type. However, overall mineralogy and texture suggest recycling.

The Lumshiwal Formation indicates low energy conditions in the sub-tidal zone. The formation of glauconite itself reveals slow rates of sedimentation and mildly reducing conditions. diagenetic history indicates the formation of glauconite, secondary quartz, feldspar and flint earlier and ferroan calcite and dolomite at a later stage. Development of stylolites in the carbonate parts and suturing of quartz grains occurred during deep burial. The last stage involves the formation of ferroan dolomite during final uplift with part converting into dedolomite.

Keywords: Sedimentology, Cretaceous, Lumshiwal Formation, Abbottabad.

C/142. Chaudhry, M.N., Jafferri, S.A. & Saleemi B.A., 1974. Geology and petrology of the Malakand granite and its environs. *Geological Bulletin, Punjab University* 10, 43-58.

A detailed geological map on the scale of 3.8" to a mile of about 50 square miles of the area around the Malakand Pass is presented on a reduced scale. Detailed petrology and geology of the Malakand granite and the associated argillaceous, calcareous and arenaceous metamorphic rocks are being presented here for the first time. Five chemical analysis of the Malakand granite, one analysis of the pegmatite vein and one analysis of the Malakand granite gneiss along with their mode and norm are given. The metamorphics range in grade from biotite to garnet grade of the regional metamorphism. Malakand granite has been derived from the Malakand Granite gneiss but has undergone reconstitution and silicification.

Keywords: Petrography, petrology, granite, Malakand.

C/143. Chaudhry, M.N., Kasuri, R.A. & Ahsan, N., 1997. Facies, microfacies, diagenesis and environment of deposition of Lumshiwal Formation at Thub near Ayubia, District Abbottabad. *Pakistan Journal of Hydrocarbon Research* 9, 57-56.

A detailed study facies, microfacies, diagenesis and environment of deposition of Lumshiwal Formation of Early Cretaceous age from Thub Top near Ayubia has been carried out for the first time. The objective was to study the facies, microfacies, provenance, environment of deposition and diagenesis of the formation in the northwestern part of the oil and gas producing Indus Basin. The formation is producing gas at Nandpur and Panjpir located near Sargodha high in the northern part of Punjab platform. This section of Lumshiwal Formation is divisible into 5 facies and 20 microfacies. Compositionally all the sandstone horizons are mature. Texturally only one microfacies is immature and one microfacies is super mature, rest of the microfacies are mature to sub-mature. The sandstone is predominantly fine to very fine grained, only one microfacies is medium grained, and two microfacies are coarse grained.

Quartz and glauconite are the common cements while iron oxides, clay and flint occurs as subordinate cements.

Accessory to trace amounts of tourmaline, zircon, epidote and sphene which may occurs either as discrete grains or as inclusions within quartz grains suggest an ultimate derivation from sialic metamorphic-igneous basement with minor contribution from basic sources. The source granitoids were mainly S-type. However, overall mineralogy and texture strongly suggest recycling.

The Lumshiwal Formation was deposited in low energy conditions in the subtidal zone. The formation of glauconite itself suggests slow rates of sedimentation and mildly reducing conditions. Diagenetic history indicates the formation of glauconite followed by flint and kaolinite. This was followed by ferroan calcite and dolomite at a later stage. Suture of quartz grains occurred during deep burial. Fracturing of quartz grains occurred during tectonic deformation in brittle regime. Microcrystalline quartz developed along fracture cleavage. The last stage involved the formation of ferroan dolomite during final uplift with parts converting into dedolomite.

Key words: Facies, microfacies, diagenesis, Lumshiwal Formation, Abbottabad.

C/144. Chaudhry, M.N., Kausar, A.B. & Lodhi, S.A.K., 1974. Geology of Timurgara-Lal Qila area, Dir District, NWFP, Pakistan. Geological Bulletin, Punjab University 11, 53-73.

One hundred and twenty square miles of the Timurgara-Lal Qila area, a part of Hindu Kush Range, and situated in the middle of Dir Distt. N. W. F. P. was mapped on 4" = 1 mile scale. A map on the reduced scale is presented. The oldest rock of the area is an amphibolite. This has been intruded by a diorite intrusion followed by a noritic intrusion. The amphibolites have formed as a result of the regional metamorphism of basic igneous rocks. The diorite body is composed of diorite, quartz diorite and tonalite. It has formed by the crystallization of a diorite magma of pyroxene andesitic composition. The latter basaltic magma of strong tholeiitic affinities formed the norite intrusion. Differential crystallization of this magma gave rise to peridotites, pyroxenites, norite and gabbro. Petrogenesis of the area is discussed at length and sixty modal analyses of the various types have been presented.

Key words: Maps, amphibolites, petrography, Dir.

C/145. Chaudhry, M.N., Mahmood, A. & Chaudhry, A.G., 1974. The ortho- amphibolites and the para-amphibolites of the Dir District, NWFP, Pakistan. Geological Bulletin, Punjab University 11, 89-96.

Extensive field and laboratory studies have been carried out on the amphibolites of the Dir District. As a result, the Dir amphibolites have been divided into southern Dir amphibolite belt and northern Dir amphibolite belt. As a result of field and laboratory studies and on the basis of textural, mineralogical and field characteristics, the northern Dir amphibolites have been called para-amphibolites, while southern Dir amphibolites have been called ortho-amphibolites.

Key words: Amphibolites, metamorphism, Dir.

C/146. Chaudhry, M.N., Mahmood, A. & Shafiq, M., 1974. Geology of Sahibabad-Bibior area, Dir District, NWFP Geological Bulletin, Punjab University 10, 73-89.

Fifty square miles of Bibior-Sahibabad area, a part of Hindukush Range and situated ten miles south of the town of Dir, was mapped on 3" = 1 miles scale. A map on the reduced scale is presented.

The area is composed of igneous and metamorphic rocks. Igneous rocks include granodiorite and some minor granite intrusions. The metamorphic sequence is represented by calcareous schists and amphibolites. Calcareous schists are the oldest rocks of the area. Study of fossils recovered from a marl band show Eocene age. Amphibolites are formed as a result of regional metamorphism of calcareous pelitic rocks.

Granodiorite is intrusive into amphibolite. It is a massive granitoid of igneous origin. A mixed zone ranging from 100 to 250 yards in width is formed due to interaction of the granitic magma and the amphibolite.

Seventy-two thin sections of various units were studied. Sixteen modal analysis of leuco-amphibolite, twenty-three of the mela-amphibolites, nine of the mixed zone, six of the granodiorite, four of the calcareous schists and two of the minor veins and bodies are presented.

Key words: Maps, granitoids, amphibolites, calcareous schists, Dir.

C/147. Chaudhry, M.N., Mahmood, T., Ahmed, R. & Ghazanfar, M., 1992. A reconnaissance microfacies study of Kawagarh Formation near Giah, Abbottabad-Nathiagali Road, Hazara, Pakistan. *Pakistan Journal of Hydrocarbon Research* 4, 19-32.

The Kawagarh Formation of Upper Cretaceous age from near Giah, Abbottabad-Nathiagali Road, Hazara, has been studied in detail for internal units, microfacies and diagenetic fabrics. A total of eighteen microfacies and five internal units have been defined. The eighteen microfacies is based on depositional textures cum composition from bottom to top are Wackestone (Biomicrite)-Dolomitic limestone, Dolomitic limestone, Wackestone (Biomicrite), Dolospar, Wackestone (Biomicrite)-Dolomitic limestone, Dolospar, Wackestone (Biomicrite)-Dolomitic limestone, Calcitic Dolomite, Wackestone (Biomicrite), Sandy Wackestone (Biomicrite), Sandy Dolomitic limestone and Sandy Dolospar. A total of five facies units have been established which (internal units) from bottom to top are mixed dolomitic limestone and dolospar Unit, Biomicrite Unit, Sandy Biomicrite Unit, Sandy Dolomitic limestone Unit and Sandy Dolospar Unit. The lower three units contain predominantly Late Cretaceous planktonic foraminifer species of Globotruncana and deeper water Algae (Oligosteginids) and are considered to have been deposited in deep water low energy environments (outer shelf close to the edge) while the upper two units which contain rare planktonic foraminifera and are sandy in nature are interpreted to have been deposited in shallower waters (Littoral to inner shelf) with ingress of detrital material. There is evidence to suggest that the dolomitization in the lower two units took place mainly during the deep burial diagenesis which dolomitization in the upper two units owes its origin to ground water mixing during early diagenesis. A study of diagenetic fabrics show that mechanical compaction is unimportant while chemical compaction is wide spread.

Key words: Reconnaissance, microfacies, Cretaceous, Kawagarh Formation, Abbottabad.

C/148. Chaudhry, M.N., Manzoor, A., Ghazanfar, M. & Ahsan, N., 1994. Sedimentology of Datta Formation at Kalapani, Abbottabad, NW Himalayas, Pakistan. *Geological Bulletin, Punjab University* 29, 11-27.

Key words: Sedimentology, Datta Formation, Abbottabad.

C/149. Chaudhry, M.N., Nadeem, M. & Ahsan, N., 2000. Sedimentological studies of Chorgali Formation at Chahla Bandi of the Western limb of Hazara Kashmir Syntaxial region in Azad Jammu and Kashmir. Abstracts, Third South Asia Geological Congress, Lahore, 62-63.

Key words: Sedimentology, Hazara Kashmir syntaxis, Chorgali Formation, Azad Kashmir.

C/150. Chaudhry, M.N., Sattar, A. & Mateen, A., 2001. Muscovite bearing peraluminous granites from upper Kaghan valley, NW Himalaya, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 61-62.

Upper Kaghan Valley in NWFP provides a cross-section through the Higher Himalayas of Pakistan. The Higher Himalayas are composed of a lower basement and an upper cover unit. The basement is comprised of granitoids,

turbidites, migmatites with minor marble and pelite-psammities horizon and discordant amphibolites. The cover consists predominantly of garnetiferous calc-pelites, marbles and pelites with extensive amphibolites at the base.

A spectacular feature of the lithologies of Higher Himalayan slab in the Upper Kaghan Valley is the occurrence of granitoids. These granitoids are peraluminous and mainly syenogranites and monzogranites, containing muscovite + biotite + garnet ± apatite + tourmaline and rare opaques.

The peraluminous granitoids are generally subdivided into two main groups; the muscovite bearing peraluminous granitoids (MPGs) and the cordierite bearing peraluminous granitoids (CPGs), which are both anatectic but can be distinguished on the basis of mineral content, texture, rock associations and mode of emplacement. A generalized petrogenetic model for peraluminous granitoids assigns that cordierite bearing peraluminous granites are generated where mantle derived magmas are injected into or have underplated crustal rocks. While muscovite bearing peraluminous granites are produced mainly in orogenic zones affected by major crustal shears or overthrust structures through wet anatexis of crustal rocks and crystal fractionation of the magma.

The granitoids from Higher Himalayas of Upper Kaghan Valley have composition close to the granitic minimum melt. They are mainly leucogranites i.e. felsic granites rich in K-feldspar and sodic plagioclase and little mafic minerals and primary muscovite, so they are categorized as muscovite bearing peraluminous granites.

Key words: Peraluminous granites, petrography, Kaghan valley, Himalaya.

C/151. Chaudhry, M.N., Shahbaz, S.T., Chaudhry, M.A., Malik, M.N., Shakir, M.K., Murtaza, G. & Shamsuddin, 1981. Lithostructural Mapping of Kalapani, Kathwal and Kakul area, District Abbottabad. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Keywords: Lithostruture, mapping, Abbottabad.

C/152. Chaudhry, M.N. & Shams, F.A., 1983. Petrology of the Shewa porphyries of the Peshawar Plain Alkaline Igneous Province, NW Himalayas, Pakistan. In: Shams, F.A. (Ed.), *Granites of Himalaya, Karakoram and Hindu Kush*. Institute of Geology, Punjab University, Lahore, 171-181.

Chemical analyses and petrography are presented of acid black porphyries and acid grey porphyries, riebeckite porphyrics and riebeckite gneisses belonging to Peshawar Plain alkaline igneous province, north-west Pakistan.

Study shows that the intrusive rocks have developed from an anatectic melt generated at deep crustal level and emplaced along roughly en-echelon weak planes of a zone which suffered intermittent and alternate periods of variable tension and compression. The alkaline rocks had developed during the period of tension whereas acidic rocks had developed during the period of non-tension to compression. This zone was a complimentary centre to the regional belt of strong but variable compression along margin of the Indo-Pak plate in the North. Implications of this study are commented upon for regional application.

Key words: Petrology, Shewa alkaline porphyries, Peshawar Plain Alkaline Igneous Province, Himalaya.

C/153. Chaudhry, M.N. & Shams, F.A., 1984a. The triple amphibolite belt of northwest Himalayas, Karakorum and Hindu Kush, northern Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, p.22.

Three amphibolite belts have been distinguished for the first time from NW Himalayas, Karakoram and Hindu Kush west of the Nanga Parbat-Haramosh loop. They have been named as 'Southern Amphibolite Belt', "Middle Amphibolite Belt" and "Northern Amphibolite Belt" Their structures, textures and mineral compositions are summed up, compared and contrasted. Their geotectonic disposition is also discussed.

It is proposed that the three belts represent obducted blocks of a subduction mélange. The "Southern Amphibolite Belt" represents the obducted mass of the subducted and transformed Tethyan tholeiites formed at the mid-oceanic rises with small amounts of marine sediments. The "Middle Amphibolite Belt" also represents subduction mélange of submarine tholeiites formed at oceanic rise with substantial amounts of marine and arc-derived sediments. This belt is dispositioned south of the outer arc. The "Northern Amphibolite Belt", again is a part of the subduction mélange formed south of the main inner arc This belt represents fairly pure transformed marine tholeiites. All the three amphibolite belts contain mantle derived d exotic blocks of peridotite, harzburgite and eclogite.

Key words: Amphibolite belts, oceanic tholeiites, Himalaya, Karakoram, Hindukush.

C/154. Chaudhry, M.N. & Shams, F.A., 1984b. Geology of northern Indus Kohistan and parts of Chilas District, northern Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, 69-70.

For the first time, a geological map of 600km² of the Northern Indus Kohistan and parts of Chilas District, Northern Areas, is being presented on a scale of 1" = 4 miles.

The rock units mapped and studied from South to North are:-

North Yasin Granite

Amphibolitic Diorite, Diorites and amphibolites

Norite, Noritic Gabbro

Amphibolitic Diorites

The Southern Amphibolite Belt

Volcano-sedimentary zone

South Salkhala

The above units have been studied petrographically as well as chemically. The petrography and chemistry are described and discussed in the light of field relations and petrotectonic dispositions.

The Salkhalas represent elements of the Indo-Pak shield edge. The sedimentary - volcanic zone may represent a remnant arc, the amphibolites and norite represent oceanic lithosphere, the diorites and amphibolitic diorites represent subduction related partial melting products of oceanic crust at intermediate depth and under hydrous conditions. The Yasin granite is a typical anatectic rock containing xenolithic elements of greenstone. This is very young and postdates subduction and obduction episodes as of independent origin.

Key words: Geology, petrography, geochemistry, Kohistan, Chilas.

C/155. Chaudhry, M.N., Spencer, D.A, Ghazanfar, M., Hussain, S.S. & Dawood, H., 1997. The location of the Main Central Thrust in the Northwest Himalaya of Pakistan: Tectonic Implications. Geological Bulletin, Punjab University 31 & 32, 1-20.

A number of workers have proposed different positions for the Main Central Thrust in the northwest Himalaya of Pakistan. These positions have varied from considering the Panjal Thrust, the Oghi Shear Zone and even the Raikot Fault, as well as many other intervening locations in the area between the Main Mantle Thrust in the north and the Main Boundary Thrust in the south, as the Main Central Thrust. All these positions are enumerated and critically appraised in their context of the geology of the area. They are subsequently evaluated to see whether, they follow the tectonic requirements of the Main Central Thrust as a Boundary Thrust that marks the contact between the Higher and Lesser Himalaya. It is subsequently argued that, except for the Batal Fault near Naran (in Upper Kaghan Valley) Luat Fault (in Neelum Valley) and the tectonic lineament near Malakand (in Lower Swat), no other position fulfils the required criteria specified for the definition of Main Central Thrust. These most likely positions of the Main Central Thrust, according to this review, were only located after extensive geological mapping of the terranes in Neelum and Kaghan Valleys and in the area of Besham and lower Swat.

Keywords: MCT, Panjal, Raikot, Kaghan, Himalaya.

C/156. Chaudhry, M.N., Taufique, A.R. & Chaudhry, M.M., 2000. Preliminary sedimentological studies of Murree Formation of outer Himalaya of Azad Kashmir & Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 55-58.

Key words: Sedimentology, Murree Formation, Himalaya.

C/157. Chaudhry, M.N., Walsh, J.N., Ghazanfar, M. & Hussain, M., 1992. The Panjal sea, Kashmir-Hazara microcontinent and Hercynide Geology of Northwest Himalaya in Pakistan. Pakistan Journal of Geology 1, 81-99.

This paper discussed the tectonic significance of the Permian Panjal Volcanics of Kaghan Valley on the basis of an over view of geology, field characteristics, associated rocks and plots of major and trace elements. On the basis of these studies it is proposed that the 400 km long Panjal rift developed into an ensialic marine basin with a thinned continental crust which in Kaghan further developed into an incipient ocean in Permian. This ocean closed in Late Permian followed by the deposition of unmetamorphosed oolitic Malkandi limestone of Triassic age.

Key words: Tectonics, continental rifting, geochemistry, Panjal volcanics.

C/158. Chaudhry, M.N., Walsh, J.N., Khan, M.S. & Ghazanfar, M., 1995. Petrology and geochemistry of the Panjal volcanics of the Northwest Himalaya in Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Geological and geochemical (major, minor and trace elements including rare earth elements) data for the Panjal volcanics of the NW Himalaya are presented. These data show that the Panjal volcanics are mainly tholeiitic basalts. The rocks are moderately enriched in trace elements and the light REE elements relative to N-type MORB. These basalts are characterized by Zr/Y 1.7 to 3.92, Zr/Nb 2.6 to 33, Ti/Y 266 to 400 ratios and LREE enrichment [(La/Yb)_N = 3.29 to 11.16, (La/Sm)_N = 1.96 to 4.09, (Sm/Yb)_N = 1.68 to 3]. These characteristics suggest derivation of magma from an enriched mantle source, probably a mantle plume. The lavas exhibit from within plate to P-type mid ocean ridge trace element characteristics with minor crustal contamination.

Trace elements and REE element data indicate that the lavas were derived by partial melting of garnet lherzolite followed by fractionation of olivine and pyroxene. The geological and geochemical data suggest that the Panjal volcanics in the Kaghan area developed in a progressively evolving rift initially within an ensiatic environment and finally reaching the stage of a PMORB type crust.

Key words: Petrology, continental rifting, geochemistry, Panjal volcanics, Himalaya.

C/159. Chaudhry, M.N. & Zaka, K.J., 1994. Terbela Dam: A discussion on the discrepancy between the laboratory testing and inservice behaviour of Indus aggregate in cement concrete. Dam Engineering 5, 63-80.

This paper discusses the problem of alkali aggregate reaction (AAR) developed in the Tarbela Dam, which was built in 1976 on River Indus in North-West Frontier Province of Pakistan. In Tarbela Dam natural sand and gravels from the riverbed were used after proper testing by petrographic, chemical and mortar bar methods (TAMS report, WAPDA 1965). After testing, aggregates were considered non-deleterious and were used with ordinary Portland cement having alkali level ranging from 0.9% to 1.03% (Table IX). These aggregates contain large amounts of slightly metamorphosed acid to intermediate volcanics, argillites and greywacks.

Although these aggregates contain large quantities of potentially deleterious rock types yet they were presumably regarded safe either because their parent rocks had undergone metamorphism or on the grounds that they had large quantities of mildly reactive rock type and therefore, would not develop deleterious reaction. The inference drawn from petrographic studies was further strengthened by the quick chemical tests carried out in accordance with ASTM C289 and mortar bar tests carried out in accordance with ASTM C227 which did not predict AAR potential of Indus aggregates at Tarbela.

Three years after the completion of Tarbela Dam only one incidence of AAR was reported. However, it was only after twelve years of completion that AAR was confirmed at a number of places. Therefore the need for alternative or modified chemical mortar bar test is stressed. Petrographic examination can however, prove most useful for quickly predicting AAR in Indus River aggregates like the ones used in Tarbela and similar aggregates which contain deleterious metamorphosed rocks like greywacks, acid to intermediate mesocrystalline volcanics and argillites.

Key words: Tarbela dam, Indus aggregates.

C/160. Chaudhry, M.N. & Zaka, K.J., 1998. Petrographic evaluation of alkali aggregate reaction concrete structures of Warsak Dam, NWFP Pakistan-A case study. 8th International IAEG Congress Vancouver/ Canada, 2841-2846.

This paper presents a case study of Alkali Aggregate Reaction (AAR) in concrete structures of Warsak Dam. The dam has suffered deterioration due to AAR and had undergone extensive repairs during 1985-86. The fractures in the concrete structures are of two types. The first type of fractures is random and may not be directly related to deleterious reaction. The second type of fractures shows distinct pattern resembling map cracks. AAR and gel formation were positively identified and confirmed. This paper is based on Petrographic, chemical and X Ray Diffraction (XRD) studies of cores and sample of AAR affected parts of the dam carried out since the confirmation of AAR. Microfractured and strained quartzite, phyllite/slate, metagreywacke partially reconstituted microcrystalline acid to intermediate meta-volcanics and jasper/cherts are directly affected by deleterious reaction.

Key words: Petrography, alkali aggregates, Warsak dam.

C/161. Chaudhry, M.N., Zaka, K.J. & Hassan, G., 1994. Geotechnical, petrographic, chemical characteristics and inservice behaviour of Indus aggregate for concrete. In: Ahmed, R. & Sheikh, A.M. (Eds.), *Geology in South Asia--I. Proceedings of the First South Asia Geological Congress*, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 378-381.

Key words: Geotechnical, petrography, Indus aggregates.

C/162. Chaudhry, M.S., 1980-82. The engineering geology and geotechnical aspects of some structures at Kalabagh Dam Project. Institute of Geology, M.Sc. Thesis, Punjab University, Lahore, 1-150.

Key words: Engineering geology, geotechnical, Kalabagh dam.

C/163. Chaudhry, R.S., 1987. Petrogenesis of Cenozoic sediments of Northwestern Himalayas. *Geological Magazine*, 108, 43-48.

Cenozoic rocks of north-western Himalayas (excluding the sub-Recent, Recent and Karewa deposits) are represented by the Subathu, Dagshai, Kasauli and Siwalik rocks, which together have a thickness of over 10,000 m and range in age from Upper Palaeocene to Middle Pleistocene. From field and laboratory investigations it is propounded that these sediments, except the Middle and Upper Siwalik, have been derived from low and medium grade metamorphic rocks, acid plutonics and sedimentary rocks of the nearby Himalayan terrains. For the Middle and Upper Siwalik rocks, detritus was supplied by sedimentary and trap rocks as well as by the underlying medium and high grade metamorphic and plutonic rocks. A major part of these sediments has been derived from the rising Himalayas rather than from the Peninsular Shield as believed hitherto. The Subathu rocks were deposited in shallow to moderately deep marine environments; the Dagshai rocks under shallow freshwater conditions; and the Kasauli and Siwalik rocks in a shallow fast-sinking basin. All these sediments accumulated under conditions of rapid erosion, short transportation and rapid deposition.

Key words: Petrogenesis, sediments, Cenozoic, Himalaya.

C/164. Chaudhry, Z.H., 1963. Petrographic study of the chromite deposits of Harichand; the enclosing dunite and surrounding rocks. M.Sc. Thesis, Munich University.

Key words: Petrography, chromite, dunite, Harichand, Malakand Agency.

C/165. Cheema, A.Q., 1999-2000. Structure, stratigraphy, petrography, micropaleontology and petroleum geology of Kotli-Tattapani area, District Kotli, Azad Jammu and Kashmir (Pakistan). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 217p.

The Himalayan mountain belt is the result of Tertiary collision between the Indian and Eurasian plates. The kotli-Tattapani area of the Kashmir foreland fold-and-thrust belt is the part of the Sub-Himalaya of Pakistan. A sequence of Cambrian to Cenozoic rocks is folded and imbricated along the northeastern margin of the Indian plate.

In Cambrian time, the calcareous to arenaceous facies of Muzaffarabad formation are deposited under shelf to outer shelf environment. The Muzaffarabad formation is unconformably overlain by the Paleocene Hangu Formation. The Hangu Formation is deposited under tropical to subtropical environments. The absence of Ordovician to Cretaceous rocks in the area is the result of non-deposition due to pre-Eocene Himalayan uplift. Subsequently, after the deposition of the Hangu Formation, the Early Eocene Tattapani Formation is deposited under shallow marine environment. This marks the Early Eocene transgression of the Neotethys ocean.

In Middle to Late Eocene the variegated shales of the Kuldana Formation are deposited in open marine, lagoonal and fluvial environments. The Kuldana Formation marks the transition from marine to continental environment. This shows the closing of the Neotethys ocean and the initiation of deposition of the Himalayan molasses in the Kashmir foreland basin.

In Oligocene to Miocene, the hinterland in the northeast was uplifted and the low to medium grade basement and cover rocks were exposed to the weathering and erosion. The detritus derived from the orogen was deposited as molasse of the Murree and Nagri Formations in the Kashmir foreland basin.

The Cambrian to Cenozoic rocks show at least three phases of deformation. These deformational phases are D1, D2 and D3. D1 deformational phase is the major event in the area and can be divided into D1a and D1b. The D1a is marked by the F1 southwest-vergent folds and northwest-directed thrusts. The F1 folds and D1a thrusts are northwest-southeast trending. The D1b is marked by northeast-directed backthrust and backsteepening of axial planes of F1 folds. The D2 deformation is related to the F2 cross-folding of northwest-southeast trending outcrops and fold axes of F1 folds. The F2 cross-folds are the result of counter clockwise rotation of Indian plate. F2 folds are associated with the development of the Hazara-Kashmir syntaxis. The D3 deformation is related to the northeast-southwest late Himalayan extension. This deformational phase caused the north-northwest trending normal faults, horst and graben structures.

Key words: Structure, stratigraphy, petrography, micropaleontology, petroleum geology, Azad Jammu and Kashmir.

C/166. Cheema, I.U., 1990. Late Astaracian small mammals of the Chinji Formation of Ghok Thalian, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p. 41.

A small mammal assemblage of a middle Chinji Formation locality PMNH 8608 contains at least fourteen species of ten rodent and insectivore families including a single specimen of chirpotera. Cricetids are represented by three species, which resemble those from the Banda Daud Shah assemblage. *Antemus chinjiensis* is the only murid recognised but included in them are the three molars of relatively larger dimensions having extra cusps (styles) which have not been noted earlier as yet. *Prokanisamys benjavuni* and *Kanismys indicus* constitute the typical middle Miocene rhycomyid site in the Siwalik sequence. Comparison with other Chinji Formation fauna indicate that this high species diversity is normal and presents a stable species composition during most of the Middle Miocene. Murid species appear to have the shortest life-span and hence their chronological successive species are used for precise faunal dating. The PMNH 8608 locality is assigned a late Astaracian age and closely resembles the Daud Khel local fauna assemblage.

Key words: Palaeontology, mammals, Chinji Formation, siwaliks.

C/167. Cheema, I.U., Rajpar, A.R. & Raza, S.M., 1997. Preliminary analysis of the vertebrate fauna from the Siwaliks of Chakwal District; Kallar-Kahar-Dhok Tahlian area, Potwar Plateau, Pakistan. Geological Bulletin, Punjab University 31 & 32, 161-168.

About 440 mammalian fossils were collected from 20 different sites in Kallar Kahar-Dhok Tahlian area. Small collection of interesting carnivores consisting of *Herpestes* SP. and gen. et. sp. Indet. of Mustelidae family are simultaneously of 130 Mya and 16.0 Mya. Gen et. sp. Indet. Of Mustelidae is the first fossil record in the Siwaliks of Pakistan, which seems to have closer affinities with African fauna. Similarly canine of a *Sivapithecus indicus* also reveals the first appearance of a Hominoid in this area

Key words: Palaeontology, mammals, vertebrates, siwaliks.

C/168. Cheema, I.U., Sen, S. & Flynn, L.J., 1983. Early Vallesian small mammals from the Siwaliks of Northern Pakistan. *Bulletin du Museum National d'Histoire Naturelle Section C Sciences de la Terre Paleontologie Geologie Mineralogie*, 53, 267-280

Key words: Palaeontology, mammals, siwaliks.

C/169. Cheema, M.R., 1968a. Biostratigraphic study of Khanaspur-Mandri Area, District Hazara. M.Sc. Thesis, Punjab University, Lahore, 109p.

Key words: Biostratigraphy, Haripur, Hazara.

C/170. Cheema, M.R., 1968b. Biostratigraphy of Changla Gali area, District Hazara, West Pakistan. M.Sc. Thesis, Punjab University, Lahore.

Biostratigraphical study of the Khanaspur Mandri area has been done. A geological map on the scale 8" -1 mile is prepared. A new time -rock unit, the Nummulitic Shales representing the youngest lithostratigraphic unit is identified and mapped. The lithologies and environments of deposition of each formation are discussed. Their ages are reviewed in the light of new faunal evidences, if any, and regional correlations are suggested.

A systematic and detailed sampling of U. Cretaceous to Middle Eocene strata was done to investigate foraminiferal assemblages of different stratigraphic units, fauna species and many genera are identified. All the species are described but only very few genera are dealt with. Three species, *Assilina mukshpuriensis* nov., *Assilina depressa* nov., and *Lokhartia smouti* nov., and a variety *Lokhartia altispira* var *conica* nov. are erected new.

Cretaceous -Tertiary boundary and Palaeocene -Eocene, boundary is placed on faunal evidence. Palaeoecologic conditions are inferred for Cretaceous and Lower Tertiary times as depicted by the faunal assemblages.

Key words: Biostratigraphy, Abbottabad, Hazara.

C/171. Cheema, M.R., 1970. Sedimentology of Miranjani algal limestone member, Nathiagali. *Geological Bulletin*, University of Peshawar 5, 57-61.

Microscopic sedimentological study of the Miranjani Algal Limestone Member of the Hazara Formation (Hazara Slates) of Nathiagali area, District Hazara, is made, following the petrographic classification of limestones of Folk (1959).

Varied association of all three basic constituents of limestones allochems, microcrystalline calcite and sparry calcite is met with indication a diversity of physiochemical conditions. Mega and microscopic sedimentary structures and composition are used to inter environment of deposition for every thin section and for the unit, as a whole. Systematic of algal material is not dealt with except for identifying it as "Green Stomatolytic Algae". Ostracodes were met within a thin section which, however, could not be identified.

Key words: Sedimentology, Miranjani limestone, Abbottabad, Hazara.

C/172. Cheema, M.R. & Alam, G.S., 1990. Pyrite deposits of Naz Bar area, Yasin valley, Gilgit District, Northern Area, Pakistan. *Geological Survey of Pakistan, Information Release* 333.

Pyrite deposits are located in the Yalter Bar Multan Bulang Bar area of Naz Bar at a distance of about 23 miles from Yasin village, Gilgit Agency. The deposits are in the form of 3 lenses and 12 pockets, exposed at 5 locations at high elevation ranging from 13,500 feet to 16,000 feet A.S.L.

The pyrite is hydrothermal in origin and is developed within the quartzites and phyllites of the Permo-Carboniferous Darkot group. Geological reserves are estimated at 1.7 lakh tons. Out of these, 1.54 lakh tons are present in one lense (Location A) with average sulphur and iron content of 30 and 45 percent, respectively. Pyrite also contains copper from 0.476 to 0.834% and cobalt from 0.061 to 0.976 per cent .

Key words: Pyrite, Yasin valley, Gilgit.

C/173. Cheema, M.R., Raza, S.M. & Ahmad, H., 1967. Cainozoic. In: Shah, S.M.I. (Ed.), Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 56-98.

Key words: Cenozoic, Pakistan.

C/174. Cheema, T.K., 1990-91. The structure, stratigraphy & petrography of the western limb of Hazara-Kashmir Syntaxis, Mansehra-Dalola areas, Hazara, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 174p.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis, Mansehra, Hazara.

C/175. Chen, W.P. & Roecker, S.W., 1980. Regional variation of the focal mechanism of intermediate depth earthquakes and seismicity in the Karkorum-East Hindu Kush area. EOS (Transactions of the American Geophysical Union) 61, 1031.

Key words: Seismology, earthquakes, Karakoram, Hindukush.

C/176. Chilasi, E.U., 1999-2000. Geological mapping of Muzaffarabad-Chattar Kalas area with special emphasis on slope instability analysis and hazards evolution of Abhal area, Muzaffarabad (A.K.). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 117p.

About 100 sq. Km area including the landslided parts was mapped to find out the possible solution of this hazard. The study was carried out to understand the landslide problems in the area. The Abhal landslide was studied in detail based on its large size and proximity to foot-tracks, residential buildings and land property. Presence of MBT, heavy rain fall, toe-cutting by river Jhelum, steep slopes and water seepages contribute to landsliding in the area. The principal types of failure in the area have been recognized as slumps, earth flows, rock fall or combination of these three types. Soil samples were collected from the slided areas to evaluate the engineering properties of soil that contribute the failure. It includes Atterberg limits, natural water content, specific gravity, plasticity character, compaction and swelling. To establish the causes of landslides all the information and field data were collected. The results suggested that the failure occur due to high swelling potential of soils, steep slopes and presence of active fault (MBT).

Key words: Mapping, slope stability, landslide hazard, Azad Kashmir.

C/177. Chishti, H.M. & Ahmad, N., 2000. Characterization of pyrolysis derived hydrotreated shale oil from a Pakistani oil shale. Abstracts, Third South Asia Geological Congress, Lahore, p.124

Hydrotreatment has received increasing attention in upgrading shale oil. The aim of this work was to elucidate the compositional changes after hydrotreatment of Salt Range shale oil. Pyrolysis derived raw shale oil from Salt Range oil shale was hydrotreated in stirred reactor with a cobaltmolybdenum (CD-Mo) catalyst at 395 °C and 15 Mpa of hydrogen pressure for 12 hours. The pyrolysis and hydrotreated oils were analysed for elemental analysis, liquid chromatography fractionation, size exclusion chromatography and gas liquid chromatography/mass spectrometry. Distribution of nitrogen and sulphur compounds in raw pyrolysis and hydrotreated upgraded oils was determined. Hydrodenitrogenation of nitrogen containing compounds occurred concurrently with the hydrogenation of non-nitrogen containing aromatic hydrocarbons. In particular the pyrolysis and catalysis oils were analysed for polycyclic aromatic hydrocarbon (PAH) compounds and for nitrogen containing PAH (PANH) and Sulphur containing PAH (PASH). Analysis of the product oils showed that three and four ring higher molecular weight compounds decreased in concentration. Removal of nitrogen and sulphur proceeded successively with time which resulted in corresponding reduction in the concentration of nitrogen and sulphur containing PAR.

Key words: Pyrolysis, oil shale, hydrocarbon.

C/178. Chishti, H.M., Ahmad, N. & Rashid, S., 2000. Influence of final pyrolysis temperature on pyrolysis of Kark oil shale from Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 124-125.

The final pyrolysis temperature has received special interest in the fixed bed pyrolysis of oil shale. Kark oil shale from Pakistan was retorted in a bench scale static bed reactor at various pyrolysis temperatures. The pyrolysis oils were collected in a series of cold traps. Gases evolved were analysed off-line by packed colour gas chromatography. The composition of oils and gases were determined in relation to the various final pyrolysis temperatures. Oils were analysed by a number of techniques for determining composition including liquid chromatography, gas chromatography/mass spectrometry size exclusion chromatography, chemical class fractionation and elemental analysis. Products of pyrolysis were liquid condensate, non-condensable gases and solid residue (spent shale). The yield of oil was maximised at 520°C. Both the hydrocarbon and non-hydrocarbon gases increased with increase in final pyrolysis temperature. A consistent decrease in spent shale was observed with increase in pyrolysis temperature. Hydrogen to carbon ratio (H/C) and the aromatic content the product oils was found to respectively decrease and increase with increase in final pyrolysis temperature.

Key words: Pyrolysis, oil shale, Kark.

C/179. Chishti, M.N.A., 1977-79. Lithostructural Mapping and Geology of Baragali-Bagnoter Area, Abbottabad District, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 169p.

Approximately 20 miles² of Baragali-Bagnoter area in the form of a strip on both sides of Nathiagali-Abbottabad road has been mapped at the scale 1:10,000. It is a mountainous humid region with fairly high relief. The stratigraphic sequence ranges from Precambrian Hazara slates to the Kuldana Formation of Middle Eocene. The structure of the area is in the form of a major synclinorium, which is interrupted and deformed by high angle thrust faults dipping southeast near the surface. Over 50 thin sections were studied under the microscope and a detailed petrography and petrogenesis are included.

Key words: Stratigraphy, structure, lithology, petrography, Abbottabad.

C/180. Chohan, N.A., Qureshi, M.H. & Faruqi, F.A., 1984. Evaluation and exploitation of some industrial minerals for the development of refractories. Abstracts, First Pakistan Geological Congress, Lahore, p. 32.

Key words: Industrial minerals, refractories.

C/181. Chroston, P.N. & Simmons, G., 1989. Seismic velocities from Kohistan volcanic arc, Northern Pakistan. Journal of the Geological Society, London 146, 971-979.

The rocks bounded by the Main Mantle Thrust and the Northern Suture in northern Pakistan constitute an exhumed section through a Cretaceous volcanic arc. Samples have been collected from all the principal lithological groups of the arc, and P and S-wave seismic velocities have been measured in the laboratory with the prime objective of comparing the velocities with those determined by seismic refraction experiments on modern volcanic arcs. Velocities were measured at up to 0.7 GPa and consideration has been given to the effect of confining pressure, pore pressure and temperature and to the deformation and metamorphism involved in the Himalayan collision.

The reconstructed velocity section through the arc shows a distinct 'upper crust' comprising granitic-dioritic intrusions, metasediments and volcanics with a P-wave velocity of 6.2–6.4 km S⁻¹ depending on the parameters used. Beneath, the 'lower crust' of amphibolites and pyroxene granulite has a velocity mainly about 6.4–6.7 km s⁻¹, though the garnet granulites extend to 7.8 km S⁻¹. The more mature arc with a higher proportion of granitic rocks would show a slightly lower upper crustal velocity than the younger arc. Velocity inversions might be expected with a thermal gradient of as little as 10–15 °C km⁻¹, depending on the pore pressure. In general, the proposed velocity structure is comparable with that of volcanic arcs and with many other sections of the continental crust.

Key words: Seismology, seismic velocity, MMT, MKT, Kohistan arc.

C/182. Chuhan, F.A., Chaudhry, M.N. & Ghazanfar, M., 1992. Microfacies, diagenesis and environment of deposition of Datta Formation from Jaster Gali, District Abbottabad, Hazara, Pakistan. *Geological Bulletin, Punjab University* 27, 47-62.

Datta Formation shows marked vertical variation in the environment of deposition from continental, subtidal, intertidal to supratidal. However, in the Galiat area this formation is predominantly marine as opposed to dominantly continental facies of Salt Range. The petrographical/sedimentological study of this formation shows the following lithologic units. Fine grained quartz and clay cemented ferruginous sublithic arenite with streaks and layers of grit; alternating bands of medium grained intraclast bearing oolitic-pelletoidal limestone intercalated with nodular marl; fine grained quartz cemented quartz arenite intercalated with shale; fine to medium grained quartz cemented quartz arenite ; nodular marl ; limestone (sparse biomicrite, - wackestone); coarse to medium grained oolitic, carbonate cemented quartz arenite with streaks and layers of grit. Recycled clastic component is dominant. Tourmaline, zircon, epidote and sphene indicate an ultimate derivation from an igneous, metamorphic sialic basement with _subordinate basic/metabasic component, the granitic component was predominantly S-type. The diagenetic events show that kaolinite cement is early as well as formed at final stage. The early "diagenetic kaolinite cement was partially transformed to illite at a depth of at least 3500-4000m whereas quartz and non-ferroan carbonate cements were formed after the early diagenetic kaolinite. The non-ferman carbonate cement was transformed to ferroan carbonate cement. A part of ferroan dolomite, so formed, was probably dedolomitized at the final stage.

Key words: Microfacies, diagenesis, deposition environment, Datta Formation, Hazara.

C/183. Ciry, R. & Amiot, M., 1965. Sur quelques foraminifères Permians d'Asie Centrale. In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), *Scientific Reports IV* (1), 127-133. *Paleontology-Zoology-Botany*. Brill, Leiden.

Key words: Italian expedition, Permian foraminifera, Central Asia.

C/184. Cita, M.B. & Ruscelli, M.A., 1959. Cretaceous microfacies from western Pakistan and Afghanistan. *Revista Italiana di Palaeontologia* 65, 3p.

Key words: Microfacies, Cretaceous, Afghanistan, Pakistan.

C/185. Clavarino, J.G., Dawney, R.L. & Sweatman, T.R., 1995. Gold exploration in northern Pakistan: Status and prospects. *Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994*, 93-119.

Key words: Gold exploration, North Pakistan.

C/186. Colbert, E.H., 1933. Siwalik mammals in the American Museum of Natural History. *Transactions, American Philosophical Society, New Series* 26, 401p.

Key words: Palaeontology, mammals, siwaliks.

C/187. Collins, D., 1988. Meltwater characteristics as indicator of glacial and hydrological processes beneath valley glaciers in Karakoram. *Abstracts, Neogene Karakoram and Himalayas*. University of Leicester.

Key words: Glaciers, hydrologic process, meltwater, Karakoram.

C/188. Collins, D.N. & Hasnain, S.I., 1994. Runoff and sediment transport from glaciated basins at the Himalayan scale. University of Manchester, Alpine Glacier Project, Working Paper 15, 14p.

Key words: Glacial basins, sediment transport, Himalaya.

C/189. Collinson, J.D., Lewin, J. & Wells, N.A., 1983. Transient streams in sand-poor redbeds: early-middle Eocene Kuldana Formation of northern Pakistan. *Special Publications of the International Association of Sedimentologists*, 6, 393-403.

The Kuldana Formation is a sand-poor redbed complex that prograded into the Persian Gulf-like Kohat depositional basin of northern Pakistan at the end of an early Eocene marine regression. It was formed by a poorly developed system of small, episodic, briefly active, shallowly incised and readily abandoned streams that wandered into a very flat, aggrading, semi-arid basin. Their deposits are about 95% red mud and 5% predominantly trough-bedded and fining-upward channel sand. The streams did not meander, however, because avulsion was too frequent. During low flow they became braided but their bedforms underwent little alteration. Partly because of the basin's flatness, the only available coarse clastics in eastern areas were calcareous soil nodules and, locally, fish and mammal bone fragments. The primary determinants of this stream system seem to have been a below-grade basin floor and a semi-arid climate.

Key words: Red-beds, drainage, basin configuration, Eocene, Kuldana Formation.

C/190. Comucci, P., 1933. Rocce del bacino del ghiacciaio Siachen. In: *Relazioni Scientifiche della Spedizione Italiana de Filippi nell'Himalaia Caracorum e Turchestan Cinese (1914)*, Series 2(11). Zanichelli, Bologna, 3-48.

This is a description of the lithology of rocks from the Siachen Glacier basin, eastern Karakoram.

Keywords: Glacier, rocks, Siachin.

C/191. Comucci, P., 1935. Scisti a Dasso nel Baltistan. *Rendiconti Accademia Nazionale dei Lincei*, Series 6(21), 284-287.

The pelitic schistose rocks of the Dasu area in Baltistan are described.

Keywords: Metamorphism, schists, Baltistan.

C/192. Comucci, P., 1936. *Relazioni sommaria sulle rocce raccolte della spedizione. Appendix La Spedizione Geografica Italiana al Karakorum, 1929.* Arti Grafiche Bertarelli, Milano, 23-28.

A summary of the Italian expedition to Karakoram mountains is given in this account. It contains some details of the rocks collected by the expedition in 1929.

Keywords: Petrography, Karakoram.

C/193. Comucci, P., 1937. Dei una singolare roccia del ghiacciaio Baltoro (Karakorum). *Rendiconti rel Accademia Nazionale dei Lincei*, Series 6, 25, 648-734.

Keywords: Baltoro glacier, Karakoram.

C/194. Comucci, P., 1938. Le rocce raccolte dalla Spedizione Geografica Italiana al Karakoram (1929). *Memorie R. Accademia Nazionale dei Lincei*, Series 6A, 7(3), 93-235.

This is a detailed description of a large number of rocks collected during the 1929 Italian Expedition to the Karakoram Mountain Range.

Keywords: Petrography, Karakoram.

C/195. Contin, G., Lombardo, B., Petrini, R., Rolfo, F., Antonini, P., Vison, D. & Le Fort, P., 1998. Geochemistry of metabasaltic and metadoleritic garnet granulites from the NE Nanga Parbat-Haramosh Massif, Northern Pakistan. Preliminary results. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop. Abstract Volume, 45-47.

In the NE Nanga Parbat-Haramosh Massif (NPHM) of the NW Himalayan syntaxis (Stak and upper Turmik valleys, Susrut Nala) metabasaltic and metadoleritic dykes of garnet granulite intrude garnet-kyanite-biotite-muscovite para- and orthogneisses of the Higher Himalayan basement complex. Compositionally the garnet granulites are tholeiitic to mildly alkaline basalts and (rarely) picritic basalt and picrite. In a Ti-Zr-Y diagram most of the samples plot in the field of within-plate basalts as defined by whereas the metapicrites and a few metabasalts lie in the compositional field of ocean floor basalts because of their higher contents of Y.

Significant variations of major and trace element contents occur between the metapicrites (mg# 0.75-0.67) and the most evolved metabasalt, an alkali metabasalt from the Subsar area of the Indus valley (mg# 0.27), which still has the pristine igneous plagioclase and titaniferous ferroaugite. Harker diagrams show a good agreement in trends of major and trace elements plotted against an index of magma evolution such as MgO and the less mobile element Zr. A positive correlation exists between Zr and P₂O₅, K₂O, TiO₂, Ba and Rb whereas Ni and Cr are negatively correlated with Zr. SiO₂, Na₂O, Al₂O₃, Y and Sr show more scattered trends relative to Zr. Such trends, particularly the enrichment in incompatible elements, and major elements variations are explained by polybaric fractional crystallization of olivine, clinopyroxene and plagioclase at low pressures and low amounts of water.

MORB-normalized spidergrams show subparallel trends of enrichment up to 100x MORB values and variable depletion of Ni and Cr from the metapicrite to the alkali metabasalt. The observed enrichment is consistent with the effects of the fractional crystallization mentioned above. A negative Sr anomaly is observed for all samples with the exception of the metapicrites. The Sr anomaly is larger for the alkaline metabasalt and it might be explained as the effect of plagioclase fractionation. REE data for one metapicrite and three metabasalts indicate a positive Eu anomaly (Eu/Eu* = 3D1.15) and LREE enrichment for the metapicrite, whereas the metabasalts appear more REE-enriched with higher LREE/HREE ratios. The positive Eu anomaly decreases with the increase of the REE content. These features may result from fractional crystallization after removal of mafic phases in an earlier magmatic stage or by presence of inherited cumulus plagioclase previously equilibrated with a magma in conditions of very low oxygen fugacity. However, the range observed in contents of REE and other trace elements (for example Rb and Nb) cannot be completely accounted for by a simple mechanism of fractional crystallization starting from a parental magma of composition similar to the less evolved metabasalts. Open-system magmatic fractionation or element mobility during metamorphism is therefore invoked for these cases. Further isotopic studies could better identify the dominant mechanism of differentiation and the possible role of crustal contamination. The NPHM metabasic dykes are geochemically similar to the Lower Carboniferous Baralacha La Dyke Swarm of SE Zaskar, Upper Lahul and NW Spiti [5] and to the amphibolite-facies metabasaltic dykes of the Higher Himalayan basement of the Western Syntaxis area [6]. On the other hand, different trends of Ba, Rb and Y during fractionation and the different contents of TiO₂ and P₂O₅ suggest a different magmatic evolution of the NPHM metabasic dykes relative to the Middle Permian Panjal Traps basalts of SE Zaskar, Upper Lahul and NW Spiti studied by.

Keywords: Geochemistry, mafic granulites, NPHM, Himalaya.

C/196. Conway, W.M., 1894. Climbing and Exploration in the Karakoram-Himalayas. Fisher-Unwin, London.

Keywords: Mountaineering, Karakoram, Himalaya.

C/197. Cornwell, K., 1998. Quaternary break-out flood sediments in the Peshawar basin of northern Pakistan. Geomorphology 25, 225-248.

The presence of horizontally bedded, fining upward sequences of sands, silts, and clays throughout the Peshawar basin of northern Pakistan has previously been ascribed to Pleistocene lakes within the basin. Close inspection of these sediments, however, show sedimentological properties that suggest these stacked sequences are more characteristic of deposits of periodic break-out flood deposits and not lacustrine deposits. Exposures near the villages of Piran, Nowshera, Jehingira, Jalala and along the Kabul River show evidence of subaerial exposure (mudcracks and bioturbation zones), lateral continuity and fracture sets. At least three distinct cycles of deposition are apparent in the basin, each exhibiting slightly different structural and sedimentological properties. The groupings and dimensions of the rhythmite sequences indicate that within each cycle multiple episodes of flooding occurred. The absence of significant erosional and depositional features, as well as the preservation of mud rip-up clasts and bioturbation zones further suggests that the periods between episodes of flooding were probably on the order of 101 to 102 years. Evidence of ice-dams and lakes in the Indus drainage system is abundant. Cross-valley moraines and lacustrine deposits that stretch many kilometers upstream are visible in the middle Indus valley between the villages of Sazin and Shatial and Skardu. Calculated ratios of sediment to water suggest that an upstream reservoir at least 32 km³ and perhaps as large as 128 km³ would have been required to produce the extent of rhythmites observed in the Peshawar basin. Generating a reservoir of this size in the Indus drainage system was accomplished near the villages of Sazin–Shatial where large cross-valley moraines and upstream lacustrine sediments indicate large ice-dams as do the moraines and lacustrine sediments near Gilgit and Skardu. The origin of the graded sediments in the Peshawar basin, however, has not been correlated to the failure of a specific ice-dam. The temporal relationship of the graded sediments is unclear. Limited thermoluminescence (TL) analysis of the youngest set of graded sediments (referred to as 'lake beds' by previous investigators) in the Peshawar basin suggest an age of at least 130,000 years BP. This time correlates to the Yunz stage of glaciation along the middle Indus valley which spans from the mid to late Pleistocene to about 130,000 years BP.

Keywords: Break-out flood sediments, Peshawar Basin, Pleistocene lakes, lacustrine deposits

C/198. Cornwell, K. & Hamidullah, S., 1992. Geomorphic evidence of catastrophic flooding along the middle Indus valley. *Geological Bulletin University of Peshawar* 25, 113-121.

Catastrophic floods have inundated the middle Indus River valley throughout the late Quaternary. These floods have produced very distinct geomorphic signatures within the valley such as boulder beds, plunge pools, and chutes. These features have been mapped and measured to develop estimates of flood hydraulic parameters. The bedrock nature of the Indus valley along this stretch constrains floodwater from lateral migration or significant down cutting within the channel. This constraint results in increased flow velocity and greater flood power.

Keywords: Floods, geomorphology, Quaternary, Indus valley.

C/199. Costello, C.P., 1864. Observation on the geological features etc. of the country in the neighbourhood of Bannoo and the sanatorium of Shaikh Bodeen. *Journal of Asiatic Society of Bengal* 33, 378-380.

Keywords: Geology, Bannu, Shaikh Badin, DI Khan.

C/200. Cotter, G. de. P., 1928. Mentions of Devonian limestone series in the Kurram Agency (Approx 33° 54' N: 70° 06'E). *Geological Survey of India, Record* 60, 102-103.

Keywords: Limestone, Devonian, Kurram Agency.

C/201. Cotter, G, de P., 1929. The erratics of the Punjab. *Records, Geological Survey of India*, 61 (4), 327-336.

Cotter gave a list of the blocks near Campbellpur, Jand and Pindi Gheb, resting on alluvium deposits (sand, silt, clay with beds of coarse gravel), or directly on Siwaliks or Mesozoic limestone. He described near Jassian a deposit of "morainic kind" formed by blocks of various lithology that emerge from a "mixture of sand and gravel". The author thought that the erratics were deposited due to some catastrophic event (glacial outburst of water or of mud-

avalanche). In proof he mentions the events of December 1840 and January 1841, when a natural dam formed by landslide near Gor, south of Bunji, collapsed, causing exceptional flooding of the Indus and the river was described as “an absolute wall of mud”.

Key words: Punjab erratics, Indus flood.

C/202. Cotter, G. de. P., 1931. Some recent advances in the geology of northwest India. Proceedings, 18th Indian Science Congress, 293-306.

Keywords: Geology, India.

C/203. Cotter, G. de. P., 1933. The geology of the part of the Attock district west of longitude 72°45' E. Geological Survey of India, Memoirs 55(2), 63-161.

This paper details the sedimentary geology, stratigraphy and structure of the area, including the Siwaliks.

Keywords: Structure, mapping, stratigraphy, siwaliks, Attock.

C/204. Cotter, G. de. P., 1934. Notes on the geological structures and distribution of the oil bearing rocks of Shaikh Boodeen. Journal of Asiatic Society of Bengal 33, 378-380.

Keywords: Structure, hydrocarbons, Shaikh Budin, DI Khan.

C/205. Coulson, A.L., 1936a. A soda-granite suite in the North West Frontier Province. Proceedings India National Institute of Sciences 2(3), 103-111.

Coulson gave an account of the sodic alkaline granites of Warsak area in Mohmand and Mullagori. He also described and correlated granitic rocks and porphyries of Shewa Shahbaz garhi with the Warsak granite. This account provided the foundation of the proposal (Kemp and Jan, 1971) for the existence of an alkaline igneous province in Northern Pakistan

Keywords: Sodic granite, Warsak, Shewa-Shahbazgarhi, NWFP.

C/206. Coulson, A.L., 1936b. Marble of the North West Frontier Province. Geological Survey of India, Record 71, part 3, 328-344.

This is one of the earlier accounts of the geology and economic potential of marbles in North West Frontier province, now part of Pakistan.

Keywords: Marble deposits, economic geology, NWFP.

C/207. Coulson, A.L., 1936c. Octahedral pyrite crystals from Kohat District, North West Frontier Province. Geological Survey of India, Record 71(4), 436-437.

Keywords: Pyrite, Kohat, NWFP.

C/208. Coulson, A.L., 1937a. Marble and dolomite of Ghundai Tarako, North West Frontier Province. Geological Survey of India, Record 72(2), 227-239.

This is one of the earlier accounts of the geology and economic potential of marbles in North West Frontier province, now part of Pakistan. The marble and dolomite deposits of Ghundai Tarkao are discussed.

Keywords: Marble, dolomite, NWFP.

C/209. Coulson, A.L., 1937b. Pleistocene glaciation in North Western India, with special reference to the erratics of the Punjab. North West Frontier Province. Geological Survey of India, Record 72, part 4, 422-439.

This is an account of the extent of Pleistocene glaciation in NW India, and in particular of the erratic rock blocks in the sandy plain of Punjab. He does not agree with the explanation given by Cotter (1929) for the origin of the erratics. He argues that owing to the aerial distribution of the erratics the alleged catastrophic flood should have advanced not along the present course of the Indus through the gorge of Attock, but along the Indobrahm, the paleoriver considered responsible for the sedimentation of the local succession of Siwaliks. He says that this ancient river followed the course of the present Soan, south of the Kala Chitta Range. However Coulson tends to consider the possibility of the erratics being moved by icebergs breaking off the snout of glaciers and then carried by water flowing into a large lake before the last tectonic events created the present fluvial system.

Key words: Pleistocene glaciation, Punjab erratics

Keywords: Glaciation, Pleistocene, Punjab, India.

C/210. Coulson, A.L. 1937c. Gold in the North West Frontier Province (with discussion). Mining Geology Institute, India, Transactions 33, part 2, 191-206. Abstract, Proceedings 24th Indian Science Congress, Hyderabad, 238-239.

Keywords: Heavy minerals, gold, NWFP.

C/211. Coulson, A.L., 1939. The underground water supply of the Peshawar and Mardan Districts of the North West Frontier Province; with an appendix on the Kohat Valley. Geological Survey of India, Record 74(2), 229-259.

Keywords: Groundwater supply, Peshawar, Mardan.

C/212. Coulson, A.L., 1940. The mineral resources of North West Frontier Province. Geological Survey of India, Record 74(2), 1-55.

Keywords: Mineral resources, NWFP.

C/213. Coward, M.P., 1985. A section through the Nanga Parbat syntaxis, Indus valley, Kohistan. Geological Bulletin, University of Peshawar 18, 147-152.

The Nanga Parbat gneisses show polyphase Himalayan age deformation, the last major phase being the development of large upright folds which form the syntaxial structure. These folds are related to a different kinematic system to the main thrust systems of Pakistan and probably formed due to localized high strain near the pinning point of the Himalayan thrusts at the western end of the Himalayan arc.

Key Words: Deformation, structure, Nanga Parbat, Himalaya.

C/214. Coward, M.P., 1985. Aspects of Kohistan tectonics. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The Himalayas are generally considered in terms of India/Asia (or Tibet) collision, the thrusts developing in a piggy bank sequence on to the foreland. The structure of Kohistan shows that this is only a small part of the story. Much of the deformation in the Kohistan arc relates to early (80-100 my) compression and southward directed overthrusting, post-dating Cretaceous collision of the arc with "Asia" and occurring while India lay some several thousand kilometers to the south. Following the collision with India there was considerable further deformation, rethrusting

the Asia Plate back over Kohistan, imbricating late to post-Cretaceous sediments and accounting for some of the necessary shortening of the Asia-Tibet plate, north of the suture. This shortening must have occurred in a break-back position relative to the main Himalayan thrusting.

Key Words: Tectonics, collision, India-Asia, Kohistan, Himalaya.

C/215. Coward, M.P., 1987. The evolution of mountain belts: structure of the Himalayas and Tibet. *Science Progress*, Oxford. 71. 249-273.

Mountain belts form by isostatic uplift, related to a decrease in density of the local lithospheric column. This may develop from (a) localized heating of the mantle, (b) by the addition of new low density material within or below the crust, but (c) more generally it develops from crustal thickening related to continental collision. Early views on mountain belts assumed homogeneous thickening processes, but we now know that horizontal or low-angle displacements play a larger part. Collision involves the subduction of oceanic crust and the eventual underthrusting of one crustal segment beneath that of another plate. The structures developed depend on the strength of the underplating crust, that is, on the original geothermal gradient, rock type and time since underthrusting commenced. For a thrust to have a large displacement, it needs to overcome the resistance to shearing. It builds up a thrust wedge, whose critical taper depends on the basal shear strength. As erosion removes material, the wedge shape is modified by thickening, or by the accretion of new material from beneath and many of the small to medium scale structures in mountain belts are related to this process. The most dramatic mountain belt is that of the Alps-Himalayas, formed as India collided with Asia at about 55 my ago, this time being fairly accurately constrained by the syn-tectonic sediments as well as the history of the Indian ocean. Structural sections through the faulted sedimentary cover to the Indian plate indicate a minimum of 470 km displacement. Thrust rates can be measured by dating syn- to post-tectonic sediments from the front of the thrust wedge, giving about 1 cm/year. From a study of the Indian ocean floor, however, we know that India has moved into Asia some 2500 km, at a rate of about 5 cm/year for the past 50 my. Some of this extra displacement may be taken up by major crustal thickening in Tibet, where the crust doubled in thickness between about 50 and 20 my ago. The remainder must be taken up further north, in central Asia, or by the lateral expulsion of parts of Tibet and adjacent China, along major faults, such as that marking the Kun Lun mountains in northern Tibet. To solve the deep structure of mountains such as the Himalayas, or high plateau such as Tibet, we need new techniques, such as the deep seismic reflection profiling. Such work will be expensive, but it is only when we understand the deep structure and its relationship to what we see at the surface, that we will be able to fully model the kinematics and mechanics of crustal movements.

Keywords: Orogeny, tectonics, Himalaya.

C/216. Coward, M.P. & Butler, R.W.H., 1985. Thrust tectonics and the deep structure of the Pakistan Himalaya. *Geology* 13(6), 417-420.

The systematic restoration of thrust systems provides a powerful constraint on the deep structure of orogenic belts. A balanced cross section, through the imbricated upper crust of the Indian plate in the footwall to the Main Mantle thrust of the western Himalaya, restores to a minimum width of 730 km, the implicit shortening being in excess of 470 km. This requires the Himalaya and southern Tibetan region to be underlain by a wedge of Indian crust. However, a full appraisal of gross crustal structure awaits deep seismic control.

Keywords: Tectonics, structure, Himalaya.

C/217. Coward, M.P., Butler, R.W.H., Chambers, A.F., Graham, R.H., Izatt, C.N., Khan, M.A., Knipe, R.J., Prior, D.J., Treloar, P.J., Williams, M.P. & Barnicoat, A., 1988. Folding and imbrication of the Indian crust during Himalayan collision. *Philosophical Transactions of the Royal Society of London A326*, 89-116.

India collided with a northern Kohistan--Asian Plate at about 50 Ma ago, the time of ocean closure being fairly accurately defined from syntectonic sediments as well as the effect on magnetic stripes on the Indian Ocean floor. Since collision, Asia has over-ridden India, developing a wide range of thrust scrapings at the top of the Indian Plate. Sections through the imbricated sedimentary cover suggest a minimum displacement of over 500 km during Eocene to recent plate convergence. This requires the Kohistan region to the north to be underlain by underthrust

middle to lower Indian crust, deformed by ductile shears and recumbent folds. These structures are well seen in the gneisses immediately south of the suture, where they are uplifted in the Indus and Nanga Parbat syntaxes. Here there are several phases of thrust-related small-scale folding and the development of a large folded thrust stack involving basement rocks, the imbrication of metamorphic zones and the local development of large backfolds. Some of the important local structures: the large late backfolds, the Salt Ranges and the Peshawar Basin, can all be related to the necessary changes in thrust wedge shape as it climbs through the crust and the three dimensional nature of the thrust movements associated with interference between the Kohistan and western Himalayan trends.

Keywords: Collision, structure, Indian crust, Himalaya.

C/218. Coward, M.P., Butler, R.W.H., Khan, M.A. & Knipe, R.J., 1987. The tectonic history of Kohistan and its implications for Himalayan structure. *Journal of the Geological Society, London* 144, 377-391.

The tectonic history of Kohistan, northern Pakistan, involves two collisional events. Cleavage and folding developed at 90-100 Ma along the northern suture between the Kohistan island arc and the Asian plate. At the same time there was major folding and shearing of the lower part of the Kohistan arc, approximately 100 km south of the suture. This deformation was followed by ocean subduction south of the Kohistan arc, generating the Kohistan calc-alkaline batholith, with subsequent ocean closure during the Eocene and obduction of the Kohistan arc, together with the adjacent part of the Asian plate, over the Indian continental crust. The construction of balanced cross-sections through the imbricated upper part of the Indian continental crust, in the footwall to this southern suture indicates a minimum displacement of 470 km, requiring the western Himalayan hinterland to be underlain by a large wedge of Indian middle to lower crust. There is some shortening of the overriding Kohistan and Asian plates by thrusts and shear zones, but it is insufficient to satisfy the palaeomagnetic data; there must be major crustal shortening, involving thrusts, in the Hindu Kush and Pamirs north of Kohistan.

The post-Eocene thrust direction, which for most of Pakistan is towards 160°, is almost perpendicular to that immediately to the east in the Himalayan belt, generating complex refolded thrust patterns in the Hazara syntaxis and large scale folding and rapid uplift with associated brittle faulting and seismic activity adjacent to the Nanga Parbat syntaxis. These different thrust trends indicate that major thrust movement as well as the folds and deformation fabrics, cannot always be related to plate movement vectors, but are modified by, or develop from, complex rotations during plate collision or from the gravitational spreading of a thickened crust. A regional approach is required to recognize and correctly attribute the various components in thrust displacements.

Keywords: Tectonics, Kohistan, Himalaya.

C/219. Coward, M.P., Izatt, C., Ries, A.C. & Williams, M.P., 1992. Passive margin subsidence and inversion along the western margin of the Indian Plate. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 15-16.

Palaeogeographical plate reconstructions, restoration of cross sections and analysis of present day outcrop data have been used to put forward a model for the development of the north-western margin of the Indian Plate (Katawaz basin, Kirthar and Sulaiman Ranges).

The margin was affected by Permo-Triassic Karroo rifting event in an approximately E-W extensional field, continuing in the early Jurassic as India and Madagascar broke away from Africa. The early Cretaceous saw a change in the orientation of the extensional stress field (N-S) as India began to break away and move north along its current path. The Cretaceous is characterized by volcanism, mainly clastic sedimentation, transtension and transpression, and end Cretaceous ophiolite obduction.

The end Cretaceous is also marked by a regional phase of uplift, and volcanic extrusion of the Raj Mahal and Deccan Traps. Rapid subsidence occurs throughout the Tertiary, marine carbonate shelves and shale rich offshore basins in the Palaeocene-Eocene, shallowing to marine-continental basins in the late Tertiary.

During the Palaeozoic NW India lay on the eastern flank of intra-continental basins whilst still part of Gondwanaland. An early basement fabric may have been acquired at this stage. The NW margin of Pakistan/India has been subjected to various phases of uplift and shortening, the most prominent being during the end-Cretaceous/Paleocene and during the Pliocene. Major tectonic inversion of the Katawaz and Sulaiman Ranges occurred during the Pliocene/Pleistocene. Previous thin-skinned models call for geometrically unreasonable amounts of shortening. Our models call for approximately 23-25 km shortening, reactivating Mesozoic faults at depth.

The western margin of the Indian plate was a passive margin, and remains connected by transitional crust to oceanic crust of the Arabian Sea until the Mio/Pleistocene. The Chaman Fault marks the eastern edge of the overriding Afghan plate expelled laterally from N. Pakistan during the Pliocene. The western edge of Pakistan then collided with this expelled block.

The inversion model has implications for the overall structure and shortening in NW Pakistan. Many of the thrust uplifts may not be thin-skinned; for example, earthquake data suggest the reactivation of faults at depth beneath the Kohat region. The thin-skinned overthrusts sheet of the Himalayas is therefore uplifted by faults reactivating basement structures. This revised model has exciting hydrocarbon potential for Pakistan.

The above history has implications for total Himalayan shortening. It suggests that the edge of the Asian plate was much farther north than previously suggested and hence if collision occurred at 55 to 40 mm, Greater India might have been much larger than previously supposed. Much of the shortening in the Himalayas/Tibet probably occurred in the Indian Plate rather than the Asian Plate.

Keywords: Plate tectonics, structure, palaeogeography, Jurassic, Cretaceous, Indian Plate.

C/220. Coward, M.P., Jan, M.Q., Rex, D., Tarney, J., Thirwall, M. & Windley, B.F., 1982. Geotectonic framework of the Himalaya of N Pakistan. *Journal of the Geological Society of London* 139(3), 299-308.

In the Karakorum Range there is a structurally complicated Cretaceous arc comprising the Kohistan sequence. On its northern side the Northern Suture consists of a mega-mélange and is bounded to the S by tightly folded pillow-bearing volcanics and sediments. To the S the Kohistan Plutonic Belt consists of (southwards): (a) early foliated and late post-tectonic tonalites and diorites, (b) aplites and pegmatites (up to 30% of rock volume), (c) basic dykes up to 10 m thick, (d) the Chilas Complex, a stratiform cumulate body over 300 km long and 8 km thick (chromite-layered dunites, gabbros and norites) with a low pressure granulite-facies mineral fabric of tectonic origin, (e) an amphibolite belt with a complex mixture of other rocks, and (f) the Jijal Complex, a 200 km² tectonic wedge of high pressure granulites and chromite-layered dunites. Cumulate graded units in the Chilas Complex show that it is folded by an isoclinal anticline (F_1). The mid-upper crust of the arc is folded by a 50 km half-wavelength F_2 syncline. The whole Kohistan sequence with its two phases of isoclinal folds was tilted during Himalayan collision so that the structures are now subvertical. The Southern Suture (Main Mantle Thrust) has a wedge of glaucophane schists. The Indian plate contains a basement of psammites and schists intruded by Cambrian granites and overlain by isoclinally folded and metamorphosed carbonates and shales.

Keywords: Geotectonics, structure, collision, Cretaceous, Kohistan, Himalaya.

C/221. Coward, M.P., Jan, M.Q., Rex, D., Tarney, J., Thirwall, M. & Windley, B.F., 1982. Structural evolution of a crustal section in the western Himalayas. *Nature* 295, 22-24.

Recent field work on the Kohistan complex in the Karakorum Range of North Pakistan has shown its stratigraphy to be repeated by several phases of tight to isoclinal folding. This reveals a close association between igneous activity and a late deformation and complicates the previously proposed island arc model.

Keywords: Structure, tectonics, collision, Himalaya.

C/222. Coward, M.P., Jan, M.Q., Rex, D., Tarney, J., Thirwall, M. & Windley, B.F., 1984. Geology of the South Central Karakoram and Kohistan. In: Miller, K.J. (Ed.), *The International Karakoram Project 2*, 71-85. Cambridge University Press.

The Indus suture in northern Pakistan splits into two branches that bring rocks of diverse nature in contact. The northern suture consists of a mega-mélange passing northwards into pelitic and calcareous rocks, which show a rapid increase in grade of metamorphism away from the suture. These rocks are intruded by the calc-alkaline Karakoram batholith. Sedimentary rocks to the north of the batholith are mostly Paleozoic in age and are dominated by slates and shale with some calcareous and arenaceous rocks, and extend up to the Chinese border. The southern suture, with associated ultramafics and a wedge of blueschists, is bordered on the south by the rocks of the Indian plate consisting of a basement of psammites and schists intruded by Cambrian granites and overlain isoclinically folded and low grade metamorphosed cover of carbonates and shales.

Between the two sutures occur rocks of the Kohistan sequence represented by, from north to south, tightly folded pillow-bearing volcanics and sediments; early foliated and late post-tectonic tonalities and diorites with small but abundant intrusions of aplites and pegmatites and basic to intermediate dykes; the Chilas complex, a stratiform cumulate body over 300-km long and 8-km thick; an amphibolite belt with a complex mixture of other rocks; and the Jijal complex, a 200-km² tectonic wedge of high-pressure mafic granulites and chromite-layered ultramafics. The Chilas complex is folded by an F1 isoclinal anticline and the upper part of the Kohistan plutonic belt by a major F2 syncline. The whole of the Kohistan sequence with its two phases of isoclinal folds was tilted during the Himalayan collision so that the structures are now sub vertical.

Keywords: Structure, tectonics, collision, Kohistan, Karakoram, Himalaya.

C/223. Coward, M.P., Khan, M.A., Butler, R.W.H., Knipe, R.J., Prior, D., Treloar, P.J. & Williams, M.P., 1986. Folding and imbrication of the Indian crust during Himalayan collision. Royal Society of London, Spec. Meeting.

India probably collided with a northern Kohistan-Asian plate at about 55 Ma ago, the time of ocean closure being fairly accurately defined from syntectonic sediments as well as the effect on magnetic stripes in the Indian Ocean floor. Since collision, Asia has over-ridden India, developing a wide range of thrust scrapings at the top of the Indian plate. Sections through the imbricated sedimentary cover suggest a minimum displacement of over 500 km during Eocene to recent plate convergence. This requires the Kohistan region to the north to be underlain by underthrust middle to lower Indian crust, deformed by ductile shears and recumbent folds.

These structures are well seen in the gneisses immediately south of the suture, where they are uplifted in the Indus and Nanga Parbat syntaxes. Here there are several phases of thrust-related small-scale folding and the development of a large folded thrust stack involving basement rocks, the imbrication of metamorphic zones and the local development of large backfolds. Some of the important local structures: the large late backfolds, the Salt Ranges and the Peshawar basin, can all be related to the necessary changes in thrust wedge shape as it climbs through the crust.

Keywords: Structure, collision, India, Himalaya.

C/224. Coward, M.P., King, G. & Windley, B.F. 1980. An island arc section in the Himalayas. *Nature* 284, p. 218.

This gives a brief description of an International Conference of the Geodynamics Working Group held at Peshawar in November 1997. There is a very brief mention of some of the rocks and overall makeup of the arc.

Keywords: Island arc, Himalaya.

C/225. Coward, M.P., Rex, D.C., Khan, M.A., Windley, B.F., Broughton, R.D., Luff, I.W., Petterson, M.G. & Pudsey, C.J., 1986. Collision tectonics in the NW Himalayas. In: Coward, M.P. & Ries, A.C. (Eds.), *Collision Tectonics*. Geological Society of London, Special Publication 19, 203-219.

West Himalayan tectonics involve the collision of microplates between the Indian and Asian Plates. The Kohistan Complex consists largely of tightly folded basic volcanics and sediments generated as Late Jurassic to Late Cretaceous island arcs. These were intruded by post-folding Mid-Cretaceous — Eocene plutonics produced from continued subduction of the Indian Plate after closure of a suture between Kohistan and the Karakoram. The Himalayan structures show major thrust sheets and the Kohistan Arc is essentially a crustal 'pop-up' with southward-upright and northward-verging structures developed above a thick ductile decoupling zone (the Indus Suture), which can be traced for >100 km beneath Kohistan on large reentrants. This pop-up formed by a two stage process, closure of the Northern Suture followed by closure of the southern Indus Suture. Granitic rocks of the Kohistan-Ladakh Batholith (dated at $\cong$ 100-40 Ma) post-date most of the structures related to the Northern Suture but were deformed and carried southwards on shear structures related to the Indus Suture. Post-collisional deformation carried this Kohistan Complex on deep decoupling zones over the Indian Plate on a series of imbricated gneiss sheets, the thrusts climbing up section in the movement direction so that in the far S some override their own molasse debris. Folds above these deep decoupling zones deformed their overlying thrust sheets into large antiforms - i.e. the Nanga Parbat and Hazara Syntaxes. The Nanga Parbat Syntaxis probably formed due to a shear couple near

a branch line where one of the main Himalayan thrusts joined the Indus Suture beneath Kohistan. Crustal delamination, to produce the imbricated gneiss sheets, could not account for all the displacement of India into Asia, suggested by palaeomagnetic data. There must also have been lateral displacement as demonstrated by the large oblique-slip shear zone in the Hunza Valley, N of Kohistan.

Keywords: Collision, tectonics, Kohistan, Himalaya.

C/226. Cox, L.R., 1930. Fossil fauna of the Samana Range and some neighbouring areas: Part 4. Lower Albina Gastropoda and Lamellibranchia. Geological Survey of India, Memoirs, Palaeontologia Indica, New Series, V. 15, Mem. 4, 39-49, 1pl.

Keywords: Paleontology, Gastropoda, Lamellibranchia, Samana range, Hangu.

C/227. Cox, L.R., 1931. Fossil fauna of the Samana Range and some neighbouring area, Pt. 8 The Mollusca of the Hangu Shales. Geological Survey of India, Memoirs, Palaeontologia India, New Series, 15, Mem. 8, 129-214, 6 pls.

Keywords: Paleontology, mollusca, Samana range, Hangu.

C/228. Cox, L.R., 1935. The Triassic, Jurassic and Cretaceous Gastropoda and Lamellibranchia of the Attock district. Geological Survey of India, Memoirs (New Series) 20(5), 1-27.

Keywords: Paleontology, Triassic, Jurassic, Cretaceous, Gastropods, Lamellibranchia, Attock, India.

C/229. Cox, L.R., 1938. Eocene mollusca from North West India. British Museum (Natural History) Annual Magazine Series 11, 1(2), 161-171.

Keywords: Paleontology, Eocene, mollusca, India.

C/230. Cox, L.R., 1956. Fossil invertebrate collection from India and Pakistan in the British Museum (Natural History). Palaeontological Society of India Journal 1, 94-98.

Keywords: Fossils, invertebrates, India, Pakistan.

C/231. Craw, D., Chamberlain, C.P., Zeitler, P.K. & Koons, P.O., 1997. Geochemistry of a dry steam geothermal zone formed during rapid uplift of Nanga Parbat, northern Pakistan. Chemical Geology 142, 11-22.

Natural dry steam zones (vapour only) are relatively rare; most geothermal systems contain both liquid and vapour and typically follow a boiling point-depth (BPD) relationship. The Nanga Parbat uplift-driven conductive thermal anomaly results in a geothermal system which follows a BPD relationship at shallow levels, but below about 3 km fluid inclusions show that the hydrothermal fluid is dry steam with fluid densities from 0.36 to as low as 0.07 g/cm³. This dry steam zone may persist down to the brittle-ductile transition. The dry steam has salinities up to 5 wt.% dissolved salts, and up to 22 mole% dissolved CO₂. The dry steam originated as meteoric water high on the slopes of Nanga Parbat, with $\delta^{18}\text{O}$ as low as - 16‰. Oxygen isotopic exchange with the host rock was facilitated by high temperatures (340° to 450°C) and low fluid densities so that the fluid meteoric isotopic signature was completely obliterated. Hence, quartz veins formed by the migrating dry steam have $\delta^{18}\text{O}$ between +9 and + 15‰, a range which is indistinguishable from quartz in the host rocks.

Quartz vein precipitation from dry steam requires 3 to 5 orders of magnitude greater volume of fluid than typical hydrothermal fluids. The dry steam zone at Nanga Parbat has formed due to near-isothermal depressurization of very hot fluid during rapid tectonic uplift at rates > 3-6 mm/year.

Keywords: Geothermal, tectonics, geochemistry, oxygen isotopes, hydrothermal, Himalaya.

C/232. Craw, D., Koons, K.O., Winslow, D., Chamberlain, C.P. & Zeitler, P.K., 1994. Boiling fluids in a region of rapid uplift, Nanga Parbat Massif, Pakistan. *Earth and Planetary Science Letters* 128, 169-182.

The Nanga Parbat massif of northern Pakistan is currently undergoing rapid uplift ($\sim 5\text{--}10\text{ mm a}^{-1}$), resulting in near-surface elevated temperatures. Numerous quartz veins cut geologically young structures ($< 2\text{ Ma}$), attesting to widespread young fluid flow. Fluid inclusions in quartz veins are predominantly low density water vapour (down to 0.05 mg m^{-3}), with some low density carbon dioxide vapour, and the fluid is predominantly meteoric in origin. Fluid inclusions provide evidence for boiling near to the critical points for water and for 5 wt% NaCl solution (up to 410°C). Head-driven meteoric water was convecting in fracture permeability under hydrostatic pressures which followed the boiling point-depth curve and near-boiling springs emanate from the surface. Hydrostatic pressures persisted to depths of about 6 km below the topographic surface, or near to sea level, where the brittle-ductile transition is inferred to lie. Numerical modelling of conductive heat flow in an area of high relief during rapid uplift indicates that the shape of the near-surface conductive geotherm is significantly influenced by topographic relief. Reasonable approximations for topography at Nanga Parbat produce a conductive geotherm which implies high, near-surface geothermal gradients ($> 100^\circ\text{C km}^{-1}$), and the isotherms describe a giant pillar of heat. Above about 4 km, fluid temperature is greater than conductive rock temperature in permeable zones which carry convecting boiling meteoric fluid.

Keywords: Hydrothermal system, fluid inclusions, uplift, NPHM, Himalaya.

C/233. Crawford, A.R., 1974. The Salt Range, the Kashmir syntaxis and the Pamir arc. *Earth and Planetary Science Letters* 22, 371-379.

The enigmatic Salt Range of Pakistan is suggested to have been rotated about 75° counter-clockwise from an original position in line with the main Himalayan front, about a pole near the eastern end of the Range. Rotation was a consequence of the creation of the Pamir Arc by major block movements in Central Asia which also produced the Kashmir Syntaxis. Although direct palaeomagnetic testing of the hypothesis is not possible, Cambrian pole positions obtained from the Purple Sandstone and Salt Pseudomorph Beds of the Salt Range lie anomalously on the Precambrian part of the apparent polar wander curve for Gondwanaland. These revert to positions in correct chronological sequence on that curve if rotation is allowed for.

Keywords: Salt Range, Kashmir syntaxis, Himalaya.

C/234. Crawford, A.R., 1974. A greater Gondwanaland. *Science* 184, 1179-1181.

Keywords: Gondwanaland.

C/235. Crawford, A.R., 1974. The Indus suture line, the Himalaya, Tibet and Gondwanaland. *Geological Magazine* 111, 369-383.

Misunderstanding exists about the origin of the Himalaya, Indo-Tibetan relationships and the extent and history of Gondwanaland. The Indus Suture Line is a relic of fracture to the mantle but for a period only represented by the faunas of the 'exotic blocks' of the Tibetan Himalaya, i.e. Permian—Late Jurassic. Tibet appears originally to have been part of a plate including India, but submerged while India remained continental. Associated with the fracture extending to the mantle represented now by the Indus Suture Line, shallower subparallel fractures developed within which the Gondwana sediments of the Himalaya were preserved. These, together with the salt at the base of the Tethyan marine sequence, facilitated intra-continental orogeny when, much later, India was affected by vigorous sea-floor spreading and plate movement in the NW Indian ocean after it had become attached to Asia.

The northern plate boundary was beyond Tibet, on the N side of the Tarim Basin Block, and along the Tien Shan. The Tien Shan present peculiar features, particularly very deep long intramontane depressions such as Issyk Kul in USSR and Turfan-Hami in China, and their stratigraphy shows persistent mobility. The Tarim Basin Block has moved sinistrally relative to Tibet and in Gondwanaland lay near northern Western Australia. The suggested extent of Gondwanaland explains the present lack of continental crust W of Western Australia, now in Tibet, and the

intracontinental origin of the Himalaya is consistent with the absence of recent volcanism in an area of considerable seismicity. The association of Tibet with India in Gondwanaland destroys the effectiveness of arguments against continental drift based upon the extension of Indian stratigraphic sequences across the Himalaya. The hypothesis of an enlarged Gondwanaland is given support by recent Chinese discoveries of terrestrial vertebrate fossils of Gondwanic type near the Tien Shan.

Keywords: Gondwanaland, plate tectonics, Indus suture, Himalaya.

C/236. Crawford, A.R., 1979. Gondwanaland Pakistan region. In: Farah, A. & DeJong, K.A. (eds), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 103-110.

Keywords: Gondwanaland, plate tectonics, Himalaya.

C/237. Crawford, A.R., 1979. The myth of a vast oceanic Tethys, the India-Asia problem and Earth expansion. *Journal of Petroleum Geology* 2, 3-9.

Keywords: Tethys, plate tectonics, Himalaya.

C/238. Crawford, A.R., 1981. Isotopic age data for the eastern half of the Alpine Himalayan belt. In: Gupta, H.K. & Delany, F.M. (Eds.), *Zagros, Hindukush, Himalaya Geodynamic Evolution*. American Geophysical Union Transaction, 189-204.

This account gives a summary and discussion of isotopic ages determined for the rocks of Himalayan region in Pakistan. The data are scanty.

Keywords: Geochronology, Himalaya.

C/239. Crawford, A.R. & Davies, R.G., 1975. Ages of Pre-Mesozoic formations of the Lesser Himalaya, Hazara District, Northern Pakistan. *Geological Magazine* 112, 509-514.

Three samples of low-grade metamorphic rocks from the Hazara Group, northern Pakistan, analysed as total-rock samples by the Rb—Sr method, give model ages of 765 ± 20 and 950 ± 20 Ma. The results are discussed in terms of the stratigraphy of Hazara, northwestern Iran, and certain other areas.

Keywords: Geochronology, metamorphic rocks, Hazara group, Himalaya.

C/240. Crawford, M., 1985. Field relationships of the Karakoram Batholith and metamorphic rocks of the Hunza valley, North Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The W-E striking Karakoram batholith in the Hunza Valley is very heterogeneous on both small and large scales but is dominantly calc-alkaline in composition. The main mineralogy is quartz, plagioclase and biotite with hornblende also often occurring in the more mafic areas. There are no mafic dykes but making up 40% of the batholith volume in places are two suites of leucogranitic dykes, one suite being concordant with the foliation and the other later and discordant. These dykes contain quartz, alkali feldspar, garnet, biotite and muscovite and probably represent the residual magma. A little tourmaline indicates late boron-rich fluid phase.

To the north the foliation dips south and low-grade metamorphic chistolite slates of the contact aureole have a south dipping contact with the batholith. A migmatitic belt forms the southern part of the batholith and this is truncated against metamorphic rocks to the south by a north dipping thrust plane.

South of the batholith the foliation dips north and there is a sharp change in the direction of foliation dip near the center of the batholith. Thrust planes and lithological contacts are parallel to the foliation suggesting the folding and thrusting episodes were synchronous and there may be related to the emplacement of the batholith. The metamorphic rocks show a Barrovian-type sequence of facies and include metapelites, calc-silicates and pure carbonate bands. With increasing grade from greenschist to amphibolite facies a series of index minerals

representing isoreaction-grade change through chloritoid to staurolite to kyanite to sillimanite with gneissic melting next to the batholith. The isogrades dip north and the metamorphism increases to the north so the sequence is therefore inverted.

Keywords: Geology, Karakoram batholith, Hunza.

C/241. Crawford, M.B., 1988. Leucogranites of the NW Himalaya: mantle-crust interaction beneath the Karakoram and the magmatic evolution of collisional belts, Ph.D. Thesis, University of Leicester.

The Karakoram Axial Batholith in N. Pakistan records the magmatic development of the Eurasian continental margin since the late Jurassic. Magmatism prior to the collision of India with Eurasia at c.45Ma is represented by subduction-related, calc-alkaline granodiorite plutonism. The chemical variation within these plutons is caused by high-level fractionation processes. However, heterogeneous isotope data suggest that the source of these magmas was the mantle wedge, enriched by a subducted slab component, with the melts being contaminated by a Sr-rich crustal component.

There are two types of post-collisional leucogranites. The Sumayar pluton is related to restricted partial melting of sillimanite-grade metapelites triggered by fluxing of fluids from the underthrust Indian crust. This water-saturated, minimum melt is considered to be an analogue of the High Himalayan leucogranites.

The other Karakoram leucogranites are related by fractionation to a more basic monzogranitic parent, whose geochemistry indicates a lower crustal source. However, melting of typical crust cannot explain the anomalously high large ion lithophile element (LILE) content of the monzogranites. Associated with the granites are ultra-potassic, LILE-enriched lamprophyres. This LILE-enrichment is attributed to alteration of the mantle wedge by fluids and /or siliceous melts from the slab. Amphibole in the resulting metasomatic assemblage acts as a sink for the otherwise incompatible LILE. As a result of heating and thermal relaxation beneath the thickened continental crust, enriched amphibole, stable in the pre-collisional after collision to give the lamprophyres. Fluid precursors to this melting contaminated the source region of the granites selectively enriching it in LILE and triggering/promoting melting. The identification of the above magma-types, which have different generative processes and magmatic triggers, in other collisional environments, will lead to information about the evolution of similar orogenic belts.

Keywords: Leucogranites, Karakoram batholith, Himalaya.

C/242. Crawford, M.B. & Searle, M.P., 1992a. Crustal structure and collision-related granitoid magmatism of the Hunza Karakoram, north Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 17.

The Karakoram batholith in the Hunza segment of the Karakoram Range, north Pakistan, is dominated by a pre-50 Ma collision, calc-alkaline, quartz diorite-granodiorite batholith which separates a dominantly sedimentary terrain to the north from a regional metamorphic terrain to the south. The southern part of the batholith and the metamorphic rocks to the south are affected by strong south-vergent thrusting related to the collision, which has brought deeper level, hotter rocks over higher level, cooler rocks, creating an apparent inverted metamorphic profile. Isograds have been disrupted by large-scale, post-metamorphic thrusts. Stretching lineations are dominantly north-dipping throughout. The northern part of the batholith is relatively undeformed and shows an intrusive contact with the sediments to the north and an andalusite-bearing contact metamorphic aureole.

A massive dyke complex, the Hunza dykes, intrude the early phase of the batholith as well as the high-grade sillimanite gneisses to the south. The Hunza dykes consist of a co-genetic suite of monzogranites, granodiorites and leucogranites, which are related by feldspar-biotite fractionation. They are volatile-depleted non-minimum melts with unevolved Sr isotope ratios and LILE-enriched signatures similar to the Baltoro pluton further east. The Sumayar pluton intrudes the kyanite and staurolite-grade metamorphic rocks south of the batholith and is a homogeneous, water-saturated, minimum-melt leucogranite, with a major element composition similar to that of the Manaslu leucogranite of central Nepal. Abundant tourmaline and high Sr isotope ratios (>0.8) together with REE modeling indicate a metapelitic source for the Sumayar leucogranite.

The massive post-collisional Baltoro monzogranite-leucogranite pluton is not continuous across to the Hunza region. The Hunza dykes are, however, almost certainly related to the Baltoro pluton, and represent lower crustal magmas derived by dehydration melting of metasediment following the India-Kohistan-Asia collision events. Consideration

of the petrogenesis of the Hunza dykes and the Sumayar pluton allow inferences to be made concerning the deep crustal structure of the Hunza Karakoram.

Keywords: Structure, granitoid magmatism, collision, Hunza, Karakoram.

C/243. Crawford, M.B. & Searle, M.P., 1992b. Field relationships and geochemistry of pre-collisional (India-Asia) granitoid magmatism in the central Karakoram, northern Pakistan. *Tectonophysics* 206(1-2), 171-192.

In the central Karakoram Range, northern Pakistan, seven major granitic units which were emplaced prior to the Eocene (ca. 50 Ma) India-Asia collision have been mapped and analysed geochemically. The mid-Cretaceous Hunza plutonic complex dominates the Karakoram batholith in the west and is composed of quartz diorite-granodiorite plutons which have been deformed in the south by later collision-related thrusting. The Sost and Khunjerab plutons intrude the Palaeozoic-early Mesozoic sediments north of the batholith. In the east pre-collision magmatic units occur both north of (K2 gneiss, Broad Peak quartz diorite, Muztagh Tower unit) and south of (Hushe gneiss) the batholith which is dominated by a Miocene monzogranite-leucogranite pluton (Baltoro unit). The plutonic units to the north of the batholith are mid- to late Cretaceous with an age range of ca. 115-80 Ma whereas the Hushe gneiss to the south is dominantly Jurassic spanning the age range 200-145 Ma.

All the pre-collision magmatic units display similar chemical and isotopic characteristics. Major, trace and REE variations in the Hunza plutonic complex are controlled by high-level fractionation of clinopyroxene, hornblende, plagioclase, biotite, ilmenite and allanite. High LILE/HFSE and LREE/HREE ratios, together with negative Nb, P and Ti anomalies suggest an ultimate source in the mantle wedge above the subducting slab. $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratios (0.7055-0.7157) in the Hunza plutonic complex can best be explained by contamination of a mantle-derived magma by a crustal component with highly radiogenic Sr.

All the units except the Hushe gneiss are probably related to subduction during closure of a back-arc basin between the Karakoram to the north and the Kohistan-Dras arc to the south during the mid- to late Cretaceous, and correlate with widespread plutonism from the same period in Kohistan, Ladakh and southern Tibet along the southern margin of Asia. The Hushe gneiss is probably related to an earlier northward-directed subduction phase during the Jurassic.

Keywords: Structure, geochemistry, pre-collision granitoid magmatism, Karakoram.

C/244. Crawford, M.B. & Searle, M.P., 1993. Collision-related granitoid magmatism and crustal structure of the Hunza Karakoram, north Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonics*. Geological Society of London, Special Publication 74, 53-68.

Keywords: Structure, magmatism, collision, Hunza, Karakoram.

C/245. Crawford, M.B. & Windley, B.F., 1990. Leucogranites of the Himalaya/Karakoram: implications for magmatic evolution within collisional belts and the study of collision-related leucogranite petrogenesis. *Journal of Volcanology and Geothermal Research*, 44, 1-19.

Two types of leucogranite have been identified in a collisional setting in the Himalaya. Type-a (e.g., Manaslu, High Himalaya) are syn-tectonic crustal melts related to "hot over cold" thrusting and subsequent fluid fluxing. Type-b (e.g., Baltoro, Karakoram) is related to lower crustal melting during/following crustal thickening and thermal re-equilibration, followed by crystal fractionation. For type-b, melting is triggered/promoted in the lower crust by input of heat and material from the sub-continental lithospheric mantle which is contemporaneously melting due to removal of the slab input and downward displacement.

Both these granite types can be explained in terms of recent thermal models for continental collision, and so might be expected to be found in other orogenic terranes. These models also show that extension and thinning will occur as a result of the crust becoming gravitationally unstable, due to thickening, sometime after collision. Thinning will lead to upwelling and melting of asthenosphere which could then intrude the base of the crust and promote further melting. This could explain the common occurrence of A-type granitoids as final plutonic events in orogenic terranes following intrusion of the collision-related type-a and type-b granites.

Existing genetic classification schemes only classify granites in terms of source-type or broad environmental affinity (e.g., collisional). To further subdivide such broad environmental fields it is considered that processes and a general

evolutionary model must be used. Source-type is not suitable due to the number of source components that are often involved and the overlap of these components from one environment to another. One or two selected features of a granite are not, however, sufficiently exclusive to identify different petrogenetic histories. We propose that an evaluation of field style, mineralogy, isotope and elemental geochemistry should be used to subdivide the collisional granite field into type-a and type-b (or Manaslu and Baltoro-types) respectively.

Keywords: Collision, leucogranites, magmatic evolution, Himalaya, Karakoram.

C/246. Cressey, G., 1986. Geikielite and perovskite in serpentine-brucite marble from Baltistan, Northern areas (Kashmir), Pakistan. *Mineralogical Magazine* 50, 345-346.

Keywords: Mineralogy, serpentine-marble, Baltistan, Pakistan.

C/247. Crick, J.C., 1904. Notes on the two cephalopoda obtained by Lt. Col. Skinner, R.A.M.C., from the valley of the Tochi River on the North West Frontier of India. *Geological Magazine* 1, 490-493.

The valley of the Tochi River is an outlying corner of the British Empire in India forming a portion of Waziristan, the boundary of which was delineated in 1894-5 by an Anglo-Afghan Commission from the Afghan provinces of Khost on the north and Birmul on the west. Mr. F. H. Smith, of the Geological Survey of India, accompanied this Commission as geologist, and his observations "On the Geology of the Tochi Valley" were published in 1895 in the "Records of the Geological Survey of India" (vol. xxxviii, pt. 3, pp. 106-110, pl. iii). On p. 109 he says:—"The range of hills between Idak and Mirán Shah is formed by an anticlinal ridge which approximately strikes north and south, and which is composed of these lower Eocene beds. In the core of the anticlinal a considerable thickness of massive dark grey limestone is exposed, in which I could find no fossil remains; the age of this limestone is therefore doubtful, and there is no evidence of any kind to show whether it belongs to the lowest tertiary or upper Mesozoic age."

Keywords: Palaeontology, cephalopods, Tochi valley, Waziristan.

C/248. Crick, J.C., 1905. Cephalopoda from the North West Frontier of India. *Geological Magazine* 2, 47-48.

This is a discussion of the previous account by the same author. Other workers have given their opinions on the subject.

Keywords: Palaeontology, cephalopods, Tochi valley, India.

C/249. Critelli, S. & Garzanti, E., 1991. Petrology of remnant ocean sandstones derived from the Himalayan suture belt. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 31-32.

After the Indian-Eurasia collision, which determined the final closure of the Neothetys Ocean in the early Eocene, "recycled orogenic" arenites began to be deposited in remnant oceanic basins at both sides of the Indian Peninsula. These sediments, of late Oligocene to early Pliocene age, were progressively incorporated in accretionary prisms formed at subduction zones both to the east (Andaman-Mentawi islands: Moore 1979) and west (Makran: Critelli et al. 1990) of the collision zone. Detritus derived from the elevated Himalayan chain is still being accumulated today in the two greatest turbiditic cones of the world, floored by remnant oceanic crust (Bengal and Indus Fans: Ingersoll and Suczek, 1979; Suczek and Ingersoll 1985).

Detrital modes of these "recycled orogen" clastic wedges are all comparable, and testify to a predominant contribution from the Himalayas. They thus represent the distal "flysch" equivalent of ancient and recent "molasses" (Siwaliks: Prakash et al; 1980, Indo-Gangetic Plain, Potter, 1978), deposited in subaerial foreland basins floored by Indian continental crust.

A major difference in detrital modes among these deposits is represented by the significant volcanic contribution from active magmatic arcs to the subduction complex sandstones (Nias and Makran). Both the Indus and Bengal

turbiditic cones and the ancient and recent foredeep deposits were instead entirely derived from the uplifted Himalayan Chain. While volcanic detritus is absent in the Siwaliks and Ganges sands, recycled volcanoclastics derived from the Transhimalayan arc and Indus-Tsangpo suture zone are transported by the Indus and Brahmaputra rivers up to the turbiditic cones of the Indian Ocean.

Indus	61	7	32	--	--	35	11	54
Ganges	74	10	16	--	--	64	0	36
Brahmaputra	51	26	24	--	--	40	27	33
Indus Fan	43	30	27	0.03	0.66	52	11	37
Bengal Fan	57	28	14	0.01	0.68	87	4	9
Siwaliks	57	7	36	0.10	--	63	tr	37
Nias	70	11	19	0.05	0.70	35	29	36
Makran	56	10	34	0.04	0.68	31	37	32

Figure 1 – Detrital modes of modern sands and Tertiary sandstones derived from the Himalayan Chain data for modern river sands are in QFR rather than QFL mode.

Keywords: Petrology, sandstone, Suture belts, Indus fan, Bengal fan, siwaliks, Himalaya.

C/250. Critelli, S. & Garzanti, E., 1994. Provenance of the lower Tertiary Murree redbeds (Hazara-Kashmir Syntaxis, Pakistan) and initial rising of the Himalayas. *Sedimentary Geology*, 89(3-4), 265-284.

The Murree Supergroup of northern Pakistan is represented by an over 6 km thick succession of deltaic redbeds and intercalated impure foraminiferal limestones of latest Paleocene to Middle Eocene (Ieridian to Lutetian) age, cropping out in the northern part of the Hazara Syntaxis, and by redbeds of younger age (early Middle Eocene to Early Miocene) cropping out in the southern part of the Syntaxis (Rawalpindi area). The quartzolithic composition of the Murree redbeds testifies to a “collision orogen” provenance. Detritus was derived from a suture belt including thrust sheets of metasedimentary and subordinately sedimentary rocks, volcanic or volcanoclastic rocks, and ophiolites. Phyllite rock fragments are most common in the Ieridian sandstones, whereas volcanic and carbonate rock fragments are more abundant in the Lutetian sandstones. Minor quantities of chert and serpentine schist, indicating contribution from uplifted subduction complex sources, as well as siltstone, shale and limestone grains, are invariably present. Detrital modes of sandstones and southwestward progradation of Tertiary clastic wedges both testify to provenance from the proto-Himalayan chain located to the north, and uplifted since the very first stages of the India/Asia continental collision at the end of the Paleocene. The coeval Chulung La redbeds of the Tethys Himalaya instead, consisting of volcanic and subordinate ophiolitic detritus, testify to exclusive provenance from the obducting Trans-Himalayan arc-trench system. This major petrographic difference may be accounted for by the different structural setting of the Chulung La “piggy-back” and Murree foreland basins. These two distinct collisional basins have been separated probably since the onset of collision by a fold-thrust belt, beginning to rise in the position occupied today by the High and Lesser Himalayan structural domains. Throughout the Murree Supergroup, main petrographic parameters do not vary greatly, and volcanic, sedimentary, low-grade metasedimentary and ophiolitic detritus persisted until the Early Miocene, indicating slow progressive growth of the chain. Only during the Middle Miocene, when the highly metamorphosed rocks of the High Himalaya were carried southward along the Main Central Thrust (MCT), the mountain range began to rise to dramatic heights, and huge amounts of detritus started to feed the Siwalik foreland basin sandstones and the remnant ocean turbidites of the Indus and Bengal Fans.

Keywords: Provenance, Murree red beds, Tertiary, Hazara Kashmir syntaxis, Himalayan orogeny.

C/251. Crompton, T.O., 1984a. The Pakistan to Russia triangulation connexion: past and project error analyses. In Miller, K.J., *The International Karakoram Project, Volume 1*. Cambridge University Press.

Using those data available, an error analysis of the triangulation connexion from Gilgit to the Russian border, which was observed by Kenneth Mason's 1913 expedition, is performed. This analysis is compared with an error analysis of the projected re-observation of this connexion. The latter analysis may be treated, in part, as an optimization process enabling crucial measurements for the control of scale, to be identified, based on a priori estimates of measuring accuracies.

The paper continues with some comments on how the calculation of the observations should proceed with a view to abstracting tectonic movements by comparison of the two epochs of measurement. The difficulties of obtaining such results and their statistical significance are described. Finally, looking to the future, the relevance of the 1980 observations is discussed in the context of possible repeat measurements within, say, the next ten years.

Keywords: Tectonic movement, triangulation, Russian, Pakistan.

C/252. Crompton, T.O., 1984b. The calculation of crustal displacement and strain from classical survey measurements. In: Miller, K. J. (Ed.). *The International Karakoram Project 2*. Cambridge University Press.

This paper identifies some of the problems inherent in the determination of planimetric displacement and strain in the earth's crust by repeated survey measurements. An approach which avoids the use of co-ordinates is developed. The technique should be familiar to the surveyor and, at the same time, useful to the geophysicist. After some discussion of the relative accuracies of 1913 and 1980 measurements, the paper concludes with a simple application using data acquired during the International Karakoram Project.

Keywords: Crustal displacement, Karakoram.

C/253. Cronin, V.S., 1982. The physical and magnetic polarity stratigraphy of the Skardu Basin, Baltistan, northern Pakistan. M.A. thesis, Dartmouth College, Hanver, New Hampshire, 226p.

Keywords: Magnetic stratigraphy, Skardu basin, Karakoram, Himalaya.

C/254. Cronin, V.S., 1989. Structural settings of the Skardu intermontane basin, Karakoram Himalaya, Pakistan. Geological Society of America, Special Paper 232, 183-202.

Skardu Basin is a northwest-trending intermontane basin along the Indus River in the Karakoram Himalaya Mountains of Pakistan. Seismotectonic domain boundaries in the Karakoram Himalaya commonly cross lithologic and some older structural boundaries. Four major structural-seismotectonic domains exist in the Skardu area: the Himalayan seismic zone, characterized by thrust tectonics; the complex Hindu Kush-Pamir seismic zone; the Skardu quiet zone, characterized by strike-slip, extensional, and rotational tectonics with relatively little seismicity; and the southern edge of Eurasian lithosphere (Tarim-Kun Lun-Tibet) northeast of the Karakoram fault. The Skardu quiet zone is interpreted to be within the Himalayan thrust prism, above an aseismic detachment along which stable sliding or ductile faulting accommodates displacement. Stresses transmitted into the Skardu quiet zone laterally from the Himalayan seismic zone toward Eurasia and perhaps upward from the inferred basal detachment result in gross clockwise rotation, translation to the north-northwest, and a right-lateral sense of shear in the Skardu region.

Landsat lineaments defined by major drainages suggest an array of fractures and faults in the Skardu quiet zone. Field data suggest that the lineaments generally reflect distributed shear along myriad small faults rather than displacement exclusively localized on major, discrete fault surfaces. Extensive glacial and fluvial erosion have accentuated trends characterized by relatively dense fracturing and faulting. At its confluence with the Indus at Skardu, the Shigar River flows through a breach that may have originated as a pull-apart structure similar to the pull-apart basin along the upper Sutlej River.

The preserved vestiges of the upper Cenozoic Bunthang sedimentary sequence reflect Skardu's early basin phase. Uplift along the Nanga Parbat-Haramosh syntaxis and along the northeastern margin of the Himalayan seismic zone

may have contributed to the ponding of the Indus River in the Skardu Basin during Bunthang time. These axes of uplift may be related to movement of the Himalayan thrust wedge from a region of easy basal slip (Skardu quiet zone) to a region of increased resistance to basal slip (Himalayan seismic zone, or, in the case of the NP-H syntaxis, the Hindu Kush-Pamir seismic areas). Regional uplift within the Skardu quiet zone may reflect thickening of the thrust prism in response to variations in shear resistance along the detachment. Quaternary glacial lake beds located on the floor of Skardu Basin are generally on deformed in the western half of the basin. Local deformation within the lake beds in the eastern half of the basin is probably due to interaction with glaciers.

Keywords: Structural setting, Skardu basin, Karakoram, Himalaya.

C/255. Cronin, V.S. & Johnson, G.D., 1992. The revised chrono-stratigraphy of the Late Cenozoic Bunthang sequence of Skardu intermontane basin, Karakoram Himalaya, Pakistan. In: Shroder, J.F. (Ed.), *Himalaya to the Sea*. Routledge, London, 91-107.

Keywords: Stratigraphy, Late Cenozoic, Skardu basin, Karakoram.

C/256. Cronin, V.S., Johnson, P.W., Johnson, N.M. & Johnson, G.D., 1989. Chronostratigraphy of the upper Cenozoic Bunthang sequence and possible mechanisms controlling base level in Skardu intermontane basin, Karakoram Himalaya, Pakistan. *Geological Society of America, Special Paper 232*, 295-305.

A 1.3-km-thick section of basin-fill sediments within the Skardu intermontane basin of the Karakoram Himalaya, termed the Bunthang sequence, is predominantly reversely magnetized. Glacial deposits and landforms are closely associated with the Bunthang sequence. This implies that basin filling took place between glacial advances and prior to the present Brunhes normal chron, i.e., between 3.2 and 0.73 Ma. Four major facies interfinger within the Bunthang sequence: glacial facies; lacustrine facies, indicative of periods during which the Indus River was ponded within the basin; aggradational fluvial facies that represent periods during which the gradient of the Indus River was controlled by rising base level downstream; and alluvial conglomerates that prograde transversely from the basin margin into the basin at different stratigraphic levels. The last facies represents periods of decreased sedimentation by the Indus River relative to alluvial sedimentation from the basin margin.

Downstream from the Skardu Basin, the Indus River crosses the Nanga Parbat-Haramosh syntaxis; this is an area of rapid late Cenozoic uplift (as much as 1 cm/yr). Differential uplift of the Nanga Parbat-Haramosh syntaxis relative to its surrounding terrain led to local variations in Indus River gradient. Temporary ponding of the Indus River is inferred to have occurred when the uplift rate of the Nanga Parbat-Haramosh syntaxis exceeded the rate of downcutting by the Indus River. Temporary blockage of the Indus River Gorge through the Nanga Parbat-Haramosh syntaxis by glaciers or by major landslides may also have led to variations in base level. Temporal variations in the gradient and base level of the Indus River downstream from the Skardu Basin, are reflected in the different facies that interfinger within the Bunthang sequence at Skardu.

Keywords: Stratigraphy, Cenozoic, Skardu basin, Karakoram.

C/257. Cronin, V.S., Schurter, G.J. & Sverdrup, K.A., 1992. Landsat image analysis of drainage lineaments to locate possible faults and structural discontinuities along the Nanga Parbat-Haramosh Massif, northwest Himalaya. *Abstract Volume, 7th Himalaya-Karakoram Workshop*, Department of Earth Sciences, Oxford University, England, 18-19.

The Nanga Parbat-Haramosh Massif (NPHM) of northern Pakistan is a prominent salient of allochthonous Indian continental crust that is exposed within the Kohistan-Ladakh magmatic arc. Nanga Parbat (8126 m) has the greatest local relief and one of the most rapid rates of uplift yet observed in continental crust. The northerly trend of the NPHM is nearly perpendicular to the active thrust faults of the Himalayan foreland. The reasons for the rapid uplift and anomalous trend of the NPHM are not yet fully understood.

A better understanding of the NPHM awaits collection of a more complete suite of primary structural, seismic, and lithologic data throughout this area. Published structural geologic mapping in this area is inconsistent and very incomplete, particularly in areas that are not close to the roads that follow the Indus, Gilgit, Hunza and Astor Rivers. In this study, satellite imagery was analyzed to supply a family of hypotheses regarding the structures exposed at the

surface that may be active in accommodating the uplift of the NPHM. The development of these hypotheses will enhance both the focus and economy of future structural reconnaissance mapping along the NPHM.

The study area is located between latitudes 35°15'N and 36°15'N and longitudes 74°15'E and 75°15'E. A collection of photographic prints of Landsat 2 MSS band 7 imagery was analyzed to identify lineaments defined by stream drainages that may have developed along structural discontinuities. Discontinuity types relevant at this scale include faults, joints, contacts, spatially persistent foliation, and lithologic variations that result in differential weathering. Virtually all of the ~2500 drainages that are clearly observable on the imagery were manually digitized using a 1200 lpi digitizer. Each drainage was recorded as a polyline of short, linear drainage segments. The azimuth of each drainage segment was determined, and the ~12,000 segments were sorted by azimuth into 36 overlapping sets. A given set contains the endpoint coordinates of each segment whose trend lies within a specified 10° wide azimuthal class. Each set of drainage segments was then automatically re-plotted on a separate map to indicate more clearly the location of linear arrays of drainage segments.

Drainage lineaments are defined as essentially collinear arrays of drainage segments that are traceable across at least one drainage divide. Assisted by the maps of drainage segments, a set of ~200 lineaments was identified by direct inspection of the Landsat imagery. Multiple images of the same Landsat frame were used to identify lineaments, taking advantage of differing sun angles and snow conditions. Most of the lineaments extend for many kilometers, and cross several drainage divides.

The drainage lineaments identified in this study include the traces of the few known active faults in the NPHM area; the Stak, Baroluma, and Raikot Faults. It is reasonable to hypothesize that structural activity is being accommodated on more than the few active faults that have been mapped in this area, given that the NPHM is in one of the most structurally active areas on Earth. Many of the lineaments that do not correlate with known faults or lithologic contacts are located in areas that have not yet been mapped adequately, or at all. We suggest that at least some of the drainage lineaments correspond to previously unmapped active faults. Evaluation of the various hypotheses concerning the origin and significance of these lineaments requires fieldwork.

Keywords: Landsat imaging, drainage, seismicity, structure, NPHM, Himalaya.

C/258. Cronin, V.S., Schurter, G.J. & Sverdrup, K.A., 1993. Preliminary Landsat lineament analysis of the northern Nanga Parbat-Haramosh massif, northwest Pakistan. In: Searle, M.P. & Treloar, P.J. (Eds.), *Himalayan Tectonics*. Geological Society of London, Special Publication 74, 193-206.

Analyses of mosaic of Landsat2 MSS band 7 images covering the northern Nanga Parbat-Haramosh Massif (NPHM) has yielded approximately 540 lineaments defined by sets of collinear drainage segments and aligned linear greytone boundaries. Segments of the few well-mapped faults along the NPHM as lineaments are identified. The paucity of field data concerning faults, joints, lithological fabric and contacts prevent from interpreting most of the lineaments. However, some of the poignant lineament trends probably mark the trace of previously unmapped active faults that accommodate the recent uplift of the NPHM. The origins of these lineaments must be established through structural geological field work.

Keywords: Structure, active faults, Landsat, NPHM, Himalaya.

C/259. Cronin, V.S., Sverdrup, K.A. & Schurter, G., 1990. Landsat drainage lineaments, seismicity and uplift of the Nanga Parbat-Haramosh Massif, northwest Himalaya. Geological Society of America, Abstract with Programs. No. 22, A232.

Consult the following account for further information

Keywords: Landsat imaging, drainage, seismicity, NPHM, Himalaya.

C/260. Crookshank, H.C., 1947. Report on mineral discovery of the GSP, since August 1947. Geological Survey of Pakistan, Record 3, part 1, 9p.

Keywords: Mineral discovery, GSP.

C/261. Crookshank, H.C., 1951. Mineral resources of Pakistan. Pakistan Journal of Science 3, 93-96.

Keywords: Mineral discovery, economic geology.

C/262. Crookshank, H.C. & Heron, A.M., 1955. Discovery of economic minerals of Pakistan. Geological Survey of Pakistan, Records 7(2), 146p.

This and the two preceding contributions of HC Crookshank, valuable at the time of publication, are now only of historic value. Subsequent publications, mostly by the Geological Survey of Pakistan, provide more up-to-date information on the mineral resources of Pakistan. These are referred to in this compilation

Keywords: Mineral discovery, economic geology

C/263. Cugia, M., 1936. Determinazioni di magnetismo terrestre. Appendix 2: La Spedizione Geografica Italiana al Karakorum, 1929. Arte Grafiche Bertarlli, Milano, 8-13.

The Italian expedition of 1929 to the Karakoram Range also conducted geophysical studies. This report is an account of the studies related to terrestrial magnetism.

Keywords: Geophysics, terrestrial magnetism, Italian expedition, Karakoram.

C/264. Currie, E.D., 1930. The fossil fauna of the Samana Range and some neighbouring areas. Part 2, the Albian Echinodea. Geological Survey of India, Palaeontologica Indica, Memoirs (New Series) 15(2) 17-23.

Keywords: Paleontology, Albian Echinodea, Samana Range, Hangu.

D/1. Dainelli, G., 1909. Italiani nel Caracorum. Nuova Antologia 265, 101-109 (Roma).

Key words: Karakoram, expedition.

D/2. Dainelli, G., 1914a. Intorno alla morfologia Himalayana. Appunti Critici ed osservazioni preliminary. Rivista Geografica Italiana 21, p.189 and 355.

Key words: Geomorphology, Himalaya.

D/3. Dainelli, G., 1914b. Italian Expedition to the Himalaya and Karakoram. 13 vols. Zanichelli, Bologna.

Key words: Italian Expedition, Karakoram, Himalaya.

D/4. Dainelli, G., 1917. Ghiacciai artificiali. Bollettino della Sezione Fiorentina dell Club Alpino Italiano 8.

Key words: Glaciers, Karakoram, Himalaya.

D/5. Dainelli, G., 1921. Sul glaciale del Caracorum e dell'Himalaia del Cashmir. Atti 8th Congresso Geografi, Italy, 2, 12-19.

Key words: Glaciers, Kashmir, Karakoram, Himalayas.

D/6. Dainelli, G., 1922a. Studi sul glaciale. Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan Cinese (1913-1914), Series II, 3, Zanichelli, Bologna, 658p.

Key words: Glaciers, Karakoram, Himalayas, Chinese Turkistan.

D/7. Dainelli, G., 1922b. A proposito della trascrizione dei nomi geografici della regione del Caracorum. Rivista Geografica Italiana 29, 162-167.

Key words: Geography, Karakoram.

D/8. Dainelli, G., 1922c. La vita dei un'oasi Balti (alta valle dell'Indo). La Terra e la Vita.

Key words: Balti, Indus.

D/9. Dainelli, G., 1922d. Study sul glaciale. Italian Expedition, De Philippi nell'Himalaya, Caracorum e Turchestan Cinese (1913-1914), Ser II, vol. 3, Bologna.

Dainelli made contribution on the glaciers of the region during the expedition. Although he did not have the opportunity of visiting the erratics of Punjab, he also addressed their problem. He summarized the views of Theobald (1874, 1877, 1880) and Wynne (1877, 1878, 1881) and explained their occurrence according to his opinion. He thought that the blocks were deposited on the bottom of a lake extending over the area where the blocks were found. The glacier snout of the Indus faced this lake. This event is thought to have taken place during the second of the four glacial expansions he considers likely to have occurred, as the lake formed between the first and the second of his suggested glacial expansions due to the marginal lifting of the Himalayan range.

Key words: Italian Expedition to Karakoram (1913-14), glaciers, Punjab erratics

D/10. Dainelli, G., 1922–34. Relazioni Scientifiche della Spedizione Italiana De Filippi nell'Himalaia, Caracorum e Turchestan Chinese (1913–14). Series II, volume I Storia dell'esplorazione (1934), volume II: La serie dei terreni (1934), volume III: Studi sul Ghiacciaio (1922), volume IV Le condizioni fisiche attuali (1928), volume VIII Le condizioni delle genti (1924). Zanichelli, Bologna.

Key words: Scientific results, Italian Expedition to Himalaya, Karakoram and Chinese Turkestan.

D/11. Dainelli, G., 1927/1931. Viaggio ai grandi ghiacciai del Caracorum orientale. Annuario del Club Alpino Accademico Italiano 1927/1931, 21p.

Key words: Glaciers, Karakoram.

D/12. Dainelli, G., 1923. I ghiacciai del Caracorum. La Terra e la Vita 2.

Key words: Glaciers, Karakoram.

D/13. Dainelli, G., 1928a. Catalogo dei ghiacciai del Caracorum. Relazioni Scientifiche della Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan Cinese (1913-1914), Series 2(4). Zanichelli, Bologna.

Key words: Expedition, Himalaya, Karakoram, Turkestan.

D/14. Dainelli, G., 1931. Il maggiore ghiacciaio della terra. Il ghiacciaio Siachen nel Caracorum. Vie d'Italia e del Mondo 37, 801-809.

This is a description of the Siachen Glacier. It is considered as the major glacier on earth.

Key words: Glaciers, Siachin, Karakoram.

D/15. Dainelli, G., 1932. A journey to the glaciers of the eastern Karakoram. Geographical Journal 79, 257-274.

This paper was read at the Evening Meeting of the Society on 11 January 1932. Following is the first page of the paper.

It may perhaps seem superfluous that I should say why I undertook this journey into Eastern Karakoram. But for its story's sake I may mention that I had the great fortune of being a member, as Geographer and Naturalist, of the memorable expedition organized by Dr. Filippo De Filippi and led by himself in 1913-14. During that time I asked and obtained from the leader the widest freedom of action and movement. And thus for a whole year and a half, nearly always alone with my very light personal caravan, I was in continual movement, because I knew it was necessary, for my own experience of the region and for the contribution I could bring to its knowledge, that I should see as many valleys and glaciers, as many plateaux and villages or shepherds' camping grounds as I possibly could. And thus at the end of the expedition I could say to myself I knew all Baltistan and all Ladakh and the first Tibetan plateaux as far as Pankong lake and the Aksai Chin. One blank, however, had remained: the Nubra valley from its mouth in the Shyok valley to its origin in the Siachen glacier. The Nubra valley in its lower half is frequented by caravans which cross the Karakoram Pass during the summer, and it has been followed by various travellers; however not much was known about it, and I had special ideas regarding its population, from an anthropological point of view. The upper half of the valley had been climbed by very few travellers indeed, of the old ones Moorecraft in 1821, Vigne in 1835, Thomson and Henry Strachey in 1848, and some years later by Drew. Then we come to quite modern times, with Longstaff in 1909 and the Vissers in 1929; but its geological conditions were practically unknown. At the head of the Nubra valley is the Siachen glacier, which is said to be the largest glacier on Earth outside Polar regions. Longstaff had discovered and been on it in 1909, the Workmans followed in 1911 and 1912, and also the Vissers climbed it in 1929, but only for a few miles from the front upwards. Of the geological

conditions of its immense basin nothing was known. And this represented the chief blank in my personal knowledge and in connection with the attempt that I have been preparing for years, of reconstructing the geological history of the entire region, which is the last part, and perhaps not the least important, of the scientific results of the De Filippi Expedition.

Key words: Glaciers, Karakoram.

D/16. Dainelli, G., 1933a. Resulti geologici e geografici: La serie dei terreni. Spedizione Italiana De Filippi nell'Himalaya, Caracorum a Turchestan cinese (1913-14). Series 2, Volume 2, Zanichelli, Bologna, 458p.

Key words: Geology, Geography, Himalaya.

D/17. Dainelli, G., 1933b. La mia spedizione al ghiacciaio Siachen nel Caracorum orientale. Bollettino Comitato Glaciologico Italiano 13, 39-57.

Key words: Glaciers, Siachen, Karakoram.

D/18. Dainelli, G., 1933c. Exploratori italiani nell'Himalaya. Le vie d'Italia e del mondo, 1, 437-457.

Key words: Italian exploration, Himalaya.

D/19. Dainelli, G., 1934a. La esplorazione della region e fra l' Himalaia occidentale e il Caracorum e Turchestan Cinese (1913-14), 2(1), 430p.

Key words: Geology, geography, Himalaya, Karakoram, Chinese Turkestan.

D/20. Dainelli, G., 1934b. Relazioni scientifiche della Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan Cinese. Series 2A, Risultati Geologici e geografici. II, La Serie dei Terreni. Zanichelli, Bologna.

Key words: Geology, geography, Himalaya, Karakoram, Chinese Turkestan.

D/21. Dainelli, G., 1934c. Relazioni scientifiche della Spedizione Italiana De Filippi nell'Himalaia, Caracorum e Turchestan Cinese (1913-14), Series Iia, La Serie dei Terreni: Vol. II, Bologna: Zanichelli, 230p.

Key words: Geology, geography, Himalaya, Karakoram, Chinese Turkestan.

D/22. Dainelli, G., 1939. Beitrage zur geologie des Himalaya. Geologische Gesellschaft (Wien), Mitteilungen, Band 30-3, 1-36.

Key words: Geology, Himalaya.

D/23. Dainelli, G. & Marinelli, O., 1915. Cenni speciali intorno alle ricerche di geologia e geografia. Relazione preliminare sui lavori scientifici della spedizione de Filippi al Caracorum (1913-14). Rivista Geografica Italiana 22, p.236.

Key words: Geology, geography, Himalaya, Karakoram.

D/24. Dainelli, G. & Marinelli, O., 1917. Osservazioni sui ghiacciai subarranti l'alta valle dello Shaiok (Caracorum). Rivista Geografica Italiana 24, 81-223 & 307.

Key words: Glaciers, Shyoke, Karakoram

D/25. Daniel, C., 1972-73. Detailed gravity survey of Gilgit Valley, northern areas of Pakistan. M.Sc. Thesis, Punjab University, Lahore, 142p.

A detailed gravity survey comprising of 256 observation covering an area of 15 miles² was conducted for delineation of subsurface geology. The spacing of stations along profiles was kept 1 furlong. Total number of profiles spread was 18 and was spaced 3 furlong apart from each other. The scale was 1:15840. The contour interval kept for Bouguer anomaly map was 0.5 mgals.

In order to get gravity values of all the stations the Master Worden Gravimeter Model 111 No. 955 with scale constant 0.0902/S.D.* was used to conduct geodetic survey, a Russian Transit Theodolite T.T.S. was used. The main gate Marcopolo Inn (Gilgit) was selected the base station, and all the profiles were connected to the base station. Since the regional gravity anomaly map should have regional effects, therefore Bouguer anomaly map was not taken into account. The residual anomaly was considered to be the most suitable. The anomalies developed in residual anomaly map were described very carefully.

Residual anomaly map was prepared after Griffin's and second derivative map was prepared after Elkin's. The various graphical curves obtained from anomalies along different cross-sections were compared with standard curves given in 'The Theory Applied Geophysics by Grant and West'.

Key words: Gravity survey, geology, Gilgit.

D/26. Danilchik, W., 1961. The iron formation of the Surghar and western Salt Range, Mianwali District, West Pakistan. USGS, Professional Paper 424-D: 222-231.

Key words: Iron ore, Surghar, Salt Range, Mianwali.

D/27. Danilchik, W. & Shah, S.M.I., 1967. Stratigraphy and coal resources of the Makarwal Area, Trans-Indus mountains Mianwali district, Pakistan. USGS, Professional Paper 131, 38p.

The Makarwal area of the Trans-Indus Salt Range (Surghar Range) presents an excellent section of thick, fossiliferous sedimentary rocks. The lower part comprises Upper Jurassic (barosh) Limestone, followed upward by Lower Cretaceous sandstone Belemnite-bearing rocks, sandstones (Lamshiwal). These rocks are followed upward unconformably by Lower Eocene Ranikot Limestone with coal seams and Patala shales, and Upper Eocene marl and Laki Limestone. These are overlain unconformably by Miocene conglomerates and sandstones of the Siwaliks. The paper gives details of stratigraphy, lithology and structure of the area, together with the iron ore in the Lower Cretaceous belemnite-bearing beds and Lower Eocene coal.

Key words: Stratigraphy, coal, Makarwal, Trans Indus.

D/28. Danilchik, W. & Shah, S.M.I., 1975. Stratigraphic nomenclature of formations in the Trans-Indus Mountains, Mianwali District, Pakistan. USGS Report 75-622, 45p.

Key words: Stratigraphy, Trans Indus, Mianwali.

D/29. Danilchik, W. & Shah, S.M.I., 1976. Stratigraphy and coal resources of the Makarwal Area, Trans-Indus mountains Mianwali district, Pakistan. A USGS, Project Report Information Release, PK-60, 115p.

Please consult Danilchik and Shah (1967) above for further details.

Key words: Stratigraphy, Trans Indus, Mianwali.

D/30. Danilchik, W. & Tahirkheli, R.A.K., 1959. An investigation of alluvial sands for uranium and minerals of economic importance in Indus, Gilgit, Nagar and Hunza Rivers, Gilgit Agency, West Pakistan. Geological Survey of Pakistan, Information Release 11, 12p.

Uniformly low uranium content of 18 samples from widely distributed sample locations on the Indus, Gilgit and Hunza Rivers suggests that economically significant concentrations of uranium are not likely to be found in the alluvium of the upper Indus watercourses. Sands collected from boulder and cobble gravels in terraces and river beds contain 0.001 percent uranium or less. Wind- and water-deposited mantle sands contain 0.001 to 0.006 percent uranium. Spectrographic analyses of sand and heavy mineral concentrates show no unusual or economically-significant concentration of rare or valuable elements.

Key words: Uranium, Indus, Gilgit, Nagar, Hunza.

D/31. Danishwar, S., 1990. Petrographic and chemical variation within rift related basic dykes in the Malka area (Lower Swat). M.Sc. Thesis, University of Peshawar, 72p.

Key words: Petrography, basic dykes, Buner, Swat.

D/32. Danishwar, S., 1994. Geochemistry of water and soil samples from Khishki and surrounding area, Nowshera and Charsadda district NWFP. M.Phil. Thesis, University of Peshawar.

Please consult the following account and Danishwar et al., 1995 for further information.

Key words: Geochemistry, water, soil, Nowshera.

D/33. Danishwar, S., Majid, M., Shah, M.T. & Haq, N., 1994a. Fluoride abundance in drinking water and related health hazards: A case study from Kheshki area, Nowshera district, NWFP, Pakistan. Geological Bulletin, University of Peshawar 27, 113-116.

Fluorides in food or drinking water have drastic effects on human health. High concentrations of fluorine in drinking water causes a disease called fluorosis. Geochemical study of groundwater and soil samples from the Kheshki area in Nowshera District, NWFP. (where from frequent cases of fluorosis are related) was carried out in February to June 1994. The results show high concentration of fluorides (0.00 to 41.2 ppm) in the groundwater samples from the studied area, which confirms fluoride toxicity. Necessary measures are required to be adopted to minimize the effect of this environmental deterioration.

Key words: Fluoride, water, health hazard, Nowshera.

D/34. Danishwar, S., Majid, M., Shah, M.T. & Haq, N., 1994b. Status and source of high fluorine contents in drinking water of Khishgi and surrounding areas, N.W.F.P, Pakistan. Symposium on Environmental Geology, Department of Geology, University of Peshawar.

Please consult the Preceding account and the following for further information.

Key words: Fluorine, drinking water, Nowshera.

D/35. Danishwar, S., Majid, M. & Shah, M.T., 1995. Mineralogy and Geochemistry of lacustrine deposits of the Kheshki area N.W.F.P. Pakistan. Journal of Science and Technology, University of Peshawar, 19, 33-38.

Kheshki area is a part of the Peshawar basin in N.W.F.P. and is covered by lacustrine deposits. A stratigraphic section north east of Kheshki, is studied in detail. These deposits predominantly contain minerals like quartz, calcite,

albite, orthoclase along with subordinate amount of chlorite, illite, tourmaline, fluorite, hornblende and vermiculite. Chemical analyses of the studied samples are compared with the average analyses of residual clay deposits of various rocks. This study suggests that source rocks of lacustrine deposits of the Khashki area are the acidic plutonic rocks of Warsak and Ambela granitic complex with influx of residual clay from the Nowshera Formation.

Key words: Mineralogy, geochemistry, lacustrine deposits, Nowshera.

D/36. Danishwar, S. & Shah, M.T., 1997. Geochemistry of ground water and the source of contamination of fluoride in the drinking water of the Naranji area, District Swabi, NWFP, Pakistan. *Pakistan Journal of Scientific and Industrial Research* 40, 5-12, 83-00.

Inhabitants of the Naranji village are known for their yellow coloration of teeth throughout the Mardan Division. A general survey of the area shows prevalence of dental and skeletal fluorosis of varied degree in the village. A detailed geochemical analysis of ground water of the village indicates fluoride concentration of 13.5 mg/L which is about 9 times more than WHO's maximum contaminant level. The source of high fluoride in drinking water is considered to be the alkaline rocks of Koga Complex. Tube well water should be supplied to the area in order to avoid the fluoride contamination.

Key words: Geochemistry, groundwater, fluorine, drinking water, Swabi.

D/37. Danishwar, S., Shah, M.T. & Majid, M., 1995. Abundance of fluoride and its source in drinking water of Khashki and surrounding area, district Nowshera, NWFP, Pakistan. *Geological Bulletin, University of Peshawar* 28, 31-37.

Fluoride, if present in minute amount in human body, is beneficial for the growth of bones and teeth. Its excess is, however, very harmful and usually causes skeletal fluorosis. Few cases of skeletal fluorosis are reported in Khashki and surrounding areas in NWFP. The drinking water of study areas has been, therefore, analyzed for the fluoride contents. It is noticed that this water has high concentration of fluoride. The source of fluoride enhancement in the drinking water of the area needs to be unraveled. For this purpose the water of Kabul river, rocks of Nowshera Formation and the lacustrine and soil samples of the area have been analyzed for fluoride. These media show elevated amounts of fluoride. The study suggests that in the lacustrine and soil deposits of the Khashki and surrounding area the detrital minerals, which accommodate fluoride in their structure, are the main contributors of fluoride to be the drinking water.

Key words: Fluoride, drinking water, Nowshera.

D/38. Daru, N.D., 1910. Alum shale and alum manufacture at and near Kalabagh, Mianwali District, Punjab. *Geological Survey of India, Records* 40(4), 265-282.

Key words: Alum, Kalabagh, Mianwali.

D/39. Das-Gupta, H.C., 1915. Paleontological notes from Hazara. *Journal of Asiatic Society of Bengal, New Series* 11, 253-257.

Key words: Palaeontology, Hazara.

D/40. Daubekku, G., 1934. La esplorazione della regione fra l' Himalaia, occidentale e il Karakorum e Turchestan Cinese (1913-14). *Mitteilungen Der Geologischen Gesellschaft In Wien* Band, 2(1), 430p.

Key words: Himalaya, Karakoram, Chinese Turkestan.

D/41. Daubekku, G., 1939. Beiträge zur Geologie des Himalaya. *Mitteilungen Der Geologischen Gesellschaft In Wien* Band, 30-31.

Key words: Geology, Himalaya.

D/42. Davidson, C.F., 1962. Uraninite-scheelite placers of the river Indus. *Economic Geology* 57, 456-457.

Takes exception to the postulated long-distance transport of detrital scheelite and uraninite in sediments of the Indus river, Pakistan, noting evidence that scheelite is present in the alluvial deposits of many of the tributary valleys.

Key words: Uraninite, scheelite, Indus River.

D/43. Davidson, D.F., 1975. The geology and mineral resources of Kakul and Lagarband phosphate deposits, Hazara District, Pakistan. US Geological Survey/Geological Survey of Pakistan Information Release PK-63.

Based on field examinations and study of all available information concerning the phosphate deposits of the Kakul-Mirpur area, Pakistan, there is believed to be approximately 700,000 tons of minable phosphate rock of a grade of 30 percent or more P₂O₅ in the area. A similar study of available information of the Lagarband deposit suggests that there may be approximately 1,000,000 tons of minable phosphate rock containing 30 percent or more p₂O₅; in addition, approximately 1,500,000 tons of rock containing 20 percent to 30 percent p₂O₅ appear to be minable,

The total resource so far identified thus appear to be just over 3,000,000 tons of rock which may or may not be usable because of its chemical and mineralogical characteristics, but which can be mined. It must be pointed out that the figures given are based on very limited physical exploration, and equally limited analytical data. Further studies in the two areas are as likely to lessen as to increase them.

Key words: Mineral resources, phosphate, Kakul, Hazara.

D/44. Davidson, T., 1864. Notes on some Carboniferous and Jurassic brachiopoda collected by Capt. Godwin-Austin in north-western Himalaya. *Geological Society of London, Quarterly Journal* 20, p.387.

Key words: Carboniferous, Jurassic, brachiopoda, Karakoram, Himalaya.

D/45. Davidson, T., 1866. Notes on some Carboniferous brachiopoda collected by Capt. Godwin-Austin in the valley of Kashmere. *Geological Society of London, Quarterly Journal* 22, 39-45.

Key words: Carboniferous, Jurassic, brachiopoda, Himalaya.

D/46. Davis, I., 1984. Analysis of recovery and reconstruction following the 1974 Patan earthquake. In: Miller, K.J. (ed.). *The International Karakoram Project 2*, 323-342. Cambridge University Press.

The Patan earthquake was the most severe earthquake in Pakistan since the 1935 Quetta disaster. This paper will review some aspects of the relief and reconstruction activities with particular reference to earthquake damage and subsequent reconstruction in Dobair Bazaar and Patan. Detail is provided concerning shelter and housing provision, and in the light of the objectives of the Housing and Natural Hazards Projects, the paper discusses changes that may have to be made in construction techniques, thus reducing future vulnerability.

Key words: Earthquakes, disaster, Pattan, Hazara.

D/47. Davies, L.M., 1918. Problem of the Himalaya and the Indo-Gangetic Trough. *Geographical Journal*, 51, 175-193.

Key words: Himalaya, Indo-Gangetic trough.

D/48. Davies, L.M., 1926. Remarks on Carter's genus *conulites* (=dictyoconocides, nuttall) with descriptions of some new species from the Eocene of the Northwest India. Geological Survey of India, Record 59(2), 237-253.

Key words: Palaeontology, Eocene, India.

D/49. Davies, L.M., 1926. Remarks on the known species of *conoclypeus* with description of two new species from the Eocene of northwest India. Geological Survey of India, Record 59(3), 358-368.

Key words: Palaeontology, Eocene, India.

D/50. Davies, L.M., 1926. Notes on the geology of Kohat, with reference to the homotaxial position of the salt marl at Bahadur Khel. Asiatic Society of Bengal, Journal, Proceedings New Series 20, 207-224.

Key words: Rock salt, Bahadurkhel, Karak.

D/51. Davies, L.M., 1927. The Ranikot beds at Thal (North-West Frontier Province of India). Quaternary Journal of the Geological Society of London 83, 260-290.

Key words: Ranikot beds, Hangu, India.

D/52. Davies, L.M., 1930a. The fossils fauna of the Samana Range and some neighbouring areas. Part 1, Introductory note. Geological Survey of India, Palaeontologica Indica, Memoir (New Series) 15(1), 1-15.

Key words: Fossils, Samana Range, Hangu.

D/53. Davies, L.M., 1930.b The fossil fauna of the Samana Range and some neighboring areas. Part 6, The Paleocene foraminifera. Geological Survey of India, Palaeontologica Indica, Memoir (New Series) 15(6), 67-80.

Key words: Fossils, Samana Range, Hangu.

D/54. Davies, L.M., 1932. The genera *Dictyoconoides* Nuttall, *Lockhartia* nov., and *Rotalia* Lamarck: their type species, generic differences, and fundamental distinction from the *Dictyoconus* group of forms. Royal society of Edinburgh, Transactions, 57, 397-428.

The author recalls the facts regarding the rediscovery, in recent years, of Carter's genus *Conulites* (= *Dictyoconoides* Nuttall). He shows how, of seven species which have been referred to this genus, three always have numerous intercalary whorls in their spires, and four never have any such whorls. The association of these two groups together within a single genus has, so far as he himself is concerned, been due to the uncertainty hitherto existing regarding the type species *cooki*, whose spire was stated by Carter sometimes to show an intercalary whorl, but generally to be "single throughout." Carter's original specimens, which had long been mislaid, have recently been found, however, and they all prove to belong to now familiar types, which invariably contain numerous

intercalary whorls in their spires. The author therefore separates the four species which do not possess such whorls into a new genus, *Lockhartia*.

The author next discusses the supposed identity of *Dictyoconoides* with *Rotalia*, and shows that the *Rotalia* must be judged by their type species *R. trochidiformis*. He shows that this species, among other characteristic features, invariably displays the structures called “astral lobes” by Carpenter and Brady, and is distinguished by the same from both *Dictyoconoides* and *Lockhartia*; while it is further distinguished from *Dictyoconoides* by the absence of intercalary whorls in its spire.

The author then compares the development of Rotalid forms, like the above, with that of piano-spiral ones like *Nummulites* and *Assilines*; and he finally shows the fundamental difference in structure between all these spirally wound types and those with an “end-on” development, like the *Dictyoconus* group of forms, with which some of them have been confused in the past.

Key words: Palaeontology.

D/55. Davies, L.M., 1938a. Eocene beds in Waziristan (India). *Nature* 142, p.296.

I SEE that Dr. Heron now accepts the fact that Ranikot beds exist in Waziristan. The evidence for this is, indeed, overwhelming, as I have pointed out elsewhere². He says, however, that Dr. Coulson could not state whether the Khirthar overlaps on the Ranikot to the north of Kotkai, so perhaps I may be allowed to quote my own observations.

Key words: Palaeontology, Eocene, Waziristan, India.

D/56. Davies, L.M., 1938b. Quelques resultants de travaux recents sur 1' Eocene du nord-ouest de 1'Inde. *Societe Geologique de France, Comptes Rendus des Seances*, 1938 (1-2), 22-23.

Key words: Palaeontology, Eocene, Waziristan, India.

D/57. Davies, L.M., 1940a. Geographical changes in northwest India during Late Cretaceous and Early Tertiary times. Abstracts with discussion, Geological Society of London, Quarterly Journal 96(2), 2-4 OR 1364, 11-14.

Key words: Geography, Cretaceous, Tertiary, India.

D/58. Davies, L.M., 1940b. Geographical changes in northwest India during Late Cretaceous and Early Tertiary times. *Proceedings, 6th Pacific Science Congress* (1939) 2, 483-501.

Key words: Geography, Cretaceous, Tertiary, India.

D/59. Davies, L.M., 1940c. Notes on the Himalayan rivers. *Geological Magazine* 77, 410-412.

This account gives the Physiographic relations between the rivers and the mountain ranges in the Himalayan region.

Key words: Physiography, rivers, Himalaya.

D/60. Davies, L.M., 1940d. Correlation of the Laki beds (Eocene, India). *Geological Magazine* 77, 252-253.

This paper gives correlation of the Eocene deposits of the Laki formation, included in these are those from northern Pakistan.

Key words: Stratigraphy, Eocene.

D/61. Davies, L.M., 1942. Tertiary Echinoidea of the Kohat-Potwar basin. Abstracts with discussion- Geological Society of London, *Proceedings* 1389, 7-9.

Consult the following account.

Key words: Tertiary, Kohat, Potwar.

D/62. Davies, L.M., 1943. Tertiary Echinoidea of the Kohat-Potwar basin (India). *Quarterly Journal of the Geological Society, London* 99, 63-77.

The author describes the results, to date, of work on the Tertiary echinoids of the Kohat district and northern Punjab. He recalls facts published in previous papers, and deals with collections more recently made. He outlines the stratigraphy of the northern basin, and shows how its echinoids help to correlate its elements with the early Tertiary deposits of Baluchistan and Sind.

A Number of Tertiary echinoids from the Kohat-Potwar basin have already been dealt with (Davies 1925, 1926A, 1927, 1937), but many more were collected during my last visit to India. An attempt is here made to summarize existing information on the subject.

By the expression "Kohat-Potwar basin" (cf. Davies 1940B, p. 489; 1940C, p. 209), is meant an area approximately covered by the Kohat district and the Potwar plateau. This region formed a fairly well-marked basin during late Cretaceous and early Tertiary times, when an arm of the Tethyan sea crossed the north-western corner of the Indian horst on its way to what is now southern Tibet (Davies 1940B). In the final phases of its marine history this basin showed increased individuality, owing to earth movements which severed its trans-Himalayan extension to the east and restricted its communications with Sind to the south.

Key words: Tertiary, Kohat, Potwar.

D/63. Davies, L.M., 1945. Age and origin of the salt deposits of Northwest India. *Proceedings (section B), National Academy of Sciences, India* 14(16), 225-232.

Key words: Salt deposits, India.

D/64. Davies, L.M., 1947. Age and origin of the salt deposits of northwest India. *Proceedings (section B), National Academy of Sciences, India* 16, part 2-4, 39-42.

Key words: Salt deposits, India.

D/65. Davies, L.M., 1950. Foraminifera and stratigraphy of the Indo-Afghan border. 18th International Geological Congress, Great Britain 15, 73-75.

Key words: Stratigraphy, foraminifera, Indo-Afghan border.

D/66. Davies, R.G., 1956. Petrographic notes on some rock types from the Panjal volcanic series of the Upper Lidar Valley of Kashmir. *Geological Survey of Pakistan, Records* 33 (3).

Key words: Petrography, Panjal volcanics, Kashmir

D/67. Davies, R.G., 1962. A green beryl (emerald) near Mingora, Swat State. *Geological Bulletin, Punjab University* 2, 51-52.

This is probably the first description of the emerald that occurs at Mingora.

Key words: Beryl, emerald, Mingora, Swat.

D/68. Davies, R.G., 1963. Some preliminary observation on the geological structure of the Hazara Slate Formation in the area of the Lora-Maqsood road. *Geological Bulletin, Punjab University* 3, 32-35.

The Hazara Slate Formation, according to Marks and Muhammad Ali (1961, p. 451, is composed of a thick succession of arenaceous and argillaceous rocks, largely fissile and well-bedded, but with true slates largely absent. The common alternations of sub-greywacke sandstones with silty and argillaceous rocks were likened by them to the Alpine Flysch; they drew attention to the graded bedding in the sandstones and to their smooth tops, flowcasts on the undersides, and worm tracks, and commented on the absence of ripple marks and current bedding. Muhammad Ali (1962, p. 32) suggested that the formation was in excess of 10,000 feet thick.

Key words: Structure, slates, Hazara.

D/69. Davies, R.G., 1964a. Some anomalous formations lying within the Attock Slates in the area immediately south of Attock, Peshawar Division, West Pakistan. *Geological Bulletin, Punjab University* 4, 101-102.

As a result of a photogeological examination of the country south of Attock, it was decided to carry out a ground check on the nature of certain bands of rock, apparently lying within the Attock Slates and giving rise to lighter tones than do the slates themselves. In August, 1964, a preliminary examination was made along the road which leads southwards from the western end of the Attock bridge and which cuts through the rock bands concerned. After passing through the slates themselves for about one thousand yards, the first band was found to form a narrow NW-SE trending ridge of a dark- coloured limestone which thickened to the south east. An exactly similar limestone occurred about half a mile to the south as a narrower band crossing the road with a W N W trend. Typical Attock slates or shales made up the area between the two limestones and also occurred again to the south of the southernmost band for about half a mile; they were followed, to the south by :

1. A band of white quartzite with some quartz veins.
2. Alternations of thinly bedded, purplish and greenish siltstones, rather fissile.
3. A white, fine-grained, compact limestone with a porcellanous appearance.

The total horizontal thickness of these (last mentioned) sedimentary rocks is about 2,000 feet; the dips are quite steep, but variable, and usually towards the south. Unit number 3 (above) is followed to the south by appreciable thicknesses of Quaternary superficial deposits belonging to the Upper Pleistocene and including silts, sands, gravels etc. The situation of these outcrops is given in Fig. I. An examination of the aerial photographs and a rapid scrutiny of the ground showed that the formations are present, not only on the west side of the Indus, but also on the east side, in the area shown by Cotter (1930), in his map, as Attock slate.

The formations extend far to the west, in the westerly trending ridges of Khattak and also to the east, in the hills north and west of Dakhner. It is seen that the structure is a rather tightly folded one with a mainly E-W trend and southerly dips; a number of very narrow folds are present which appear to be overturned towards the north. Small faults, often with N-S to NE-SW trends are present. A microscopic examination of thin sections of the more important lithologies present has led, in the case of the more northerly of the two limestone bands, to some rather unexpected results. The band concerned, which is narrow and enclosed by typical Attock slate, appears to have been plastically deformed and fractured and was found to be speckled with small Foraminifera. Among these, have been identified, by Mr. Riaz Ahmad, the following genera: *Miscellanea*, *Nummulites* and *Assilina*; fragments of gasteropods are also present, including *Turritella*. It is evident that this rock is of Palaeogene (probably Paleocene-Lr. Eocene, age). The rocks of the other, more southerly, outcrops do appear to be in a much better state of preservation than are the adjacent slates, and give the impression of being much younger, despite the overall complex structure. They seem to bear certain similarities to some of the rocks of the Abbottabad Formation of Marks and Ali (1962, p. 56).

It is thought that these outcrops represent in- folded and, perhaps, unfaulted representatives of two formations of different ages, both of which are younger than the Attock slates. Careful mapping is required, both to the west, in the Khattak hills, and to the east towards Dakhner. This may be undertaken by this department when time permits.

Key words: Photogeology, Attock slates.

D/70. Davies, R.G., 1964b. The orthoconic nautiloids of the Kala Limestone-A correlation. *Geological Bulletin, Punjab University* 4, p.105.

The specimens extracted from the Kala limestone and described in the last issue of the bulletin (1963, p. 1-5), were re-examined by Dr. C. Teichert. He confirms the identification of *Michelinoceras* and feels that the specimen

compared with *Harrisoceras* may be correctly identified, although further information, about the annulosiphonate deposits and of the presence of an endosiphuncular tube, is needed. The identification of *Arthophyllum* is, however, regarded as incorrect, although the specimen is clearly one of the *Michelinoceratidae*. What appear to be the radial lamellar structures in the camera1 deposits are, in all likelihood, due to portions of crinoids having been introduced into the specimen during deposition. This identification has, therefore, to be withdrawn. The stratigraphic significance is, however, little changed and it is still true to say that a Middle Palaeozoic age is indicated. Should, however, it be possible (by further collecting) to confirm the presence of *Harrisoceras*, the upper portion of the Lower Palaeozoic (Silurian) would probably be a more precise date.

Key words: Stratigraphy, palaeontology, Kala limestone.

D/71. Davies, R.G., 1965. The nature of the Upper Swat Hornblendic Group of Martin et al. 1962. *Geological Bulletin, Punjab University* 5, 51-52.

The Upper Swat hornblendic group crops out in a northeast-trending band in northern West Pakistan. Widely varied rock types ranging from granite to gabbro are cut by narrow, very coarse-grained pegmatoid veins and dikes. In thin section the rocks are seen to be mainly plutonic, although some metamorphic rocks are included, especially in the southern part of the outcrop area. Unpublished data from a gravity survey confirm that the zone under study is an overthrust.

Key words: Hornblendic group, pegmatoids, petrography, Swat.

D/72. Davies, R.G. & Ahmad, R., 1963a. The orthoconic Nautiloids of the Kala Limestone and the probable age of the Swabi Formation. *Geological Bulletin, Punjab University* 3, 1-5.

Some orthoconic Nautiloids from the Kala Limestone of the Swabi Formations are described, figured and discussed. It is considered that they indicate a Siluro-Devonian age for these formations which, prior to 1969, have usually been regarded as Pre-Cambrian. The broader stratigraphic implications are also discussed. This is the first time that definite Middle Paleozoic fossils have been recorded from West Pakistan.

Key words: Stratigraphy, orthonautiloids, palaeontology, limestone.

D/73. Davies, R.G. & Ahmad, R., 1963b. Fossils from Hazara Slate Formation at Bara Gali, Hazara, West Pakistan. *Geological Bulletin, Punjab University* 3, 29-30.

This is a preliminary report of some fossils from Hazara slates near Baragali. The samples were collected during a visit to the area in year 1962. The authors discussed these samples with other paleontologists and were of the view that further studies need to be carried out in the area to find any fossils which may help in deciphering the stratigraphy of the area. The authors have suggested that the Hazara slates are Lower Paleozoic rather than Pre Cambrian.

Key words: Fossils, Hazara slates, Baragali, Hazara.

D/74. Davies, R.G. & Gardezi, A.H., 1965a. The problem of the Triass in Hazara, West Pakistan. *Journal of Scientific Research, Punjab University* 1(1), 1-11.

Key words: Triassic, Hazara.

D/75. Davies, R.G. & Gardezi, A.H., 1965b. The presence of *Bouleiceras* in Hazara and its geological implications. *Geological Bulletin, Punjab University* 5, 23-30.

The discovery of ammonite, *Bouleiceras nitiscens* Thevenin, below the base of the limestones which underly the equivalent of the Spiti shales in the Hazara Mesozoic succession, shows that the Trias is not represented in them and that they belong entirely to the Jurassic, in the Thai-Bara Gali section at least. The presence of the fossil indicates a Toarcian (Upper Liassic) age for the beds in which it is found. Some of the implications of its presence are discussed.

Key words: Palaeontology, ammonites, Hazara.

D/76. Davies, R.G. & Ghazanfar, N., 1967. A revision of the stratigraphy of the formations lying below the “Spiti Shale” in Hazara. Abstracts 18th–19th All Pakistan Science Conference, Jamshoro.

Key words: Stratigraphy, Spiti shale, Hazara.

D/77. Dawar, A.H., 1980. Geology of Issha area, Miran Shah, North Wazirsitan. M.Sc. Thesis, University of Peshawar, 25p.

Key words: Maps, geology, Miran Shah, North Waziristan.

D/78. Dawar, A.K., 1995. The tectonic stratigraphic net of the Black Mountain and its economic minerals. M.Sc. Thesis, University of Peshawar, 79p.

Key words: Stratigraphy, tectonics, economic minerals, Black Mountain.

D/79. Dawar, H., Wazir, U.A. & Wazir, M.A., 1985. Groundwater conditions, Parachinar plain. M.Sc. Thesis, University of Peshawar, 70p.

Key words: Groundwater, Parachinar.

D/80. Dawney, R. & Clavariono, J., 1994. Gold exploration and mineral analysis project (GEMAP) northern Pakistan. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, 9-10.

The GEMAP project was designed to assist the Government of Pakistan develop its metalliferous mining sector through strengthening its mineral exploration and geochemical analysis capabilities.

The project is built around four components: Gold exploration in Northern Pakistan, centred on the Eurasian Plate and the Kohistan Arc complex and with associated field training of geologists from PMDC and SDA (A small component of the project with GSP is centred on the Makran of Balochistan).

Training of personnel in Pakistan and Australia in exploration philosophy, methodology and techniques, exploration management, analytical chemistry, mineralogy, cartography, mineral law formulation and administration. Provision of equipment for both field and laboratory activities. Provision of specialised analytical equipment and training of personnel to support exploration for lead/zinc. Integrated, early-stage exploration, including interpretation of satellite images and aerial photographs and systematic drainage sampling, is in progress to systematically cover the project area on a regional basis for the first time. Fast-track investigation of identified mineral occurrences is also being undertaken.

Exploration is primarily directed towards rapid identification of commercially viable deposits. Preliminary results to-date indicate a number of area requiring follow-up investigations.

In addition, the project is developing reliable data base (of world class standard) sufficient to demonstrate the mineral potential of Northern Pakistan and attract foreign and local, private sector investment in the mineral exploration and mining industry.

Key words: Exploration, gold, minerals, Eurasian plate, Pakistan.

D/81. Dawood, H., 1980. Geology of Warai Joga, Bunj area, District Dir. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, maps, Buner.

D/82. Dawood, H., Hussain, S.S. & Chaudhry, M.N., 1996. Geology of Thana-Barikot quadrangle (sheet No. 43/2). Natural History Bulletin 2, 15-24.

Key words: Geology, mapping, Barikot, Malakand, Swat.

D/83. Dawood, S., Razaq, A. & Rahim, A., 1982. Stratigraphy, petrography and structural geology of Kohat pass. M.Sc. Thesis, University of Peshawar, 204p.

Key words: Stratigraphy, petrography, structure, Kohat pass.

D/84. Day, E.A., 1963. Case histories of the Dhulian and Balkassar oil fields, West Pakistan. ECAFE, Mineral Resources Development Series 20, 83-93.

Key words: Oilfields, Dhulian Balkasar, West Pakistan.

D/85. Deans, T. & Powell, J.L., 1968. Trace elements and strontium isotopes in carbonatites, fluorites and limestones from India and Pakistan. Nature 218, 750-752.

Carbonatites discovered in south-west Asia have typical trace elements, but some have unusually high ratios of strontium-87 to strontium-86. Related hydrothermal fluorites have quite different strontium isotope ratios and no distinctive trace elements, emphasizing difficulties in identifying ultimate sources of fluorites.

Key words: Carbonatites, trace elements, isotopes, fluorite, limestone, India, Pakistan.

D/86. Debon F., 1992. Geological setting of Eocene “Batura Granites” (Western Karakorum axial batholith, Northern Pakistan). Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.108.

In the Karakorum, contrary to the Trans Himalaya, the existence of an Eocene plutonic episode remains poorly documented. Such an episode corresponds to the Batura plutonic unit (BAPU) of Debon et al. (1987) that only relies on a petrographic, geochemical and isotopic study of boulders from the terminal moraines of the Batura, Pasu and Ghulkin glaciers (draining the northern part of the Western Karakorum axial batholith, on the west of the Upper Hunza valley). The BAPU is dominantly made up of light-coloured and unfoliated biotite $\pm$ amphibole granites s.l. Based on the Rb-Sr whole-rock isotope analysis of five samples from the Batura moraine, it is Eocene in age [45 ± 7 Ma (5 samples) or 43 ± 3 Ma (4 samples), with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ isotope ratio of 0.7055 ± 3 or 0.7056 ± 3 and a MSWD of 3.3 or 0.7 respectively]. It does not outcrop along the Hunza valley and differs in texture, composition and age from all the rock types [mainly foliated dark-coloured (meta) granodiorites] that compose the huge Mid-Cretaceous (95 ± 41 -6 Ma by U-Pb on zircons; Le Fort et al., 1983) Hunza plutonic unit of the Karakorum axial batholith, as also from the Upper Cenozoic dense network of peraluminous leucocratic dykes cutting through this unit.

The field trip I carried out in September 1991, in the framework of a joint EEC project, was mainly devoted to the BAPU, along the northern margin of the Western Karakorum axial batholith [Kuk-i Jerab (and Yashkuk) glaciers, south of the Chapursan valley; Batura glacier]. Among the observed features, the following ones seem of particular interest:

- The BAPU corresponds, but in part only, to the aplite-granite etc. group previously described and roughly mapped by Schneider (1957), Desio (1964), and Desio & Martina (1972).

- The BAPU displays sharp contacts and typically intrusive relationships with its Upper Palaeozoic (?) metasedimentary surroundings (e.g. Kuk-i Jerab glacier) as well as with the Cretaceous Hunza plutonic unit (Pup-i Shikorga, north of the Middle Batura glacier).

- The BAPU is composite. It comprises several (~ 2) individual plutons, up to more than 20 km in size. Texture and composition are rather homogeneous within a given pluton but vary significantly from pluton to pluton. Microgranular porphyritic textures are not rare.

-The BAPU may be associated with large coeval(?) gabbroic stock(s?) (Western branch of the Upper Kuk-i Jerab glacier).

In order to better constrain and understand the magmatic and geodynamic evolution of the Karakorum, complementary field and laboratory studies devoted to the BAPU are needed. In particular:

The possible extension of the BAPU on the east of the Upper Hunza valley (e.g. Distaghil Sar-Pumori Chhish area) has to be checked up

The emplacement age (s?) of the BAPU must be refined.

A comparison between the BAPU and the still very poorly-known Giraf syenite pluton, some 40 km north of the Karakoram axial batholith and maybe also Eocene in age (53 Ma according to a biotite Rb-Sr date of Desio et al., 1964), could be fruitful.

Key words: Geochemistry, geochronology, granite plutons, Batura, Karakoram.

D/87. Debon, F., 1995. Incipient India-Eurasia collision and plutonism: the Lower Cenozoic Batura granites (Hunza Karakoram, North Pakistan). *Journal of the Geological Society, London* 152, 785-795.

Plutonism of the Karakorum, north of the India-Eurasia suture zone, comprises two major intrusive stages: the oldest, mid-Cretaceous, predates the collision; the youngest, Miocene, is post-suturing. In between, Lower Cenozoic plutonism, roughly syn-suturing and represented by the Batura complex, is made up of a few small and usually undeformed plutons. The complex has a subalkaline (i.e. intermediate between alkaline and calc-alkaline) and feriferous association, dominated by light-coloured metaluminous and slightly peraluminous granites and adamellites with biotite $\pm$ amphibole $\pm$ titanite. Whole rock Rb-Sr isochron ages of 63 Ma (this study) and 43 Ma (Debon et al. 1987b) have been obtained for two plutons, with rather low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (0.7050, 0.7056). A comparison with granitoids of similar age from Kohistan suggests that the complex relates to the subduction of the Tethys ocean, and originates from a mantle source with but small crustal contribution, through a two-stage melting process. The apparently limited extent of Lower Cenozoic plutonism in the Karakorum contrasts with its wider development in the Transhimalaya and Kohistan. This contrast could be partly accounted for by changes in tectonic and magmatic subduction-related processes after the initial contact between India and Eurasia was established, in the NW Himalaya.

Key words: Tectonics, plutonism, Batura granites, Karakoram.

D/88. Debon, F. & Khan, N.A., 1993. Field Study of the Western Karakoram axial batholith along the Karambar valley (Northern Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 15.

The detailed study of the Karakoram axial batholith undertaken by different teams for the last ten years has shown its composite character. Different plutonic units, dominantly ranging in age from Cretaceous to Miocene, have been recognized. However, their inventory is far from being over, and their extent and relationships remain often ill-defined.

Our 1992 field trip in the Karakoram Range was mainly devoted to the Karambar valley (N. Pakistan), the choice of which was based on several grounds; - the Karambar valley offers a complete and easily accessible N-S section of the western axial batholith, perpendicular to its elongation; this section, hitherto poorly known (review in Casnedi, 1984), cross-cuts a cartographic plutonic "blank", about 120-km long, separating two already investigated N-S sections of the batholith, namely the Yasin-Darkot and the Hunza-Batura sections. The study concerns a section around 40-km long, 28 of them for the batholith itself.

Along the Karambar valley, surrounding rocks of the batholith are essentially made up of metapelitic formations, usually trending WNW-ESE. Metamorphism is dominantly developed south of the batholith, where biotite-garnet metapelites are crosscut by a conspicuous swarm of diversified leucocratic dykes that could be hold responsible for their transformation into migmatites of the injection type. This migmatitic zone is about 4-km wide. More to the south, around 6-km far from the batholith, dykes almost completely disappear and metamorphism decreases abruptly (phyllites, slates).

At its northern and southern margins, the batholith intrudes metapelites along sharp, normal and steep contacts, roughly concordant at map scale. Metasedimentary xenoliths, a metre up to several decametres in thickness, are frequent close to either margins, particularly along the southern one where they occur within a zone some 700 m

wide. Metasedimentary rocks seem to be completely lacking in the internal part of the batholith. The huge screen, which, more to the west, divides the batholith into two branches, does not reach the Karambar valley.

Three major types of plutonic rocks can be distinguished along the section studied: (1) strongly foliated biotite amphibole granodiorite, often rich in mafic enclaves, sometimes blastomylonitic, representing the westward continuation of the well-known mid-Cretaceous calc-alkaline “Hunza Granodiorite” (HG); (2) diversified foliated amphibole-biotite granite, locally porphyritic, corresponding to the mid-Cretaceous subalkaline “Darkot Pass Granite” (DPG); (3) various and more or less foliated fine grained rocks of acidic and intermediate composition (FGR). From north to south, the arrangement of the different units is: HG + metapelitic xenoliths (~0.2-km)/DPG, often porphyritic, + FGR + HG (~0.5-km)/DPG, often porphyritic, ($\sim \leq 1.5$ -km)/DPG + FGR (+ HG) $\sim \geq 3.5$ -km)/FGR + HG (often as angular enclaves within FGR) (~ 5.5 km)/HG (~ 16-km)/HG + metapelitic xenoliths (~ 0.7-km). The different units usually display sharp and sinuous contacts. HG was emplaced before FGR, whereas FGR and DPG could be coeval.

On the whole, the section shows a very complex imbrication between the Hunza and Darkot Pass plutonic units, as also between them and the fine-grained igneous group (FGR), of uncertain affinity.

Numerous leucocratic dykes of various composition cross-cut the batholith. At least part of them were emplaced during or before the deformation(s) responsible for the foliation of their host granitoids. Their study, in relation with deformation and metamorphism, both within and out of the batholith, remains to be done and should be of particular interest.

Key words: Geology, Karakoram axial batholith, Karambar, Gilgit, Karakoram.

D/89. Debon, F. & Khan, N.A., 1995. Cretaceous Alkaline Granitoids in the Karakoram axial batholith (Karambar valley, N Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Karambar valley offers a complete and easily accessible section of the western Karakoram axial batholith (Fig. 1). Following a reconnaissance study by Casnedi (1984), the section was mapped (Fig. 2), sampled, and briefly described by Debon & Au Khan (1993). Geochemical data (Table 1) allowed us to discover an alkaline complex in the northern part of the section. As in the Transhimalaya, subalkaline intrusives (i.e. intermediate between alkaline and calc-alkaline) are widespread in the Karakoram batholith (e.g. Le Fort, 1988). But it is the first time that alkaline granitoids are reported in this batholith.

The alkaline complex crops out for some five kilometres (Fig. 2). It is a heterogeneous body made up of medium-grained rocks associated with various fine-grained granitoids and mafic igneous enclaves.

Medium-grained rocks, at times deformed and foliated, are predominant and represent the most typical members of the complex. They form a widely differentiated group comprising metaluminous monzonites, quartz monzonites, granites and leucogranites (Table 1), with amphibole (ferroedenite, .4, highly ferri-ferous biotite, ilmenite, clinopyroxene, $\pm$ allanite, apatite, sphene, zircon. They are two-feldspar granitoids, with plagioclase usually of the albite-type. They define a coherent alkaline (Fig. 3) and highly ferri-ferous series (Table 1), including some slightly peralkaline members [$Al / (Na+K) < 1$]. From monzonites to leucogranites, differentiation is characterized by a rapid increase of the quartz content counterbalanced by a decrease of the mafic mineral and feldspar contents (Fig. 3). In the field, at the scale of the complex, this differentiation broadly progresses from south to north. Light-REE contents are high (LaN up to 549). REE patterns of the different rock types are comparable (Table 1; Fig. 4). They show a regular increase of the negative Eu anomaly from monzonites to leucogranites, most probably related to the decreasing abundance of feldspars. Four monzonites and two quartz monzonites have yielded a Rb-Sr isochron age of 87 ± 3 Ma (2σ), with an initial $87\text{Sr}/86\text{Sr}$ isotope ratio of 0.70439 ± 8 (2σ) and a MSWD of 1.8 (when taking for calculations errors of 2% and 0.01% on the $87\text{Rb}/86\text{Sr}$ and $87\text{Sr}/86\text{Sr}$ ratios respectively) (Table 2; Fig. 5). The three analysed granites and leucogranites scatter below the isochron.

Working hypotheses include: (1) Emplacement of the Karambar alkaline complex could relate to the early Late Cretaceous collision between the Karakoram and Kohistan island arc along the Northern suture (Fig. 1). (2) Its alkaline character suggests a relationship with extensional processes, maybe linked to an oblique collision between the two domains, with subsequent strike-slip faulting. (3) Its initial $87\text{Sr}/86\text{Sr}$ isotope ratio is low (0.7044 ± 1), and undistinguishable from that of the mid-Cretaceous (109 ± 4 Ma) Darkot Pass granitoids (0.7044 ± 1 ; Figs 1, 5). Such features are compatible with a derivation of both plutonic complexes, one alkaline and the other subalkaline, from a similar mantle source, with but small crustal contribution.

Key words: Granitoids, Cretaceous, Karakoram axial batholith, Karambar, Gilgit, Karakoram.

D/90. Debon, F. & Khan, N.A., 1996. Alkaline orogenic plutonism in the Karakorum batholith: The upper Cretaceous Koz Sar Complex (Karambar, N. Pakistan). *Geodinamica Acta* 9(4), 145-160.

The Karakorum is located north of the India/Kohistan-Ladakh/Eurasia sutures. Along the Karambar valley, its axial batholith comprises four plutonic complexes. (1) The largest one represents the westerly continuation of the huge mid-Cretaceous calc-alkaline Hunts plutonic unit. This unit here displays a remarkable reverse zoning that would result from a differentiation at depth followed by multipulse intrusions. (2) A stock of subalkaline (i.e. intermediate between alkaline and calc-alkaline) granitoids (Warghut porphyritic granite). (3) A composite group of fine-grained granitoids. (4) The so-called Koz Sar alkaline complex (KSAC), a unique example of this composition of plutonism so far reported in the batholith. In addition, leucogranite dykes and rare alkaline mafic ones occur. The KSAC is a heterogeneous and more or less deformed body, ca. 5 km wide and possibly 20 km long, comprising two coeval groups of rocks. (1) Medium- to coarse-grained rocks are the most representative members of the complex. They consist of metaluminous to slightly peralkaline monzonite, quartz monzonite, granite and leucogranite, with iron-rich mafic silicates and Fe-Ti oxide. These subsolvus granitoids define a strongly ferriferous alkaline series. Five monzonite and quartz monzonite samples yield an isochron Rb-Sr age of 88 ± 4 Ma ($\text{Sr-87/Sr-86(i)} = 0.70440 \pm 7$; MSWD = 1.7). (2) Fine-grained rocks (monzogabbro to quartz syenite) are compositionally comparable to the dark-coloured members of the preceding group. The KSAC was emplaced into a post-collisional environment resulting from the accretion, maybe at least since Aptian times, of the Kohistan island arc to the Karakorum. Its alkaline character testifies to the development of extensional tectonics, a process compatible with an oblique collision and/or with the decrease, at the time of collision, of the convergence velocity between the two colliding terranes. Available data suggest that this alkaline complex (1) is late-orogenic, (2) is genetically-related to the nearby subalkaline granitoids and originates from the same mantle-source with a small crustal contribution, and (3) represents the ultimate member of the mid-Cretaceous subduction-related plutonism emplaced into the Karakorum continental margin.

Key words: Alkaline plutonism, tectonics, Cretaceous, Karakoram axial batholith, Karambar, Gilgit.

D/91. Debon, F. & LeFort, P., 1984. Chemical-mineralogical classification of plutonic rocks and associations. Examples from southern Asia belts. In: Xu, K.Q. & Tu, G.C. (eds.), *Proceedings International Symposium on geology of granites and their metallogenic relations*, Nanjing University 1982. Science Press, Beijing, 293-311.

Key words: Plutonic rocks, chemical-mineralogical classification, Asia belts.

D/92. Debon, F., Le Fort, P., Dautel, D., Sonet, J. & Zimmermann, J.L., 1985. Plutonism in western Karakoram and northern Kohistan (Pakistan): a composite Mid-Cretaceous to Upper Cenozoic magmatism. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The petrography, the chemical-mineralogical typology, and the ages of six plutonic units from the Karakoram axial batholith (Darkot Pass, Ghamu Bar, Batura and Hunza units) and the northern Kohistan (Gindai and Nomal plutons) are defined and compared based on field data and analyses of up to 78 samples (major elements, REE, Rb-Sr and K-Ar isotopes).

The Karakoram axial batholith is a composite body. Two major stages of intrusive emplacement occurred: by Mid-Cretaceous times (ca. 110-95 Ma) with the emplacement of subalkaline, i.e. monzonitic, (Darkot Pass) and calc-alkaline (Hunza,? Ghamu Bar) units;

during Palaeogene, at least up to 43 Ma (Batura subalkaline unit). A strong tectonometamorphic event, recorded in the gneissification of the Cretaceous intrusive, happened between these two phases; it may be of Palaeocene age. P-T estimates of the highest metamorphic grade rocks of the Hunza unit have yielded values of 580-640°C and 5 ± 0.5 kbar. Finally, a conspicuous network of aplo-pegmatitic dykes emplaced in the Hunza area, possibly from the Eocene up to the Upper Cenozoic with a maximum during the Middle Miocene (ca. 15 Ma).

These major magmatic stages are met again among the acidic intrusive and dykes of northern Kohistan: the first one as blastomylonitic tholeiitic plutons (Noma; ca. 102 Ma; Petterson & Windley, 1985), the second one as subalkaline

plutons (Gindai; ca. 58.5 Ma), and the third one as leucocratic dykes, of Oligocene age (ca. 30 Ma; Petterson & Windley, 1985).

These data may be related to the geodynamic evolution of the NW part of the India-Eurasia suture zone, this allowing to better constrain the major steps of this evolution. The partly synchronous closures, by N-dipping subduction, of the two Tethys branches assumed to have encircled the Kohistan arc in Upper Mesozoic times, may have generated both the Karakoram and the Kohistan intrusive. The northern branch very likely closed before the southern one. By the time of the second stage of intrusive emplacement (Palaeogene):

Kohistan and Karakoram had already collided, were welded and had suffered the same major tectonometamorphic event;

subduction of the southern Tethys floor beneath the welded Kohistan-Karakoram was still active;

however, collision between India and Kohistan-Karakoram may have already begun, particularly at the level of the Nanga Parbat promontory.

Key words: Plutonism, magmatism, Cretaceous, Cenozoic, Karakoram, Kohistan.

D/93. Debon, F., Le Fort, P., Dautel, D., Sonet, J. & Zimmermann, J.L., 1987. Granites of western Karakoram and northern Kohistan (Pakistan): A composite Mid-Cretaceous to Upper Cenozoic Magmatism. *Lithos* 20, 19-40.

The petrography, the chemical-mineralogical typology and the ages of six plutonic units, four from the Karakoram axial batholith (Darkot Pass, Ghamu Bar, Batura and Hunza units) and two of northern Kohistan (Gindai and Nomal plutons) are defined and compared based on field data and analyses of up to 78 samples (major elements, REE, Rb-Sr and K/Ar isotopes). The Karakoram axial batholith is a composite body. Three major intrusive stages occurred: (1) around Mid-Cretaceous times (ca. 110-95 Ma) with the emplacement of subalkaline, i.e. monzonitic (Darkot Pass) and calc-alkaline (Hunza, ?Ghamu Bar) units; (2) during Palaeogene, maybe up to 43 Ma (Batura subalkaline unit). A strong tectonometamorphic event, recorded in the gneissification of the Cretaceous intrusives, occurred between these two stages; it may be of Palaeocene age. *P-T* estimates of the highest metamorphic grade rocks of the Hunza unit have yielded values of 580–640°C and 5 ± 0.5 kbar; and (3) during Upper Miocene (ca. 9 Ma; Baltoro subalkaline unit; Debon et al., 1986c). In addition, a conspicuous network of aplo-pegmatitic dykes emplaced into the Hunza area, possibly from the Eocene up to the Upper Cenozoic with a maximum during the Middle Miocene (ca. 15 Ma). Most of these major magmatic stages are met again among the acidic intrusives and dykes of northern Kohistan: the first one as blastomylonitic tholeiitic plutons (Nomal; ca. 102 Ma; Petterson and Windley, 1985), the second one as subalkaline plutons (Gindai; ca. 59 Ma), and a third one as leucocratic dykes, of Oligocene age (ca. 30 Ma; Petterson and Windley, 1985).

These data may be related to the geodynamic evolution of the NW part of the India-Eurasia suture zone, thus allowing better constraints on the major steps of this evolution. The partly synchronous closures, by N-dipping subduction, of the two Tethys branches which are assumed to have encircled the Kohistan arc in Upper Mesozoic times, may have generated both the Karakoram and the Kohistan intrusives of Cretaceous and Palaeogene ages. The northern branch very likely closed before the southern one. At the time of the second intrusive stage (Palaeogene): (a) Kohistan and Karakoram had already collided, were welded and had suffered the same major tectonometamorphic event; (b) subduction of the southern Tethys floor beneath the welded Kohistan-Karakoram was still active; (c) however, collision between India and Kohistan-Karakoram may have already begun, particularly at the level of the Nanga Parbat promontory. Finally, it is emphasized that the intrusive processes continued in the Karakoram long after the collision (e.g., Baltoro granite).

Key words: Granites, petrography, mineralogy, Karakoram, Kohistan.

D/94. Debon, F., Zimmermann, J.L. & Bertrand, J.M., 1986. Le granite du Baltoro (batholite axial du Karakoram, nord, Pakistan); Une intrusion subalkaline d'âge Miocene superior. *Comptes Rendus des Seances de l'Academie des Sciences, Paris*, 303, Series 2, 463-468.

Key words: Granites, glaciers, Baltoro, Karakoram.

D/95. Debon, F., Zimmerann, J.L. & Le Fort, P., 1996. Upper Hunza granites (North Karakorum, Pakistan): a syn-collision bimodal plutonism of mid-Cretaceous age. *Comptes Rendus des Seances de l'Academie des Sciences, Paris*, 323, Series 2, 381-388.

Key words: Granites, Hunza, Karakoram.

D/96. De Bruijn, H., 1986. Is the presence of the African family Thryonomyidae in the Miocene deposits of Pakistan evidence for fauna exchange? In: *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen. Series B*, 89, 125-134.

Key words: Palaeontology, Miocene, Rodentia, Africa, Pakistan.

D/97. De Bruijn, H., Hussain, S.T., & Leinders, J.J.M., 1981. Fossil rodents from Murree Formation near Banda Daud Shah, Kohat, Pakistan, 1 and 2. *Koninklijke Nederlandse Akademie van Wetenschappen, Series B*, 84 (1), 71-84.

Key words: Fossils, rodents, Murree Formation, Karak.

D/98. De Bruijn, H., Hussain, S.T. & Leinders, J.J.M., 1982. On some early Eocene rodent remains from Barbara Banda, Kohat, Pakistan, and the early history of the order Rodentia. *Koninklijke Nederlandse Akademie van Wetenschappen, Series*, 85, 249-258.

Key words: Fossils, rodents, Murree Formation Kohat.

D/99. Decade, W., 1962. Devonian fossils from "opposite Reshun" in Chitral, Pakistan. *Geological Magazine* 92, 3-8 & 49-58.

Key words: Palaeontology, Devonian, Chitral.

D/100. De Filippi, F., 1910a. La spedizione nel Karakoram. Balogna, Zanichelli.

Key words: Expedition, Karakoram.

D/101. De Filippi, F., 1910b. The Exploration of H. R. H. the Duke of the Abruzzi to the Karakoram Himalayas. *Geographic Journal* 37, 19-30.

This is a summarized account of the Duke of the Abruzzi Expedition to the Karakoram Range.

Key words: Italian Expedition, Karakoram, Himalaya.

D/102. De Filippi, F., 1912a. La spedizione di S. A. R. il principe Luigi Amedeo di Savoia duca degli Abruzzi nel Karakoram e nell'Himalaya occidentale (190-9). Zanichelli, Balogna.

Key words: Italian Expedition, Karakoram, western Himalaya.

D/103. De Filippi, F., 1912b. Karakoram and the western Himalaya (1909). Account of the Expedition of H. R. H. Prince L. A. Savoy, Duke of the Abruzzi. Constable, London.

Key words: Italian Expedition, Karakoram, western Himalaya.

D/104. De Filippi, F., 1915a. Rlazione preliminare sui lavori scientifici della Spedizione “De Filippi” al Caracorum, 1913-1914: cenni generali. *Revista Geografia Italiana* 22, 225-300.

Key words: Italian Expedition, Karakoram.

D/105. De Filippi, F., 1915b. Spedizione scientifica italiana in India ed in Asia, 1913-14. *Geographic Journal* 46, 85-105.

This is the English version of the above account.

Key words: Italian Expedition, Karakoram.

D/106. De Filippi, F., 1921. Pubblicazione dei risultati della Spedizione Italiana nell’Himalaya, Caracorum et b Turchestan cinese (1913-1914). *Atti 8th Congress Geografica Italiano*, 2, 1-6.

This is a bibliography of the publications coming out of the Italian 1913-1914 expedition to the Karakoram and Himalaya.

Key words: Italian Expedition, publications, Karakoram.

D/107. De Filippi, F., 1923. Storia della Spedizione scientifica italiana nel Himalaia, Caracorum e Turchestan cinese (1913-1914). Con capitol aggiuntivi di Giotto Daielli e J. A. Spranger, Zanichelli, Bologna.

Consult the English version of De Fillipi, 1932.

Key words: Expedition, Himalaya, Karakoram, Turkestan.

D/108. De Filippi, F. (Ed.), 1929. Relazione scientitiche Spedizione italiana de Filippi nell, Himalaia, Caracorum e Turchestan Cinese (1913–14). Ser. 1, 3 Volumes, Bologna.

Key words: Expedition, Himalaya, Karakoram, Turkestan.

D/109. De Filippi, F., 1930. Geological work of the Italian Expedition to the Karakoram, 1929. *Geographic Journal* 75, 402-411.

Consult the following account.

Key words: Italian Expedition, Karakoram.

D/110. De Filippi, F., 1932. The Italian expedition to the Himalaya, Karakorum and eastern Turkestan (1913–14). (English Transl.) Arnold, London.

The Italian Expedition 167 barren plateaux of the Karakoram were undertaken in the summer of 1914. The arrangements for "supplies and transport" needed to maintain so large an expedition, encumbered by elaborate and heavy scientific equipment, for months at a stretch on elevated ground utterly devoid of resources might well by themselves have sufficed to absorb the leader's energy and attention. All the same Dr. De Filippi managed to find time during those stays for a careful study of varied aspects of local life, customs, religious organization, architecture, etc. To this we owe inter alia the detailed description contained in chapter vi of the monastic institutions of Ladak, their structures, art, etc. Illustrated by a wealth of excellent photographs, which the skill of Colonel Antilli provided as for the rest of the book, this chapter helps the general reader perhaps better than any previous book of travel to realize the remarkable wealth of products of local industry, art, and craft to be found in that comparatively small portion of Western Tibet. Considering the very limited extent of arable ground, the

adversity of climatic conditions at those great altitudes, and the very scanty population, the Census of 1911 gave for Ladakh and adjacent tracts only some 36,511 Buddhists? The abundance of monasteries, shrines, religious monuments, and other structures, whether maintained or in ruins, must impress every visitor. By contrast with the Dard and Balti tracts, which also were once Buddhist, this wealth conveys a very instructive lesson to the antiquarian student as to the way in which peculiar cultural factors may affect the extent of structural and other remains of the past in neighbouring territories. A distinctive and very useful feature of the book is the diligent, one might almost say loving, care which Dr. De Filippi has bestowed upon notices of previous travellers' visits to those regions and of the records left of their observations and labours. All students interested in the geography and history of that fascinating borderland between India and Central Asia must feel grateful for this

Key words: Expedition, Ladakh, Baltistan, Karakoram.

D/111. Dehm, R. & Oettingen-Spielberg, T., 1958. Palaontologische und geologische untersuchungen in Tertiär von Pakistan: Part 2, die Mitteleocänen Säugetiere von Ganda Kas bis Basal in nordwest Pakistan. Bayerische Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, Abhandlungen 9, 54p.

Key words: Palaeontology, geology, Tertiary, Pakistan.

D/112. DeJong, K.A. & Qayum, A., 1981. Collapsed anticline in Kohat, south west Himalaya foothills, Pakistan. Geological Society of America, Abstracts with Program 13, p.437.

Key words: Structure, Kohat.

D/113. DellAngelo, L.N. & Tullis, J., 1989. Fabric development in experimentally sheared quartzites. *Tectonophysics* 169, 1-21.

A fine-grained quartzite was deformed under a combination of simple shear and axial compression to varying amounts of shear strain (1.3 to 2.9). The experiments were conducted at 800 °C, 1500 MPa, and an axial strain rate of 10–6/s, in the dislocation creep regime. Shear zone boundaries were oriented at 45° or 30° to the compressor axis. The progressive development of deformation microstructures, including planar fabrics and c axis preferred orientations, was studied as a function of increasing shear strain. Elongate original grains define a foliation (S) which rotates from 45° to 0° to the shear zone boundary with increasing strain, producing a sigmoidal foliation in a single shear zone. A second foliation, invariant in orientation, is defined by elongate recrystallized grains, which lie at about 30°–40° to the shear zone boundaries. No C-surfaces, parallel to the shear zone boundaries, were observed. However, extensional crenulation cleavages (C'), defined by parallel zones of recrystallized grains as well as impurity and melt segregations, were observed even at low strain, lying at approximately 30° to the shear zone boundaries, and these could easily be mistaken for C-surfaces. C axis preferred orientations of original grains define symmetric type I crossed circle girdles at low strain ($\gamma < 2$) and asymmetric broad maxima at high strain ($\gamma > 2$), with the greater concentration of c axes in the direction of shear. These features are very similar to those observed in natural ductile shear zones.

Key words: Structure, shear strain.

D/114. Dell'Mour, R.W. & Rodgers, M., 1993. Deformation history and structural pattern within an exploration concession in the Eastern Potwar basin (NE Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 68-69.

Structural Data gained from fieldwork carried out in 1992, Satellite TM interpretation and seismic interpretation provides the basis for a Tectono-Kinematic interpretation of a small portion of the Eastern Potwar Plateau (Fig. 1).

The Potwar Basin is part of the Central Fold Belt of Pakistan, the northern portion of which forms part of the Himalayan foreland fold and thrust belt. This deformed belt is a product of the ongoing collision between the Eurasian and Indian plates which forms the northernmost element of the Indus Basin. Compressional deformation throughout the Himalayan foreland is taking place as the Indian Shield is overridden by sediments along its northern

margin. In the eastern Potwar deformation is distributed along a broader zone of northeast/southwest trending, tight to overturned anticlines separated by broader synclines.

Three phases of deformation have been observed within this compressional stress field (Fig. 2):

Phase 1: Thrusting and folding WNW/ESE

Phase 2: Strike-slip faulting (W)NW/(E)SE

Phase 3: Strike-slip faulting NE/SW

Intensity of deformation increases to the NW as expressed by the more intensely sheared and compressed Riwar anticline. The easternmost Kallar anticline shows only minor deformation of the crest owing to southeast directed thrusting which does not appear to have significantly disturbed the stratigraphic sequence.

The most extensively developed thrust zone has been observed on the eastern limb of the Buttar anticline although the poorly developed outcrop exposure prevents accurate identification on the Satellite images. Southeasterly directed thrusting over several hundreds of metres is likely and lithologic indicators in the kataclastic zone suggest probable detachment within the Kamlial or Chinji Formations.

Key words: Structure, Himalayan Foreland, Deformation, Potwar basin.

D/115. Dennell, R.W., 1992. Fossil and archaeological investigations of the Upper Siwalik of northern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.67.

Consult RW Dennell, 1997 also for further details.

Key words: Palaeontology, siwaliks.

D/116. Dennell, R.W., 1993. Evidence on human origin: A rediscovered source in the upper Siwaliks of northern Pakistan. *Interdisciplinary Science Reviews* 18, 379-389.

Consult RW Dennell, 1997 also for further details.

Key words: Human origin, siwaliks.

D/117. Dennell, R.W., 1995. Do human origins lie only in Africa? New evidence from northern Pakistan. *Cranium*, 12(1), 21-24.

Consult RW Dennell, 1997 also for further details.

Key words: Human origin, Pakistan.

D/118. Dennell, R.W., 1997. Palaeoanthropology of South Asia and the upper Siwaliks of Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 69-71.

The Upper Siwaliks of northern Pakistan provide one of the longest and most detailed fluvial sequences for the Pliocene and Lower Pleistocene outside East Africa, the source of most early hominids. Although China and Indonesia have provided younger specimens of *Homo erectus*, there is scarcely any relevant fossil or archaeological evidence between these parts of East Asia, and East Africa, over 5,000 miles to the west. Northern Pakistan is, thus, one of the key areas for linking the early East African evidence for human evolution with the later East Asian material.

Recently palaeoenvironmental reconstructions have shown that in the late Pliocene, grasslands were continuous between northern China and Western Africa (Dowsett et al. 1994). There was therefore no ecological barrier - such as the present-day Sahara- that prevented early hominoids from living outside East Africa. Other work from northern Pakistan indicates that the South Asian grasslands are substantially older than those of East Africa (Quade et al. 1989), and Upper Siwalik faunal remains also indicate the prevalence of a grassland fauna, broadly comparable to that of East Africa. Recent discoveries from Chad (Brunet et al. 1995) indicate that hominids may have colonised the grasslands of Africa on a continental scale by 3 million years ago; if grasslands extended further east into Asia, they could also have occupied these. In the last two years, hominid remains from Indonesia (Swisher et al. 1994), China (Wanpo et al. 1995) and Georgia (Gabunia and Vekua 1995) have been dated to 1.8 million years, raising

again the possibility that hominids had left Africa by 2 million years ago. Although each of these claims is highly contentious, an obvious working hypothesis that needs testing by fieldwork in northern Pakistan is that hominoids were living in South Asia by the late Pliocene/early Pleistocene (Dennell 1995).

Despite the potential palaeoanthropological importance of the Upper Siwaliks, they are still largely unexplored. As predicted as long ago as 1953 by Louis Leakey - the discoverer of *Paranthropus boisei* and *Homo habilis* at Olduvai Gorge, Tanzania - the discovery of early hominids in the Upper Siwaliks is only likely to result from several years, if not a life-time, of exploration (Leakey 1953: 214). Unlike East Africa, the Upper Siwaliks are a predominantly fluvial sequence formed by large perennial rivers. Although vertebrate fossil remains are often abundant and well-preserved, they tend to be highly dispersed, and rarely occur in the localised and repeated manner that often occurs in East Africa. Although carnivores are present, they tend to be very localised, and found mainly in association with very dense accumulations of fossils that probably represent their prey. For these reasons, fossil collecting surveys have to be conducted over a much larger area, and the discovery of fossils in one horizon rarely leads to the discovery of other material in the same place in later contexts. An additional problem is that the fossils found are overwhelmingly from animals more than 100 kg in weight - in other words, larger than most primates, including early hominids. Smaller animals are present, but found only after repeated and sustained searching.

A promising start to palaeontological and palaeoanthropological investigations of the Upper Siwaliks was made by the author, in collaboration with GSP and the Department of Archaeology, between 1985 and 1990, following on from earlier work conducted with the Department of Archaeology between 1980 and 1983 (Ashfaq and ul-Haq 1988, Dennell 1993, Jenkinson et al. 1989). The Pabbi Hills, Gujrat District, proved to be extremely promising. Over 40,000 fossil remains were collected, of which ca. 15,000 were identifiable to taxon and/or skeletal element, from horizons between 0.9 and 2.0 million years old. Preservation was often extremely good, and three exceptionally rich fossil localities were excavated. One important result of this work is that GSP now has a useful comparative collection from the Upper Siwaliks that is available for other scholars to study. The fieldwork in the Pabbi Hills has also provided much useful information of the type and spatial distribution of fossil vertebrate remains in these kinds of fluvial landscapes.

Although hominid remains have not so far been found, indirect evidence that they were present in the late Pliocene and early Pleistocene was found in the form of stone tools. The oldest are those from Rawat, Southwest of Islamabad, which were dated initially to a minimum of 1.9 million years (Dennell et al. 1988). In the light of subsequent analyses, this date has been revised to 2.4 million years, which implies that stone tool-making in Pakistan is of comparable age to that in East Africa (Rendell et al. in press). Stone tools were also found in the Pabbi Hills, in the course of collecting fossil remains from the erosional surfaces of deposits between 1 and 2 million years old (Hurcombe and Dennell 1992), and one was found in situ in a horizon 1.2 million years old (Dennell et al. 1992). It is only a matter of time before more, and better, evidence is found.

These results are now being prepared for publication by the author, for a monograph to be completed in 1997. The author very much hopes to continue palaeoanthropological investigations of the Upper Siwaliks, both in the Pabbi Hills and in other promising areas. Fieldwork need not be on a large scale, providing it is sustained over several years. At some stage, early hominid remains more than a million years old will be found in the Upper Siwaliks of either Pakistan or India; however, they are unlikely to be found unless people look, and are prepared to search for several years.

Key words: Palaeontology, early hominids, fluvial sequence, siwaliks.

D/119. Derbyshire, E., 1984a. Sedimentological analysis of glacial and proglacial debris: a framework for the study of Karakoram glaciers. In Miller, K.J., The International Karakoram Project, Volume 1, 347-364. Cambridge University Press.

Sediments of mixed grain sizes exhibiting multimodal particle size curves (diamictos) are widely distributed. Processes producing them include glacial deposition, periglacial solifluction, debris slide and flow, mudflow, lahar flow (volcanic) and lacustrine and marine density currents (turbidities). Glaciers and ice sheets are a major source, deposits of this origin, mostly Pleistocene age, being found over about one third of the land area of the earth.

Diamictos of glacial, periglacial and mud and debris flow origin are abundant in glaciated terrain, and they have considerable significance in the study of both pure and applied geomorphology.

This paper presents a framework for the study of Karakoram glacial and proglacial debris based on knowledge of the processes involved and the properties of sediments.

Key words: Sedimentology, glacial deposits, Karakoram.

D/120. Derbyshire, E., 1984b. Till facies and glacial regime in parts of High Asia: Karakoram and Tian Shan. In: R.O. Whyte (ed.), *The Evolution of the East Asian Environment*, University of Hong Kong, vol.1 (Geology and Palaeoclimatology), 84-110.

Key words: Glaciation, till, Karakoram, Tian Shan.

D/121. Derbyshire, E., 1989. The Karakoram glacial depositional system. In: Derbyshire, E. and Owen, L.A. (Eds.), *Quaternary of the Karakoram and Himalaya*, *Zeitschrift für Geomorphologie*, Supplementband 76, 33-73.

Key words: Glacial deposits, Karakoram.

D/122. Derbyshire, E., 1996. Quaternary glacial sediments, glaciation style, climate and uplift in the Karakoram and northwest Himalaya: review and speculations. *Paleogeography, Palaeoclimatology, Palaeoecology* 120, 147-157.

Opinions on the extent and style of the Quaternary glaciations of the Karakoram and northwest Himalaya have ranged from restricted alpine-style glaciation to extensive inundation by montane ice caps, too overwhelming by sheet ice from the Qinghai-Xizang (Tibet) Plateau. The sedimentological and geomorphological evidence underpinning these contrasting opinions is used to integrate the sedimentary record with what is known about uplift and incision rates and broad-scale changes in the regional climate. By reference to the independent record of monsoon-versus westerly strength provided by the lacustrine and loess record of central and east Asia, increasing relative relief and topographical discordance are considered as influences upon glaciation style, glacier extents, and sediment budgets since the Middle Pleistocene. Ice extent may have progressively declined with increasing constraints on glaciation limits through time, but total ice volumes during glaciations may have shown less variation as valley systems enlarged in conditions of quasi-balance between uplift and incision.

Key words: Glacial sediments, climate, uplift, Karakoram, Himalaya.

D/123. Derbyshire, E., Li, J., Perrott, F.A., Xu, S. & Waters, R.S., 1984. Quaternary glacial history of the Hunza Valley, Karakoram mountains, Pakistan. In: Miller, K.J. (ed.), *The International Karakoram Project*, Volume 2, 456-495. Cambridge University Press.

The glacial landforms and glacial and paraglacial sediments, of the upper Hunza valley were mapped and resolved into a chronological sequence on the basis of morphostratigraphy, superposition, and degree of surface weathering. Sediments recognized include fluvial, gaciofluvial, debris flow and lacustrine types together with tills of predominantly meltout origin. Sediments were analysed for particle size, projection roundness, surface texture, clast and microfabric and clay mineralogy. Weathering of surface boulders, degree of subsurface weathering, point compressive strength of boulder surfaces, desert-varnish development and percentage lichen cover were used to establish a relative chronology, the desert varnish index providing results consistent with other tests.

Eight glacial phases of varying magnitude were recognized, as follows:

A widespread glaciation, leaving isolated and deeply weathered erratics on summit surfaces above 4150 m altitude. This occurred when valleys were much less incised and is considered to be the earliest Pleistocene glaciation represented in the area and termed Shanoz.

(2) and (3) A second series of valley glaciations (c. 2500m) was recognized from weathered till remnants on benches in the main Hunza valley. These are attributed to the Yunz and Borit Jhell glacial stages, the former being older than 139, 000 yr BP (TL dating of lake silts) and correlated with the penultimate Pleistocene glaciation. The Borit Jhell glaciation filled the high diffuence cols and is dated (TL) as early last Pleistocene glaciation.

A stage of 'expanded foot' and minor valley glaciation (Ghulkin I); this is younger than 47,000 yr (TL). A more limited glacial advance of several km, blocking the Hunza River, occurred in the Ghulkin II stage; considered to be a late phase of the last Pleistocene glaciation. A glacial extension of 1-2 km left larger, well defined moraines with well varnished and weathered surfaces (Batura stage; considered mid-Holocene). A minor advance restricted to tributary valleys is indicated by mildly varnished moraines (Pasu I). It is bracketed by 14C dates of 840±80 and

325±60 yr BP. Minor oscillations of 19th and 20th centuries, which left sharp, unweathered metastable moraine forms and termed the Pasu II stage.

Key words: Glacial history, Quaternary, Hunza, Karakoram.

D/124. Derbyshire, E. & Miller, K., 1981. Highway beneath the Ghulkin. *Geographical Magazine* 53, 626-635.

Key words: Glaciers, Ghulkin.

D/125. Derbyshire, E. & Owen, L.A. (Eds.), 1989. Quaternary of the Karakoram and Himalaya. *Zeitschrift für Geomorphologie, Supplement Bd.* 76.

Key words: Quaternary, Karakoram, Himalaya.

D/126. Derbyshire, E. & Owen, L.A., 1990. Quaternary alluvial fans in the Karakoram Mountains. In: Rachocki, A.H. & Church, M. (Eds.), *Alluvial Fans - a Field Approach*. Wiley, Chichester, 27-53.

Key words: Quaternary, alluvial fans, Karakoram, Himalaya.

D/127. Derbyshire, E. & Owen, L.A., 1997. Quaternary glacial history of the Karakoram Mountains and Northwest Himalayas: a review. *Quaternary International*. 38–39, 85–102.

The style and extent of glaciation in the NW Himalayas and Karakoram Mountains of Pakistan, and the Himalayas in NW India are reviewed. At least three glacial events, progressively less extensive with time, can be recognised in most regions. The timing and status of these glacial successions is poorly known. This is partially due to poor dating constraints, but also arises from a lack of adherence to strict stratigraphic procedures. Recommendations are made for a more rigorous approach to the study of Himalayan Quaternary glacial histories.

Key words: Glacial history, Quaternary, Karakoram, Himalaya.

D/128. Derbyshire, E., Owen, L. A. & Fort, M., 1987. Fabric and the problem of distinguishing glacial and non-glacial diamictations in the Karakoram and Himalaya. Abstracts, 3rd Himalaya-Karakorum Workshop, Nancy.

Key words: Diamictation, fabric, Karakoram, Himalaya.

D/129. Dercount, J., Zonenshain L., Ricov, I.E., Kazmir, V.G., Le Pichon, X., Knipper, A.L., Grandjacquet, C., Sborschchikov, I.M., Geyssant, J., Lepvrier, C., Pechersky, D.H., Boulín, J., Savosin, L.A., Sorokhtin, O., Westphal, M., Bezhenov, M.L., Lauer, L.P. & Biju-Duval, B., 1986. Geological evolution of the Tethys Belt from the Atlantic to the Pamirs since the Liassic. *Tectonophysics*, 123, 241–315.

We discuss nine palinspastic geological maps (Plates 1-9) at 1/20,000,000 scale, which depict the evolution of the Tethys belt from the Pliensbachian (190 Ma) to the Tortonian (10 Ma). A Present structural map (Plate 10) is shown for comparison at the same scale with the same conventions. Our reconstructions are based on a kinematic synthesis (Savostin et al., 1986). a paleomagnetic synthesis (Westphal et al., 1986) and geological compilations and analyses concerning in particular the western domain (Ricou et al., 1986), the eastern passive margins (Kazmin et al., 1986a), the eastern active margins (Kazmin et al., 1986b) the Black Sea-Caspian Sea basins (Zonenshain and Le Pichon, 1986) and the ophiolites (Knipper et al., 1986).

A key feature of our reconstructions is that we have adopted on the basis of the paleomagnetic synthesis, a unique 30° counter-clockwise rotation of Apulia with respect to Africa between 130 and 80 Ma. Before 130 and after 80 Ma, Apulia was rigidly linked to Africa. Between 130 and 80 Ma, Apulia collided with Eurasia to the north and separated from Africa to the south. The separation of Apulia from Africa resulted in the formation of the Mesogea, which included the present Eastern Mediterranean. Concerning Iberia, the kinematic solution indicates that it moved with Africa between 110 and 54 Ma. Between 130 and 110 and between 54 and 35 Ma, Iberia moved independently of both Africa and Eurasia. Prior to 130 and after 35 Ma, Iberia belonged to Eurasia. In the Late Triassic, pieces of Gondwana collided with Laurasia and as a result the Paleo-Tethys Ocean disappeared. A Neo-Tethys ocean opened to the south within Gondwana and reached Pangea to the west where it ended in sphenochasm.

During the Mesozoic and Paleogene, most of the consumption of surface in the Tethys area was the result of subduction of oceanic or highly thinned continental crust although continental collision occurred as early as the Lower Cretaceous to the north of Apulia and the Middle Eocene to the north of Arabia. However, distension and oceanic accretion played a major role in redistributing oceanic space within the shrinking Tethys belt during the Mesozoic. A northern 3000 km long intra-continental east-west system of deep oceanic basins which we interpret as marginal basins ^{s1} extended from the Valaisan trough and Carpathian basin to the west to the South Caspian basin to the east, between the Upper Jurassic and the Upper Cretaceous; it has since been progressively destroyed. A southern oceanic belt extended from the opening Central Atlantic to the shrinking Neo-Tethys. The connection between the Neo-Tethys and the Central Atlantic occurred first through a North Apulian seaway (the Maghrebian-Ligurian Sea) formed during the Jurassic and completely destroyed at the end of the Cretaceous.

At the same time as the North Apulian seaway was almost completely destroyed the accreting Neo-Tethys plate boundary was subducted below Eurasia. The accreting plate boundary system jumped to the south in the Middle-Upper Cretaceous; it resulted in the formation of a South Apulian seaway (Mesogea) and extended along the northern border of Arabia within the Neo-Tethys. This new accreting plate boundary was shortlived and its eastern Neo-Tethys portion was abducted over the Arabian margin at the end of the Cretaceous. During the Paleogene, the consumption of surface was mostly the result of oceanic subduction without oceanic accretion and at the beginning of the Neogene, with the collision of India with Eurasia, the Neo-Tethys ocean had essentially disappeared. From then on consumption of surface mostly occurred by shortening through continental collision processes. However, new oceanic accretion was initiated in the western Mediterranean. Thus, even in the Present mostly continental collision stage, the few remaining oceanic bodies (Mediterranean Sea, Black Sea and Caspian Sea, Gulf of Oman) still play a significant role in the establishment of the strain pattern.

Key words: Structure, tectonics, kinematics, Mesozoic, paleogene, tethys, atlantic, Pamirs.

D/130. Derry, L.A. & France-Lanord, D., 1996. Neogene Himalayan weathering history and river ⁸⁷Sr/⁸⁶Sr. Impact on the marine Sr record. *Earth and Planetary Science Letters* 142, 59-74.

Clastic sediments in the Bengal Fan contain a Neogene history of erosion and weathering of the Himalaya. We present data on clay mineralogy, major element, stable and radiogenic isotope abundances from Lower Miocene-Pleistocene sediments from ODP Leg 116. Nd and Sr isotope data show that the Himalayan provenance for the eroded material has varied little since > 17 Ma. However, from 7 to 1 Ma smectite replaces illite as the dominant clay, while sediment accumulation decreased, implying an interval of high chemical weathering intensity but lower physical erosion rates in the Ganges-Brahmaputra (GB) basin. O and H isotopes in clays are correlated with mineralogy and chemistry, and indicate that weathering took place in the paleo-Gangetic flood plain. The ⁸⁷Sr/⁸⁶Sr ratios of pedogenic clays (vermiculite, smectite) record the isotopic composition of Sr in the weathering environment, and can be used as a proxy for ⁸⁷Sr/⁸⁶Sr in the paleo-GB basin. The Sr data from pedogenic clays shows that river ⁸⁷Sr/⁸⁶Sr values were near 0.72 prior to 7 Ma, rose rapidly to 2.074 in the Pliocene, and returned to 0.72 in the middle Pleistocene. These are the first direct constraints available on the temporal variability of ⁸⁷Sr/⁸⁶Sr in a major river system. The high ⁸⁷Sr/⁸⁶Sr values resulted from intensified chemical weathering of radiogenic silicates and a shift in the carbonate-silicate weathering ratio. Modeling of the seawater Sr isotopic budget shows that the high river ⁸⁷Sr/⁸⁶Sr values require a ca. 50% decrease in the Sr flux from the GB system in the Pliocene. The relationship between weathering intensity, ⁸⁷Sr/⁸⁶Sr and Sr flux is similar to that observed in modern rivers, and implies that fluxes of other elements such as Ca, Na and Si were also reduced. Increased weathering intensity but reduced Sr flux appears to require a late Miocene-Pliocene decrease in Himalayan erosion rates, followed by a return to physically dominated and rapid erosion in the Pleistocene. In contrast to the view that increasing seawater ⁸⁷Sr/⁸⁶Sr results from increased erosion, Mio-Pliocene to mid-Pleistocene changes in the seawater Sr budget were the result of reduced erosion rates and Sr fluxes from the Himalaya. This contribution is on

samples collected in ODP rather than related directly to northern Pakistan, but it has relevance to the area and is therefore included.

Keywords: Neogene, clay mineralogy, weathering, Bay of Bengal, ODP, Himalaya.

D/131. Desio, A., 1930a. Geological work of the Italian expedition to the Karakoram. *Journal of the Royal Geographical Society* 75, 402-411.

Keywords: Geology, Italian expedition, Karakoram.

D/132. Desio, A., 1930b. Geological work of the Italian expedition to the Karakoram. *Journal of the Royal Geographical Society* 75, 505-518.

Keywords: Geology, Italian expedition, Karakoram.

D/133. Desio, A., 1930c. Itinerari percorsi durante La Spedizione Geografica Italiana al Karakoram 1929. *Bollettino della Società geografica italiana*, series 6,7, 163-181 and 277-300.

Key words: Italian Expedition, Karakorum, geography, geology.

D/134. Desio, A., 1936a. La Spedizione Geographica Italiana nel Karakoram, Storia Del viaggio e risultati Geographici, in collaborazione can S.A.R. Aimone di Savoia Aosta, Arti Crafiche Bertarelli, Milano. Vol. In 8 di 620p.

This is a detailed description of the journey and results of the Italian Geographic Expedition to the Karakoram undertaken during 1929. The 620 page volume contains 254 figures, 39 pictures and four topographic maps.

Key words: Italian Expedition, Karakoram, geography.

D/135. Desio, A., 1936b. La Spedizione Geografica Italiana al Karakoram (1929), Arti Crafiche Bertarelli, Milano.

The preceding five papers by A. Desio describe the activities of the 1929 Italian expedition to the northern part of the central Karakoram mountain range, located in present day Pakistan. The expedition concerned various aspects of the geography and geology of the region.

Key words: Italian Expedition, Karakoram, geography, geology.

D/136. Desio, A., 1940. Il Baltoro. *Le Alpi* 59, 477-478.

This is a description of the Baltoro Glacier and its basin.

Key words: Glaciers, Baltoro, Karakoram.

D/137. Desio, A., 1953~1955. The Italian Expedition to the Karakoram (Himalaya): preliminary geological petrographical information on the basin of the Baltoro glacier.

After a reference to previous information, the authors give a preliminary description of the geological structure of the Baltoro basin, with particular stress on the main petrographic problems. The geological structure of this area is characterized by a big pluton of granitic nature outcropping widely in the western section. The metamorphic rocks (prevalently gneiss) of the K2 and Falchan Kangri are directly related. Another smaller intrusive mass, of a dioritic facies, occurs in the later group, while the semimetamorphic series, of sedimentary origin, and referable to the upper Paleozoic and Mesozoic, form the main part of the Gasherbrums group and a part of the Falchan Kangri and of the western slopes of the Godwin Austen glacier.

Key words: K2 gneisses, Baltoro, Structural geology.

D/138. Desio, A., 1953a. Uno sguardo al Pakistan, il paese tagliato in due, *L' Universo*, Anno 33, No.6, 837-841.

Key words: Pakistan.

D/139. Desio, A., 1953b. Sull' eccezionale avanzamento di un ghiacciaio himalayano. *Rendiconti dell' Accademia Nazionale dei Lincei*, Ser. 8, 15, 253-255.

Key words: Glaciers, Himalaya.

D/140. Desio, A., 1953c. La triade dei colossi: Everest (8840 m), K² (8611 m), Kanchenjunga (8585 m). *Riv. Mensile del Culb Alpino Itaiano* 71, 3-8.

Key words: Everest, K2, Kanchenjunga.

D/141. Desio, A., 1954a. An exceptional glacier advance in the Karakoram-Ladakh region. *Journal of Glaciology*, 2 (16), 383-385.

Key Words: Glaciology, Karakoram, Ladakh.

D/142. Desio, A., 1954b. La mia ricognizione al Karakorum del 1953. *La Ricerca Scientifica* 24, 253-262.

Key Words: Reconnaissance, Karakoram.

D/143. Desio, A., 1954c. La mia ricognizione preliminare al K 2 (Karakorum occidentale) nel 1953. *Riv. Mensile del Culb Alpino Ital.* 73, 3-14.

Key Words: Reconnaissance, Karakoram.

D/144. Desio, A., 1954-1957. La conquista del K2. (Italian editions of 1954, 1955, 1956, 1957), Garzanti Milano 1988 edition, Marsilio ed. Venezia. English, Ger, French, U.S.A., Spanish, Swedish, Hungarian, Russian, Japanese editions.

Key words: K2, Italian Expeditions, Karakoram.

D/145. Desio, A. (Leader), 1954-1991. Italian Expeditions to the Karakorum (K2) and Hindukush. Scientific Reports, ISMEO, Milano.

The Italians have contributed to our understanding of the geology, geography, and other aspects of the Karakoram Mountains more than any other. Apart from the earlier voyages for scientific work, contributions of which are reported in this work at different places, a series of expeditions were conducted in the leadership of Professor Ardito Desio. The following account is a verbatim copy of the preface that Desio wrote for Volume 1.

This volume is the ninth in the series of Scientific Reports of the Italian Expeditions to the Karakorum and Hindu Kush organized under Desio's leadership from 1953 to 1975. The list of contents of this collection, which is given at the beginning of each volume, gives the first subject as geography, which means that this volume should in fact have been published first. However, for a number of reasons which will be mentioned later, it is one of the last to be printed. Here below are the titles of the eight volumes already published.

I.—GEOGRAPHY

- Vol. 1: 1st part – Geographical features of the Karakorum by A. Desio.
 2nd part – Meteorological observations of Desio's 1954 Expedition by F. Petrucco.
 3rd part – Geodetic and topographic survey of Desio's 1954 expedition.

II. - GEOPHYSICS

- Vol. 1: Geophysics of the Karakorum by Antonio Marussi, 1954.

III. – GEOLOGY – PETROLOGY

- Vol. 1:** Geology and Petrology of Haramosh-Mango Gusor Area by Bruno Zanettin, 1964.
Vol. 2: Geology of the Baltoro basin by Ardito Desio and Bruno Zanettin, 1970.
Vol. 3: Geology of Central Badakhshan (North-East Afghanistan and Surrounding Countries) Ardito Desio Editor, 1975.
Vol. 4: Geology of the Shaks gam Valley, North-East Karakorum, Xinjiang (Sinkiang) by Ardito Desio, 1980

IV. – PALEONTOLOGY – ZOOLOGY – BOTANY

- Vol. 1:** 1st part – Fossils of Karakorum and Chitral by M. Amoit, R. Ciry, N. Fantini Sestini, I. Premoli Silva, C. Rossi Ronchetti, P. Sartenaer, A. Vandercammen, A. Von Schuppe, C. Zanin Buri.
 2nd part – Results of the study of the entomological collection of the Karakorum and Hindu Kush (1954-1955) by E. Gridelli and G. Muller with collaborators.
 3rd part – List of Spermatophyta collected in the Karakorum above 4000 m (1953-1954) by L.H.J. Williams, 1965.
Vol. 2: Fossils of North-East Afghanistan: Carboniferous fossils by A. von Schoupe – Triassic Fossils by P.D.W. Barnard – Jurassic fossils by C. Rossi Ronchetti – Cretaceous and Paleogene fossils by A. Berizzi Quarto di Palo and I. Premoli Silva, 1970.

V. – PREHISTORY – ANTHROPOLOGY

- Vol. 1:** Prehistoric research in North-Western Punjab – Anthropological research in Chitral by Paolo Graziosi, 1964.

As can be seen from the list given above, not all the subjects planned were carried out in a uniform manner. This was the result of the fact that some of the research, such as the geological work, was given precedence. In actual fact other work, such as the geophysical research would have benefited from further collaboration in the scientific reports. It should be remembered with regard to this, that the only volume published on this subject refers principally to the results of the 1954 expedition, while the same research in fact also carried out geophysical research during the 1955 and 1961 expeditions. Only brief notes actually appeared on these expeditious though a further volume was to have been published on this subject. Again, in the Prehistory-Anthropology section, a second anthropological volume was planned on the population of the Hunza valley by Prof. Paolo Graziosi. Unfortunately, in 1954 when he tried to reach me a month later, he was unable to obtain a permit to travel to the valley.

I should like to point out that while the previous seven volumes of this series deal with the scientific results of my expeditions in the Karakorum and Hindu Kush area from 1953 onwards, the eighth book reports on an area I explored back in 1929 in the capacity of geographer and geologist of the Italian Geographical Expedition led by Aimone di Savoia-Aosta, Duke of Spoleto, and organized on behalf of the Italian Royal Geographical Society and the Milan City Administration. An official volume on this expedition was published in 1936 with the title 'La Spedizione Geografica Italiana nel Karakorum – 1929. Storia del viaggio 'Risultati Geografici'.

The reason why I thought it appropriate to publish the volume on the valley Shaks gam lies in the fact that the geological results of the expedition had been mentioned very briefly in the 1936 volume, which was basically devoted to illustrating the geographical results. On the other hand, I was in fact the only geologist on that expedition and it was therefore my task to detail the results achieved in field, despite the fact that there was very little to add in the way of new discoveries as I stated in the preface to the above volume. This is why I decided to include in the collection a work which refers to an earlier expedition, than those I organized.

Starting from 1953, I organized and led several scientific explorations in the Karakorum and Hindu Kush and more precisely in 1953, 1954, 1955, 1961, 1962, 1973, and 1975. The last two had purely geological aims, while the 1954 expedition had two programmes to fulfill: a climbing programme which led to the first ascent of K2, and a scientific programme which was carried out not only in the Baltoro glacier basin and in the Stak valley, an affluent of the Indus, but also in the territory, lying between the two.

The volumes so far published do not illustrate all the results of research carried out in that area. Owing to intense scholastic and scientific duties, nothing has been published on the far western area of the Karakorum and on the

eastern side of the Hindu Kush though I and some collaborations have published preliminary reports. Some information, however, is included in the volumes dedicated to Paleontology.

I am now planning the tenth volume of this collection to be devoted to the results of glaciological research carried out during my expeditions in that area of Central Asia which have so far only been occasionally and sporadically reported.

The purpose of this volume is to report the results of observations and measurements of different types made mainly during the 1954 expedition. The geodetic and topographic measurements carried out by the captain (now general) Francesco Lombardi of the Italian Military Geographical Institute are of particular importance. The Institute was entrusted with the task, and theirs is the merit of drawing up the four topographic maps included in this volume.

I considered it useful to include the meteorological data as a contribution to knowledge of the climate of the region as recorded day by day at the base camp of K2 and in the surrounding areas during the months of May, June, July and August of 1954, principally at an altitude of 5000 m. The data was processed by Dr. Francesco Petrucco during her undergraduate studies under the direction of Prof. Silvio Polli, professor of Technical Physics and Climatology of the University of Trieste.

Before concluding this preface I should like to thank all those who have collaborated on this volume, in particular the authors of the two chapters mentioned above and the Italian National Council of Researches and the Finmeccanica which contributed to financing this volume.

Ardito Desio

Key words: K2, Italian Expeditions.

D/146. Desio, A., 1955a. Le ricerche scientifiche della spedizione Italiana al Karakoram K-2 1954. Rendicorto dell' Accademia Nazionale dei Lincei 34, 9p.

Key Words: Italian Expedition, Karakoram.

D/147. Desio, A., 1955b. Nuovi ritrovamenti di calcari fossiliferi del Paleozoico superiore nel bacino del Baltoro (Himalaya-Karakorum). Rendicorto dell' Accademia Nazionale dei Lincei, ser. 8^a, vol. XVIII(G), 587-598, Roma, giugno 1955.

This is an account of paleontology of the Baltoro basin sedimentary rocks. Calcareous fossils of Early Paleozoic are described.

Key Words: Paleozoic, Baltoro, Karakoram.

D/148. Desio, A., 1955c. The ascent of K2. The Geographical Journal, vol CXXI, pte 3^a, 261-273pp., 6 fig., London, September 1955.

The Italian 1954 Expedition under the leadership of Ardito Desio was the first to climb K2, the highest peak (8611 m) of the Karakoram, second only to the Mount Everest (8840 m) in the Nepal Himalaya. The conquest was, indeed, unique because K2 is considered a very difficult peak from the point of view of mountaineering. This is one of several narratives of the expedition to which references are given above and in the following.

Key Words: K2 ascent, Karakoram.

D/149. Desio, A., 1956. Cretaceous beds between Karakorum and Hindu Kush Ranges (Central Asia). Review Italiana Paleontologica 65, 221-229. 28th International Geological Congress, Mexico 7, 345-354 (in Italian)

Key Words: Cretaceous, Karakoram, Hindukush.

D/150. Desio, A., 1958a. Il Cretaceo fra il Karakorum e l'Hindu Kush (Asia Centrale). 20th International Geological Congress, Mexico City, 7, 345-354.

Fossiliferous rocks of the Cretaceous age occur in several areas in northeastern Hindukush, Kohistan (Yasin) and Karakoram ranges. The author describes and compares these rocks. For further information, consult Desio (1959) in the following.

Key Words: Cretaceous, Karakaoram, Hindu Kush.

D/151. Desio, A., 1958b. La Spedizione Italiana al Karakorum e la conquista del K 2. Op. in 8° di 24p, 8 fig., Cairo.

For further information, see Desio, 1955c.

Key Words: Italian expedition, Karakaoram.

D/152. Desio, A., 1959. Cretaceous beds between karakoram and Hindu Kush ranges. *Rivista Italiana di Paleontological e stratigrafica* 45 (3), 211-229.

This paper describes the occurrence and nature of the Cretaceous beds in the “border” area between western Karakoram and eastern Hindukush. The author describes the Cretaceous sequence in the Yasin area, together with the fossils which were studied by his colleagues. The following species were studied:

Horiopleura haydeni DOUVILLE

Praerdiolites gilgitensis DOUVILLE

Adiozoptyx coquandiana (D'ORBIGNY)

Adiozoptyx renauxiana (D'ORBIGNY)

Nerinea vogtiana DE MORTILLET

Nerinea desioi FARIOLI MIRELLI

Rhabdophyllia cf. *gracilis* DE FROM

Isastrea cf. *regularis* DE FROM

Orbitolina discoidea GRAS

Key words: Cretaceous beds, Yasin Group, Hindu Kush, Karakoram.

D/153. Desio, A., 1960. Sull'estensione dei plutoni granitici nell'Karakoram e nell'Hindu Kush (Asia Centrale), *Rendicorto dell' Accademia Nazionale dei Lincei* 8, 28(6), 783-786.

This paper presents information on the extension of granitic plutons of the Karakoram and Hindukush mountain ranges. Ages for various of the plutons are shown in Desio et al. 1960 below.

Key Words: Granitic plutons, Karakaoram, Hindukush.

D/154. Desio, A., 1961. Resti glaciali Quarternari nelli valli Panjkora, Chitral e Swat, (Pakistan Nord-Occidentale). *Bollettino del Comitato Glaciologico Italiano*, 9, Ser.2, (1959-60), Parte I, 3-10, 4 fig.

The valleys of Chitral, Dir and Swat, now drained by the Kunhar, Panjkora and Swat rivers, respectively, were extensively affected by Quaternary glaciation. This is one of the earliest account of glaciation (morphology, glacial deposits, etc.) in the three valleys.

Key Words: Quaternary glaciation, Panjkora, Swat, Chitral.

D/155. Desio, A., 1962. Appunti geologici preliminary sui bacini dei ghiacciai Biafo e Hispar (Karakorum-Himalaya). *Bollettino della Societa Geologica Italiana* 81, fasc. 1, 69-84, 6 fig.

The Biafo and Hispar are two of the longest glaciers of the Karakoram Range. This is a preliminary account of the geology of the basins of the two glaciers. After having shortly examined the precedent studies on the considered territory, the Author illustrates compendiously the geological constitution of the basins of the Biafo and Hispar glaciers, by reporting the data which he collected in 1954 on occasion of a trip from the village of Askole as far as the Hunza town, crossing the Hispar pass.

The determinations of the samples collected along the way were made by B. Zanettin. The lower portion of the Biafo basin is composed by a metamorphic formation chiefly formed by gneiss, garnetiferous mica schist and crystalline limestone (Dumordo Formation). The upper portion is formed by granite followed by bands of migmatite. The Dumordo Formation appears also in the lower valley of the Hispar glacier. Upstream prevails another metamorphic formation, richer in gneiss (K2 Gneiss), and poorer in crystalline limestone. In the north-western portion of the Hispar basin and south of the Hispar pass outcrop the granite, here too followed by more or less thick bands of migmatite. The formations are folded; the Dumordo Formation more intensely than the other ones. In the Biafo basin there is a sequence of anticlines and synclines roughly directed east-westwards. Other folds with the same direction have been identified in the lower Hispar.

Key Words: Geology, glaciers, Biafo, Hispar, Karakoram.

D/156. Desio, A., 1963a. Notizie preliminary sulla “Spedizione Desio al Karakorum 1962” Notiziario de “La Ricerca Scientifica” vol. 3(5), 485-488.

The 1962 Italian Expedition to the Karakoram was led by the author. Here he gives a preliminary account of it.

Key Words: Italian 1962 Expedition, Karakoram.

D/157. Desio, A., 1963b. Review of the geologic “Formation” of the western Karakoram (Central Asia). Rivista Italiana di Paleontologia e Stratigrafia 69, 475-501.

The geology and stratigraphy of the rocks of western Karakoram is presented.

Key Words: Geology, stratigraphy, Karakoram.

D/158. Desio, A., 1963c. Travels in the Karakorum. Pakistan Quarterly, XI(3), 14-21, 13 fig., Karachi.

This is a popular paper describing the travels of Ardito Desio and his many expeditions in the Karakoram, Hindu Kush, and Himalayan ranges.

Key Words: Tourism, travels, Karakoram.

D/159. Desio, A., 1963d. Qualche osservazione sopra un recente studio geologic sul Karakorum (Asia Centrale). Rend. Accadme Nazionle de Lincei, series 8a, 34, 358-363.

Key Words: Tectonics, Karakoram.

D/160. Desio, A., 1964a. Tectonic relationship between the Karakoram, Pamir, and Hindu Kush (Central Asia). 22nd International Geological Congress, New Delhi, 11, 197-213.

Key Words: Tectonics, Karakoram, Pamir, Hindukush.

D/161. Desio, A., 1964b. Geological tentative map of the western Karakoram 1:500 000. Dipartimento di Scienze della Terra, Universita di Milano.

This is the first geological map of the large area. It covers the area bounded by 74°-77° 15' East longitude and areas in Karakoram Range lying to its north. Brief notes on a large numbers of lithostratigraphic units are given in 35°15'-37° North latitude. The geological sketch map covers Nanga Parbat and adjacent areas and is presented together with ages. A list of pertinent references has also been given.

Key Words: Geological map, Nanga Parbat, Karakoram.

D/162. Desio, A., 1964c. Sulla presenza del Cretaceo fossilifero nel vallone del Burji-la presso Skardu (Baltistan), Asia Centrale. *Rendiconti Accademia Nazionale dei Lincei*, series 8^a, 37, 360-363.

Key Words: Cretaceous, fossils, Skardu.

D/163. Desio, A., 1965a. Sulla struttura geologica dell' Asia Centrale. *Rendiconti Accademia Nazionale dei Lincei* 38, 780-786.

This is a regional account of the geo-tectonic framework of the Central Asia, including northern Pakistan. Tectonic zones and major faults are recorded.

Key Words: Structural geology, Tectonics, Central Asia.

D/164. Desio, A., 1965b. On the tectonic connection between Pamirs and Hindukush. In: D.N., Wadia Commemorative volume. Mining and Metallurgical Institute of India, Calcutta, 716-721.

Key Words: Tectonics, Pamirs, Hindukush.

D/165. Desio, A., 1965c. Introduction. In: Italian Expeditions to the Karakorum (K2) and Hindu Kush (A. Desio leader). IV-Paleontology-Zoology-Botany, Volume 1, 1-9. Brill, Leiden.

The many Italian Expeditions to the Karakoram and Hindukush ranges have resulted in a wealth of information contained in a very large number of papers. This particular volume deals with paleontology, zoology and botany. The monumental contributions are also listed under "Italian Expeditions to the Karakorum (K2) and Hindu Kush (A. Desio leader)".

Key Words: Italian expedition.

D/166. Desio, A., 1966. The Devonian system in Mastuj valley (Chitral, NW Pakistan). *Rivista Italiana di Paleontologiae e Stratigrafia* 72, 293-320.

Key Words: Palaeontology, Devonian, Mastuj.

D/167. Desio, A., 1974a. Geological reconnaissance in the middle Indus valley between Chilas and Besham Qila (Pakistan). *Bollettino della Societa Geologica Italiana*. 93, 345-368.

The geology of the area is described, together with petrographic notes. The area is covered by rocks (gabbro-norites, diorites, amphibolites, local granites and, mostly in Duber-Besham section, sediments. Prasanitic schists are shown to form a prominent zone near Sazin. These are now considered as a major shear in the gabbro-norites of the Chilas complex.

Key Words: Reconnaissance, Chilas, Besham, Kohistan, Indus valley.

D/168. Desio, A., 1974b. Karakorum Mountains. In: Spencer, A.M. (ed.), *Mesozoic-Cenozoic Orogenic Belt*. Geological Society of London, Special Publication 4, 255-266.

Regional framework of the geology and tectonics of the Karakoram Range are described. A useful regional map of lithotectonic blocks of the Central Asia is also given.

Key Words: Orogenic belts, Mesozoic, Cenozoic, Karakoram

D/169. Desio, A., 1974c. On the geology of southern slope of Masherbrum peak and the upper Hushe valley (Karakorum, Central Asia). *Rendiconti Accademia Nazionale dei Lincei*, series 8, 79-100.

Key Words: Mountain peaks, Masherbrum, Karakoram.

D/170. Desio, A., 1975a. Some geological notes and problems on the Chitral valley (NW Pakistan). *Rendiconti Accademia Nazionale dei Lincei*, Series 8, 58, 611-617.

Key Words: Geology, Chitral valley.

D/171. Desio, A., 1975b. Una visita al Ghiacciaio Kuthiah nel Karakorum Centrale (Pakistan). *Bollettino della Societa Geologica Italiana*. 22, (1974), 39-44.

Key Words: Glaciers, Kuthiah, Karakoram.

D/172. Desio, A., 1976a. Introductory Report on the geotectonics of the Kashmir Himalaya – Karakorum – Hind Kush – Pamir orogenic belts. *Accademi Nazionale dei Lincei: International Colloquium on the Geotectonics of the Kashmire Himalaya – Karakorum – Hind Kush – Pamir Orogenic Belts*, 1974, Roma, 9-13.

Key Words: Geotectonic, Kashmir, Himalaya, Karakorum, Hindukush, Pamir

D/173. Desio, A., 1976b. Some geotectonic problems of the Kashmir-Himalaya-Karakorum-Hindukush and Pamir area. *Atti dei Convegni Lincei: International Colloquium on the Geotectonics of the Kashmire Himalaya – Karakorum – Hind Kush – Pamir Orogenic Belts*, 1974, 115-129.

Key Words: Geotectonic, Kashmir, Himalaya, Karakorum, Hindukush, Pamir

D/174. Desio, A., 1977a. Correlation entre les structures des chaines du Nord Est de l'Afghanistan et du Nord-Ouest du Pakistan. *Societe Geologique France, Memoirs* 8, 179-188.

In order to proceed to the structural correlations between the mountain chains of NE Afghanistan and chains of the NW Pakistan, both the regions have been divided in tectonic zones, on the ground of their stratigraphic compos and of their tectonic structure which express their geological evolution. The tectonic zones have been grouped in relation to the age in which the last orogenic phase (that is to say Hercy Cimmerian and Alpine), happened. Each zone has been separated from the surrounding zones by some of the deepest and persistent faults.

The NE Afghanistan has been divided in two folding areas the Hercynian one west and south-westward, and the merian one east and south-eastward. In the first area three tectonic zones have been distinguished. From the west to the they are : a) Surkhab zone ; b) Fayzabad zone ; c) western Hindu Kush zone.

The mean fault of the Badakhshan and that of Herat (or Hari Rud) delimitate the Hercynian zones from the Cimmones. The last ones are represented by : a) Safed Khers zone ; b) South eastern Badakhshan zone ; c) Nuristan zone. All these are to be correlated with the tectonic zones of Pamir; except the western Hindu Kush.

In north-western Pakistan two tectonic zones have been distinguished: a) Eastern Hindu Kush zone; b) Karakorum: Southward there is the Kohistan zone. The former is included in the early Alpine folding, the latter in the late Alpine folding former represents the north-eastern part of the Nuristan zone, the latter doesn't find any correlation in Afghanistan, as its metral faults close before reaching the frontier. The Kohistan zone is to be related with the tectonic zones of the central south Afghanistan and then it's out of the examined area.

The present structure of the region is the consequence of the tectonic splitting up during the geological time reach and reelaborated in consequence of the collision of the Indian and the Arabic plates with the Euroasiatic plate.

Key Words: Structure, tectonics, Afghanistan, Pakistan.

D/175. Desio, A., 1977b. The works of the Italians in the scientific exploration of Karakorum (Central Asia). *Accademia Nazionale dei Lincei*, No. 374, Quderno, 231, 1-22 and the *Himalayan Journal* 36, 126-136.

Key Words: Scientific exploration, Karakoram.

D/176. Desio, A., 1977c. The occurrence of blueschists between the Middle Indus and the Swat valleys as an evidence of subduction. *Rendiconti Accademia Nazionale dei Lincei*, series 8, 62, 653-661.

Blueschist occurrence in Shangla area of Swat was the first of its type reported in the Indus suture zone. Dated at mid-Cretaceous, the blue amphibole occurs in a number of lithologies. Its occurrence is attributed to northward subduction of the Indian plate.

Key words: Blueschists, High-pressure metamorphism, Indus Suture, Swat.

D/177. Desio, A., 1978. On the geology of the Deosai Plateau (Kashmir). *Memorie dell'Accademia Nazionale dei Lincei*, Series 8, Volume 62, 15, 1-19.

Desio visited the Deosai area and studied the rocks previously described in some detail, (Wadia 1937). He provided additional details on the geology and structure of the area (also known as Little Tibet) and petrography of the rocks which show low grade alteration. He also mentioned the occurrence of andesite among the volcanics. Desio presented a geological map covering the area between Skardu, Astor, Kalapani, Dras, Kargil, and Parkutta, however, the central part of this area was not covered. He described a great number of rock types including sediments of various ages including Precambrian, cal-alkaline plutonic rocks, gneisses and schists and so on.

Key Words: Geology, maps, Deosai Plateau, Kashmir.

D/178. Desio, A., 1979. Geological evolution of the Karakorum. In: Farah, A. & DeJong, K.A. (eds.), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 111-124.

The Karakoram mountain range is divided into five zones. The central zone, a granitic batholith, is the core of an anticlinorium. The northern zone contains mostly unmetamorphosed rocks of the Paleocene to Late Cretaceous age. The southern zone is mainly composed of metamorphic Paleozoic (or Precambrian) to Upper Tertiary formations. Farther to the south are two other zones, one to the east (Ladak-Deosain zone), and the other to the west (Kohistan zone) of the Nanga Parbat Haramosh Massif. This massif is oriented perpendicular to the main Karakorum trend and penetrated deeply into the southern zones. It is interpreted as the most prominent spur of the old Indian continent. The tectonic evolution of the Karakorum is related to the Indian subcontinent's northward displacement and collision with Eurasia along the Upper Indus Suture Line and, to the west, the Kohistan line. The main tectonic phase began in Cretaceous and continued through the Tertiary; the upheaval of the mountain belt began in the late Neogene and is still occurring.

Key Words: Orogeny, geology, Karakoram.

D/179. Desio, A., 1980. The age of the blueschists and the Indus-Kohistan suture line, NW Pakistan. *Rendiconti Accademia Nazionale dei Lincei*, series 8, 75-79.

White mica is dated by K/Ar method at 80 Ma.

Key words: Blueschists, radiometric dating, Indus suture, Swat.

D/180. Desio, A., 1982a. Scienziati italiani nel Karakorum e nell'Hindu Kush (Asia Centrale). *Annuario del C.A.I.*, 1981, 9-13.

Key words: Karakoram, Hindu Kush.

D/181. Desio, A., 1982b. Geological notes on the K² (Chogo-ri Massif) in the Karakorum. *The Himalayan Journal* 38 (1980-1981), 142-145.

Key words: Geology, K2, Karakoram.

D/182. Desio, A., 1982c. A geological section across Himalaya and its relation with the seismic profile Punjab-Pamir. *The Pamir Himalaya Deep Structure of the Earth's Crust*, 144-152. Moscow (in Russian).

Key words: Seismic profile, geologic cross-section, Pamir-Punjab.

D/183. Desio, A., 1983a. A geological section across the Karakorum and Kashmir Himalayas and its relationship to the seismic profile Punjab-Pamirs. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 339-349.

Key Words: Seismic profile, geological cross-section, Punjab, Pamir, Karakoram, Himalaya.

D/184. Desio, A., 1983b. Geological notes on the Falchan Kangri (Broad Peak, 8047 m) in Karakorum. *Himalayan Journal* 39 (1980-1981), 129-135.

Key words: Geology, broad peak, Karakoram.

D/185. Desio, A., 1984a. L'esplorazione del ghiacciano Abruzzi e l'ascensione all "Probable Saddle" di Martin Conway. *Dal Polo al K², sulle orme dell Duca degli Abruzzi, 1899-1954*, 67-72. Museo della Montagna, Torino.

Key words: Karakoram.

D/186. Desio, A., 1984b. Gli italiani e l'esplorazione scientifica del Karakorum e dell' Hindu Kush. *Ibid* 97-104.

Key words: Italian Scientific Exploration, Karakorum, Hindukush.

D/187. Desio, A., 1984c. Quattro visioni del K2 nel Karakorum. *Dai miei diari di viaggio. Notiziario della Bmca Popolare di Sondrio*, 34, 1-12.

Key words: K2, Karakoram, Desio's travelogue.

D/188. Desio, A., 1984d. Notes on the Gasherbrum ridge in the Karakorum Range. *Himalayan Journal* 40, 143-149.

Gasherbrum is one of the most prominent ridge of the central Karakoram and lies in the K2 region. Desi's contribution is important about the ridge which has been investigated by only few. The rocks are metasedimentary with granitic intrusions.

Key words: Geology, Gasherbrum, Karakoram.

D/189. Desio, A., 1988a. Italian Expedition to Tibet and Pakistan to conduct further observations on the altitude of Mount Everest and K². *The American Alpine Journal* 30, 180-183.

Key words: Altitude, K2, Everest.

D/190. Desio, A., 1988b. Which is the highest peak in the World? *The Explorer Journal* 66, 90-95, *New York, and Himalayan Journal* 45, 17-23.

Key words: K2, Everest.

D/191. Desio, A., 1989a. Risultati dell misure altimetriche dell' Everest e del K2 effettuate della spedizione italiana Ev-K2 CNR. *Rediconti Accademia Nazionale Lincei, Series 8 (82)* 309-312.

Key words: Everest, K2.

D/192. Desio, A., 1989b. Which is the highest Mountain in the World? Report of the Expedition Ev-K2-CNR to the Mt. Everest and K2 1987. *Atti dell'Accademia Nazionale Lincei, Memoire, Series 8(17), Sez. 1a*, 174-194.

Key Words: Italian expedition, Everest.

D/193. Desio A., 1991. Geographical features of the Karakorum. Italian Expedition to the Karakorum (K2) and Hindu Kush (A. Desio leader). *I-Geography, volume 1*, 1-73, ISMEO, Milano (Scientific Reports 1-Geography).

This article is a detailed account of the geography of the Karakoram and contains 59 illustrations. These and the text cover the origin of the names of the mountain, its orography, drainage, subdivision into mountain ranges, the boundaries of the Karakoram and the location of the range in regional tectonic framework. The author also gives a useful summary of the scientific activity of Italians in the exploration of the Karakoram before the Second World War (10 pages), followed by a brief history of Desio's expeditions to the Karakoram and eastern Hindu Kush (5 pages), and topographic maps surveyed by Italian expeditions in the Karakoram (14 pages). These last pages also show excellent maps of some major glaciers. The account is followed by an extensive, but not complete, list of publications (302) by the Italian expeditions to Karakoram, and NE Hindukush, and a list of the five major maps produced earlier.

Key Words: Italian expedition, geography, bibliography, Karakoram, Hindukush.

D/194. Desio, A. (ed.), 1991. Italian Expeditions to the Karakoram (K2) and Hindukush. ISMEO, Milano (Scientific Reports 1-Geography).

Of these volumes, the ones related to Earth Sciences specifically are listed under Italian Expeditions to the Karakoram (K2) and Hindu Kush in the appropriate place.

Key Words: Italian expedition, Karakoram, Hindukush.

D/195. Desio, A., Biggioggero, B., Casnedi, R., et al., 1976. The 1975 geological-geophysical expeditions in the Kashmir Himalayas and in the Western Karakorum (Pakistan): geological research. *Atti Societa italiana Scienze natural* 117, 303-309.

Key words: Geology, Italian Expedition, Kashmir, Karakoram.

D/196. Desio, A., Casnedi, R., Forcella, F., Nicoletti, M. & Petrucciani, C., 1978. Absolute age of some granitoid rocks between Hindu Raj and Gilgit River (Western Karakorum). *Rendiconti Accademia Nazionale dei Lincei*, Ser. 8(64), 204-210.

Key words: Geochronology, granites, Hindu Raj, Gilgit, Karakoram.

D/197. Desio, A. & Cita, M.B., 1955. Nuovi vi trova menti di calcari fossiliferi del Paleozoico super ore nel bacino del Baltoro (Himalaya-Karakorum). *Rendiconti dell' Accademia Nazionale dei Lincei*, Series 8 (17/18), 587-598.

Key Words: Fossiliferous limestone, Paleozoic, Baltoro.

D/198. Desio, A. & Giobbi Mancini, E., 1974. On the geology of the southern slope of the Masherbroom Peak and the upper Hushe valley (Karakorum, Central Asia). *Memoire Accademia Nazionale de Lincei*, Series 8 (12), 79-100.

Key Words: Geology, Masherbrum, Karakoram.

D/199. Desio, A. & Longinelli, A., 1961, Sull' eta dei graniti del Baltoro (Karakorum-Himalaya), *Rendiconti Accademia Nazionale dei Lincei*, Ser. 8 (30), 437-448.

Key Words: Granites, glaciers, Baltoro, Karakoram.

D/200. Desio, A. & Martina, E., 1972. Geology of the upper Hunza valley, Karakorum, West Pakistan. *Bulletino della Societa Geologica Italiana* 91, 283-314.

The Paleozoic and Mesozoic sedimentary rocks of the area have been described together with some description of the Late Cretaceous granite intrusions. The authors produced the first geological map of the upper Hunza valley, and the sedimentary formations were shown as following:

Misgar Slate

Kilik Formation

Gircha Formation

Passu Slate

Gujhal dolomite

Shanoz conglomerate.

This paper describes the geology of the region explored during the summer of 1962 by the DESIO's Upper Hunza expedition. The northern boundary is represented by the Pakistan-China border; the southern boundary by the axial batholith of the Karakorum range. The igneous rocks have been divided as follows: Giraf Syenite (Eocene), Granodiorite of the axial batholith (Pliocene), with pegmatite and aplite stocks and dykes (Late Pliocene); Syenite porphyry and amphibolite dykes crossing the Misgar Slates, the Gircha Formation and the Gujhal Dolomite. The metamorphic rocks have been divided in the Dumordo Formation and the migmatic plagioclase-gneiss of unknown age outcropping to the south of the batholith.

The sedimentary formations of Palaeozoic and Triassic age have been sub divided as follows: Misgar Slate, probably the oldest, Kilik formation of uncertain stratigraphic and tectonic position, Gircha Formation with Permian megafossils and microfossils, Pasu Slates of uncertain stratigraphical position and Gujhal Dolomite, Triassic and possibly Lower Jurassic.

The tectonic structure of this region is characterised by overthrust, folded and faulted blocks with the fault-planes generally dipping south on the northern side of the Karakorum range (Batura ridge), and in the opposite direction on its southern side. The strike of the tectonic units is north-west that is parallel to the axis of the axial batholith.

The stratigraphy of the Upper Hunza valley is similar to the stratigraphy of the Shaksam valley. The two valleys are located to the north of the Karakorum axial batholith. In the Upper Hunza valley and in some tributary valleys, remnants (till) of two, and probably three, glaciations associated with fluvio-glacial deposits are present.

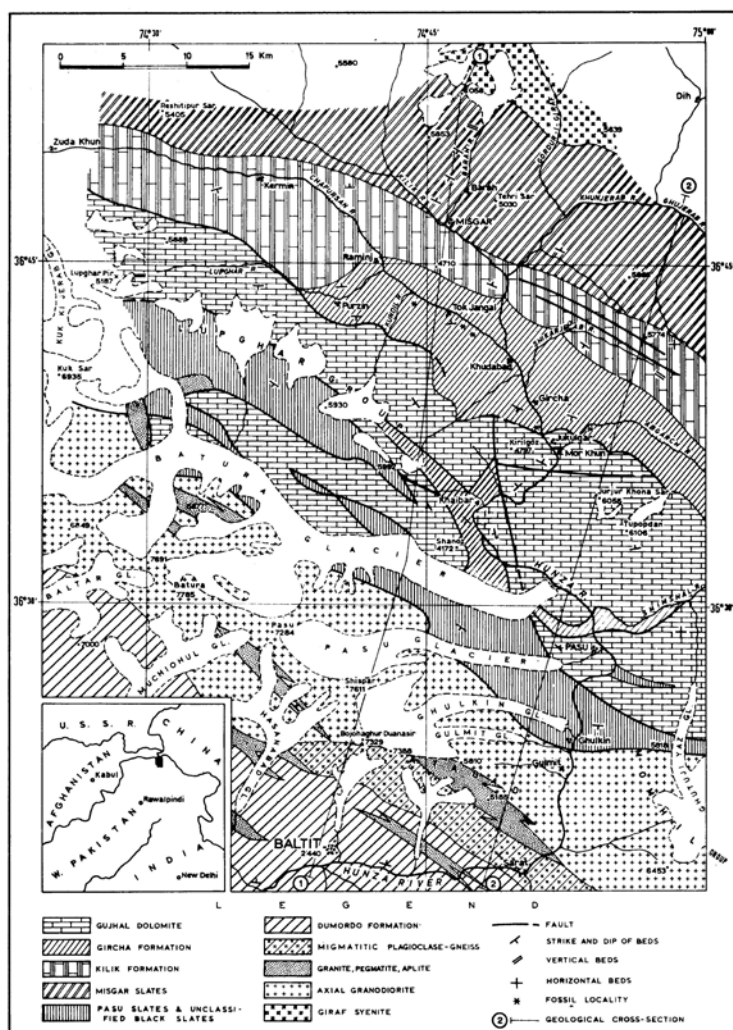


fig. 1 — Geologic sketch-map of the upper Hunza valley (the area to SW of Batura glacier according to SCHNEIDER, 1957).

Key words: Geology, stratigraphy, granites, Hunza valley.

D/201. Desio, A., Martina, E. & Galimberti, R., 1963. Notizie geologiche preliminari sull' Alta valle di Hunza (Karakorum-Himalaya). Rendiconti Accademia Lincei, Series 8 (34), 115-117.

Consult the preceding account.

Key Words: Geology, Hunza, Karakoram.

D/202. Desio, A., Martina, E., Spadea, P. & Notarpietro, A., 1985. Geology of the Chogo Lungma-Biafo-Hispar area, Karakorum (NW Pakistan). Memoire Accademia Nazionale dei Lincei, Series 8, 18(1), 1-53.

Key Words: Geology, glaciers, Chogo Lungma, Biafo, Hispar, Karakoram.

D/203. Desio, A. & Marussi, A., 1960. On the geotectonics of the granites in the Karakorum and Hindu Kush Ranges (Central Asia), International Geological Congress, Reports of 21st Session, Part 2, Proceeding 2, 156-162.

Key Words: Geotectonics, granites, Karakoram, Hindukush.

D/204. Desio, A., Marussi, A. & Caputo, M., 1961. Glaciological research of the Italian Karakorum expedition 1953-55, International Association Hydrological Sc., Snow and Ice Commission, Publication 54, 224-232.

Key Words: Glaciology, Italian expedition.

D/205. Desio, A. & Orombelli, G., 1971. Notizie preliminary sulla presenze di un grande ghiacciaio valliro nella media valle dell' Indo (Pakistan) durante I Pleistocene. Accademia Nazionale Dei Lincei 51(8), 387-392.

In the summer 1971 during the exploration of the middle Indus valley between Chilas and Besham Qila, three huge end moraines of the Pleistocene Indus glacier were discovered. The uppermost deposit blocks the bottom of the valley near Gunar (1220 m a.s.l.), the second near Dudishal (840 m), and the third near Shatial (800 m). The first is more recent than the other two. Some more recent end moraines were discovered in the lower Gilgit valley, near Dak Chanki and upstream of Gilgit town. The above end moraines are to be referred to three different Pleistocene glaciations for their different location and state of preservation.

Key Words: Glaciers, Pleistocene, Indus valley.

D/206. Desio, A. & Orombelli, G., 1983. The "Punjab Erratics" and the maximum extent of the glaciers in the Middle Indus Valley (Pakistan) during the Pleistocene. Memorie Accademia Nazionale de Lincei, Series 8(17), 135-180.

Key Words: Punjab Erratics, Glaciers, Pleistocene, Indus valley.

D/207. Desio, A., Petrucco, F. & Lombardi, F., 1991. Italian expeditions to the Karakorum (K2) and Hindu Kush, 1-Geography, 1, Milano, 158p.

Key Words: Italian Expedition, Karakoram, Hindukush.

D/208. Desio, A., Premoli S.I. & Rossi Ronchetti, C., 1977. On the Cretaceous outcrop in the Chumarkhan and Laspur valleys, Gilgit-Chitral, northwest Pakistan. Riviews Italian Paleontology 83, 561-569.

Key Words: Palaeontology, Cretaceous, Gilgit, Chitral.

D/209. Desio, A. & Savoia Aosta, A., 1936. La Spedizione Geografica Italiana net Karakoram. Arti Grafiche Bertarelli, Milano.

Key Words: Italian Expedition, geography, Karakoram.

D/210. Desio, A. & Shams, F.A., 1977. The occurrence of blueschists between the Middle Indus and Swat Valley as an evidence of subduction (N. Pakistan). *Accademia Nazionale dei Lincei, Series 8*, 62, 1-9.

Consult the following account.

Key Words: Subduction, Indus suture, blueschists, Indus, Swat.

D/211. Desio, A. & Shams, F.A., 1980. The age of blueschists and the Indus-Kohistan suture line, NW Pakistan. *Accademia Nazionale dei Lincei, Series 8*, 68, 74-79.

Outcrops of blueschists occur in the Indus suture *mélange* at Shangla, Swat. Petrography and tectonic significance of the rocks is described. Blueschist metamorphism has an age of 85 Ma (K-Ar muscovite) and is related to subduction.

Key Words: Indus suture, blueschists, Swat.

D/212. Desio A., Tongiorgi, E. & Ferrara G., 1964. On the geological age of some granites of the Karakorum, Hindu Kush and Badakshan (Central Asia). *Proc. 22nd Int. Geol. Congress*, 11, 479-496.

The authors report Rb-Sr dates on 22 samples of granitic rocks of the region. Sample numbers and dates are plotted. The cores of the Karakorum and Hindu Kush ranges are mostly composed of granite and granodiorite, which form large arches around the vertex of Himalayan syntaxis. Smaller granitic bodies crop out laterally from the main arches.

Previously, the age of the granitic rocks was known only locally by means of stratigraphic methods. The authors present new data about the age of the granites obtained by the Rb/Sr method. They found granites of seven different ages belonging to the Lower Triassic (Hercynian); Upper Triassic and Upper Jurassic (Cimmerian); and Upper Cretaceous, Oligocene, Miocene and Pliocene (Alpine).

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Key words: Geochronology, granites, Karakoram, HinduKush.

D/213. Desio, A. & Zanettin, B., 1956a. Sul la costituzione geologica della catena del Karakorum Occidentale (Himalaya), *International Geological Congress 20th Session, Mexico*, 15, 1-11.

Key Words: Orogeny, Karakoram, Himalaya.

D/214. Desio, A. & Zanettin, B., 1957a. Sul la constitution geologique de K-2 (8611 m) dan la chiane du Karakorum (Himalaya). *Bulletin de la Societe Geologique de France, Ser. 6e, tome 6*, 829-837.

Key Words: Geology, K2, Karakoram.

D/215. Desio, A. & Zanettin, B., 1957b. Notizie geologico-petrografiche preliminari sul bacino del ghiacciaio Baltoro, *La Ricerca Scientifica*, anno, 27(3), 657-673.

Key Words: Glaciers, geology, petrography, Baltoro, Karakoram.

D/216. Desio, A. & Zanettin, B., 1970. Geology of the Baltoro Basin. Italian Expeditions to the Karakorum (K2) and Hindu Kush (leader A. Desio). Scientific Report III, Volume 2, 35-148. Brill, Leiden.

This paper gives many Rb-Sr and K-Ar dates for the Karakoram granitoids. These include:

38 Ma on granite pebble in Himis (Ladakh) conglomerate; 30 Ma Rb-Sr whole rock age for biotite-muscovite paragneiss west of Younghusband glacier near contact with Baltoro granite; 12.5 Ma whole rock on amphibole-sphene-epidote gneiss from moraine of Younghusband glacier coming from southern wall of Mustagh tower.

Key words: Baltoro Basin, radiometric ages, Central Karakoram.

D/217. De Terra, H., 1932. Geologische Forschungen im Westliche Kun-Lun und Karakorum-Himalaya. Wiss Ergebnisse Trinkler' Schen Zentralasien Exped., 11 D. Reimer, Berlin.

Key Words: Himalaya, Karakoram, Kun Lun.

D/218. De Terra, H., 1932–1935. Geological studies in the northeast Himalaya between the Kashmir and Indus valleys. North India Exped., Connecticut Acad. Arts and Science, Yale University Memoir, 8(2), 17–76.

Key Words: Geology, Kashmir, maps, Himalaya.

D/219. De Terra, H., 1934. Neuere Forschungsergebnisse im Himalaya-Gebiet, Central bl. fur Mi, Abt.B, 7, 317-318.

Key Words: Himalaya.

D/220. De Terra, H., 1936. Himalaya and Alpine orogenesis. 16th International Geological Congress U.S.A. Rep. 1(2), 859–971.

Key Words: Alpine orogenesis, Himalaya.

D/221. De Terra, H., 1938. Correlation between glacial and fluvial cycles during the great Ice Age. Geological Society of America Bulletin, 12, p. 49.

Key Words: Glacial, fluvial, ice age.

D/222. De Terra, H. & De Chardin, P.T., 1936. Observations on the upper Siwalik Formations and later Pleistocene deposits in India, Proceedings American Philosophical Society, 76, 791-822.

The authors detailed the relationship of the Siwaliks to later Pleistocene sediments deposited in from of the Himalayan orogeny. They consider the 'Boulder Conglomerate stage' as the uppermost unit of the Siwalik group. They place this unit in the Middle Pleistocene and associate it with the second glaciation of Kashmir. The Punjab erratics are closely correlated with the deposits of the Boulder Conglomerate stage. They are thought to have been jointly carried with the coarse deposits of the conglomerate during catastrophic floods due to the breakthrough of lakes dammed by the ice in the Upper Indus basin. This is likely to have happened during the withdrawal period of second glaciation when the erratics may have been moved along the Indus at a time when the river running at the foot of mountains followed the course of the present Haro river rather than at its present course. The authors deny the presence of a large lake in the northern Punjab at the time when erratics were scattered.

According to these authors, the 'Boulder Conglomerate stage' is followed with disconformity by the series 'Potwar silt' formed of sand and gravels at the base (known as 'Potwar gravel') and of silt for approximately 100 mIt is considered to be a deposit of the loess-type having been reworked by runoff and stream flow waters. The 'Potwar loessic silt' is attributed to the Late Pleistocene and correlated with the 3rd glaciation of Kashmir. [Authors' Comments: This description is a nearly verbatim copy of the account given in Desio and Orombelli, 1983, p. 141-142].

Key words: Glaciation, glaciers, Karakoram, Himalaya, Punjab erratics

D/223. De Terra, H. & Hutchinson, G.E., 1936. Data on postglacial climatic changes in northwest India. *Current Sciences* 5, 5-10.

Key Words: Post-glacial climate change, NW India.

D/224. De Terra, H. & Tongiorgi, E., 1964. Notizie preliminari sull eta geological di aclune rocce Granitoidi del Karaorum Hindu Kush e Badakhshan (Asia Centrale). *Rend. Accad. Lincei*, 35, 776–773.

This paper gives preliminary geological descriptions of granitic rocks from the ranges of Karakoram, Hindukush and Bakhshan in Afghanistan.

Key Words: Granites, Karakoram, Hindukush, Central Asia.

D/225. De Terra, H., Tongiorgi, E. & Ferrara, G., 1964. On the geological age of some granites of the Karakorum, HinduKush, and Badakhshan, Central Asia. 22nd International Geological Congress New Delhi, Proceedings 11, 479–496.

Key Words: Chronology, granites, Karakoram, Hindukush, Central Asia.

D/226. De Verneuil, E., 1866. Note on fossils collected in Kashmir, etc., by M.A.V. Verchere, Asiatic Society of Bengal Journal, 36(2), 201-229.

Key Words: Fossils, Kashmir.

D/227. Dewey, J.F., Cande, S. & Pitman, W.C., 1989. Tectonic evolution of the India/Eurasia collision zone. *Eclogae Geologicae Helvetiae* 82, 717-734.

Key Words: Tectonics, India-Eurasia, collision, Island arc.

D/228. Dichter, D., 1968. The physical evolution of the North West Frontier Region of West Pakistan. *Pakistan Geographical Review* 23, 78-91.

This contribution deals with the physical geography/geomorphology of the province. The mountain regions, river valleys, intermountain basins, and plains are described.

Key Words: Geography, geomorphology, NWFP.

D/229. Dichter, D. & Popkin, N., 1967. The North West Frontier Province of West Pakistan. A study of regional geography. Clarendon Press, Oxford, 231p.

Key Words: Geography, NWFP.

D/230. Dickins, J.M., 1952. Upper Paleozoic fossils from the North West portion of the Gilgit Agency, Pakistan, Commonwealth. Australia Bur. Mm. Rec. Geol. Geophys., Rec. 1952, 42p.

Key Words: Fossils, Paleozoic, Gilgit.

D/231. Diemberger, K., 1968. Ein Apfel auf dem Tirich Mir (Reisebericht der Osterr. Hindukusch Expedition 1967). Jahrbuch der Osterreichischen Alpenverein, Bd. 1968, Verlag Wagener, Innsbruck, 143–157.

Key Words: Hindukush expedition, Tirichmir, Chitral.

D/232. Diener, C., 1912. The Trias of the Himalaya. Geological Survey of India, Memoir. 36(3), 202-360.

Key Words: Himalaya, Triassic, mapping.

D/233. Di Florio, M.R., Faccenna, C., Lorenzoni, S. & Zanettin Lorenzoni, E., 1992. Lithological analysis of materials used in the buildings of the sacred area of Panr I (Swat Valley—N.W.F.P. Pakistan) and their origins. In: Faccenna, D. (ed.), “Panr I (Swat Pakistan)”, IsMEO (Istituto Medio Estremo Oriente) Report and Memories, Roma, 357p.

Key Words: Lithology, sacred area, Swat.

D/234. Di Florio, M.R., Lorenzoni, S. & Zanettin Lorenzoni, E., 1991. Geo-archaeological study of Gandhara remains in the Swat valley (NW Pakistan). Abstracts, International Geological Congress, Kyoto, 2, p.388.

The Swat valley has been a cradle of the Gandhara civilization. There are many ruins, statues and artifacts, some of which are preserved in the Museum of Archeology and some in Butkara near Saidu Sharif. These have been the subject of long studies by Facenna and his colleagues. Many of the remains comprise low-grade metasediments (graphitic schists, greenschists, dolomite-talc rocks, serpentinite, granitic rocks, etc. These have been extracted from the nearby terrain belonging to the Indian plate and the Indus suture mélange north of Mingora.

Key Words: Geoarchaeology, Gandhara, Swat.

D/235. Di Florio, M.R., Lorenzoni, S. & Zanettin Lorenzoni, E., 1991. Geo-archaeological study of Gandhara remains in the Swat valley (NW Pakistan). In: “Archaeological Stone” The British Museum, London.

Please consult the preceding account for further details.

Key Words: Geoarchaeology, Gandhara, Swat.

D/236. Di Florio, M.R., Lorenzoni, S. & Zanettin Lorenzoni, E., 1997. Relationships between ancient settlements and Geology, lithology, geomorphology in the Lower Swat valley (NWFP, Pakistan). In: Sinha, A.K., Sassi, F.P. & Papanikolaou, D. (eds.), Geodynamic Domains in Alpine-Himalayan Tethys. Oxford & IBH Publishing Co., New Delhi, 209-220.

Key Words: Geology, geomorphology, lithology, Swat.

D/237. Di Florio, M.R., Lorenzoni, S., Olivieri, L. & Zanettin Lorenzoni, E., 1993. Evidence of ancient stone quarrying in Lower Swat, N.W.F.P., Pakistan. A geo-archaeological study. *Science and Technology for Cultural Heritage* 2, 63-74.

Traces of ancient quarries are widespread in Lower Swat. Two type of quarry work were found: a) scattered excavations in the zone surrounding Buddhist sacred areas, which provided rocks (phyllites, calc-schists, gneisses) for common building use; b) intensive excavations in the areas with exposures of prized rocks such as soapstone, chlorite-schists, and talc schists, which were used for the facing of walls and for sculptures and decorations. In both types of quarry, blocks and discs were detached directly from the outcrop by chiseling and levering. A quarry village (Swegalai) was found in the main quarry area.

In addition to quarries, traces of excavation such as tanks for working «stucco» (a kind of plaster), small outcrops possibly for milling materials, and cooling instruments and cavities for preserving food were found. The map of the Indus suture is also given.

Key Words: Geoarchaeology, Indus suture, Swat.

D/238. Dilles, J.H., Snee, L.W. & Laurs, B.M., 1994. Geology, Ar-Ar age, and stable isotope geochemistry of suture related emerald mineralization, Swat, Pakistan Himalayas. *Geological Society of America, Programs with Abstracts*.

Key Words: Chronology, isotopes, geochemistry, emerald, Swat.

D/239. Din, A., Rassol, G. & Rana, N.A., 1963. Purification of commercially exploited glass sands of West Pakistan. *Pakistan Journal of Scientific and Industrial Research* 15, p.20.

Key Words: Sand, optical glass, heavy minerals, Pezu.

D/240. Din, A., Sindhu, S.D. & Faruqi, F.A., 1963. Purification of Dera Pezu sand for making colourless optical glasses. *Pakistan Journal of Scientific and Industrial Research* 15, 157-162.

Purification studies (grading, washing, floatation and others) of sand have been carried out. The sand initially contained about 0.26% heavy minerals

Key Words: Sand, optical glass, heavy minerals, Pezu.

D/241. Din, F. & Rafiq, M., 1997. Correlation between compressive strength and tensile strength/index strength of some rocks of North-West Frontier Province (Limestone and Granite). *Geological Bulletin, University of Peshawar* 30, 183-190.

The use of the building stones is increasing day by day and engineering activities are also in progress. Therefore the mechanical properties of building stones such as limestones, marbles, granites etc are required to be investigated to estimate the strength and give recommendations in designing safe structures. The present research deals with the investigation and correlation of compressive, tensile and index strength of granites and limestones from different localities of North-West Frontier Province. The test results are given in table 1-2, which reveal suitability of Shahbaz Garhi micro granite for heavy constructions and in foundations of buildings while Malakand granite in light constructions, crushed stones, floor material and ballast under railway tracks. The strength values of Cherat and Kohat limestones are low, and very much suitable for cement, chemical industry and ballast under roads.

Key Words: Geotechnical, building stones, NWFP.

D/242. Din, F., Rafiq, M. & Mohammad, N., 1993. Strength properties of various building stones of NWFP, Pakistan. *Geological Bulletin, University of Peshawar* 26, 119-126.

Domestic resources of both dimension and crushed stones used for construction and adequate to fulfil the expected demand indefinitely in N. W. F. P. Various types of building and decorative stones including limestone, marbles, granite, granitic gneisses, slate, quartzite, dolerite, gabbro, serpentinite etc., are found in large amount in NWFP. Geotechnical properties of these rocks including compressive strength and tensile strength show compatible values to the recommended ASTM range for Thana marble, microporphyrates of Shewa Shahbaz Ghari, Marbles of Nowshera and Pir-Sabak, limestones of Kohat, Cherat and Nizampur areas, and granites of Ambela, Utlā and lower swat. Higher values for compressive, tensile and shear strength are for slate from Attock and Cherat ranges. Though the shear strength values for most of these rocks are low, they are free of geotechnical defects.

The data is useful not only for those using these rocks as building and foundation stone and crushed and broken material but also for those interested in designing openings in these rocks.

Key Words: Geotechnical, building stones, NWFP.

D/243. Din, F., Rafiq. M. & Mohammad, N., 1995. Triaxial study of granites and limestones from north and south of Peshawar Basin, NWFP, Pakistan. Geological Bulletin, University of Peshawar 28, 15-25.

Determination of uniaxial and triaxial strength of different building stones is important both from practical as well as academic point of views. Triaxial testing is the most appropriate method, which provides identical field conditions. In order to achieve this objective, granite and limestone from four different localities (Malakand granite, Shahbaz Garhi granite, Kohat limestone and Cherat limestone) were selected to carry out triaxial tests.

Four samples of each rock, having length-to-diameter ratio of about two were tested under confining pressure of 0-30 MPa range. The observations made and results obtained are plotted and after drawing Mohr's envelope for each rock shear strength is calculated corresponding to different triaxial confining pressure. The finding of the study are summarized in the form of conclusion and recommendations at the end of the manuscript.

Key Words: Geotechnical, granites, limestones, Peshawar Basin,

D/244. Din, K.S., Shami, M.D. & Dilawari, A.H., 1967. A study of Pakistani micas. Pakistan Journal of Scientific and Industrial Research 19, 146-156.

Key Words: Minerals, mica.

D/245. Din, N., 1997. Petrography, geochemistry and provenance of Kuldana Formation, Kohat basin, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 85-89.

The Kohat Basin constitute the westernmost part of the Himalayan foreland basin. It is bounded to the north by Main Boundary Thrust and to the south by Surghar Range Thrust. The Kalabagh Fault and Kurram Fault forms the eastern and western boundaries of the basin respectively. Stratigraphically the Kohat basin consists predominantly of Eocene and younger rocks. The Kuldana Formation is the part of Eocene strata and well-exposed in the whole Kohat basin. It generally consists of about 95% uniform red shale and 5% channel sandstone. The formation is continental and fluvial facies, and has been interpreted as a deposit of poorly developed system of small streams by Wells (1983).

A section of Kuldana Formation, near Bahadurkhel village in central Kohat basin, was measured and sampled. The section is 110 meters thick and consists of red clays with subordinate sandstone and granulestone. Sandstones are brownish red to red on fresh surface while dark red on weathered surface. Sandstones are fine to coarse grained, thin to medium bedded and calcareous. In sandstone various sedimentary structures, like cross-beddings, sole marks, graded beddings are present. The formation is devoid of any mega-fossil. The basal contact of the formation with Jatta Gypsum is mostly covered by recent debris while upper contact with Kohat Formation is conformable. The samples from the sandstone beds of the Kuldana Formation was studied in detail.

PETROGRAPHY: The petrography of sandstones of Kuldana Formation reveals that they are immature both mineralogically and texturally. The quartz and lithics are the dominant mineral along with subordinate feldspar. Quartz grains are mainly monocrystalline, however, polycrystalline variety is also present. Quartz grain are generally devoid of inclusions and show non-undulatory extinction. The detrital lithics consists of sedimentary and

volcanic lithics while metamorphic lithics are virtually absent. Sedimentary lithics constitute 80-85 percents of the total lithic fraction and include fragments of limestone, granules, shale and fossil. Volcanic lithics are mainly volcanic glass and altered rock fragments. The feldspar content of Kuldana sandstone is very low. Hematite, limonite and siderite are dominant opaque heavy mineral present. Calcite is the major cementing material. The texture of sandstones is typical of litharenite. The grains show point and concavo-convex contacts. The sandstones are poorly sorted. Grains are mostly subrounded to subangular.

Modal composition of ten sandstone samples of Kuldana Formation was determined by point-counting. The point-counting was done according to Ghazzi-Dickinson point-counting method (Ingersoll et al., 1984) to determine the proportion of monocrystalline and polycrystalline quartz types (Q), feldspars (F) and lithics (L). The modal composition of the sandstones is given in Table I. QFL diagram after Folk (1968; Fig. 1) shows that sandstones fall in litharenite category.

GEOCHEMISTRY: The geochemical analysis of sandstone of the Kuldana Formation for major elements was done by XRF (Table 2). The $\text{SiO}_2/\text{Al}_2\text{O}_3$ and $\text{Na}_2\text{O}/\text{K}_2\text{O}$ ratios plot (after Pettijohn et al. 1985, Fig. 2) shows that sandstones fall in "Sublitharenite" field. This difference in sandstone classification from the petrographic classification is probably due to slightly high values of Al_2O_3 contributed by clay. The chemical analysis shows that the variation in the proportion of major oxides across the sequence are appropriate to those of modal analysis. The higher content of quartz and carbonates (lithics) with small amount of feldspar in modal composition are compatible to higher quantity of SiO_2 and CaO , and lesser Al_2O_3 , Fe_2O_3 and Na_2O in chemical composition.

PROVENANCE: The textural and mineralogical immaturity of sandstones suggests a derivation of constituent materials under the conditions of greater mechanical disintegration and comparatively little transportation. The lack of feldspars and metamorphic lithics, and abundance of sedimentary and volcanic rock fragments imply the absence of any large area of eroding metamorphic and intrusive rocks. The presence of volcanic glass and rock fragments, and properties of quartz grains suggests a possible volcanic source. The sedimentary rock fragments that can be identified easily with the rocks of the Kohat basin section such as fragments of granules, limestone, fossil, and soft pelitic rocks, demonstrate that some materials were being supplied by local source area within the basin. In short, the petrographic studies suggests a volcano-sedimentary provenance of the Kuldana Formation.

The point-counting data was plotted on QFL provenance discrimination diagram after Dickinson (1985, Fig. 3). The data plots in the recycled orogen field of the diagram. It means that constituent material of sandstones have been derived from one of the following setting: Subduction complex; Collision orogen; Foreland uplifts (Dickinson, 1985). The high lithics percentage, high quartz ratio to feldspar, intermediate quartz content and low L_{vi} ratio indicate a collision orogen provenance (Dickinson, 1985). Thus, the modal composition of the Kuldana Formation indicates that constituent materials were derived from collision tectonic setting. The major element geochemical data when plotted on the provenance discrimination diagram after Bhatia (1983, Fig. 4) also indicate a similar tectonic regime. The paleocurrent analysis data of Kuldana Formation in whole Kohat basin reported by Wells (1983) demonstrates that depositing streams flowed into the basin from west and north. The flow from the edges of the former continental shelf of Indian plate suggests that orogeny on the continental slope had reversed the paleoslope. All these evidences from the petrography, modal composition, geochemistry and paleocurrent analysis suggests that detritus of Kuldana Formation has been derived from the collisional orogenic setting. It means that by the time of deposition of Kuldana Formation the India had collided against Eurasia or at least with Afghan microplate.

Key Words: Petrography, geochemistry, provenance, Kuldana Formation, Kohat basin.

D/246. Din, N., Abbasi, I.A. & Khan, M.A., 1998. Provenance of early-middle Eocene fluvial Kuldana Formation in Kohat Basin, northern Pakistan. In: Ghaznavi, M.I., Raza, S.M. & Hasan, M.T. (eds.), Siwaliks of south Asia. Geological Survey of Pakistan, Islamabad, 93-97.

Key Words: Provenance, Kuldana Formation, Eocene, Kohat basin.

D/247. Din, S.M.U., 1990-92. Geological mapping of Nauseri-Muzaffarabad-Garhi Habibullah area and evaluation of landslide hazards on western limb of Hazara-Kashmir Syntaxis. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 52p.

A large scale (1:15,000) geological map of Nauseri-Muzaffarabad-Garhi Habibullah area was prepared and all the rocks type in the area from Pre-Cambrian to Recent were thoroughly studied and investigated. The northwestern part of Muzaffarabad and western limb of Hazara-Kashmir syntaxis is the area of high landslide hazards. Steep slopes

silty, sandy and clayey soils, heavy rainfalls, water seepages and under cutting of the river all contribute to the landsliding in the region. The instability of the area has been further increased by road widening and effect of Main Boundary Thrust (MBT), resulting in the form of major landslides such as, slumping, earthflows, rockfalls, sinkholes and combination of these. The active Lohar Gali landslide is investigated in detail because of its large size and proximity to roadways. Soil samples were collected to evaluate engineering properties of material involved in these failures. The investigated area is a limb of Hazara Kashmir Syntaxis of folded and faulted, low grade metamorphic rocks, which have been further deformed by the important Muzaffarabad fault and regionally significant Main Boundary Thrust (MBT).

Key Words: Mapping, landslide hazards, Hazara Kashmir syntaxis.

D/248. Di Pietro, J.A., 1990. Stratigraphy, structure, and metamorphism near Saidu Sharif, Lower Swat, Pakistan. Ph.D. thesis, Oregon State University, Corvallis, 182p.

Key Words: Metamorphism, stratigraphy, structure, Swat.

D/249. Di Petro, J.A., 1991. Metamorphic pressure-temperature conditions of Indian Plate rocks south of the Main Mantle Thrust, Lower Swat, Pakistan. *Tectonics* 10, 742-757.

The Lower Swat rock sequence, in northern Pakistan, is composed of greenschist and amphibolite facies Indian plate rocks that crop out in a dome directly south of the Main Mantle thrust zone and Kohistan arc terrane. The metamorphism is Eocene to Oligocene in age and records the collision of the Indian plate with the Kohistan arc. This paper presents mineral assemblage, mineral composition and garnet zoning data on the Lower Swat rock sequence in order to estimate the pressure-temperature conditions of metamorphism and to infer a possible pressure-temperature-time path. The stratigraphic sequence consists of Precambrian to Cambrian (?) Manglaur formation unconformably overlain by late Paleozoic to early Mesozoic Alpurai group. The Alpurai group is further subdivided into the Marghazar, Kashala, Saidu and Nikanai Ghar formations. The Manglaur formation, in the core of the dome, is at kyanite grade. Metamorphic grade decreases in the overlying Alpurai group where a garnet "isograd" is mapped in calcareous schist of the Kashala formation. Mineral composition geothermometers and geobarometers indicate final metamorphic equilibrium conditions of about 600°–700°C and 9–11 kbar in the Manglaur and Marghazar formations. These conditions are associated with a phase of static recrystallization which postdates the main phases of deformation. Correlation of the structural-tectonic history with the pressure-temperature estimates, and with the garnet zoning analysis, suggests that in the Eocene the Lower Swat rock sequence was subducted to a depth of 35 to 45 km beneath the MMT suture melange. Subduction was followed immediately by exhumation. The initiation of exhumation is believed to have been triggered by a change from subduction to strike slip motion in the MMT, thereby allowing the relatively buoyant Lower Swat crust to rise. The entire metamorphic-deformational cycle lasted from 7 to 16 m.y., ending in the late Eocene about 38 Ma when the rocks cooled through the argon blocking temperature in hornblende ($\approx 550^\circ\text{C}$).

Key Words: Metamorphism, MMT, Swat.

D/250. Di Pietro, J.A. & Ahmad, I., 1995. Tectonic setting of the Ahingaro serpentinite zone within the Kohistan arc complex, Swat, Pakistan. *Geological Bulletin, University of Peshawar* 28, 27-29.

In this report we discuss the tectonic significance of a large serpentinite zone that is present within the Kohistan arc complex approximately 10 km north of the Indus suture zone. We have named this the Ahingaro serpentinite zone for excellent exposures at Ahingaro Banda Kandao located along the road between Tutan Banda and Kitiarai. The serpentinite zone was first reported by Rehman & Zeb (1970) who suggested that it was tectonically emplaced within the Kohistan arc complex.

Key Words: Tectonics, ultramafics, serpentinite, Indus suture, Kohistan arc, Swat.

D/251. Di Pietro, J.A., Ahmad, I. & Hussain, A., 1997a. Field evidence on the emplacement of the Dargai mafic/ultramafic Complex, Malakand area, Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 25-26.

The Dargai mafic/ultramafic complex is widely regarded as a klippe of Indus Suture Zone rock obducted onto the Indian plate in the Late Cretaceous or Early Cenozoic during or prior to continent-continent collision (Hussain and others, 1984, Lawrence and others, 1989). An alternative interpretation consistent with recent field mapping suggests that the Dargai mafic/ultramafic complex is not a klippe but is an imbricate slice sandwiched within Indian plate rock. This interpretation more adequately explains the contrasting stratigraphic sequences in Swat and in Malakand (Figure 1). The stratigraphy in Swat consists of Cambrian-Ordovician Swat augen/flaser orthogneiss unconformably overlain by Alpurai group which consist of Carboniferous-Permian Marghazar psammitic schist and amphibolite overlain by Early Mesozoic Kashala schistose marble and Saidu graphitic phyllite. Amphibolite and intrusive rock of any kind are virtually absent in the Kashala and Saidu Formations. The stratigraphy in Malakand consists of Precambrian Pinjkora complex unconformably overlain by Paleozoic (?) Mekhband Formation (both are new names). The Mekhband Formation consists of Kashala-like marble interlayered with amphibolite and intruded by Chakdarra orthogneiss. The abundance of both amphibolite and Chakdarra orthogneiss prevents a direct correlation with the Kashala Formation and suggests instead that the Mekhband is older than both the Kashala and Saidu Formations. Below the Mekhband Formation the Pinjkora complex consists of undifferentiated schist, marble, orthogneiss, and intrusive rock in which Swat orthogneiss is virtually absent. In the southeast part of the area the Mekhband Formation structurally overlies presumably younger Saidu Formation along a contact that is sharp but not intensely sheared relative to the surrounding rock. The contact is interpreted as a pre or syn-metamorphic fault that separates Swat stratigraphy below from allochthonous Malakand stratigraphy above. The Dargai mafic/ultramafic complex is an imbricate slice located between these two stratigraphic sections. In Figure 1, the Main Mantle Thrust (MMT) is shown as the series of faults that lie at separate amphibolite of the Kohistan arc complex from Indian plate rock and Indus melange. These faults show brittle deformation (post-Early Oligocene) with possible right-lateral oblique motion particularly in the Talash-Katgalai area where the Indus melange is cut out. The Ahingaro serpentinite zone represents a brittle deformation zone within Kohistan arc amphibolite that contains slices of serpentinite.

Key Words: Ultramafic rocks, Dargai complex, Malakand, Indian plate.

D/252. Di Petro, J.A., Ahmad, I., Hussain, A. & Isachsen, C.E., 1998. Tectonics of the Indus suture zone in Northwest Pakistan. *Geological Bulletin, University of Peshawar* 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop), 53-55.

The Indus suture zone in Northwest Pakistan is composed of three internally imbricated melange slices (Fig. 1). All three slices contain greenstone, serpentinite, talc-schist, and phyllitic schist. The "Swat" melange is characterized by blueschist; the "Dargai" melange by ultramafic rock, and the "Nawagai" melange by marble. The basal fault of each slice is the Kishora, Dargai, and Nawagai fault respectively. The Swat melange extends from the Indus syntaxis westward to Malakand where it is truncated by the Malakand slice which is an allochthonous block of metamorphosed Indian plate rock. Farther west, the Malakand slice is truncated by the Dargai melange which, in turn, is truncated by the Nawagai melange. All four of these fault slices overlie a coherent stratigraphy of metamorphosed Indian plate rock that extends southward to the Khairabad fault. The Main Mantle thrust (MMT) is the boundary between Indus melange and the Indian plate. It is therefore equivalent to the Kishora, Dargai, and Nawagai faults where these faults overlie the Indian plate and is equivalent to the Main Boundary zone (MBZ) of Beck and others (1996). The large-scale fold sequence on the Indian plate is syn-metamorphic, west-vergent, overturned folds followed by late-metamorphic, N-S-trending, open folds. This fold sequence implies that the Indian plate was affected by E-W compression throughout metamorphism and not N-S compression as is widely assumed. The Malakand, Kishora, Dargai, and Nawagai faults are syn-metamorphic faults that pre-date the metamorphic peak in the underlying Indian plate. The Swat melange appears to be the first of the slices to be emplaced. The existence of syn-metamorphic, west-vergent folds on the Indian plate suggests that emplacement may have been from the east or Northeast. Thus, the Swat melange, and the underlying Indian plate, may have been affected by the same west-southwest-vergent deformation that is preserved east of the Hazara syntaxis. The stacking sequence of the other slices suggests that the Malakand slice, the Dargai melange, and the Nawagai melange were emplaced from the west or northwest following emplacement of the Swat melange. Metamorphism on the Indian plate may have begun as early as 88 Ma based on a concordant U-Pb zircon age from Precambrian gneiss in the Indus syntaxis. This implies that metamorphism was a long-lived event that began with Late Cretaceous ophiolite abduction. Rather than initiate metamorphism, the India-Asia collision resulted in exhumation and cooling of the metamorphic pile between about 67 and 31 Ma. The Kohistan fault is a late- to post-metamorphic fault that cuts across the structural and

metamorphic fabric of the melange slices and the Indian plate. The Kohistan fault completely cuts out melange in areas east and north of the Indus syntaxis and in the area north of the Malakand slice. Final emplacement of the Kohistan is along the Kohistan fault probably occurred in the Oligocene. This emplacement, therefore, has no direct connection to the much older metamorphism that affected the Indian plate and gives no direct information to the timing of initial contact between India and Asia. West of Saidu, the Kohistan fault is a right-lateral strike-slip fault suggesting emplacement of the Kohistan arc from the west or Northwest. Following the emplacement of Kohistan, foreland structures including the Khairabad fault and the MBT transported the metamorphosed Indian plate, the Kohistan arc, and the three melange slices southward as a single block. In Afghanistan, the Kunar fault appears to truncate both the Kohistan arc and the Indus (Nawagai) melange. Indus Melange reappears south of the MBT but intervening faults suggest several 100 kilometres of displacement separating this melange from the three melange slices in the north.

Key Words: Tectonics, structure, Indus Suture.

D/253. Di Pietro, J.A., Baig, M.S., Pogue, K.R., Hussain, A. & Ahmad, I., 1995. Preliminary geologic map of the Indus syntaxis, Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

We present a preliminary geologic map of the Indus Syntaxis (Figure 1) based on 3-1/2 months field mapping by DiPietro and one month by Pogue during the Fall of 1994, unpublished mapping by the Geological Survey of Pakistan under the direction of Hussain, and previous work by the authors (Baig and others 1989, Baig 1990, DiPietro 1990, DiPietro and others 1993; Ahmad 1991, Pogue and others 1992). This research will continue, and the map revised, expanded, and completed during the next three years.

The main observations thus far are: 1) there is no major disruption of stratigraphy west of the Puran fault zone. 2) Stratigraphy is disrupted east of the Puran fault zone by post-metamorphic northerly trending faults. 3) The amount of recent uplift is greatest near the Indus River and decreases toward the west.

A large north to northwest plunging syncline dominates the area west of the Puran fault. This syncline deforms foliation and correlates with the F3 fold phase of DiPietro and Lawrence (1991). Stratigraphy differs slightly on the east and west limbs of the syncline. On the west side, the stratigraphy consists of Swat gneiss overlain by Manglaur formation (these two units are exposed west of the area shown in Figure 1) which, in turn, is overlain by a second layer of Swat gneiss. The Marghazar formation unconformably overlies the Swat gneiss and is followed by the Kashala and Saidu formations. The Kashala formation is unusually thin in the area north of Dosara (Figure 2). On the east limb of the syncline a sequence of interlayered schist, gneiss, amphibolite, and marble crop out along the west side of the Puran fault zone and form the base of the stratigraphic section. These rocks are similar to rock units in the Tanawal and Salkhala formations as described by Calkins and others (1975) along strike to the south. These rocks are intruded by an overlying layer of Swat gneiss except near Derai where the contact is a brittle fault. This layer of Swat gneiss correlates with the lower layer of Swat gneiss that is exposed on the west limb of the syncline. The Swat gneiss, in turn, is overlain by the Manglaur formation. A second layer of Swat gneiss is absent on the east limb. Overlying the Manglaur formation is a new formation named the Duma Formation. Near the middle of the area, the Duma Formation consists of an upper and lower marble member and a middle amphibolite-rich member. The marble is typically white, grey, or banded in appearance. Much of the marble is pure although phlogopite-rich marbles are common and tremolite or other calc-silicate minerals are locally abundant. Some of the marble is similar in appearance to marble in the overlying Kashala formation, however, marble in the Duma formation is interlayered with amphibolite, minor quartzite and biotite schist. These lithologies are not present in the Kashala formation within the confines of Figure 1. Where the lower contact has been observed, phlogopite-rich marble is consistently interlayered with, or gradational into, biotite schist of the Manglaur formation. Nowhere does the contact appear to be an unconformity. The upper contact is placed where white marble, banded marble, or phlogopite marble is in contact with garnetiferous marble typical of the Kashala Formation. The contact is interlayered or gradational and is consistently near the stratigraphically highest appearance of amphibolite within the Duma formation. The Duma formation can be traced southward around the nose of the syncline to the vicinity of Budal where white marble of the upper marble member pinches out or changes facies with typical dark grey marble of the Kashala formation such that the middle amphibolite member directly underlies the Kashala formation. In addition to amphibolite, the middle amphibolite member contains biotite schist and minor quartzite and marble. Lithologically it is similar to the Marghazar formation. The Marghazar formation and the middle amphibolite member are at the same stratigraphic position, therefore, they are probably the same age (Late Paleozoic). This leaves the age of the lower marble member unresolved. The middle amphibolite member thins and pinches out

toward the north where the Duma formation consists of marble with abundant thin interlayers of amphibolite. Excellent exposures of the Duma formation can be found south of Tangora and east of Alpurai. All of the rock units described above were metamorphosed at least to garnet-grade during Himalayan deformation.

The stratigraphy described above can be followed westward for at least 45 km without crossing a major fault zone (DiPietro and others, 1993). However, eastward, toward the Indus River, the stratigraphy becomes highly disrupted across a series of brittle, post-metamorphic fault zones. These include the Puran, Chakesar, Besham, and Thakot fault zones (Baig, 1990). All of the rock units within these fault zones are Precambrian in age, however, Paleozoic and/or Tertiary granitic rock intrudes the sequence particularly between the Puran and Chakesar fault zones. The faults cut across stratigraphy and show a complicated history that includes a strong component of strike slip displacement. The four major faults converge into a narrow imbricate zone in the vicinity of Kamach and Garhi. From west to east, these faults bring up progressively deeper-seated rock units that culminate with a thick section of Archean and Proterozoic basement gneisses of the Besham group between the Thakot and Besham faults. West of the Besham fault a basement-cover angular unconformity separates graphitic schists and marbles of the Karora group from the Besham group. This unconformity is probably the clearest example within the entire Himalaya of a depositional contact between true Indian shield basement rock and overlying metasedimentary rock. The stratigraphy is complicated between the Puran and Chakesar faults, however, a depositional contact between the undifferentiated Tanawal/Salkhala unit and the Karora group is exposed west of Chakesar. Thus, although disturbed by faults, it may be possible to piece together a complete stratigraphic section from Precambrian basement rock (Besham group) to the Mesozoic cover. However, the stratigraphy is further complicated by the presence of gneisses within the undifferentiated Tanawal/Salkhala sequence. In some areas, the contact between gneiss and schist appears depositional and is consistently marked by a thin sequence of marble and amphibolite. In other areas, the contact between schist and gneiss is knife sharp. One possibility is that these contacts represent pre or syn-metamorphic faults that were later reactivated and/or cut by the younger brittle faults.

The Karora and Besham groups are unique in that they do not show the strong Himalayan-age amphibolite facies metamorphism that affected all of the surrounding rock units (Treloar and others 1989, Baig 1990). The eastern limit of rock not affected by strong Himalayan-age metamorphism is sharply defined by the Thakot fault. The western limit, however, is not well defined. Rocks between the Puran and Chakesar fault zones appear to have been involved in Himalayan-age amphibolite facies metamorphism, therefore, the Chakesar fault zone is tentatively suggested as the western limit of rock not affected by this metamorphism.

The Indus syntaxis region is seismically active. Armbruster and others (1978) defined the Indus-Kohistan seismic zone as extending in a northwest direction through the Indus syntaxis at Besham as well as a second smaller seismically active area in the southern part of the Indus syntaxis surrounding Tarbela Lake. Baig (1990) identified uplifted terraces and deformed Holocene sediments near Besham and Yeats and Hussain (1989) identified late Quaternary deformation in the Tarbela Lake region. In addition, there is a clear increase in relative uplift as the syntaxis is approached from the west. The average height of stream terraces and mountain tops, for example, increases toward the Indus syntaxis. Near Budal well preserved stream terraces are 100 m above present-day stream level and, at one location, stream deposits are tilted 340° from the horizontal and are offset by about one meter along a N65E-trending fault. This fault may be part of a conjugate fracture/fault system that includes additional minor brittle faults trending N65E and N65W. It may be significant that the N65W faults are parallel with the trend of the Indus-Kohistan seismic zone.

A working hypothesis suggests that the Indus syntaxis is a strike-slip imbricate zone that formed as a tear fault associated with thrust faulting farther south in the foreland. The brittle faults may have reactivated old fracture and/or fault zones in the Precambrian basement and cut up through the overlying rock. The Besham gneiss may be a sliver of uplifted basement rock caught in the imbricate zone. The older fracture/fault zones may have formed during Late Paleozoic rifting and/or during earlier Precambrian deformation. Active uplift suggests that the Indus syntaxis is an incipient microcosm of Nanga Parbat.

Key Words: Stratigraphy, structural geology, deformation, Indus Syntaxis, Indian plate.

D/254. Di Pietro, J.A., Hussain, A., Ahmad, I. & Khan, M.A., 1999. The character of the Main Mantle Thrust in Pakistan. Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 32-33.

The Main Mantle Thrust (MMT) represents The tectonic boundary between the metamorphic shield and platform rock of the Indian plate hinterland, and dominantly mafic and ultramafic of the Kohistan-Ladakh arc complex in Pakistan. In some area, this boundary is a sharp planar fault with development of mylonite; in other areas, it is a

brittle-ductile imbricate zone; in still other areas, it contains large, discontinuous, slices of internally sheared and deformed ophiolitic melange. The major through-going fault is the Kohistan Fault, which marks the southern boundary of the Kohistan arc from the Afghan border eastward to the Babusar area (Figure 1). The Kohistan Fault is dominantly a right-lateral strike-slip Fault from the Afghan border eastward to Saidu. From Saidu to Babusar, it is a thrust fault with a strong, oblique, right-lateral component. Fault zone fabrics are dominantly brittle and cataclastic, suggesting that the Kohistan Fault is a late to post-metamorphic fault, active in the Oligocene to Early Miocene. East of Babusar, the Kohistan Fault merges with and is reactivated by, the active Raikot Fault, which marks the eastern boundary of the Kohistan arc along the western flank of the Nanga Parbat-Haramosh Massif. The Raikot Fault has been active since at least the Miocene with a strong component of right-lateral strike-slip displacement. The Raikot Fault appears to die out at the NW margin of the massif and it may be the Kohistan Fault that is folded around the north flank of the massif to continue southward as the MMT boundary between the Indian plate and the Ladakh arc along the eastern flank of the massif. In these areas, MMT is marked by a ductile mylonite zone that was active presumably in the Oligocene and Early Miocene, and which again shows a strong component of right-lateral displacement. This contact was subsequently folded, rotated to the vertical, and locally reactivated by brittle shears during exhumation of the Nanga Parbat-Haramosh Massif. Thus, along its entire trace, the Kohistan-Ladakh arc appears to have been displaced in a ESE-direction relative to the Indian plate in the Oligocene to Early Miocene.

From the Naran area eastward, the MMT is a narrow fault zone represented by the Kohistan-Raikot fault system and its continuation on the east side of the Nanga Parbat-Haramosh massif. In these areas ophiolite fragments are sparse. West of Naran, large discontinuous fault slices of ophiolitic melange appear south of the Kohistan Fault and form a separate terrane between the Kohistan arc and the Indian plate. The melange slices have traditionally been considered to be part of an MMT zone equivalent with the Indus Suture Zone. From east to west, the slices are the Shergarh, Kishora, Dargai, and Nawagai melange units (Figure 1). Also present south of the Kohistan Fault, and partly surrounded by melange, is a fault-bound slice of Indian plate rock referred to as the Malakand slice. All five slices are truncated by Kohistan Fault. Contacts between the fault slices and the underlying Indian plate are not intensely sheared relative to the surrounding rock and are folded by late-metamorphic, N-S trending folds that do not deform the Kohistan Fault. This suggests syn-metamorphic emplacement of all five slices. The age of metamorphism indicates that all of the fault slices were emplaced before 50-40 Ma. The maximum age of emplacement is unconstrained and could have occurred as early as the Late Cretaceous. Based on field relationships and stretching lineation data, we suggest that the Shergarh, Kishora, and Dargai slices correlate and that they were emplaced in a southwestward direction. The Nawagai and the Malakand slices are tentatively interpreted to have been emplaced in an E or SE-direction, implying that rotation from SW to ESE-directed transport occurred during metamorphism in western Pakistan, and well before final ESE emplacement of the Kohistan arc in the Oligocene to Early Miocene.

The Kohistan-Raikot fault system is the only through-going structure along the MMT zone. It marks the entire southern and eastern boundaries of the Kohistan arc complex and it may be the Kohistan fault that continues around to form the MMT along northern and eastern flanks of the Nanga Parbat-Haramosh Massif. The Kohistan Fault includes the best known location of the MMT at Jijal and it would seem logical to refer solely to this fault as the MMT. Restricting the definition of the MMT to the Kohistan-Raikot fault system would, however, exclude the large slices of ophiolitic melange which are part of the original definition and which are consistently referred to in the literature as part of the MMT. The Indus Melange, on the other hand, is discontinuous below the Kohistan Fault therefore, no single through-going fault could be considered to be the MMT.

Consistent with the previous usage, we suggest that the melange slices such that the MMT represents the series of faults of different age and tectonic history that collectively mark the northern edge of the Indian plate in Pakistan. Where melange slices are present, the MMT fault line would be placed south of the melange slices, and the northern boundary of the MMT (Indus Suture) zone would be marked by the Kohistan Fault. Where melange slices are absent, the MMT fault line would be represented solely by the Kohistan-Raikot fault system and its continuation along the east side of the Nanga Parbat-Haramosh Massif. This definition follows the original intent of the MMT and is consistent with how the term is used in the literature. The only difference between this definition and the original definition is that the history of the MMT is longer (extending to the active Raikot Fault) and more complicated.

Key Words: Tectonics, structural geology, Indus suture, Kohistan island arc, Indian plate.

D/255. Di Pietro, J.A., Hussain, A., Ahmad, I. & Khan, M.A., 2000. The Main Mantle Thrust in Pakistan: its character and extent. In: Khan, M. A., Treloar, P.J., Searle, M.P. & Jan, M.Q.

(Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 375-393.

The Main Mantel Thrust (MMT) represents the tectonic boundary between metamorphic shield and platform rock of the Indian plate hinterland, and dominantly mafic and ultramafic rock of the Kohistan-Ladakh arc complex in Pakistan. In some areas, this boundary is a sharp planar fault with development of mylonite; in other areas, it is a brittle-ductile imbricate zone; in still other areas, it contains large, discontinuous, slices of internally sheared and deformed ophiolitic melange. The character of the MMT along its entire trace discussed and it is concluded that there is no single continuous fault, which marks the contact between the Indian plate and the Kohistan-Ladakh arc. On this basis, we propose a revised definition for the MMT that is consistent with both the original definition and with the usage of the term in literature. We suggest that the MMT fault contact be defined as the series of faults, of different age and tectonic history that collectively define the northern margin of the Indian plate in Pakistan. On this basis, faults that define MMT vary in age from Quaternary to possibly as old as Late Cretaceous. Discontinuous lenses of ophiolitic melange that overlie the MMT fault contact, and which intervene between the Indian plate and the Kohistan-Ladakh arc, are considered to be part of an MMT zone that is equivalent with the Indus Suture Zone.

Key Words: Tectonics, structural geology, Indus suture, Kohistan island arc, Indian plate.

D/256. Di Pietro, J.A. & Isachsen, C.E., 1997. An Early Proterozoic age for Precambrian rock units in the Indus Syntaxis, NW Himalaya, Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 137-138.

U/Pb zircon ages have been obtained from two intrusive rock complexes, the Kotla and Black Mountain complexes, that crop out in the Indus syntaxis region of the metamorphic hinterland of the Indian Plate (DiPietro and others, 1996). The Indus syntaxis is located along the Indus River generally between the village of Besham in the north and Tarbela Lake in the south. The Kotla complex occurs as sill-like bodies within and near the top of a Precambrian metasedimentary rock sequence that includes the Kotla complex, and the rock selected for zircon dating, is a fine-grained, muscovite-biotite-quartz-feldspar orthogneiss that typically contains small (<0.5 cm) feldspar augen. This rock, which is also found in the Besham intrusive complex, is associated with mafic dikes and sill, leucogneiss, migmatite, and pegmatite. Zircons from the Kotla sample are predominantly small (<100 microns), clear, and equant prisms that yield a preliminary U-Pb age of 1839 ± 9 Ma, which is interpreted as an intrusive age. A fraction of less common larger grains (100 to 200 microns) is discordant and gives a slightly older Pb-Pb age of 1881 Ma indicating the presence of an older inherited component. The age of Kotla orthogneiss corresponds with a U/Pb zircon age of 1852 ± 14 Ma from the Iskere gneiss in the Nanga Parbat region (Zeitler and others, 1989) and with $40\text{Ar}/39\text{Ar}$ and K/Ar ages of between 2160 and 1862 Ma on hornblende from mafic dikes in the Besham area (Treloar and others, 1989, Treloar and Rex, 1990, Baig and others, 1989, Baig, 1990). The argon ages from the Besham area were originally interpreted as metamorphic ages but were reinterpreted as intrusive ages by DiPietro and others (submitted).

The Black Mountain complex occurs along the crest of the Black Mountains, which border the eastern side of the Indus River, where it is completely surrounded and intruded by Late Cambrian Mansehra augen gneiss but where it also structurally and topographically overlies the Karora and Gandaf formations. The principal rock in the Black Mountain complex, and the one selected for zircon dating, is a dark, equigranular, fine-grained, biotite-quartz-feldspar orthogneiss. Other subordinate rock types include biotite and/or garnet-bearing gneiss, migmatite, pegmatite, and mafic rock. Zircons from the Black Mountain sample are also predominantly small equant prisms, but contain a greater proportion of larger grains (200 to >450 microns). Preliminary U-Pb data for fractions of large zircons from this sample appear to have experienced severe Pb-loss with a crudely defined lower intercept age of 739 ± 150 Ma. Further abrasion studies will be conducted to better delineate the upper intercept age for this orthogneiss, which is presently unconstrained by the data but consistent with an Early Proterozoic protolith age. Pb-loss may have been contemporaneous with intrusion of the Mansehra augen gneiss which has a whole rock Rb/Sr age of 516 ± 16 Ma (Le Fort and others, 1980).

The ages indicate that the Karora and Gandaf formations are Early Proterozoic or older and suggests further that probable correlative rock units, including the Dakhner Formation in the Attock-Cherat Range, the Manki Formation in the Attack-Cherat and Gandghar Ranges, and the Hazara and Salkhala formations in the Hazara-Kaghan-Kashmir region, are also Early Proterozoic or older and not Late Proterozoic as is widely assumed. The ages and correlations suggest that an early Proterozoic crust is widespread along the northern margin of the Indian Plate. An older

(Archean?) crustal component is exposed in the Besham area the Karora Formation unconformably overlies a sequence of granitic gneiss.

Key words: Chronology, U-Pb ages, Early Proterozoic, Indus syntaxis, Black Mountain, Tanawal, Mansehra.

D/257. Di Pietro, J.A. & Isachsen, C.E., 2001. U-Pb zircon ages from the Indian plate in the northwest Pakistan and their significance to Himalayan and pre-Himalayan geologic history. *Tectonics* 20(4), 510-525.

U-Pb zircon isotopic ages of seven rock samples are combined with field data to provide constraints on deposition, intrusion, and metamorphism in the northwestern part of the Indian plate (Pakistani) hinterland south of the Indus suture zone in Pakistan. The results suggest deformation, intrusion, and regional metamorphism at ca. 2174 Ma, an event that may correlate with granulite facies metamorphism in the Nanga Parbat area. This was followed by erosion and deposition prior to a second Proterozoic deformation at ca. 1850 Ma, which was associated with widespread intrusion and possibly with low-grade regional metamorphism. Metasedimentary and intrusive rocks of this age are present within the Lesser Himalaya of Nepal but are apparently absent in the High Himalayan crystalline slab north of the MCT. This intrusive/deformational event was followed by erosion and Late Proterozoic (?) deposition with development, in the Cambrian, of an epicontinental, shallow marine shelf. Intrusion in Late Cambrian-Middle Ordovician resulted only in minor uplift/erosion and development of a disconformity. Marine shelf conditions were reestablished in the Middle Paleozoic prior to a widespread intrusive event in the Carboniferous-Permian and normal faulting, erosion, and syndeformational deposition and volcanism in the Late Permian. Marine shelf conditions were reestablished in the Triassic prior to the Himalayan orogeny. Zircons with a concordant age of 89 Ma coupled with field and published isotopic age data suggest that Himalayan deformation and metamorphism in the Pakistani hinterland began between 90 and 75 Ma due to subduction of the Indian plate beneath Indus ophiolitic melange and reached peak amphibolite facies conditions between 70 and 48 Ma. This metamorphism precedes Eocene (54–50 Ma) collision of India with the Kohistan arc complex. Field data suggest that the presently exposed Pakistani hinterland from Afghanistan to Babusar was never significantly overthrust or buried by the Kohistan arc. Rather than initiating the metamorphism, the collision of Kohistan with India resulted in uplift, exhumation, and cooling of the metamorphic pile.

Key words: Chronology, isotopes, U-Pb ages, Precambrian, Early Proterozoic, Indus syntaxis, Black Mountain, Tanawal, Mansehra, Nanga Parbat.

D/258. Di Pietro, J.A. & Lawrence, R.D., 1991. Himalayan structure and metamorphism south of the Main Mantle Thrust, lower Swat, Pakistan. *Journal of Metamorphic Geology* 9(4), 481-495.

During the Eocene-Oligocene, the Indian plate collided with the Kohistan arc along the Main Mantle Thrust (MMT) zone. The structure of the Lower Swat rock sequence, on the Indian plate directly south of the MMT, is a dome with a basement of granitic gneiss and quartz-rich schist unconformably overlain by amphibolitic and calcareous schist. The earliest superposed small-scale folds (F1 & F2) represent a progressive F1/F2 deformation that is associated with a single set of WSW-vergent large-scale folds (termed F2). These folds are inferred to have developed during oblique, WSW-directed overthrusting of the MMT suture complex onto the Lower Swat rock sequence. Metamorphism began during F1/F2 as indicated by an S1 foliation that developed during biotite-grade metamorphism. S1 is preserved as a relict texture in porphyroblasts that grew during a subsequent interkinematic phase during garnet- and higher grade metamorphism. The dominant, regional foliation (S2) developed following the interkinematic phase. S2 is associated with transposition of S1 and rotation or dismemberment of porphyroblasts. Annealing recrystallization followed S2 and continued during F3 thereby destroying or masking possible pre-existing stretching fabrics. Superposed F3 folds are upright and open with N-S axial trends. They may correlate with early doming of the Lower Swat rock sequence and with strike-slip displacement in the northern part of the MMT zone, north of the Lower Swat area. F3 was followed by retrograde metamorphism and development of E-W-trending, S-vergent F4 folds. F4 may be associated with a final phase of southward directed thrusting and inactivity in the MMT zone. Correlation of published $^{40}\text{Ar}/^{39}\text{Ar}$ ages with the metamorphic fabrics suggests that F1/F2 and F3 occurred in the Eocene, and that F4 developed in the Oligocene. F4 is the earliest indication of southward verging structures on this part of the Indian plate.

Key words: Structure, Himalayan deformation, metamorphism, Indian plate, Swat.

D/259. Di Pietro, J.A., Pogue, K.R., Hussain, A. & Ahmad, I., 1996. Precambrian rock of the black mountains NW Himalaya, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 44-45.

The Black Mountains area is a previously unmapped area composed of metamorphic Indian Plate rocks located along the Indus River (Figure 1). Precambrian metasedimentary rocks were variably intruded and metamorphosed in the Precambrian prior to strong Paleogene metamorphic overprint. The rocks are exposed in the south-plunging Indus River anticline which is a late fold that deforms foliation. Earlier deformations are evident by the existence of transposed beds and rootless folds. The anticline is cut by high-angle, post-metamorphic faults oriented roughly parallel with axial trace of the fold. The largest of these faults is the Chakesar fault but stratigraphic relationships suggest only a few kilometers of offset. Numerous minor faults and sheared contacts also occur but these cannot be traced along strike. The field relationships do not support a sharp structural or metamorphic break between the Precambrian rocks and the overlying Paleozoic/Mesozoic sequence. From the base up, the Precambrian metasedimentary sequence is Karora graphitic schist and marble, unnamed Precambrian garnet schist and metasammite and Manglaur/Tanawal quartz mica schist and quartzite. On the west side of the anticline, the Manglaur Formation is unconformably (?) overlain by Paleozoic Duma marble and amphibolite, and Mesozoic Alpurai marble, garnet-calcite schist and graphitic schist. The unnamed unit is a transitional unit with elements of both the Karora Formation (graphitic schist) and the Tanawal Formation (quartz mica schist and quartzite). It is characterized by a distinctive garnet schist marker bed that can be followed from the vicinity of Thakot southward to the southern edge of Figure 1 and around the nose of the anticline to the vicinity of Martung. The presence of Kotla granitic gneiss, which intrudes the unnamed unit, suggests that the unnamed unit is older than the Tanawal Formation. The contact between the unnamed unit and the Karora Formation appears depositional. The contact between the unnamed unit and the Manglaur/Tanawal Formation is obscured by intrusion of the Swat/Mansehra gneiss. The contact between the unnamed unit and the Mansehra gneiss is sheared in the vicinity of Thakot but southward the contact becomes discordant with abundant cross-cutting relationships. The discordant relationship continues to the southern edge of Figure 1 where Tanawal-like quartzite emerges from below the Mansehra gneiss. These rocks are shown as part of the unnamed unit until additional fieldwork clarifies the relationship between the two units. The Besham complex is composed of undifferentiated orthogneiss of Precambrian and possibly Paleozoic age. West of Besham village, the Besham complex consists of fine-grained biotite gneiss that unconformably underlies the Karora Formation. Elsewhere, the dominant rocks are fine to coarse-grained, leucocratic, biotite-bearing granitic gneisses that are associated with pegmatite. These rocks intrude the Karora Formation whereas other rocks intrude the Karora Formation. North of Martung, a pegmatite/amphibolite sequence, that probably correlates with the Besham pegmatites, intrudes the unnamed unit. The Kotla biotite granitic gneiss (new name) is a sill-like body that intrudes within and near the top of the unnamed unit. The Black Mountain biotite granitic gneiss (new name) is an isolated body within the Mansehra gneiss structurally above the unnamed unit. The Cambrian-Ordovician Swat/Mansehra augen granitic gneiss intrudes the unnamed unit, the Manglaur and Tanawal Formation, the Kotla gneiss, and the Black Mountain gneiss. The structural evolution of the Black Mountain area may parallel the early evolution of Nanga Parbat.

Key words: Sedimentary rocks, metamorphic, Indian plate, Indus river, Swat.

D/260. Di Pietro, J.A., Pogue, K.R., Hussain, A. & Ahmad, I., 1999. Geologic map of the Indus syntaxis and surrounding area, northwest Himalaya, Pakistan. In: Macfarlane, A., Sorkhabi, R.B. & Quade, J., (eds.), Himalaya and Tibet: Mountain root to mountain tops. Geological Society of America, Special Papers 328, 159-178.

The stratigraphic, structure and metamorphism of the hinterland area of the Indian plate in northwestern Pakistan is described in relation to a geologic map. We conclude that this is one of the few areas in the Himalaya where amphibolite facies rock can be traced southward from the Indus-Tsangpo suture zone to low-grade fossiliferous rock without crossing a major fault. The absence of a major fault provides an opportunity to constrain the depositional ages of the metamorphic stratigraphy by direct correlation with fossiliferous rock in conjunction with isotopic dating of intrusive rock. The stratigraphy is divided into the following age groups, each bounded by an unconformity: Early Proterozoic, Late Proterozoic; early-middle Paleozoic, late Paleozoic-Triassic, and Mesozoic. Within this stratigraphy there is evidence for plutonism in the Early Proterozoic, Late Proterozoic, early Paleozoic, late

Paleozoic; and Cenozoic; deformation in the Early Proterozoic and late Paleozoic; and volcanism in amphibolite facies metamorphism in the Late Cretaceous-Cenozoic as result of the obduction of Indus melange onto the Indian plate along the Main Mantle Thrust and the ensuing collision, thrusting, and final emplacement of the Kohistan arc complex along the Kohistan fault.

The Main Mantle Thrust is a pre-metamorphic or syn-metamorphic fault that dates the time of obduction as pre-late Eocene and possibly as Late Cretaceous. Obduction along the Main Mantle Thrust is associated with west-southwest-vergent folds on the Indian plate. Exhumation and cooling of the Indian plate following peak metamorphism may have begun by the late Paleocene or early Eocene in the Indus syntaxis, and by the middle Eocene in the Loe Sar dome. Cooling and exhumation are associated with the development of large-scale, north-south-trending folds that fold the Main Mantle Thrust. The time of initial collision of Kohistan with the Indian plate is unconstrained in the field area, but brittle-ductile fabrics along the Kohistan fault indicate that final emplacement occurred during retrograde metamorphism, probably in the late Oligocene. Final emplacement of Kohistan is associated with the initial development of south-vergent folds on the Indian plate. Neogene and younger deformation is present in the Indus syntaxis area, in contrast to the Loe Sar dome area, where deformation largely ended in the early Miocene. There is no conclusive evidence for pre-Cenozoic amphibolite facies metamorphism in rock as old as Early Proterozoic. Compare Di Pietro et al., 1995.

Key words: Metamorphism, structure, stratigraphy, MMT, Indian plate, Swat, Himalaya.

D/261. Di Pietro, J.A., Pogue, K.R., Lawrence, R.D., Baig, M.S., Hussain, A. & Ahmad, I., 1992. Stratigraphy and dome structure, Lower Swat, Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 21.

The metamorphic sequence in Lower Swat is described and placed into the geologic framework of Pakistan. The stratigraphic sequence consists of Precambrian-Cambrian(?) Manglaur formation unconformably overlain by the Alpurai group which is subdivided into the Carboniferous or younger Marghazar formation, and the Triassic or younger Kashala, Saidu, and Nikanai Ghar formations. Type sections are indicated for each rock unit. The rocks crop out in a dome that is truncated on the north side by the Main Mantle suture melange (MMT). The major structures and associated metamorphism are Eocene-Oligocene in age. The earliest structures are west-verging and upright folds, both with ~north-south axial trends. Later east-west trending cross folds produced the dome structure. Geothermobarometry on rocks in the center of the dome suggest peak metamorphic conditions at ~600-700 °C and ~9- 11 kbar during development of the early folds. Metamorphism decreases southward to lower greenschist facies in the Peshawar Basin. Comparison with the stratigraphy in the Peshawar Basin indicates that the Lower Swat area existed as a highland with active normal faulting during and perhaps before deposition of the Marghazar formation. The Marghazar formation appears to be a rift facies that correlates with the "agglomeratic slates" and Panjal Traps of western India. The Kashala and Nikanai Ghar formations represent a transition to a stable, shelf environment. These units may correlate, in part, with the Zaskar Super group of western India. The Saidu formation may represent drowning of the shelf as it was pulled down and overridden by the MMT. It may correlate with the Lamayuru Formation of western India. The Alpurai group thus records the entire history, from Late Paleozoic breakup of Gondwana, to development of a Mesozoic passive shelf, to drowning of the shelf during the Himalayan orogeny.

Key words: Metamorphism, structure, stratigraphy, MMT, Swat.

D/262. Di Petro, J.A., Pogue, K.R., Lawrence, R.D., Baig, M.S., Hussain, A. & Ahmad, I., 1993. Stratigraphy south of the Main Mantle Thrust, lower Swat, Pakistan. In: Treloar, P.J. & Searle, M.P. (eds.), Himalayan Tectonics. Geological Society London, Special Publications 74, 207-220.

The metamorphic sequence in Lower Swat is described and placed into the geological framework of Pakistan. The stratigraphic sequence consists of the Precambrian-Cambrian(?) Manglaur formation unconformably overlain by the Alpurai group which is subdivided into the Carboniferous or younger Marghazar formation, and the Triassic or younger Kashala, Saidu, and Nikanai Ghar formations. A third unit, the Jobra formation of unknown age, is present as discontinuous lenses unconformably below the Alpurai group. Type sections are indicated for each rock unit. Comparison with the stratigraphy in the Peshawar Basin indicates that the Lower Swat area existed as a highland with active normal faulting during and perhaps before deposition of the Marghazar formation. The Marghazar formation appears to be a rift facies that correlates with the Panjal Traps of western India. The Kashala and Nikanai

Ghar formations represent a transition to a stable shelf environment. These units may correlate, in part, with the Zaskar Supergroup of western India. The Saidu formation may represent drowning of the shelf as it was pulled down and overridden by the Main Mantle Thrust suture melange. It may correlate with the Lamayuru Formation of western India. The Alpurai group thus records a depositional history from Late Paleozoic breakup of Gondwana, to development of a passive Mesozoic shelf, to drowning of the shelf at the onset of Himalayan orogeny.

Key words: Metamorphism, structure, stratigraphy, MMT, Indian plate, Swat.

D/263. Dogar, A.M., 1985-87. Geological studies of Khanspur Dewal Area with special emphasis on mineralogy and petrology. M.Sc. Thesis, Punjab University, Lahore, 94p.

Key words: Mineralogy, sedimentary petrology, Khanspur, Abbottabad.

D/264. Dong Zhi-Bin, D., Ferrari, R.L., Francis, M.R., Mustil, G., Oswald, G.K.A. & Xiangsong, Z., 1984. Impulse radar ice-depth sounding on the Hispar glacier. In: Miller, K.J. (ed.), The International Karakoram Project, 2, 100-110. Cambridge University Press.

The work carried out by a radio-echo sounding team on the Hispar glacier is described. Results of impulse radar depth-soundings at eleven different sites are given. The measurements are discussed in relation to the effects of surface moraine and melt-water upon the echo signal.

Key words: Glaciology, Hispar, Hunza, Nagar, Karakoram.

D/265. Dougloss, R.C., 1970. Morphologic studies of Fusulinids from Lower Permian of West Pakistan. US Geological Survey Professional paper 643G.

A suite of samples from the Amb Formation in the Salt and Khisor Ranges of West Pakistan has yielded an abundance of fusulinids previously assigned to several species. There are many obvious differences between specimens and between samples in this suite. Traditional comparisons based on measurements at each volution support the idea that the visual differences are real; however, comparisons made at equal radii show great similarities between specimens and between samples. The differences are related to the size of the proloculus and are not considered sufficient evidence for specific discrimination; thus, these specimens are assigned to one species, *Monodiexadina kattaensis*. A new species, *Codonofusiella laxa*, occurs in one of the samples with the larger fusulinids and represents the earliest known occurrence of this genus.

Key words: Morphology, palaeontology, Permian, Khisor Range, Salt Range.

D/266. Douville, H., 1924. Le Cretace inferieur de Himalaya, Compte Rendu Societe geologique de France, 59-61.

For additional information, consult the following account.

Key words: Himalaya, Cretaceous.

D/267. Douville, H., 1926. Fossiles recueillis par Hayden dans le Kashmir en 1906 et les Pamirs en 1914; leur description. Geological Survey of India, Records, 58 (4), 349-357, plates 13, 14.

Douville restudies in greater detail the fossils of the Yasin valley collected in 1914 by Hayden. He recorded several Lower Cretaceous fossils. These included the corals, to which he added two genera *Thecosmilia* sp. and *Montastrea* sp.

Key words: Palaeontology, Kashmir, Pamir.

D/268. Drew, F., 1873. Alluvial and lacustrine deposits and glacial records of the Upper Indus Basin; part 1, Alluvial Deposits. Quaternary Journal of the Geological Society of London 29, 441-471.

The tract of country in which occur the deposits of which I propose to give a somewhat detailed though concise account, is that part of the Maharaja of Kashmir's territory which is drained by the Indus. The greater portion of this country has been visited by travellers whose attention has been drawn to the deposits in question, and who have recorded some observations upon them. While considerable light has been thrown by some of these observers, it has seemed to me well both to add my quota and to try to systematize the facts, so as to prevent the confusion likely to arise from mixing, in description, accumulations of various origin, though they may all be classed in one sense as alluvium, and to see what general conclusions can be drawn from all that we have learned. The writers who have told most about the alluvial and lacustrine deposits are Col. H. Strachey, Gen. Cunningham, Dr. Thompson, Major Godwin-Austen, and Dr. Stoliczka. Col. Strachey, whose paper on the Physical Geography of Western Tibet is a wonderful store of accurate and valuable information compressed into a small compass, has given in it a description of the alluvium of the neighbouring basin of the Sutlej, with some reference to the corresponding deposits of the Indus; his conclusions I shall discuss further on. Gen. Cunningham, in his book on Ladākh, has given some notices of lacustrine deposits and of the former extension of lakes, which bear on the subject

Key words: Alluvial deposits, lacustrine deposits, glacial record, Indus basin

D/269. Drew, F., 1874. The upper Indus River. *Geological Magazine*. (Decade II)/ 1(02), 94-94.

Whenever Colonel Greenwood writes on the subject of rain and river action, we are sure to learn a good deal. I am very glad that he has noticed the facts about the Upper Indus alluviums which I laid before the Geological Society, and has entered into the discussion of their causes. With much that he has written I heartily agree; and if on one point I still differ, it is with a mind open to be convinced if the causes I proposed to account for the present state of the alluvial deposits should seem after further argument either inadequate or unnecessary.

I grant the "hard gorge and soft valley" theory of Colonel Greenwood generally; in some instances where I have observed the alteration, a difference in the rocks can be seen to account for it; in others the reason is less clear. Still I am ready to believe that further knowledge of the character and position of the rocks would show that this theory is applicable to most cases. But I feel great difficulty in agreeing that the accumulation and subsequent denudation of thick alluvial deposits were due only to the variation in slope of the river bed. In the first place I cannot see how hundreds of feet of alluvial strata could be formed one upon another in a wide valley ending in a gorge, while the bed of the gorge was sinking from erosion. Secondly, we have the alluvial gravels, to the great thickness, in the gorges as well. This is evident that at the accumulating time, alluvium (of varying degrees of fitness very likely) was deposited though not in all places to the same relative height above its rock bottom, nor probably with one uniform gradient.

Key words: Upper Indus basin, Alluvium, Gorges.

D/270. Drew, F., 1875. The Jammu and Kashmir Territories. E. Stanford, London

This is a general account of the Jammu and Kashmir region, including parts of northern Pakistan. It covers geomorphology, geology, and glaciation.

Key words: Jammu, Kashmir, glaciation, sedimentary rocks, Himalaya, Karakorum

D/271. Dubertret, L., 1957. *Lexique stratigraphique international... Volume 3. Asie: sous la direction de L. Dubertret. Fascicule 8.* a) "India", Pakistan, Nepal, Bhutan. b) "Burma", Birmanie. c) "Ceylon", Ceylan. Publisher: Centre national de la recherche scientifique, Paris.

Key words: Stratigraphy, India, Pakistan.

D/272. Dunbar, C.O., 1940. Permian fusulinids from the Karakorum. *Records, Geological Survey of India*, LXXV, 1-5.

Key words: Paleontology, Permian, Karakoram.

D/273. Dunkle, D.H., Teichert, C. & Rahman, H., 1963. Stratigraphic research as applied to mineral resources exploitation and development in Pakistan. UN Conference on Application of Science and Technology for the Benefit of Less Developed Areas, Geneva 1963. Natural Resources 2, 173-182.

Key words: Stratigraphy, mineral resources, Pakistan.

D/274. Duroy, Y., 1986. Subsurface densities and lithospheric flexure of the Himalayan foreland Pakistan interpreted from gravity data. MS Thesis, Oregon State University, Corvallis, 74p.

Consult the following account for further details.

Key words: Foreland fold-and-thrust belt, structure, gravity, Kohistan island arc NW Himalaya.

D/275. Duroy, Y., Farah, A. & Lillie, R.J., 1989. Surface densities and lithospheric flexure of the Himalayan foreland in Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), Tectonics of the Western Himalayas. Geological Society of America, Special Papers 232, 217-236.

Gravity data along a north-south profile from Kohistan to the Punjab plain of Pakistan have been incorporated into recent interpretations of the gross structure of the foreland fold-and-thrust belt of the Himalaya. In northern Pakistan, large deviations from Airy Isostatic equilibrium are observed. An excess of mass characterizes the northern Kohistan arc, and a deficit of mass underlies a broad area extending from southern Kohistan to the Salt Range, while to the south a slight excess of mass seems to prevail in the region of the Sargodha high. This anomalous distribution of mass can be understood if the Indian elastic plate, which is assumed to overlie a buoyant "fluid," is flexed down under the weight of both the overthrust mountains and the sediments eroded off the mountains and deposited in the foredeep basin. In many respects the intracontinental subduction of India beneath the Himalaya is similar to island arc formation, including the seismically active Sargodha high, a basement ridge analogous to the flexural bulge encountered seaward of oceanic trenches. Analysis of Bouguer gravity anomalies along a profile extending from the Sargodha high to the Main Mantle Thrust (MMT) shows that most of the negative-northward gravity gradient can be attributed to crustal thickening. In the Sargodha high area, an additional contribution of about 25 mgal appears to be due to excess of mass at lower crustal or upper mantle levels. The Moho discontinuity is interpreted to bulge up beneath the Sargodha high, then gradually increase in dip from 1° to 3° beneath the Salt Range and Potwar plateau (approximately equal to the change in dip of the basement surface). The Moho is interpreted to change from upwardly convex to upwardly concave beneath southern Kohistan. Finally, north of the Main Mantle Thrust it appears to bend down again, but at a steeper angle of about 15° .

Shorter wavelength anomalies, superimposed on the regional Bouguer gradient, are modeled in terms of upper crustal density changes, including those due to: (1) offsets of the basement surface; (2) variable thickness of the Eocambrian evaporite sequence that forms the basal décollement; (3) thrusting and folding of relatively high-density, older parts of the stratigraphic section to higher structural levels, particularly in the Salt Range and northern Potwar plateau; and (4) thickening of the low-density Neogene molasse sequence into the axis of the Soan Syncline, a structural depression between the Salt Range and northern Potwar plateau. Subsurface densities of the overthrust wedge, as well as the definition of the shape of the top surface of the Indian plate interpreted from seismic reflection and drilling data, place bounds on the flexural rigidity of such a plate and the forces that deform it. In northern Pakistan, a steeper Bouguer gravity gradient suggests that the flexural rigidity of the elastic plate ($D = 4.0 [\pm 2.0] \times 10^{23} \text{ Nm}$) is a factor of 10 smaller than the current values interpreted for the central and eastern Himalaya. Moreover, the maximum flexural stresses are probably concentrated within the crust, which may account for the seismic activity of the Sargodha high and southern Kohistan. At the end of the Indian elastic plate (arbitrarily chosen at the MMT), a large positive vertical shear stress, $9.2 \times 10^{12} \text{ N/m} < S_0 < 1.6 \times 10^{13} \text{ N/m}$, is applied to account for the topographic load north of the MMT. In addition, to fit the gravity constraints it was necessary to apply a large negative bending moment, $-1.4 \times 10^{18} \text{ N} < M_0 < -0.85 \times 10^{18} \text{ N}$, at the end of the plate. The negative bending moment can be explained by the combined effect of the northward migration of the Indian plate and the southward differential compressional force generated by the crustal rocks stacked at mid-upper crustal levels beneath the northern Kohistan arc. In addition, buoyancy of the crustal rocks at deeper levels beneath the Kohistan arc may contribute to the negative bending moment. Consequently, in southern Kohistan the surface of the Indian plate is

concave up; compressional stresses in the upper part of the plate are probably the primary source of the Hazara seismic zone, where incipient reverse faulting seems to take place. In contrast, the pronounced upward convexity developed along the flexural bulge can account for (1) tensional stress in the upper part of the Indian plate, which is large enough to produce basement normal faults interpreted beneath the Salt Range and Sargodha high; and (2) compressional stress in the lower portion of the crust, which causes the excess of mass and seismicity beneath the Sargodha high.

Key words: Foreland fold and thrust belt, structure, gravity, NW Himalaya.

D/276. Durrani, K.P., 1992. Geology and petroleum potential of the Kohat-Bannu basin, NWFP, Pakistan. Geological Bulletin, University of Peshawar 25, 134-135.

The Kohat Plateau and Bannu depression, a part of the foreland fold and thrust belt of Pakistan, lies to the south of Himalaya and Karakorum mountains on the Indian Plate. The anticlinal structures of Marwat, Khisor, Surghar, and Bhattani Ranges, "the Trans-Indus Ranges", are the southernmost extension of the fold-and thrust-belt. Seismic study suggests that the Kohat-Bannu plateau has been overthrust to the south along a sole thrust fault, which has also been reported earlier. Many thrust faults, mostly verging to the south and southeast, cut the sedimentary strata, implying that the Kohat-Potwar plateau was thrust southward and south-eastward as a direct consequence of the crustal shortening that resulted from north-south (post-Paleocene) lateral compression.

A variety of reservoir rocks of carbonate and clastic origin are also present in area. Most of the hydrocarbons in the region have been found in Paleogene rocks but other rocks of Cambrian, Permian, Jurassic and Cretaceous age also show good reservoir qualities.

Key Words: Structure, petroleum potential, Kohat plateau, Bannu basin.

D/277. Durrani, K.P. & Ahmed, I., 1992. Evidence of salt-tectonics in the trans-Indus Salt ranges, NWFP, Pakistan. Geological Bulletin, University of Peshawar 25, 133-134.

The Kohat-Bannu basin is one of the most important zones in an active foreland fold and thrust-belt of Pakistan. It was originated by compressional tectonics at the northern margin of the Indian Plate. This basin is moving southward over a salt layer, which acts as a decollement surface between the Precambrian basement rocks and the Eocambrian-Neogene sediments of the Indian Plate. The Trans-Indus ranges (TIR) are the surface expression of the leading edge of a decollement thrust in which the crystalline basement is not involved. The decollement along the salt in the fold and thrust-belt of Pakistan is formed by the combining processes of sediment load and sliding as a result of north-south compression. Salt behaves like a viscous fluid under stress. When the horizontal compressive stresses exceed the overburden stress of sediment, movement along the salt occurs in the weak zone forming a decollement zone. Some of the salt moves upsection along the thrust faults as a detached salt wedge forming pinch and swell structures. Salt tongues also form in this process.

Key Words: Salt-tectonics, Trans-Indus Salt ranges.

D/278. Durrani, M.M., Muhammad, L. & Zada, N., 1998. Microfacies and environment of deposition of Chorgali Pass Khair-Murat Range, Punjab, Pakistan. M.Sc. Thesis, University of Peshawar, 8 p.

Key words: Microfacies, depositional environments, Khair Murat, Murree.

D/279. Durrani, N.A., 1983. Ruby mineralization and its relationship with late magmatic metasomatism of Darkut Group in Hunza valley. Geological Bulletin, Balochistan University, 1, 1-7.

Ruby mineralization in marbles and related rocks in Hunza has yielded good quality ruby and some other stones (spinel, green amphibole). This paper relates them to magmatic activity.

Key words: Metasomatism, mineralization, ruby, Hunza.

D/280. Dweeb, M.M., Ibrahim, H. & Yahya, 1976. Geology and the structure of the phosphate bearing rocks west of Kakul, Abbottabad. M.Sc. Thesis, University of Peshawar, 51 p.

Key words: Geology, structure, phosphate, Abbottabad.

D/281. Dyhrenfurth, G.O., 1939. Baltoro, B. Schwabe Verlag, Basel, 32-35.

Key words: Baltoro, glaciers, Karakoram.

E/1. Eames, F.E., 1950. The position of the Laki Limestone in the Eocene succession in West Pakistan. *Geological Magazine* 87(3), 214-216.

This paper does not strictly concerns the area of the present work, however, it is included as a compliment of a series of related papers by the author as given in the following.

It has previously been thought that in Sind the Meting Limestone Laki Limestone succession was equivalent to the Bolan Limestone, and that argillaceous beds, which are occasionally developed above the Laki Limestone and below the overlying Khirthar, represented the Ghazij Shales. Recent evidence indicates that these higher argillaceous beds are the representatives of the Shales with Alabaster of the Western Punjab, that in Sind the Ghazij Shales are cut out at the Laki/Ranikot unconformity, and that the Meting Limestone-Laki Limestone succession represents calcareous horizons higher up in the Laki series than the Bolan Limestone.

Key words: Stratigraphy, Laki Limestone, Eocene, Punjab, Sindh.

E/2. Eames, F.E., 1951a. A contribution to the study of the Eocene in Western Pakistan and Western India; Part A, The geology of standard sections in the western Punjab and in the Kohat District. *Quaternary Journal of the Geological Society of London* 107, 159-171.

Detailed descriptions are given of the geological successions in the Eocene of standard sections in the Rakhi Nala and at Zinda Pir in the western Punjab, and at Tarkhobi, Panoba, the Shekhan Nala and Sirki Paila in the Kohat district. The work forms the first stage in the reinvestigation of the classification and correlation of the Eocene in western Pakistan and western India. Comprehensive collections of fossils were made.

Key words: Stratigraphy, Eocene, Kohat, western Punjab.

E/3. Eames, F.E., 1951b. A contribution to the study of Eocene in Western Pakistan and Western India; Part B, The description of the lamellibranchia from standard sections in the Raki Nala and Zindapir areas of the western Punjab and in the Kohat District. *Philosophical Transactions of the Royal Society of London, Series B*, 235, 311-476.

Key words: Lamellibranchia, Stratigraphy, Paleontology, Eocene, Kohat, India.

E/4. Eames, F.E., 1952a. A contribution to the study of the Eocene in Western Pakistan and Western India; Part C, The description of the Scaphopoda and Gastropoda from standard sections in Punjab and Kohat District. *Philosophical Transactions of the Royal Society of London, Series B*, 236, 1-168

The Scaphopoda here described comprise three new species. The Gastropoda here recorded or described comprise 138 forms, 117 of which have received specific names. Of the 23 previously named species, two had not been recorded from Pakistan or India before. Largely owing to the nature of some of the beds from which collections were made, 96 of the species described are new. Four new genera and five new subgenera are proposed, and also one new generic name to replace a pre-employed name. The fauna recorded, together with the Lamellibranchia previously described, forms part of the material constituting the basis for the consideration of the classification and correlation of the Eocene of western Pakistan and western India, which the writer has published elsewhere.

Key words: Stratigraphy, Eocene, Paleontology, Scaphopoda, Gastropoda, Kohat, India.

E/5. Eames, F.E., 1952b. A contribution to the study of Eocene in Western Pakistan and Western India: D. Discussion of the faunas of certain standard sections and their bearing on the classification and correlation of the Eocene in Western Pakistan and Western India. *Quaternary Journal of Geological Society of London* 107, 173-200.

Local paleontological subdivisions are established for the Eocene of the Rakhi Nala, Zinda Pir and Kohat areas as a result of the examination of extensive collections of fossils recently made in these areas. The distribution of the

different phyla in various facies developments is discussed. Comparison is made with the pre-existing major subdivisions of the Eocene in western Pakistan and western India. In the Rakhi Nala and Zinda Pir area, it is concluded that the Khirthar-Laki boundary has previously been taken at too low a horizon, and that beds previously referred to as lower Middle Khirthar include representatives of the upper Middle Khirthar, the Upper Khirthar, and still younger horizons of Upper Eocene age.

The lithological and mapping evidence and the paleontological evidence from the Rakhi Nala and Zinda Pir areas are each considered separately and finally synthesized in order to arrive at as precise a correlation as is possible. The evidence from the Kohat Eocene beds has been synthesized with that from the Rakhi Nala-Zinda Pir area in like manner, and it is evident that only the major palaeontological subdivisions can be correlated. The present investigations have confirmed the usefulness of the terms “Ranikot Series”, “Laki Series” and “Khirthar Series” for subdivisions of the Eocene in western Pakistan and western India. The writer considers that the basic and fundamental soundness of these terms is not affected by the fact that beds and faunas have occasionally been incorrectly allocated to one or other of them. Certain beds, which are here named the “Tapti Series”, and which are not of very widespread occurrence, contain a fauna which is distinct from that of the Khirthar Series below and is of Upper Eocene age. The fauna of this series, in addition to several species of Upper Eocene age and a number of new species, includes the genus *Pellatispira*, which is also of Upper Eocene age and has not yet been unquestionably recorded from horizons as low as those containing the genus *Assilina*.

A consideration of all the available evidence indicates that published information concerning the ranges of some species is incomplete and that in some cases the existing conception of a species requires modification. The author is of the opinion that the “zones” which have been previously proposed within the Ranikot, Laki and Khirthar Series are of local rather than regional value, and that there has been too great a readiness to assign regional chronological significance to local facies faunas. It is evident that further work is necessary before regional zoning of the series can profitably be attempted.

Key words: Paleontology, stratigraphy, Eocene, Rakhi Nala, Zinda Pir, Kohat.

E/6. Ebblin, C., 1976a. Tectonic lineaments in Karakorum, Pamir and Hindu Kush from ERTS Imageries. *Rend Accademia Nazionale Dei Lincei, Series VIII* (60), 245-253.

ERTS imageries have been used to map major lineaments, structural trends and faults of the region. Further information not available to us.

Key words: Tectonics, Karakoram, Pamir, Hindukush.

E/7. Ebblin, C., 1976b. Structural Geology of the Thalle Area, Baltistan, Karakorum, Central Asia. *Nota I, Nota II*. Published: *Accademia Nazionale dei Lincei, Serie VIII*, vol. LX, fasc. 5, 1976, 663-671 & fasc. 6, 1976, 853-857.

Key words: Structure, Baltistan, Karakoram.

E/8. Ebblin, C., 1976c. Geological structure of the Yasin-Ishkuman area, Central Asia. *Records, Geological Survey of Pakistan*, 43.

Key words: Structure, Yasin, Ishkuman, Karakoram.

E/9. Ebblin, C., 1978. Deformation in the area of the Pamirs-Himalayan syntaxis and strain patterns on the Earth's surface. *Bollitin Geoessy Esc. Affini*. 37, p.223.

Further information not available to us.

Key words: Structure, Pamirs, Himalaya.

E/10. Ebblin, C., 1982. Gravity profile along the middle Indus valley, northern Pakistan. *Bollitin dei Geofisica Toerica ad Applicata* 24, 39-55.

Key words: Gravity, Geophysics, Gilgit, Hunza.

E/11. Ebblin, C., 1983. Nature of the south Karakorum synclinorium. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 375-384.

Further information not available to the authors.

Key words: Structure, Karakoram.

E/12. Ebblin, C., Marussi, A., Poretti, G., Rahim, S.M. & Richardus, P. 1983. Gravity measurements in the Karakoram. *Bollettino di Geofisica Teorica ed Applicata, Pamir-Himalaya*, 25, 303-316.

Further information not available to the authors.

Key words: Gravity, geophysics, Karakoram.

E/13. Edmond, J.M., 1992. Himalayan tectonics, weathering processes, and the strontium isotope record in marine limestones. *Science* 258, 1594-1597.

The time evolution of the isotopic composition of seawater strontium (the ratio of strontium-87 to strontium-86) over the last 500 million years has the form of an asymmetric trough. The values are highest in the Cambrian and Recent (0.7091) and lowest in the Jurassic (0.7067). Superimposed on this trend are a number of smaller oscillations. Consideration of the geochemical cycle of strontium and the dynamics of weathering shows that only Himalayan-style continental collisions can influence the isotope ratio on the scale observed. The contemporary Himalayan orogeny is by far the largest since the late Precambrian Pan-African event that produced the high in the Cambrian.

Key words: Weathering, tectonics, geochemistry (isotope), marine limestones, Himalaya.

E/14. Edwards, M.A., 1998. Examples of tectonic mechanisms for local contraction and exhumation of the leading edge of India, southern Tibet and Nanga Parbat, Pakistan. Ph.D. Dissertation, State University of New York at Albany, 308p.

This is a detailed account of the structure and tectonics of the Nanga Parbat area. Attention has been paid to explain the rapid rise of the Himalaya during the late Tertiary and Quaternary. Some of the information has appeared in the publications of the author.

Key words: Structure, tectonics, Nanga Parbat, Himalaya.

E/15. Edwards, M.A., 1999. The "Marginal Areas" (e.g., Namche Barwa, Nanga Parbat, Tian Shan). Can they tell us anything truly significant about the collision? *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 44.

For the purposes of this discussion, regions that are not in the principal regions of the India Asia collision (i.e., Tibet and the Himalaya) are termed the "Marginal Areas". Under the term Marginal Areas are included (e.g.) Namche Barwa, Nanga Parbat, Tian Shan, all of which are being reported on elsewhere in the workshop.

Although the Marginal Areas have much to offer regarding tectonic interest in general, in particular because of the relatively recent nature of much of the tectonic activity, it is by no means clear if the recent accumulation of deformation in any of these areas is a predictable product of the India-Asia collision. Does the present information, and/or will further information significantly enlighten us as to the timing, thermal and mechanical evolution of the converging crust?

There are presently very active tectonics at Nanga Parbat at the western end ("syntaxis") of the Himalayan chain (e.g., 1.4 Ma age of Mazeno Pass leucogranite pluton at Nanga Parbat - Schneider et al., 1999), and also at Namche Barwa at the eastern end of the Himalayan chain (where cooling ages are also notably young, e.g., Burg, 1998). For Nanga Parbat, there is evidence to suggest that significant exhumation has been only within the last 10 Ma. -10 Ma

is also identified by some as an approximate date for the attainment of a gravitationally unstable thickness of the crust beneath Tibet. Are events at Nanga Parbat related to elevation increase in Tibet?

It has been proposed that there is a significant and predictable partitioning of strain, with arc-parallel extension accumulating at the in the "syntaxial regions" of the straining arc (Seeber & Pecher., 1998). It has been subsequently suggested that fossil Nanga Parbat-type features will be found in ancient collisional belts, and various types of modelling have been presented in which displacement or weakening is concentrated at the tips of the arc (e.g., Koons et al., submitted). On the other hand, it is known that a wide range of features can be generated by modelling using geologically reasonable input.

In the Tian Shan, there is some evidence for significant Late Oligocene exhumation (Hendrix et al., 1994). Modern exhumation rates in the Tian Shan are also high however, and these cannot have continued for the last ~25 m.y. How can these periods of deformation be a predictable or obvious result of the ongoing convergence of India & Asia?

Key words: Tectonics, collision, Nanga Parbat, Namche Barwa, Tian Shan.

E/16. Edwards, M.A. Kidd, W.S.F., Khan, M.A. & Schneider, D.A., 1998. Structural geology around southern Nanga Parbat; Synkinematic granite and truncation of MMT footwall in the SW, deformation styles in Rupal, and the Shonthar Thrust traced to the SE. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 61-64.

The Main Mantle Thrust (MMT) is the regional contact between collider India and the overthrust Kohistan-Ladakh fossil island arc in the Pakistan Himalaya². The Nanga Parbat-Haramosh Massif (NPHM). Pakistan [NW Himalaya syntaxial region] is a tectonic half window of partly re-worked, largely Proterozoic, Indian plate rocks that have been exhumed from beneath Kohistan-Ladakh³. Early Himalayan age, general MMT thrust displacement is modified by very young (e.g. 1.4 Ma leucogranite Th-Pb ages⁴) tectonism at Nanga Parbat Haramosh Massif (NPHM). Our investigations in SW NPHM reveal a complex interplay of features related to (1) MMT-convergence, and (2) subsequent NPHM general uplift and tectonism.

In the area that is encompassed by the N-S trending Bunar valley, and NW trending Diamir valley, the main fabrics trend mostly N to NNE. In this area, the Indian "cover" passive margin rocks that form the original MMT footwall include sequences of carbonates and amphibolites (probably the Permian "Panjal Traps") interlayered with metapelites. In Diamir valley, these are not more than a few 100's metres thick. Here, the regionally NW-dipping cover sequences and MMT hanging wall (Kamila amphibolite) are overturned to become SE-dipping. These overturned layers are traceable to a recumbent open fold (the Gashit fold) in Airl Gah near the village of Gashit, where they form the upper (overturned) limb. The hinge line and axial plane of the fold plunge gently NS of this fold, the lower limb is exposed, thus sequences are not overturned and are observed to dip moderately to steeply west. The thickness of the cover sequence increases markedly to the south; carbonates, amphibolites and metapelites of several kilometres of structural thickness are present in the W-E Airl-Nashkin section, 10 km to the south of Diamir valley.

Structurally lower in the MMT footwall, and to the east (fig. 3), the cover sequence passes into a dominantly plutonic, ~5 km thick crystalline sequence that forms a continuous, ~30 km long, ~N-S belt with vertical to steeply E-dipping fabrics. The Diamir and Airl Gah (both ~W-E) valleys offer almost continuous outcrop sections through the belt. From these valleys, it is clear that a coarse-, to medium-grained biotite granite (the Jalhari granite) grades into granitic and porphyroclastic gneiss due to syn- to post-plutonism deformation. Jalhari leucogranite lenses (10's - 100's m thick) showing little to no sub-solidus deformation are separated by 10's - 100's m thick layers of gneiss where deformation of the granite has been localised. These higher strain layers anastomose around the granite lenses, and mark reverse faults that "climb" to the west. The granitic gneiss shows significant sub-solidus strain, including S-C porphyroclastic fabric whose sense of shear consistently indicates east side (NPHM) up and over west. Well-developed ductile/brittle shear bands and local fault gouge horizons, both of the same range of orientations as the ductile fabric, are also common. Late strain is often indicated by narrow (metres) zones where hydrothermal flux has developed thick biotite accumulations. Spectacular asymmetric folding (cm-wavelength) of the biotite layers indicates East Side up and over west. In the eastern portions of the Diamir valley section through the granite, a series of highly stretched, constant width (10-30 cm) amphibolite sheets can be followed for >100's m in continuous outcrop. These are parallel to sub-parallel to the deformed Jalhari granite. If these amphibolite sheets pre-date the granite, they imply a very large contrast in mechanical competence both during and after intrusion of

the Jalhari granite. Th-Pb microprobe [UCLA's Cameca IMS1270] analyses of monazites separated from deformed and undeformed portions of the granite give ages ranging from 3-12 Ma.

Overall, the granite gneiss belt defines an N-S trending, W-vergent reverse sense shear zone ~5 km in width. We term this the Jalhari shear zone. The E over W displacement sense of the Jalhari shear zone is consistent with the development of the Gashit fold and with the upper limb that includes the overturned cover/MMT layers. This shear zone forms the mechanical continuation of the main Raikhot Fault (a NW-vergent reverse fault with NPHM in the hanging wall). The Raikhot Fault is much narrower (5-km) however, and represents more focused strain.

The geology between the Jalhari shear zone and the central portions of massif is well exposed in the Diamir and Airl Gah valleys. The zone boundary is marked by brittle deformation within layers/lenses of retrograde (highly chloritised) metapelite. These then pass to more typical basement gneisses (e.g. showing metric banding due to differing Fe-weathering & biotite content). From here to Rupal valley, structures are more complex. Across Mazeno Pass, the 1.4 Ma pluton shows evidence of some normal motion associated with its emplacement. (Top to NW on steep, NW-dipping fabric). Principal gneissic fabric is N-NE trending. In places this is cut by quartz-pegmatites, and by leucogranite dykes that stem from the Mazeno Pass pluton. Some of the leucogranite dykes cross-cut the quartz-pegmatites, and in both cases, wall rock margins show normal sense of opening, but this may not be significant if (e.g.) the granite remained super-solidus during much of the strain.

Normal structures (top-to-NNW) are seen throughout Rupal valley. All, however, are brittle, probably very late, and of minor displacement. Most are developed on older thrust planes that are ~W-E trending, the western portion of the Rupal Chichi Shear Zone (RCSZ). There is vast thickness of orthogneiss in Rupal showing top to SSE thrusting. The NW-dipping fabric is continuous throughout the Rupal Face, biotite gneiss dips ~43°NW at the summit of Nanga Parbat. The Rupal Face is very steep. Locally, a ~2 km thick leucogranite with irregular margins intrudes western Rupal Face, above Shaigiri village (between ~5000 & ~6800 m). This may be emplaced in the axial zone of a tight antiform with NW-dipping axial surface, and whose axial trace passes to the south side of the summit ridge. This antiform is seen on Chongra ridge (again NW-dipping) and can be traced to the "western antiform" (Edwards & Kidd, 1997) described from the Astor Gorge. In both of the valley walls, amphibolite, coloured marbles and metapelites are found as fairly homogeneously deformed meter-scale layers/lenses within the extensive orthogneisses. At lowest elevations in the valleys walls of central Rupal, numerous thick fault gouge zones are seen, possibly indicating that at least part of Rupal valley has provided a (topographic) local crustal weakness to focus late brittle deformation. In the southern portions of western Rupal (in Shaggin Glacier valley, and all along the south side of Rupal & Toshain Glaciers) gneissic fabric dips SW to S and shows excellent SW stretching lineation, typically with a clear top-to-SSW sense of shear. Intrusive, now-L-tectonised granite pods pre-date this fabric, which may be very young.

Part of our continuing work in Chichi Nullah (SE NPHM) has included mapping of the southern portion of the RCSZ whose margin is well exposed here. It is sub-parallel to the Chichi Nullah and marked by a contact between the non-coaxially sheared granitic orthogneiss (continuous north to central Rupal) and the extensive marbles, amphibolites and metapelites of local Indian plate cover sequences. The foliation of the cover rocks and the gneisses are largely parallel, and orientation switches from NW dipping (overturned) in northern Chichi, through vertical, to SE-dipping in southern Chichi. This is another example of southern NPHM "bulging out" in cross sectional view (c.f. 7). In southernmost Chichi, within the locally SE-dipping marbles and amphibolites, several reverse faults define a >200m wide, NW-vergent thrust zone. This is most spectacularly expressed by a clear box fold (box = 10's m² area of section) within the zone. The thrust is observed to continue SW over the southern wall of Chichi Nullah. Its surface trace can be drawn from here and confidently joined with the Shonthar (Gali) thrust that has been mapped in Azad Kashmir near the Pak-Indo Line of Control, 9. Also noteworthy is that in southern Chichi, the sheared orthogneiss of the RCSZ dies out. This is replaced (further south) by a largely undeformed, fine-grained leucogranite of several 100's km² area. The (apparently intrusive) margin of the granite does not visibly cut the foliation of the country rock (i.e. marbles). Close to the margin, the granite shows minor sub-solidus deformation; however, we found no part of the granite that can be termed gneiss. The granite forms dull brown craggy towers along the tops of the valley walls, exactly like the sheared orthogneiss to the NE. We are investigating whether the granite and the orthogneiss may be originally related in some manner.

Key Words: Structure, tectonics, Indus suture, Synkinematic intrusions, Nanga Parbat, Himalaya.

E/17. Edwards, M.A. & Kidd, W.S.F., 1997. Structural investigation around southern and eastern Nanga Parbat. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 29-30.

The western Himalaya syntaxis includes the Indian-plate Nanga Parbat Haramosh (NPHM). The contact between collider India & the overthrust Kohistan series (KLS) is regionally termed the Main Mantle Thrust (MMT). It forms a plan-view, “oxbow” shape around NPHM, yet NPHM is not a relict promontory of India that has acted as a horizontal indenter and “bowed out” the visible MMT. This is recognized by the absence of appropriate deformation of the northern margin of the KLS (Pecher et al., 1996). NPHM has enjoyed accelerated exhumation from beneath the KLS since ca. 10 Ma (Zeitler, 1985; Zeitler et al., 1993), and locally plutonism has been constrained as young as 1.4 Ma (Schneider et al., 1996), tens of kilometers of crustal section are required to have been removed from above Nanga Parbat. This has prompted speculation (e.g. Hubbard et al., 1995) that the NPHM may be another Himalayan core complex (c.f. Nyainqentanglha-Pan and Kidd, 1992).

Our structural mapping in the eastern and southern massif, coupled with geochronologic analysis, and previous mapping in NPHM (e.g. Butler et al., 1992) indicates that recent NPHM exhumation (<10 Ma) is not due to significant unroofing via a low-angle normal faulting. Large amounts of mass have not been tectonically denudation from NPHM drainage area.

Along the oblique (~NW-SE) NPHM section formed by the Astor River gorge, two antiforms with different lithology are apparent. The western antiform is asymmetric with thinned E-limb. The eastern antiform is asymmetric with a thinned W-limb. Both axial planes trend ~N-S. These thinned limbs mark the Dashkin Synform, a pulled-down isoclinal fold whose axial plane trends ~N-S, and dips steeply W. Migmatitic orthogneiss dominates the W antiform. Cross-cutting amphibolite dykes are more frequent close to the thinned limb. The KLS is exposed in the hills 2-3 km above the Astor Gorge on the crests of both antiforms. There is no petrographic evidence for part of the KLS in the core of the Dashkin synform within 1000m of exposure above the river, although obliteration due to stretching of the synform remains possible.

Gneisses and schist in the eastern antiform are steadily N-S trending, vertical to steeply dipping, with lineation typically plunging gently N. These rocks are largely non-granitic/migmatitic, and there is no magmatism which post-dates the N-S lineation that we (as others, e.g. Butler et al., 1992) regard as original fabric due to either thrust or normal motion on the MMT (Edwards et al., 1996). The sequence of gneisses and schists that from the E limb of the eastern antiform has been divided into several mappable units, including the KLS rocks at the contact. This sequence is fully continuous from Astor gorge north over Dichil Gali to the Indus gorge, and to the south. We mapped this sequence in seven ~E-W valleys between Astor village and Rattu. Nowhere was the NPHM-KLS contact marked by a significant brittle structure nor any evidence of significant kinematics features not attributable to the MMT. Between Astor Village and North Lower Rupal, the NPHM-KLS contact sequence dips 40-80° E. From South Lower Rupal to near Rattu, the sequence is overturned and dips 40-80° W: the NPHM here is “bulging out”.

We infer W side up; thrust sense localized ductile displacement to be represented by the Dashkin synform based upon the relative differences in height of the overlying KLS rocks and the migmatitic gneisses in the western antiform. Interpreted satellite imagery (TM, SPOT) shows this zone continuing and widening to Chongra glacier and the Rupal-Chichi shear zone (see below) where a strain is much greater. The two contrasting synforms are not inconsistent with the most recent data from the equivalent NPHM section along the ~W-S Indus gorge (Wheeler et al., 1995).

The Rupal-Chichi Shear Zone is a several km wide belt of granitic orthogneiss showing a pervasive. NW side up with dextral shear indicated by augen asymmetry and S-C fabric. Associated overprinting lineation plunges ~30-60°SSW to WSW. Foliation shows some change: NE-trending in Chichi; NNE trending at Tarshing; ~W-E trending near Tapp Meadow. Dip is to the north. Kinematics indicated by this pattern are consistent with SE “corner” of Nanga Parbat moving up and NE relative to the eastern margin. There appears to be a large contrast in ages across this zone (Schneider et al., this volume). West of Tapp Meadow to Toshe Gali at the head of Rupal valley (~20 km) there is a return to ~N-S trending foliation and lineation.

In the central Rupal Valley there is an increase in (deformed) granitic component to the gneiss, greater on the south side. It is noteworthy that the more granitic areas appear to be concordant to the local (regional?) ~N-S fabric and yet analyses of preliminary samples give <5 Ma (Schneider et al., this volume). Other areas of “unstrained” granite crosscut the local fabric. The Mazeno Pass pluton (~5400m) emplaced at 1.4 Ma (Schneider et al., this volume), is discordant to the local fabric. In Upper Rupal Valley there is large contrast in fabric: N-dipping lineation in more rich gneisses on the N side, as opposed to SW plunging lineation in gray gneisses on the S side that contain large (Dm-scale) pods or boudins of lineation parallel granitic L-tectonic. Although foliation in the gray gneisses is steep and NE trending, and although the SW-plunging lineation may be a rotated MMT (originally N dipping) structure, there may have been some top to SW shear in this area. To the SW is Azad Kashmir, outside of the NPHM drainage area, and this is a part of the massif where some tectonic exhumation could have occurred.

Between the NPHM-KLS contact near the mouth of Lower Rupal valley and the Rupal-Chichi shear zone at Tarshing, is found the Churit Fault. The Churit Fault is a diffuse zone of steep, W side up N-S trending brittle faults

~1.5 km wide. The fault juxtaposes sillimanite grade orthogneiss in the west over staurolite grade metapelites in the east. The Churt Fault lacks significant ductile overprinting of regional N-S lineation, and seems to represent relatively minor exhumation of the massif.

We conclude that deformation for NPHM is largely indicative of a pop-up structure. This is evidenced by (1) NE-vergent folding visible along the Astor section, and (2) overturning of the eastern margin of southern NPHM, consistent with greater differential uplift indicated by (3) the W or NW side up, E-vergent Churit and Rupal-Chichi structures. This is consistent with NW vergent, NE dipping thrust structures on the western margin (e.g. Raikhot/Liachar) that form the corresponding western part of the pop-up structure. Our proposal of an asymmetric pop-up (Edwards et al., 1996) is consistent with preliminary data from the seismic experiment (Meltzer et al., 1996) that indicate that the Raikhot/Liachar system continues as the SE dipping basal thrust below the massif soleing to an area of dense seismicity that is truncated at 6 km below sea level. This is consistent with a model invoking large NW-trending relative surface velocities for either the entire western Himalaya (e.g. McCaffrey & Nabalek, 1996) or simply at the syntaxis, due to arc parallel extension (Seeber et al., 1996).

Key words: Structural geology, Nanga Parbat.

E/18. Edwards, M.A. & Kidd, W.S.F., 1999. New map of southern Nanga Parbat. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 43-44.

A new structural and lithologic map (as part of the Nanga Parbat Continental Dynamics Project) has been made for the southern Nanga Parbat area in the Pakistan Himalaya. About 90% of the mapped area was hitherto unreported in recent geological literature, the remaining 10% being covered by preliminary work.

The portions of the massif where mapping was conducted include: (Clockwise from Mazeno Pass) Diamir, Bunar, Biji and Jalhari Gah area (in the SW), the Astor Gorge and Dichil Gah-including the two tributaries that intersect the Eastern margin, Rama, Bulan and Ghurikot Gah areas (including the two northern tributaries of Ghurikot Gah), The Lower Rupal Valley (Tarshing Area) and northern Rattu valley, Chichi valley (to the foot of the pass to the Kishanganga) and central and Upper Rupal areas (to the foot of Toshe Gali and up to and over Mazeno Gali).

Three major findings include (1) a major new shear zone, the Rupal-Chichi Shear Zone, (2) the Diamir-Rupal Shear Zone-a significant continuation of the Raikot system for >60 km to the SW, and (3) that the original MMT on the east side has not been significantly modified or displaced, only rotated to vertical (for all three see Edwards et al., and Schneider et al., this issue). The map originally appeared in Edwards (1998).

Key words: Structure, lithology, mapping, Nanga Parbat.

E/19. Edward, M.A., Kidd, W.S.F., Khan, M.A. & Schneider, D.A., 2000. Tectonics of the SW margin of the Nanga Parbat-Haramosh massif. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 77-100.

We present an analysis of the tectonic evolution of the southwestern portions of the Nanga Parbat massif, Pakistan Himalaya, based upon detailed mapping and structural analyses from the Bunar, Biji, Diamir, Airl, Niat and SW Rupal valleys. Mainly metasedimentary cover rocks of the Indian plate are divided into upper and lower cover. There is a marked structural thinning of the cover in the main Bunar valley from south to north, and this is attributed to a major frontal ramp in the original Main Mantel Thrust (MMT). A hitherto unmapped shear zone, the Diamir Shear Zone, is identified, that is associated with a syn-kinematically intruded belt of granitic rocks, the Halhari Granite. The shear zone is a several kilometer thick, generally W-vergent, ductile to brittle shear zone that is associated with local overturning of the entire MMT section, typified by the Gashit Fold. ⁴⁰Ar/³⁹Ar cooling ages from across the area indicate as steep cooling age gradient across the Diamir Shear Zone from >40 to <5 Ma. The Diamir Shear Zone is mechanically linked to part of the Raikhot Fault System and, together, they are seen to be crustal-scale reverse fault that has allowed relative uplift and overthrusting of the core of Nanga Parbat.

Key words: Tectonics, Nanga Parbat, Himalaya.

E/20. Edwards, M.A., Kidd, W.S.F., Khan, M.A., Schneider, D.A., Zeitler, P.K. & Anastasio, D., 1997. Structural geology of the southwestern margin of Nanga Parbat. EOS, Transaction of the American Geophysical Union 78, F651.

The Main Mantle Thrust (MMT) is the regional contact between collider India and the overthrust Kohistan-Ladakh series in the Pakistan Himalaya. Early Himalayan-age thrusting and some later (~20 Ma?) normal motion on/near the MMT is modified by very young (e.g. 1.4 Ma leucogranite Th-Pb ages) tectonism at Nanga Parbat-Haramosh Massif (NPHM); the Himalaya's western syntaxis. Our investigations in southwestern NPHM reveal a complex interplay of MMT-related (mostly convergent) structural features followed by those related to uplift and tectonism of NPHM. Across the Diamir/Bunar area, main fabrics trend N to NE. In Diamir Valley, Indian cover passive margin metapelites and carbonates in the MMT footwall are not more than a few 100's of metres thick. Here, the regionally NW-dipping Indian cover sequences and MMT hanging wall (Kamila amphibolite) are overturned (SE-dipping). These overturned layers are traceable to the Gashit fold, whose hinge line plunges ~N and axial surface dips gently-moderately east. The cover sequence thickness increases markedly to the south; several km structural thickness of carbonates, metapelites and amphibolites are present in the W-E Airl-Nashkin section, only 8 km to the south of Diamir valley. The cover sequence passes east into a dominantly plutonic 5-10 km thick crystalline sequence where coarse to fine grained granite (the Jalhari granite) grades, due to syn- to post-plutonism deformation, into granitic and porphyroclastic gneiss intercalated with gneissic basement. Regionally the cover and crystalline rocks follow the subvertical to steeply E-ESE dipping foliation, and displacement sense is consistently east side (NPHM) up and over west. Within Diamir valley, granitic and gneissic foliation, shear bands, and local fault gouge zones anastomose around less- to un-deformed Jalhari granite lenses of 10-100's metres width. Plutonism seems to be in part synkinematic, and may provide an older age limit for NPHM tectonism. The E over W sense is consistent with the development of the Gashit fold and the upper limb that includes the overturned cover/MMT layers. The sharp attenuation of the cover sequence in northern Bunar valley could be a result of excision by normal motion along the MMT but we find no compelling evidence for this. We propose that the attenuation is a result of (1) a large frontal ramp in the MMT and an underlying related duplex largely of Indian cover and/or (2) original MMT thrust belt morphology where a lateral ramp-related duplex system has imbricated (and/or infolded) local thin slices of the cover and basement.

Key words: Structural geology, Nanga Parbat.

E/21. Edwards, M.A., Kidd, W.S.F., Seeber, L., Pêcher, A., LeFort, P., Riaz, M., & Khan, M.A., 1996. An upwardly-mobile indenter? The Nanga Parbat Haramosh Massif viewed as a crustal-scale Pop-up structure. EOS, Trans., American Geophysical Union, 77, F692.

The western Himalaya syntaxis [Fig 1] includes the Indian-plate Nanga Parbat Haramosh Massif (NPHM) [Fig 2]. The contact between collider India & the overthrust Kohistan-Ladakh series (KLS) is regionally termed the Main Mantle Thrust (MMT). It forms a plan-view, "oxbow" shape around NPHM, yet NPHM is not a relict promontory of India that has acted as a horizontal indenter and "bowed out" the visible MMT. This is recognised by the absence of appropriate deformation of the northern margin of the KLS. Pervasive lineation in NPHM is ~N-S, and sense of shear on the eastern margin is often dextral where recognised. Although this agrees with horizontal indenter model predictions, the broadly antiformal nature of NPHM allows the steep N-S foliation near the margins to be the result of rotation of the original, ~E-W, gently north-dipping MMT system about an axis ~parallel to the pervasive lineation. Therefore, the eastern margin and dextral shear sense, respectively, can be restored and recognised as top-to-south, MMT zone Himalayan thrust structures, largely unaltered. Observations now extending to seven main valleys confirm that there is no large brittle fault defining the eastern NPHM-KLS contact; the contact is essentially unmodified MMT. The antiformal nature of the massif is illustrated by the degree of apparent exhumation. Within NPHM, exhumation of the central portions of the massif (e.g. Nanga Parbat) has formed a complete window through Indian plate cover sequence schist and gneiss (garnet-staurolite grade) into basement gneiss (sillimanite grade $\pm$ granulite facies, cordierite-bearing anatectic segregations). This exhumation has been accommodated in part by large ductile and brittle shear zones within SE NPHM. The Rupal Shear Zone is a wide belt of ~N-S trending orthogneiss showing a pervasive, west side up with dextral shear S-C fabric and overprinting lineation. Closer to the eastern margin, the Churit Fault in lower Tarshing valley juxtaposes sillimanite (?) grade orthogneiss in the west over staurolite grade metapelites in the east, but lacks significant ductile overprinting of regional N-S lineation. Near Raikot, the original MMT contact of the western margin is largely obscured by east-over-west thrusting with some

overprinting the regional ~N-S lineation. Qualitative changes in the relative development of some fault and shear zone features may indicate diminishing strain to the north. Within NPHM and in Kohistan, late, NW-vergent structures dominate (young pegmatitic dyke sets, fault propagation folds, antithetic faults) and are suggestive of an asymmetric pop-up or flower structure. The NW-vergence in NPHM late brittle structures is consistent with the direction of axes of maximum compression derived from brittle fault kinematics in both crystalline and quaternary rocks near and west of the Raikot fault. Our evidence confirms and strengthens the view that NPHM is an asymmetrical antiformal structure, verging NW.

Key words: Structure, tectonics, Nanga Parbat.

E/22. Edwards, M.A., Schneider, D.A., Kidd, W.S.F., Khan, M.A. & Zeitler, P.K., 1999. Summary of selected tectonic and geochronologic observations arising from the Nanga Parbat Continental Dynamics Project. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 40-41.

The Nanga Parbat Continental Dynamics Project (c.f., Zeitler et al., this volume) employed various disciplines (e.g., Meltzer et al., this volume) to investigate the tectonic processes that have contributed/contribute to present situation at the Nanga Parbat Haramosh Massif (NPHM). This is a summary of some of our tectonic and geochronologic observations in Central and SE NPHM.

Astor valley and SE NPHM: Two antiforms (with broadly differing overall lithology) are observed in the main Astor Gorge; the Burdish Ridge and Dichil antiforms, in the west and east, respectively. The Burdish Ridge antiform is asymmetric with a thinned E-limb, while the Dichil antiform is asymmetric with a thinned W-limb. This is recognised by a very tight, pinched fold morphology of the accompanying (Dashkin) syform. The Iskere gneiss (Madin, 1986; Madin et al., 1989; Treloar et al., 1991) is present near the core of, and west of, Burdish Ridge antiform as a series of 100's m to < 2-km sections interlayered with the porphyroclastic and coarsely to finely laminated, occasionally calc-silicate gneisses. We suggest that the discontinuous nature of the Iskere gneiss in Astor Gorge compared to the Indus Gorge (ibid.) is largely due to "fingering" (thinning / pinching out of multiple tabular or elongated peripheral portions) of the edge of the main body that is seen along the Indus Gorge, and we note that the bodies should, in principle, be traceable northward to join the Indus Gorge main body (possibly in a non-continuous fashion, if certain Iskere layers are km-scale boudins or lenses). The original intrusive contact of the Iskere protolith may have been either inter-fingering or may have been planar.

The Dichil antiform includes various conspicuous gneisses and schists that can be followed (discontinuously) through the (~W-E trending) valleys of SE NPHM, including (e.g.) the "lath unit" (Edwards, 1998; Edwards & Kidd, this volume; Schneider et al., this volume; Argles et al., this volume; Foster et al., this volume). These form the footwall of the original MMT and present therein are impressive high strain zones related to both original MMT thrust-sense, and, locally, to MMT-normal sense (!) displacement (ibid.). There is no significant displacement fabric related to the uplift of NPHM, only overturning of the previous "high Himalayan" fabric that is part of the "bulging out of southern NPHM".

NPHM-uplift-related shear zones in the SE: The Rupal-Chichi shear zone (RCSZ) is a km-scale, dextral, W-side up, high strain zone defined by a continuous belt of non-coaxially sheared granitic orthogneiss with impressive C/S fabrics along its entire length. This hitherto unrecognised feature is a fundamentally important discovery for constraining the tectonics of NPHM; it is now clear that the RCSZ has acted as the conjugate, "retro-" shear zone to the southern Raikhot & Diamir shear zone system (see below) to define a crustal scale pop-up structure. Displacement along the RCSZ may have migrated "inwards" to the centre of the massif based upon the ages of (1) cross-cutting leucocratic\granitic dykes, and (2) total fusion Ar/Ar biotite-cooling ages of the orthogneiss, both of which show an overall younging towards the centre of the massif (Schneider et al., this volume - a & b). To the south of the RCSZ is the newly discovered early Miocene Southern Chichi leucogranite pluton (ibid.).

Shonthar Thrust: North and east of the Southern Chichi pluton, the cover sequences are marked by extensive marbles, amphibolites and metapelites of local Indian plate cover sequences. The foliation here switches from NW dipping (overturned) in northern Chichi, through vertical, to SE-dipping in southern Chichi. This may mark the southern limit of the NPHM "bulging out". Within the locally SE-dipping marbles & amphibolites, several reverse faults define a >200m wide, NW-vergent thrust zone. This is expressed by a clear box fold (box 10's m area of section) within the zone. The thrust is observed to continue SW over the southern wall of Chichi Nullah. Its surface trace can be drawn from here and confidently joined with the Shonthar (Gali)'thrust that has been mapped in Azad Kashmir near the Pak-Indo Line of Control.

Deformation in Rupal: Normal structures (top-to-NNW) are seen throughout Rupal valley. All, however, are brittle, probably very late, and of minor displacement. Most are developed on older thrust planes that are ~W-E trending; the western portion of the Rupal Chichi Shear Zone (RCSZ). There are vast thickness of orthogneiss in Rupal showing top to SSE thrust sense-of-shear. The NW-dipping fabric is continuous throughout the Rupal Face; biotite gneiss dips ~45°NW at the summit of Nanga Parbat. Locally, a ~2-km thick leucogranite with irregular margins intrudes the very steep western Rupal Face, above Shaigiri village (between ~5000 & ~6800 m). This may be emplaced in the axial zone of a tight antiform with NW-dipping axial surface, and whose axial trace passes to the south side of the summit ridge. This antiform is seen on Chongra ridge (again NW-dipping) and can be traced to the “western antiform” described from the Astor Gorge. In both of the valley walls, amphibolite, coloured marbles and metapelites are found as fairly homogeneously deformed metre-scale layers/lenses within the extensive orthogneisses. At lowest elevations in the valleys walls of central Rupal, numerous thick fault gouge zones are seen, possibly indicating that at least part of Rupal valley has provided a (topographic) local crustal weakness to focus late brittle deformation. In the southern portions of western Rupal (in Shagin Glacier valley, and all along the south side of Rupal & Toshain Glaciers) gneissic fabric dips SW to S and shows excellent SW stretching lineation, typically with a clear top-to-SSW sense of shear. Intrusive, now-L-tectonised granite pods pre-date this fabric. The orientation, petrographic texture, and sense of shear of the fabric resembles the mylonitic and high strain zones of the MMT footwall that we see elsewhere. We note that the top-to-SSW sense of shear is best explained by rotation (from ~N-dipping) of the original MMT thrust-displacement fabric; such a rotation is to be anticipated here on the SW flank of the uplifting massif.

The brittle normal faulting seen in a number of places in the massif indicates that the central part of southern NPHM is in a state of extension near the surface. It seems that there is a small value for normal stress on existing fractures of many orientations, and that only a small rotation of the stress field is required to switch from reverse to normal motion on pre-existing fault surfaces. Some focal mechanisms for resolvable seismic events within southern NPHM are consistent, showing extensional first motions occurring to ~6-km depth (Meltzer et al., this volume). Note, however, that there is no evidence for large-scale tectonic exhumation of NPHM.

Key words: Structure, tectonic, geochronology, Nanga Parbat.

E/23. Edwards, M.A., Schneider, D.A., Kidd, W.S.F., Khan, M.A. & Zeitler, P.K., 1999. Summary of selected tectonic and geochronologic observations in SW NPHM arising from the Nanga Parbat continental dynamics project. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 42-43.

This abstract is a summary of some of tectonic and geochronologic observations in SW NPHM arising from the Nanga Parbat Continental Dynamics Project (Zeitler et al.).

Truncation of cover sequence: In the area that is encompassed by the N-S trending Bunar valley, and NW trending Diamir valley, the main fabrics trend mostly N to NNE. In this area, the Indian “cover” passive margin rocks that form the original MMT footwall include sequences of carbonates and amphibolites (probably the Permian “Panjal Traps”) interlayered with metapelites. In Diamir Valley, these are not more than a few 100’s metres thick. Here, the regionally NW-dipping cover sequences and MMT hanging wall (Kamila amphibolite) are overturned to become SE-dipping. These overturned layers are traceable to a recumbent open fold (the Gashit fold) in Airl Gah near the village of Gashit, where they form the upper (overturned) limb. The hinge line and axial plane of the fold plunge gently N. South of this fold, the lower limb is exposed, these sequences are not overturned and are observed to dip moderately to steeply west. The thickness of the cover sequence increases markedly to the south; carbonates, amphibolites and metapelites of several km of structural thickness are present in the W-E Airl-Nashkin section, 10 km to the south of Diamir valley.

The abrupt northward thinning of cover sequences in SW NPHM is orders of magnitude too large to be original depositional variation and there must be some type of tectonic excision. Large amounts of STDS-type normal motion have not been reported from the MMT. Similarly, we have found no compelling evidence around NPHM for large-scale normal motion on the MMT (the MMT-normal motion seen in SE NPHM cannot account for several km of exhumation). Consequently, we suggest that a large-scale frontal ramp in the original MMT gave rise to a local duplex structure that imbricated thin slices of cover, and possibly basement. This model is consistent with our mapping in Niat Gah, the next main valley to the west of NPHM, where a basement slice occurring close to the MMT implies large-scale imbrication of the cover sequences.

Jalhari Granite synkinematic in Diamir Shear Zone: Structurally lower in the MMT footwall, and to the east, the cover sequence passes into a dominantly plutonic, ~5-km thick crystalline sequence that forms a continuous-along-

strike (>30 km), ~N-S belt with vertical to steeply E-dipping fabrics. The Diamir and Airl Gah (both ~W-E) valleys offer almost continuous outcrop sections through the belt. From these valleys, it is clear that a coarse-, to medium-grained biotite granite (the Jalhari granite) grades into granitic and porphyroclastic gneiss due to syn- to post-plutonism deformation. Jalhari leucogranite lenses (10s-100s m. thick) showing little to no sub-solidus deformation are separated by 10's-100's m thick layers of gneiss when deformation of the granite has been localized. These higher strain layers anastomose around the granite lenses, and mark reverse faults that climb to the west. The granitic gneiss shows significant sub-solidus strain, including S-C porphyroclastic fabric whose sense of shear consistently indicates east side (NPHM) up and over west. Well-developed ductile/brittle shear bands and local fault gouge horizons, both of the same range of orientations as the ductile fabric, are also common. Late strain is often indicated by narrow (metres) zones where hydrothermal flux has developed thick biotite accumulations. Spectacular asymmetric folding (cm-wavelength) of the biotite layers indicates east side up and over west. Th-Pb ion microprobe [UCLA's Cameca IMS 1270] analyses of monazites separated from deformed and undeformed portions of the granite give ages ranging from 2-8 and 12 Ma, respectively (Schneider et al., this issue). Overall, the granite gneiss belt defines a N-S trending, W-vergent, reverse sense shear zone ~5-km in width. We term this the Diamir Shear Zone. The E over W displacement sense of the Diamir Shear Zone is consistent with the development of the Gashit fold, and with the upper limb that includes the overturned cover/MMT layers (again note that here on the NPHM SW flank the massif is again "bulging out" in cross-sectional view). The Diamir shear zone forms the mechanical continuation of the main Raikhot Fault: at Raikhot Bridge, where last seen, the structure is marked by a NW-vergent reverse fault with NPHM in the hanging wall (Madin, 1986; Madin et al., 1989). The Raikhot Fault is much narrower (<<5-km) however, and represents more focused strain. We interpret the emplacement of the Jalhari granite to be at least partly syn-kinematic with exhumation of NPHM, intruded in discrete episodes between 2 and 12Ma.

Eastern margin of Diamir Shear Zone and Mazeno Pass section: The geology between the Diamir Shear Zone and the central portions of massif is well exposed in the Diamir and Airl Gah valleys. The zone boundary is marked by brittle deformation within layers/lenses of retrograde (highly chloritised) metapelite. These then pass to more typical basement gneisses (e.g. showing metre-scale layering due to differing Fe-weathering & biotite content). From here to Rupal Valley, structures are more complex. Across Mazeno Pass, the 1.4 Ma pluton (Schneider et al., this volume) shows evidence of some normal motion associated with its emplacement. (top to NW on steep, NW-dipping fabric). Principal gneissic fabric here is N-NE trending. In places this is cut by quartz-pegmatites, and by leucogranite dykes that stem from the Mazeno Pass pluton. Some of the leucogranite dykes cross-cut the quartz-pegmatites, and in both cases, wall rock margins show normal sense of opening, but this may not be significant if (e.g.) the granite remained super-solidus during much of the strain.

Conclusion: In conjunction with our observations of Central and SE NPHM (Edwards et al., this issue), we conclude that the uplift of the NPHM massif is accommodated upon two conjugate shear zones that define a pop-up structure. The RCSZ (on the eastern flank) is the "retro" structure while the Raikhot Diamir system (on the western flank) is the "pro" or "dominant" structure. The overturning (bulging out) of the massif is occurring on both flanks, however this occurs out with the main shear zone on the eastern flank (away from the centre of the massif); this is consistent with an overall more-diffuse focus of strain in the retro shear zone. We have recognized original "high Himalayan" features in the areas out with of central NPHM, including (1) the original MMT, and (2) evidence for Early Miocene plutonism that is ubiquitous to the main Himalaya and hitherto unrecognised in the NW Himalaya.

Key words: Tectonic, geochronology, Nanga Parbat,

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Further information not available to the authors.

Key words: Seismicity, earthquake, Bannu.

E/25. Eguchi, M., 1965. Cretaceous corals from the eastern Hindu Kush. In: Matsushita, S. & Huzita, K. (Eds.), *Geology of the Karakoram and Hindu Kush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindu Kush (1955)* 7, 131-136. Nippon Printing & Publishing Co., Ltd., Japan.

This is a study of two samples of corals, one of which was collected from Yasin group at the type locality and the other from the Green series at Rawat, east of Shamran. The former is identified as genus *Eugyra*, suggesting a Lower Cretaceous age for the Yasin Group. The one from the green series is genus *Thamnasteria*, found in Jurassic and Cretaceous rocks.

Key words: Corals, Greenstones, Yasin Group, Gilgit, Eastern Hindu Kush.

E/26. Ehsan, F., Nisar, A., Siddiqui, F.A. & Khan, A.H., 1983. Chemistry and mineralogy of some Eocene and associated limestones of Kohat District, N.W.F.P. Pakistan Journal of Scientific and Industrial Research 26, 212-219.

Key words: Geochemistry, mineralogy, limestone, Eocene, Kohat.

E/27. Elahi, H.I., 1994-96. Geological mapping of Dunga Gali to Kuza Gali, Khanpur Area, and Site investigation of Ghazi-Barotha Hydro-Power Project, District Abbottabad, NWFP. M.Sc. Thesis, Punjab University, Lahore, 47p.

The area mapped and studied is located in the form of a strip extending between Dunga Gali and Barian in the Northwest Himalayas (ca, 33° 57"-34° 4"N, 73° 23"-73° 25"E). The area falls mainly in Abbottabad, administrative district of N.W.F.P It is located on the survey of Pakistan Toposheet no 43 5/8 and 43 G/5.

Key words: Stratigraphy, hydel power, Abbottabad, Hazara.

E/28. Elahi, M.K. & Martin, N.R., 1961. The physiography of the Potwar, West Pakistan. Geological Bulletin, University of Punjab 1, 5-14.

The highly dissected plateau of the Potwar is a clearly defined and well-known Physiographic region of West Pakistan, with a distinctive landscape. An attempt is made to divide it into physiographic units, and to show the close relationship of the geology and minor landforms.

Key words: Geomorphology, physiography, Potwar.

E/29. Elahi, S.M., 1962. Geology of Abbottabad area, Hazara. M.Sc. Thesis, Punjab University, Lahore.

This is an account of the geology, lithology and stratigraphy of the Abbottabad area, along with a preliminary geological map.

Key words: Stratigraphy, Abbottabad.

E/30. Elbersen, C.W.W., 1967. Reconnaissance soil survey of Peshawar Valley, Peshawar and Mardan Districts. Soil Survey Project of Pakistan.

Key words: Soil science, reconnaissance, Mardan, Peshawar.

E/31. Engineers Combine Limited, Lahore, 1979. Preliminary mineral survey in Kotli and Poonch districts of Azad Kashmir. Report Prepared for Azad Kashmir Mineral & Industrial Development Corporation, 1, 25-58.

Note: Engineer Combine Limited, Lahore, a private company, produced a series of reports on mineral occurrences of the North-West Frontier Province and Azad Jammu and Kashmir. These reports are not readily available. However, parties interested in further exploration and exploitation of these mineral can obtain the relevant report from the provincial/state directorates.

Key words: Mineral survey, Kotli, Poonch, Azad Kashmir.

E/32. Engineers Combine Limited, 1975. A survey report on the selected minerals of the northwest Frontier Province. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Mineral survey, NWFP.

E/33. Engineers Combine Limited, 1977. Detailed geological investigations of nepheline syenite of Koga area, Swat, 111p. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Syenite, Koga, Swat.

E/34. Engineers Combine Limited, 1977. Preliminary survey report on marbles, manganese, asbestos, mica, pyrite and corundum of North West Frontier Province, 130p. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Economic geology, mineral deposits, NWFP.

E/35. Engineers Combine Limited, 1977. Detailed geological investigation of China clay of Timargara (Dir) and Ahll (Hazara) area. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar, 95p

Key words: Economic geology, Mineral deposits, Dir, Hazara.

E/36. Engineers Combine Limited, 1978. Preliminary investigations of minerals along the borders of Dir and Swat, 191 p. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Economic geology, Dir, Swat.

E/37. Engineers Combine Limited, 1978. Malakand graphite; Detailed geological investigations 1, 176 p. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Economic geology, mineral deposits, graphite, Malakand.

E/38. Engineers Combine Limited, 1978. Malakand graphite; Detailed geological investigations 2 (maps and annexures only). Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Economic minerals, graphite, Malakand.

E/39. Engineers Combine Limited, 1978. Preliminary mineral survey in Kotli and Poonch Districts of Azad Kashmir. Azad Kashmir Mineral and Industrial Development Corporation, 1, 249p, & 2, 161p.

Key words: Minerals, Poonch, Kotli, Azad Kashmir.

E/40. Engineers Combine Limited, 1979. Delineation of low iron bearing zones of nepheline syenites, Koga area, Swat, 185 p. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Syenite, Iron Ore, Koga, Swat.

E/41. Engineers Combine Limited, 1979. Exploration of magnetite and other minerals in Allai Kohistan, 174 p. Directorate of Industries Commerce and Mineral Development, Government of North West Frontier Province, Peshawar.

Key words: Magnetite, Allai, Kohistan.

E/42. Etheridge, R., 1864. Note on the Jurassic fossils collected by Captain Godwin Austen. Quarterly Journal of the Geological Society, London, 20.

Key words: Paleontology, Karakoram.

F/1. Faccena, C., Lorenzoni, S., Olivieri, L.M. & Lorenzoni, E.Z., 1993. Geo-Archaeology of the Swat Valley (NWFP, Pakistan), in the Charbagh-Barikot stretch, preliminary note. *East and West (IsMEO)* 43, 257-270.

The Charbagh-Barikot area lies along the Indus suture and contains rocks of the northern edge of the Indian plate as well as those of the suture mélange. There is a whole range of lithologies: pelitic schists (up to kyanite grade), calcareous schists, graphitic schists (commonly garnetiferous), granites and granitic gneisses, greenschists, phyllites, amphibolitized metabasites, and altered ultramafic rocks (serpentinites, magnesite-talc rocks). These rocks have been used in the manufacture of the archeological artifacts of the Gandhara age.

Key words: Geoarchaeology, Charbagh, Swat.

F/2. Faisal, S. & Afridi, S.K., 1996-97. Geology of the Kalachitta Hill Range at the western bank of the Indus River south of Nizampur, District Nowshera: Implications for the structural evolution of Main Boundary Thrust. M.Sc. Thesis, University of Peshawar, 70p.

For further details, consult the following account.

Key words: Structure, MBT, Kalachitta, Nizampur, Nowshera.

F/3. Faisal, S., Afridi, S.K. & Khan, M.A., 2001. Structure study at the western bank of the Indus River south of Nizampur, District Nowshera: Implications for the structural evolution of Main Boundary Thrust (MBT). Abstracts, 4th Pakistan Geological Congress, Islamabad, p.62.

The study area is a part of the western Kala Chitta Range, on the right bank of Indus river, around Jhungrai village, Nizampur. An area of about 110 km² was studied and mapped to work out the structural patterns. The area comprises, strata ranging in age between Jurassic and Miocene formations. Limestone, shale and sandstones make principle lithologies of the sequence. The region exhibits complex structural features including small and large-scale folds and thrust faults. Two phases of deformation are recognized in the area. An earlier D1 phase that resulted in the development of a large thrust sheet (MBT), which was displaced southward and have resulted in the horizontal shortening and vertical thickening of the region. This thrust (MBT) brings Patala Formation (Paleocene) over the Kuldana Formation (Eocene). The D2 phase not only caused the folding of MIBT but also the rocks underlying the thrust sheet. The subsequent erosion to the D2 folding has exposed younger footwall lithologies in the core of antiforms forming window structures. An open synform between the two such antiformal window structures represents a klippe.

Key words: Structure, Main Boundary Thrust, Indus River, Nizampur.

F/4. Falconer, H., 1842. Cataclysm of Indus. *The Asiatic Journal*, New Series 38, 39.

Falconer has furnished some additional particulars of the grand cataclysm of the river Indus, in the early part of last year. It would appear that the river had been observed, during several months, to be unusually low, so that its deep bed at Attock was converted to an easy ford. All at once, the river burst in an awful debacle through the obstacles which had impeded its course higher up, and rushed down the valley in a mighty flood, sweeping villages and towns away, with thousands of human beings. The Cabul river, which joins the Indus, above the fort of Attock, had its waters held up, and forced back, so as to inundate the towns of Noushera and Akora, in the plains of Peshawur. In the Hazara country, the flood is said to have swept away artillery gum, with many hundred Sikh troops, and the authorities on the Indus report many bodies washed down of a "very foreign" appearance. Dr. Falconer has little doubt that it was occasioned by some un-usual barrier temporarily established in the bed of the river somewhere high up its course, damming up its waters till they attained a volume which overcame the obstruction. He is of

opinion, that the place must have been higher up than Ghilgeet, on the Noobra-tsoh river, or Shayook, above its junction with the Ladakh, or great branch. "During my stay at Iskardoh," he says, "I learnt from the Rajah Ahmed Shah, that great floods occasionally take place, at irregular intervals, in consequence of the Noobra-tsoh getting blocked up by avalanches and masses of ice. This river has one of its principal origins in a great lake, as yet unvisited by Europeans, in the KaraKorum mountains. After winter seasons of unusual severity, the lake gets sheeted over with an enormous mass of ice, and the valley of the river below the lake is liable to be filled up with great avalanches of ice and snow. When events of this kind go together, the disrupted masses of ice from the lake, added to the avalanches, go on accumulating till a huge barrier is formed, which dams up the river, leading to tremendous floods when the water bursts through the obstacle."

Key words: Floods, Indus, Nowshera, Kabul River.

F/5. Falconer, H., 1863/1864. Discussion of Godwin Austen's paper "Glaciers of the Mustagh Range". *Proceeding, Royal Geographical Society* 8, 38-42.

Key words: Glaciers, Mustagh Range

F/6. Falconer, H. 1868. Notes on fossil remains found in the Valley of the Indus below Attock, and at Jubbulpoor. In: Murchison, C. (ed.) *Palaeontological Memoirs and Notes of the late Hugh Falconer, vol. I. Fauna Antiqua Sivalensis*. Robert Hardwicke, London. 414–419.

Key words: Paleontology, Attock, Indus, Jubbulpoor.

F/7. Fantini S.N., 1965. Permian fossils of the upper Hunza Valley. In: Desio, A. (ed.) *Italian Expeditions to the Karakorum and Hindu Kush. Scientific Reports* 3(1), 135-148. Brill, Leiden.

Key words: Paleontology, Permian, Hunza valley.

F/8. Farah, A., 1976. Study of recent seismotectonics in Pakistan. Report of CENTO Working Group on Recent Tectonics, Istanbul.

Key words: Tectonics, seismology, Pakistan

F/9. Farah, A., Abbas, G., DeJong, K.A. & Lawrence, R.D., 1984. Evolution of the lithosphere in Pakistan. *Tectonophysics* 105, 207-227.

The geological setting of Pakistan in the framework of the modern concept of plate tectonics is unique in the sense that, within an area of about 800,000 km², critical tectonic junctions of different interacting plates and microplates are present in an environment where field exposures are excellent.

Here we discuss the dynamics of these various plate boundaries. Two types of active plate boundaries are conspicuous: (1) convergent boundaries characterized by continent-continent collision, obduction, and thrusting in the northern region of the Himalaya and by oceanic crust subduction with a volcanic arc and a wide accretionary wedge in the southern region of Chagai and Makran; (2) a transform boundary, the Chaman transform zone, characterized by very large strike-slip and lesser thrusting. The Chaman transform zone connects the Makran convergence zone, where oceanic lithosphere is being subducted beneath the Lut and Afghan microplates, with the Himalayan convergence zone, where the Indo-Pakistan lithosphere is underthrusting Eurasia. The Chaman zone is at present an intracontinental plate boundary with oblique motion, characterized by north-south strike-slip faults and eastward thrusting and folding in the Kirthar-Sulaiman mountain belt. This mountain belt, the northwestern margin of the Indo-Pak subcontinent, was an

Atlantic-type margin from the late Paleozoic until the Cretaceous. In the Cretaceous, the continental margin became a plate boundary; a thrust belt was formed in the Paleocene, and fragments of the oceanic crust were obducted, either as thrust sheets (Muslimbagh) or as an ophiolitic mélange (Bela and Waziristan).

Key words: Tectonics, Plate tectonics.

F/10. Farah, A. & DeJong, K.A. (eds.), 1979. Geodynamics of Pakistan. GSP, Quetta, 363p.

This is a compilation of 27 papers on, along with an introduction to, the geodynamics of Pakistan. Following introduction there is an account of speculative tectonic history of Pakistan and surroundings. The book covers various aspects of petrology, biostratigraphy, structure (including new tectonics) seismicity, gravity anomaly, paleomagnetism and metallogeny. Abstracts for the papers dealing directly with northern Pakistan are given elsewhere.

Key words: Geodynamics.

F/11. Farah, A., Lawrence, R. D. & DeJong, K.A., 1984. An overview of the tectonics of Pakistan. In: Haq, B.U. & Milliman, J.D. (Eds.), Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan. Von Nostrand Reinhold Co., New York, 161-176.

Key words: Tectonics, plate boundaries.

F/12. Farah, A. & Mirza, M.A., 1984. Recent crustal deformation and seismicity in Pakistan. Abstract, First Pakistan Geological Congress, Lahore, p.63.

Recent crustal deformation in Pakistan is expressively noticeable along expansive active faults some of which have been the sites of major earth-quakes. Geological features indicating recent movements, historical and instrumental record of earthquakes provide proof of accumulation of crustal strain and deformation causing seismogenic failure of geological material in the zone of 'active faults'. The 'active faults' in Pakistan, comprising large thrusts and strike slip faults splayed into several small fractures, are associated with the Plate Margins where accumulation of strain is taking place. This is happening as a result of the stresses applied by tectonic forces which stem from northward plate motion estimated to be 3-4 cm per year. Evidence are also available for intraplate deformation in the subsurface zones of weakness.

Key words: Tectonics, seismicity.

F/13. Farah, A., & Shah, S.H.A., 1976. Reflections on regional geology and geophysics: Data on the Karakorum Belt and of the buried shield in Punjab. Atti. Dei. Convegi. Lincei, 21, 145-158.

Key words: Tectonics, geophysics, Karakoram.

F/14. Faridi, M.A.F., Anjum, A.R. & Anjum, G., 1981. Algae associated with alluvial gold of Indus at Attock. Geological Bulletin, University of Peshawar 14, 151-157.

Soil algal flora from auiferous alluvials of the river Indus in the vicinity of Attock Fort were studied. In all 31 species belonging to 18 genera were found. The blue green genera were Aphanocapsa (1 sp.), Calothrix (1 sp.), Chroococcus (3 spp.), Gloeotheca (1 sp.), Lyngbya (1 sp.), Merismopedia (1 sp.), Nostoc (1 sp.), Oscillatoria (8 spp.), Phormidium (3 spp.), Stichosiphon (1 sp.) and Symploca (2 spp.). The Chlorophyceae found belong to 6 genera viz., Gloeocystis (1 sp.), Microspora (1 sp.) and Ulothrix (1 sp.). Xanthophyceae was represented by a single plant, Heterococcus. This is the first study of algae found in relation with gold and may help in gold prospecting.

Key words: Algae, gold, Indus.

F/15. Farn, A.E., 1964. Please test emeralds. *Journal of Gemology* 9, 223-234.

Key words: Gemology, emerald testing.

F/16. Farooq, A., Durrani, M. & Darvaish, M. 1982. Geology of the Sirban Hill area, District Abbottabad. M.Sc. Thesis. Peshawar University, 97p.

Key words: Tectonics, stratigraphy, plate boundaries.

F/17. Farooq, A., 1985-87. The geology and petrography of upper Havelli (District Bagh) & Balligran-Manjhoter (District Muzaffarabad) with special emphasis on Panjal volcanics. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 90p.

The project area covers 150 square miles (417 square kilometers) located in District Bagh and Muzaffarabad, Azad Kashmir. The work has involved geological mapping of the area on a scale of 1:25,000 and 1:15,000 respectively.

This thesis deals with the geology and petrography of the Panjal volcanics. The geological sequence of the area consists of sedimentary, volcanic and metamorphic rocks. The area is tectonically highly disturbed being involved in Himalayan orogeny. Lithologically metamorphic rocks present in the area are schists, slates, phyllites, quartzite and marble. The volcanic rocks have been metamorphosed upto green schist facies. The mineral assemblage in volcanics is plagioclase+chlorite+ epidote $\pm$ quartz $\pm$ calcite.

The volcanic rocks belong to two distinct ages. Dogra trap are of Precambrian age and occur within the Dogra slates. Mineralogical studies show these rocks to be Basaltic. The Panjal trap flows are basaltic to andesitic and of Upper Carboniferous age. The pyroclasts occur in association with Panjal trap flows. Petrographic analysis of Panjal volcanics, Agglomeratic slates, limestone and marble have been carried out. Petrogenesis of Panjal volcanics is interpreted. Field evidences and laboratory data reveals that the Panjal volcanics are of submarine origin.

Key words: Petrography, volcanics, Muzaffarabad, Azad Kashmir.

F/18. Farooq, M., 1983-85. Litho-structural studies of Bhirina-Fitni-Paniali and Haddo Bandi Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 162p.

There is a specific relationship between the geological structures, landforms and the climate. This relationship can be worked out by qualitative as well as quantitative analysis of the topographic map. The most commonly exposed lithologies in the project area are schists from chlorite to garnet grade, Susalgali granite gneiss, Mansehra granite, quartzites and hornfelses. The rocks of the project area have been classified into nine lithologic units for the sake of mapping purposes at a scale of 9.2 Cm. to a kilometer on 5.8 inch to a mile. The area is deformed by different deformation phases, among which three are recognized on mesoscopic as well as microscopic scale and area is characterized by heterogeneous deformation. The rocks have been folded isoclinally and later being refolded into open folds. The area lies in the zone of brittle deformation and show extensive fracturing instead of folding. Mesoscopic and microscopic deformational features are well developed in the area. The rocks exhibit effects of polymetamorphism. The thermal metamorphism is superimposed on the regional metamorphism.

Key words: Lithology, structure, Mansehra.

F/19. Farooq, M., 1996. Depositional environments and provenance study of the Warchha sandstone, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 75p.

The Warchha Sandstone, of Lower Permian age is present in the Salt and Trans Indus Ranges. Three stratigraphic sections selected for detail study included Warchha Gorge and Zaluch Nala in the Salt Range

and Saiduwali Nala in the Khisor Range. The six lithofacies recognized in the Warchha Sandstone are: 1. Trough cross bedded pebbly sandstone; 2. Pebbly Sandstone/ conglomerate, 3. Cross bedded sandstone, 4. clay/siltstone, 5. Massive sandstone, and 6. Faintly laminated sandstone lithofacies. It is suggested that the Warchha Sandstone is an alluvial fan deposit. The similarity of Warchha Sandstone with the underlying Tobra Formation (in clasts collected and lithology) points either to a common source rock for both formations or indicates reworking and incorporation of Tobra Formation into the Warchha Sandstone. In thin section study; according to QFL triangular diagrams after Folk (1954-1980), the rocks are classified as arkose, with relative abundance of quartz, feldspars ($K > P$) and lithic fragments. In the QFL provenance discrimination diagrams of Dickinson et al.; (1982, 1983) the point count data occupy the field of continental block provenance. It is suggested by paleoclimatic and paleotectonic characteristics, that the Warchha Sandstone provenance was the area of low relief, humid and semiarid climate with lack of vegetation.

Key words: Sedimentology, provenance, sandstone, Warchha.

F/20. Farooq, M.A., 1985-87. The Geology of Parrai-Dodahera Area, District Swat, NWFP. M.Sc. Thesis, Punjab University, Lahore, 76p.

The topic of this thesis is Geology of Parrai-Dodahera Area with special emphasis on Mineralogy and Petrology. The prescribed area lies in the lower Swat Region. The area consists of about 35 miles². It lies between latitudes 34° 11' 30" to 72° 15' 00" in toposheet No. 43 B/2.

The area was mapped by the party through foot traverses on eight times enlarged toposheet at the scale 1:50,000. Notes were taken on different units, their lithology and contact relationship, and geomorphology and also on social set up of the people. Details regarding the structure of the area, i.e., folds, faults, fractures, joints, foliation and lineation were taken. Stations were marked on the map. Samples were also collected. Photographs of geological and geomorphic features were also taken. Back in laboratory, petrographic study of thin section was carried out by microscope.

The project area is not very rich in economic minerals. No mine is present. However, the following rocks and minerals are of economic importance. These are marble, graphitic schist, graphite and garnet.

Key words: Petrology, structure, Swat.

F/21. Farooq, M.S., 1997. Geotechnical study of landslide problems along the Murree-Kohala-Muzaffarabad Road, Pakistan. Institute of Geology, Punjab University, Lahore, Ph.D. Thesis.

Key words: Landslides, Muzaffarabad.

F/22. Farooq, S., 2000. Landslide risk evaluation of a site near Gilgit. Abstracts, Third South Asia Geological Congress, Lahore, p.105.

Key words: Landslides, Gilgit.

F/23. Farooq, S.A. & Jabbar, M., 1985. Geology and petrography of a part of Ambela granitic complex Malandarai area, District Mardan. M.Sc. Thesis, University of Peshawar, 58p.

Area under discussion occupies the south western part of the Ambela granitic complex, it covers about 20 sq. km. area and exposes granite, alkali granite, Biotite granite, Quartz syenite, quartz, chlorite, Carbonate schist, quartz mica schist, Quartz chlorite schist and Epidote muscovite schist. The schistose rocks are belonging to the lower swat Buner schistose group in which the granitic rocks are Implaced on a huge plutonic mass. The rocks are mainly exposed as elongated masses with a general trend, Of NEE conforming the regional trend of the granitic pluton, petrographic studies and field investigation reveals

that it is an alkaline complex and intruded as a large granitic pluton in the Pleistocene unit of the Indian Plate.

Key words: Petrography, petrology, granite, Buner.

F/24. Farshori, M.Z., 1967. Petrographic study of Siwalik sediments in Sihala area near Rawalpindi. Sind University, Science Research Journal 11, 1-11.

Key words: Petrography, Siwaliks, sediments, Rawalpindi.

F/25. Farshori, M.Z., 1968. Decade of mineral development. In: "Pakistan during the decade" (1958-68). Sind University, Special Publication, 75-81.

Key words: Mineral development.

F/26. Farshori, M.Z. & Baig, A.A., 1970. Geological bibliography of the Salt Range, Sulaiman Range, Potwar and Hazara areas. Department of Geology, University of Sind, Jamshoro, 40p.

This is a comprehensive bibliography of both published and unpublished reports. There is an introduction and a list of abbreviations, but no index.

Key words: Bibliography, Salt Range, Sulaiman Range, Potwar, Hazara.

F/27. Farukh, T.M., 1997-99. Geotechnical studies and geological mapping of left saddle embankment of Khanpur Dam Project Area. M.Sc. Thesis, Punjab University, Lahore, 90p.

The project area comprises of Khanpur Dam, its area around reservoir and some area of Haripur- Taxila Road near New Khanpur Town. There are three major aspects of the project work, first to do the geological mapping of the project area, to study the different problems of the dam, and third to perform different tests in detail on the material of the site to assess the properties and utility of these materials in connection with the construction of the dam.

HISTORY OF THE PROJECT

The idea of the dam was based originally, on the development of irrigation. The feasibility studies were undertaken in 1959-60 and an authentic feasibility report was submitted in 1962. After the careful investigation of expert and authorities, the project was started in 1963. The scheduled date of completion of the project was 1973. But the project work was stopped for long due to financial and certain political problems. Ultimately the F.W.O. was called to complete the project as a challenge within a period of one year and F.W.O. completed the project successfully in July 1983 and is onward construction that was completed in 1985.

PURPOSE OF PROJECT

Basically it was planned to construct 137 feet high earthen dam with a reservoir of 5,900-acre feet for irrigation purposes. But later on to meet the needs of municipal and industrial use of Islamabad and heavy engineering complex Taxila, the height of the dam was increased to 167 feet with a reservoir of 1,06,000-acre feet.

LOCATION

Khanpur dam is located on Haro River, about 1 Km South of old Khanpur Town, where the river flows through a comparatively narrow gorge. The site falls on; a topographic sheet No.43 C/13 of geological survey of Pakistan at coordinates 33degree 48.5' latitude and 72.56 longitudes. The altitude at the dam site ranges from 1830ft to 4450 ft. above sea level. It is very hot in summer, but very pleasant in winter.

Key words: Geotechnical studies, geological mapping, Khanpur Dam.

F/28. Faruqi, F.A., 1967. Properties of glass making sands of Pakistan. Pakistan Journal of Scientific and Industrial Research 5, p.335.

Key words: Glass, sand, Salt Range, Sulaiman Range, Potwar, Hazara.

F/29. Faruqi, F.A., Aslam, M. & Ayub, M., 1966. An investigation of beneficiation of glass sand from Hazara and Sylhet Districts. Pakistan Journal of Scientific and Industrial Research 9, 217-224.

Key words: Glass, Sand, Hazara, Sylhet.

F/30. Faruqi, F.A., Aslam, M. & Ayub, M., 1967. Mineralogy of the Swat kaolinite. Pakistan Journal of Scientific and Industrial Research 10, 58-67.

Fifty one samples of the raw and the beneficiated Swat Kaolinite have been analysed. Two representative samples of the raw and the washed kaolinite have been prepared from 79 samples received and their DTA and X-ray studies made. On the basis of the data obtained, the mineralogy of the deposit and that of the treated kaolinite has been ascertained. X-ray studies indicate that the mineral kaolinite in the raw samples is between 15 to 20%, whereas in the washed samples it is between 45 to 50%.

Key words: Mineralogy, kaolinite, Swat.

F/31. Faruqi, F.A., Beg, M.A., Yusuf, M. & Ayub, M., 1969. Ceramic colours, Part II.- Pink Stains. Pakistan Journal of Scientific and Industrial Research 12, 67-68.

The formation and application of chrome-alumina and chrome-tin pinks were studied. Various compositions were calcined at different temperatures from 1150' to 1350°C. The stains developing good colour were selected and tested in different glaze compositions. Some commercially exploitable stains along with suitable glazes were developed.

Key words: Ceramic colors.

F/32. Faruqi, F.A., Chohan, N.A. & Ashraf, M., 1968. Mineralogy and ceramic properties of West Pakistan feldspars. Pakistan Journal of Scientific and Industrial Research 11, 325-329.

Feldspar samples collected in Hazara District were studied for mineralogical classification and ceramic utility. Specific gravity, chemical composition, IR spectrum, softening temperature, colour of the softened products, thermal expansion and petrography were investigated. Most of the feldspars could be used in the glass and ceramics industries.

Key words: Mineralogy, ceramic, feldspar.

F/33. Faruqi, F.A., Din, A. & Sindhu, S., 1968. Purification of Dera Pezu sands for making colourless and optical glasses. Pakistan Journal of Scientific and Industrial Research 14, p.63.

Key words: Sand, glass, Pezu.

F/34. Faruqi, F.A. & Haq, A., 1962. Properties of some Pakistani bentonites. CENTO Symposium on Industrial Rocks and Minerals, Lahore, 161-165.

Key words: Bentonites.

F/35. Faruqi, F.A. & Qureshi, H., 1965?. Mineralogy of the Ahl kaolinite. Pakistan Journal of Scientific and Industrial Research 17? p.4.

Key words: Mineralogy, kaolinite, Ahl.

F/36. Faruqi, F.A., Safdar, M., Haque, A., Ahmad, M. & Aslam, M., 1970a?. Ceramic properties of Swat clay. Part 1. Physical characteristics. Pakistan Journal of Scientific and Industrial Research 12 (4)?, 66-73.

Key words: Ceramic, clay, Swat.

F/37. Faruqi, F.A. Safdar, M., Haque, A., Ahmad, M. & Aslam, M., 1970b?. Ceramic properties of Swat clay. Part 2. Chemical characteristics. Pakistan Journal of Scientific and Industrial Research 12?, 74-78.

Key words: Ceramic, clay, Swat.

F/38. Faruqi, S.H., 1965a. Report on the Limestone and Dolomite Resources of Surghar Range and Adjoining area, for WPIDC's proposed Kalabagh Steel Mill.

Sizable deposits of workable grades of limestone and dolomite occur in Surghar Range. A total tonnage of 966 million of quarryable reserves of medium and good quality limestone occurring at four different localities has been proved in Chichali, Kalabagh, and Mari – Indus areas. While 921 million tons of quarryable reserves of good to average quality dolomite scattered over three localities, have been established in Gullakhel area (about 15 miles NWW of Jalalpur).

Abundant and cheap labour is available at the localities concerned and the deposits are connected through unmetalled / metalled roads with the chief towns of the area.

Key words: Limestone, dolomite, Surghar Range.

F/39. Faruqi, S.H., 1965b. Report on the Chichali Iron Ore Deposits and their Development.

The total proved and probable iron ore reserves of the workable grade of Chichali area are of the order of 165.5 million tons and 136.5 million tons respectively.

The deposits may be developed by three developmental tunnels namely the "Chapri low – level tunnel", the Muhabbat Khel low level tunnel" and the Muhabbat Khel high – level tunnel". The said tunnels would have to be driven for 5,892 feet, 10,385 feet and 857 feet respectively, to tap the main ore belt. It would be advisable to develop the south limb iron ore deposits, which have not been worked or explored so far, through a connecting drift in between the two low level tunnels. Precautions are to be taken against possible outcome of gas while tunneling the Makerwal stage, Lumshiwal beds and the lower part of Baroch beds.

Key words: Iron ore, Chichali, Lamshiwal.

F/40. Faruqi, S.H., 1966a. Report on the Fireclay Deposits for Kalabagh Steel Mill.

Sizable deposits of the workable grade of Fire Clay occur in Gullakhel, Musakhel and elsewhere in the 'Surghar – Range' and Salt Range at accessible localities. Any one or two of the four proposed deposits may meet the entire requirements of the steel mill for several decades.

Key words: Fireclay, Surghar Range.

F/41. Faruqi, S.H., 1966b. Report on the Sand Deposits for WPIDC's Kalabagh Steel Mill.

The sand horizon occurs as a continuous belt beyond Datta area in both sides along strike and the total reserves actually go to the 'unlimited' extent. However, as a possible source of sand for steel mill, only the triangular area in between the two main tributaries of Datta nala would be considered. This block is exposed from three sides and a considerable portion of the same may be worked open cast.

Key words: Sand, Datta.

F/42. Faruqi, S.H., 1968a. Supplementary Report on Chichali Iron Ore Deposits. Part-1. A critical report on M/S Krupp's Project report on Kalabagh Steel Mill.

Key words: Iron ore, Chichali, Lamshiwal.

F/43. Faruqi, S.H., 1968b. Supplementary Report on Chichali Iron Ore Deposits. Part-2. A critical report on M/S Krupp's Project report on Kalabagh Steel Mill.

Key words: Iron ore, Chichali, Lamshiwal.

F/44. Faruqi, S.H., 1969. Report on Graphite Deposits of Azad Kashmir and their development.

Azad Kashmir has been bestowed sizable deposits of the workable grade of amorphous (cryptocrystalline) and dense phanerocrystalline graphites. The amorphous type is, in general, pure enough to be marketed in as mined state while there are good prospects of concentrating the various phanerocrystalline graphites through the conventional methods of crushing, screening and flotation, on commercial scale. The deposits are comparable, in quite a few respects, to some of the commercial deposits of the world e. g. of Korea, the United States of America and at least some of Russia.

In view of the handsome amounts of foreign exchange involved in the import of graphite and graphite products, it is imperative to appoint some leading graphitic processing and marketing agency as WPIDC's consultants for feasibility studies of Azad Kashmir deposits, with the least possible delay.

Key words: Graphite, Azad Kashmir.

F/45. Faruqi, S.H., 1970a. Graphite Deposits of Azad Kashmir and their Development. National Seminar on Mineral Development, Lahore.

Key words: Graphite, Azad Kashmir.

F/46. Faruqi, S.H., 1970b. Report on Mica Deposits of Gummot – Saral area, Azad Kashmir.

Key words: Mica, Azad Kashmir.

F/47. Faruqi, S.H., 1970c. Report on China Clay Occurrences of Henzal Area Gilgit Agency. Azad Kashmir.

Key words: China clay, Azad Kashmir.

F/48. Faruqi, S.H., 1970d. Utilization of certain indigenous iron ores with local resources. Symposium on Development with Local Resources, Lahore.

Key words: Iron ore, Azad Kashmir.

F/49. Faruqi, S.H., 1970e. Pyrite Deposits of Reshian Azad Kashmir. National Seminar on Mineral Development, Lahore.

Key words: Pyrite, Azad Kashmir.

F/50. Faruqi, S.H., 1970f. Discovery of Limonite Deposits in Reshian Azad Kashmir (urdu article). 12th Science Conference, Lyallpur.

Key words: Limestone, Azad Kashmir.

F/51. Faruqi, S.H., 1972a. "Kalabagh Iron Ore Deposits and their utilization". 13th Science Conference, Karachi.

Key words: Iron ore, Azad Kashmir.

F/52. Faruqi, S.H., 1972b. "Problem of the Establishment of Steel Industry in Pakistan and Local resources. 13th Science Conference, Karachi.

Consult the following account for further details.

Key words: Steel, Indigenous resource.

F/53. Faruqi, S.H., 1972c. Pakistan Steel Mill Problem and its Solution. Proceedings of "First National Seminar on Metallurgy" at the Engineering University Lahore pages 43 - 49.

The main or basic part of the iron and steel industry is the separation of iron from its ore. There are several processes in use to achieve this purpose. Amongst these, under normal conditions, the easiest cheapest and much preferred one is the 'Blast Furnace Process'. If the ore is good enough to be directly charged into the blast furnace it is well and good. But in case, on account of the low grade (low iron high impurities) of ore, it may not be possible then the ore is first upgraded. For blast furnace use the ore should contain at least 35-40% iron with a reasonable amount and balance of other constituents present. It is also necessary that the ore should be in lump form and not as small grains or powder. But in most of the upgrading processes powder or small size results. As such, before charging the upgraded ore (the concentrate) in to the furnace, it is pelletised, briquetted or sintered. Some iron ores, on account of their mineralogical set up do not smelt as such in the blast furnace but they may behave very well in the furnace when converted into sinter. Our Kalabagh iron ore belongs to this type. It is why sintering process has been selected for the proposed Kalabagh Steel Mill.

Key words: Steel mill, Indigenous resource.

F/54. Faruqi, S.H., 1973. Report on the Pezu Iron Ore Deposits of Bannu, Northwest Frontier Province.

The results of a field and laboratory investigations conducted so far on Pezu Iron Ore Deposits are very encouraging and it may be safely reckoned that these deposits would play an important role in the economy of North – West Frontier Province if proper attention is paid to their development. From mining point of view at least, these deposits stand as the best iron ore deposits of the country.

Chemical and mineralogical studies of a number of representative samples collected from surface and underground workings indicate that this ore has a favorable composition from smelting point of view.

Average Iron contents of the ore are 31.3% silica constitutes about 19.8 %, calcium oxide 4.8 % and magnesium oxide 3.6 %. The ore is basically of limonitic-sideritic type. About 68.9 % of the total iron present is in the form of limonite (hydrated iron oxide) and about 27.8 % is in the form of siderite (iron carbonate), the remaining 3.2 % is owed by glauconite (hydrous silicate of iron and potassium with aluminium and magnesium)

With an ore bed thickness of about 16 feet, outcrop extent of about 2 miles and the fact that both ends of the outcrop are structural end rather depositional, the deposits show good prospects of substantial ore reserves capable of supporting a mini steel mill.

Key words: Iron ore, Pezu, Bannu.

F/55. Faruqi, S.H., 1977. Evaluating Rich Ruby Deposits in Northern Pakistan. "World Mining", California U.S.A.

Key words: Gemstones, ruby, North Pakistan

F/56. Faruqi, S.H., 1978a. Find Report Hunza Ruby Project.

Nature has bestowed Hunza, like its scenic beauty, with an immense wealth of gemstones, both precious and semi-precious. With a thickness or breadth of 7000 to 10,000 feet, the Hunza Ruby Belt which mainly consists of a coarse crystalline richly mineralized marble criss crossed by acid dykes, extends for about 15 accessible miles in strike.

While the Hunza rubies of selected localities compare with or excel in colour and size their counterparts from any source of the world, they lag behind in flawlessness and transparency especially when it comes to bigger size and darker shades.

During the exploratory operations spread over 4.5 years, 1,17,670.695 carats (according to Project's weightment) of rubies, sapphires and ruby spinels were produced. This is in addition to hundreds of thousands of carats illegally extracted by the local people during pre – project period which found their way to the Pakistani and foreign gemstone markets bringing in turn good prosperity to some of the families of Hunza.

Unfortunately no worth considering portion of the rubies recovered during the exploratory operations has been cut or marketed in an open market till the completion of this report due reasons beyond the control of Project's staff. As such nothing can be commented safely regarding the feasibility of the Project.

However the sporadic valuation attempts made in the past of some of the rough and cut stones by some of the foreign and local experts have given quite encouraging results except of course the hurried valuation of the rough stones by the values of the State Gem Corporation of Sri Lanka in April 78 at Peshawar, which gives a rather gloomy picture of the feasibility of the Project.

Key words: Gemstones, ruby, North Pakistan

F/57. Faruqi, S.H., 1978b. Origin of Hunza rubies and nature of the deposits. National Seminar on Development of Mineral Resources, Lahore, 19-31.

The nature of Hunza rubies and their relation to the surrounding geologic environment suggest a hydrothermal origin instead of generally considered regional metamorphic one.

With thickness of 7000 to 10,000 feet, the Hunza Ruby Belt, which mainly consists of a coarse crystalline richly mineralised marble crisscrossed by acidic dykes, extends for about 15 accessible miles in strike.

While the Hunza rubies of selected localities compare well or excell in colour and size their counterparts from any other source of the world, they lag behind in flwlessness and transparency, specially when it comes to bigger size and darker shades.

Key words: Gemstones, ruby, North Pakistan

F/58. Faruqi, S.H., 1983a. Hunza ruby deposit and their genesis. 2nd National Seminar on the Development of Mineral Resources, Peshawar, 1.

Consult the preceding two accounts for further information.

Key words: Gemstones, ruby, genesis, North Pakistan

F/59. Faruqi, S.H., 1983b. Malakand chromite deposits. 2nd National Seminar on Development of Mineral Resources, Peshawar, 1, 5p.

Malakand chromite deposits have been discussed in this paper indicating their occurrences, reserves and grades. The involvement of the PMDC for the exploration and exploitation of these deposits and the beneficiation test work carried out at the PCSIR have also been described.

Key words: Chromite, Malakand.

F/60. Faruqi, S.H., 1983c. Nature and origin of the salt deposits of Pakistan. 2nd National Seminar on Development of Mineral Resources, Peshawar, 1, 18p.

Recent detailed geological investigations for salt in the Salt – Range and Kohat district have given an entirely new picture of the nature and origin of Pakistani salt deposits.

Identification of typical diapiric structures including salt walls salt dykes and “salt flows” over the denuded surfaces of younger formations clearly suggests a diapiric mode of occurrence as against the presently accepted bedded or in situ one.

Prospects of fresh reserves of salt and oil and techniques / approaches for their exploration and exploitation may have to be reoriented in view of the new picture.

Key words: Salt deposits.

F/61. Faruqi, S.H., 1983d. Special features of the geology of Makerwal coal fields. 2nd National Seminar on Development of Mineral Resources, Peshawar, 1, 4p.

Special features of Makerwal’s geology are: 1) A low angle thrust undercutting the entire or most of the Surghar – Range placing the Mesozoic and early Tertiary sequence together in a basin of the younger Siwaliks 2) Structural control of the thickness of Makerwal coal seam and 3) Shale diapirism displayed by the Patala Formation.

In view of the expected disturbances in the deeper workings of the left – over coal areas, future of Makerwal Collieries would depend on a very careful study of the prevailing geological conditions, prudent planning patient development work.

Key words: Coal fields, structure, Makerwal.

F/62. Faruqi, S.H., 1984a. The Salgi oil sand. Abstracts, First Geological Congress, Lahore, 21-22.

Key words: Oil, Sand, Salgi.

F/63. Faruqi, S.H., 1984b. Azad Kashmir ruby deposits. Abstracts, First Pakistan Geological Congress, Lahore, p.24.

Located at a road distance of 112 miles NE of Muzaffarabad in the Shontar valley, these newly discovered ruby deposits excel in some respects, when compared to the already known and worked Hunza deposits. However, both gem stone deposits appear to be analogous in age and genesis belonging to the same Darkot Group (Permo-Carboniferous) and of hydrothermal origin.

Since mother marble is well mineralized and extensively developed in the Shontar and adjoining valleys, there are good prospects of locating additional and richer gem stone deposits through intensive exploration.

Key words: Gemstone, ruby, Azad Kashmir.

F/64. Faruqi, S.H., 1984c. Structural similarities between Salt Range and Kohat salt area. First Pakistan Geological Congress, Lahore, p.28.

Structures at the eastern and western extremities of the Salt Range have been found to be surprisingly similar in detail to those at the Kohat Salt area in general, suggesting that these area have identical diapiric and tectonic histories, various evidence are presented in support.

Key words: Structure, Salt Range, Kohat,

F/65. Faruqi, S.H., 1984d. The heterogeneous “Jatta Gypsum” horizon of Kohat. Abstracts, First Pakistan Geological Congress, Lahore, 34-35.

Field investigation in the Kohat salt area have shown that the so called ‘Jatta Gypsum’ horizon of reportedly Eocene in age actually consist of bodies of gypsum-anhydrite and marl etc. it belongs to four different horizons, ranging in age from Recent to Precambrian (?). Detail of the rocks and subdivision are given.

Key words: Stratigraphy, Jatta Gypsum, Eocene, Kohat

F/66. Faruqi, S.H., 1986. Precambrian Oil in the Salt Range and Potwar Pakistan. Published in vol. 4 Kashmir Journal of Geology

Precambrian rocks, both sedimentary and non-sedimentary types, hold good promise of commercial resources of oil/gas in Pakistan.

Field evidences indicate important relationship between intrusive Khewra Trap and oil / gas shows of the Salt Range Formation (Precambrian). Future development of Precambrian hydrocarbons would, to a considerable extent, depend on the correct understanding of this relationship.

In addition to the conventional structures within immediately overlying reservoir rocks and the internal structures of carbonate zones within Salt Range Formation, there are quite good prospects of Precambrian basement reservoirs in all regions of Salt Range Formation and basement, at workable depths.

Key words: Petroleum resources, Khewra trap, Salt Range formation, Precambrian.

F/67. Faruqi, S.H., 1988. Brief Report on Recent Finds of Precious Metals in Pakistan.

Precious metals (gold, silver and platinum group elements) bearing rock types have been discovered at a number of localities under promising geological environments in Baluchistan, Gilgit, Azad Kashmir, Chitral, Hazara, Waziristan and Punjab.

Comprehensive geological investigations have been recommended at the concerned localities as well as in all regions of similar geology to assess actual potential of precious metals of the country. Side by side, beneficiation and processing tests have been proposed to be undertaken in and outside Pakistan at suitable laboratories on bulk samples to establish commercial processing and exploitation of these deposits.

Immediate drafting and promulgation of incentiveful mineral concession rules, in respect of precious metals, has been strongly recommended in order to attract local and foreign capital and know – how in this relatively new but highly important industrial field.

It has been suggested to commission suitable consultants of international repute to explore various promising precious metal regions of the country with the assistance of local geologists so that the nation could have a realistic assessment of what it has, in a reasonable period of time.

Key words: Precious metals, Gilgit, Hunza, Chitral, Baluchistan.

F/68. Faruqi, S.H., 1989a. Exploration of Precious Metals by PMDC. Seminar on Prospects and Problems of Minerals Based Industries in Pakistan, Peshawar.

PMDC's exploration department has been able to locate some interesting precious metals bearing rocks in different parts of the country. Main areas as per current knowledge are: Gilgit region in the north and the Volcanic Belt of Chagai District (Baluchistan) in the west.

PCSIR Laboratories, Lahore have already evolved, after necessary experimentation, a flow sheet for concentration of at least the precious metals bearing Chilghazi cupriferous magnetite of Baluchistan. Values of copper, platinum, gold and silver in the final flotation concentrate of PCSIR are 22%, 21.8 gms / ton, 5.3 gms / ton and 45.8 gms / ton respectively.

It is unfortunate that no mineral concession rules have as yet been promulgated in the country in respect of precious metals. This is considered necessary if we want any meaningful mineral development.

It is suggested that all prospective mineral deposits in Pakistan should be made open for the public, both local and foreign. This is considered necessary if we want any meaningful mineral development in the country.

Key words: Precious metals, Gilgit, Baluchistan.

F/69. Faruqi, S.H., 1989b. Rock Salt – The Most Potential Mineral Resource of Pakistan. Seminar on Prospects and Problems of Minerals Based Industries in Pakistan, Peshawar.

Key words: Mineral resources.

F/70. Faruqi, S.H., 1990a. Kalabagh iron ore deposits and there economic importance. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.9.

The Kalabagh iron ore deposits could play an important role in the economy Pakistan if they are duly exploited by the establishment of an integrated iron and steel project on the same.

The iron ore deposits are ideally located in respect of the co- occurrence of most other raw materials of the steel industry and in respect of the infrastructure facilities. The deposits are also suitably located with reference to the local markets of their steel mill's finished products.

It would therefore be in the fitness of things to revive the hitherto cold storage 'Kalabagh Steel Mill' and establish it with the least possible delay to initially meet the gap between the current production of the Karachi Steel Mill and the country's actual iron and steel requirements.

Key words: Iron ore, Kalabagh.

F/71. Faruqi, S.H., 1990b. The Kalabagh Dam Site: A critical study. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.14.

The Kalabagh Dam, if constructed at its proposed site, will be unique in the sense that it would be the first dam of its kind and size to have been located on the rim syncline of a salt dome.

Since the massive and still active 'Kalabagh salt dome' is chiefly being fed from the east by the area which is supposed to support the proposed Kalabagh dam and its vast water reservoir, it is feared that additional weight of that magnitude might disturb the present balance of salt extrusion and erosion and might in addition generate enough seismicity to destroy or seriously damage the colossal Kalabagh dam. Accelerated part- subsidence at dam site, simply due to the extra-weight at a particular locality aided of course by the reactivation of the already existing subsidence-fault at and close to the dame site, will be the other and equally important factors to play hell with the safety of the dam.

Prevailing geologic conditions in the Salt Range and the adjoining Kohat salt area suggest that no dam of such magnitude should be thought of in Kalabagh area upto roughly the confluence of Kohat Toi and the Indus located about 33 miles north-east of Kalabagh.

Key words: Damsite, Kalabagh.

F/72. Faruqi, S.H., 1990c. Carbonatite status in Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 27-28.

So far, according to the available geologic literature, carbonatite is known to occur in Pakistan only at four different localities which are linked together to form the so called 'Alkaline Province Pakistan'. This 'Province' is considered to extend arcuately around Peshawar from Warsak area in the west, Malakand in the north up to Tarbela dam in the east. The carbonatite localities are: Loe Shilman (64 Km NW of Peshawar), Malakand, Koga (S. Swat) and Tarbela. Of the four occurrences, Loe Shilman and Malakand are worth considering, the other two are too limited and only of secondary interest. Malakand has no associated alkaline igneous rocks except of course the carbonatite themselves.

Recent studies by the author indicate that the carbonatite situation in Pakistan may be very different as these rocks seem to be of quite widespread occurrence in Azad Kashmir, Northern Areas and possibly also in the Volcanic Belt of Chaghai district of Baluchistan.

Field and Lab evidences, though not decisive, indicate that a number of carbonate bodies or masses in northern Azad Kashmir and Gilgit, etc. which have so far been treated as marbles, calcareous schists or xenoliths of calcareous country rocks within the intrusives, could actually be carbonatites. Brief account is given of three such carbonatite (?) occurrences in Shardi-Doarian region of Azad Kashmir and Bagrot and Henzal areas of Gilgit.

There are grounds to suspect that the onyx marble (travertine) of Chaghai Baluchistan is mothered by burned carbonatite mass thus possibly establishing its analogy with the travertine bodies of the Arkansas River valley in Colorado (USA), which are also believed to owe their origin to the nearby occurring McClure Mountain Carbonatite Complex.

Key words: Carbonatite, Malakand, Loe Shilman.

F/73. Faruqi, S. H., 1990d. Export-Oriented Development of the Rock Salt Deposits of Pakistan. First SEGMITE Conference on Industrial Minerals, Peshawar.

Nature has bestowed upon Pakistan an inexhaustible wealth of high grade rock salt deposits in the Punjab and Frontier provinces. These deposits generally occur at and above normal ground level thus rendering themselves workable through cheap surface as well as sub - surface mining methods.

Rock salt alone may have favorable impact on the economy of this country provided we accept the dictates of nature and exploit these deposits to the optimum extent at competitive rates using modern methods of mining and processing.

There are bright prospects of the export of rock salt and its products by Pakistan to the international market including Japan which is the giant importer of salt and its chemicals in Asia.

Kalabagh Warcha and Makerwal salt deposits in the Salt Range (Punjab) and the Bahadurkhel deposits of Kohat / Karak salt area (Frontier Province) show brighter prospects of cheap large scale production.

Key words: Salt deposits, Bahadurkhel.

F/74. Faruqi, S.H., 1990e. Dolomite resources of Surghar and Salt Ranges. Proceedings, First SEGMITE Conference on Industrial Minerals, Peshawar, 29-33.

Inexhaustible deposits of industrial grade dolomite occur in the Northern Surghar Range and the Western Salt Range. The available dolomite belongs to three different stratigraphic horizons namely: the Salt Range Formation (Precambrian), the Jutana Dolomite Formation (Cambrian) and the Kingriali Dolomite Formation (Triassic).

Precambrian horizons are of academic and/or of 'Petroleum Geologists' interest only. Cambrian horizon though extensive but lacks desired purities. Triassic horizon (Kingriali) affords inexhaustible quarryable reserves of industrial grade (both chemical and metallurgical) dolomites both in the Surghar Range and Salt Range. Geology and chemistry of the deposit has been discussed with detailed field and laboratory data.

Key words: Dolomite, Surghar, Salt range, Precambrian, Cambrian, Triassic.

F/75. Faruqi, S.H., 1994. The unique Hunza ruby and sapphire belt. Proceedings, Second SEGMITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, p.44.

Rubies and Sapphires occur in association with ruby spinels in a coarsely crystalline marble formation with an apparent thickness of 2134 to 3050 meters and strike extent of more than 24 km. The marble is heavily criss crossed by dykes and sills of intrusive igneous rocks: aplite, granite and pegmatite as well as quartz veins.

Mineralization of ruby/sapphire and spinel apparently owes its origin to the intrusives and is considered to be a direct product of their mineralizing solutions acting along suitably positioned and favourably compositioned bedding planes, fissures, fractures and joints of host marble.

The colour of ruby/sapphire is in general, appealing and has a wide range of pink, purple violet to typical pigeon blood red. Transparency is also tolerable but the calcite partitioning, grooving and the general fractured nature of stones are the main drawbacks. However, the area yields the finest quality specimens of ruby, sapphire and spinel with enhanced beauty by the associated ruby mica, green mica (fuchsite) and graphite alongwith golden crystals of the fool's gold (pyrite).

The nature and origin of Hunza rubies is strikingly similar to those of the famous Mogok Ruby Belt of Burma (Myanmar) which has supplied the best rubies to the world for the last 700 years. Potential of the area is great and inexhaustible; systematic exploratory efforts at Hunza may be well rewarded. The exploratory efforts undertaken by PMDC and GEMCP have so far been restricted to simply mining the more accessible areas in crude and haphazard way.

Key words: Gemstone, ruby, sapphire, Hunza.

F/76. Faruqi, S.H., 1996. Granites of Pakistan. Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, 35-43.

Nagarparkar in south (Sindh) and Mansehra in the north (NWFP) so far were the only source of granites of the country. But recent investigations by Eastern Technique for commercial granites in the Northern Area of Pakistan, specially the Gilgit region, have indicated great potential of variety, quality and quantity. The Karakoram Highway (KKH) with its much relaxed and relatively cheap downhill carriage has eased the transport situation greatly despite a fairly long lead of about 600 km from Islamabad. The unique white, jet black, a variety of shades and textures in white – grey and greenish types along with some of the typical greens bestow superiority to Gilgit granites over all other parts of Pakistan under the present state of geological knowledge.

Key words: Granites, mineral resources, KKH, Nagarparkar, Mansehra.

F/77. Faruqi, S.H., 1997a. The unique graphite glacier of Chapursan valley, Gilgit. In: Abstract volume Colloquium on Geology and the Human Life. Pakistan Academy of Geological Sciences, 29-30.

Key words: Glaciers, Chapursan.

F/78. Faruqi, S.H., 1997b. Nature and origin of Salajit. Colloquium on Geology and the Human Life. Pakistan Academy of Geological Sciences, 30-32.

Recent field and laboratory investigations for salajit collection and study of its complete and intact natural bodies along with host rocks have resulted in entirely new concepts regarding the nature and origin of this unique rock product of great medicinal value. Its often claimed origin as: 1) a member of petroleum family (asphalt) 2) latex of some nearby Plants, 3) an alteration product of entombed ancient vegetative material (fossil wood), 4) accumulated dropping of a mountain bird or 5) the urine residue of a rare mountain animal etc. may all be safely discarded on logical and scientific bases. There are quite appealing grounds to suggest the recent coniferous forests growing on hard and fractured igneous rocks and possibly also the mineral biotite $[K(MgFe)_3 AlSi_3O_{10} (OH)_2]$ and orthoclase feldspar $(KAlSi_3O_8)$ are responsible for the development of salajit. Schistose biotite granite, occurring along lines of major structural disturbances in the Himalayas specially around the peripheries of large intrusive masses of igneous rocks, is the most

favoured host rock, while very steep, vertical to over-hanging bare rock cliffs at high altitudes but still below or adjacent to the coniferous forests, are the most favoured sites of salajit occurrences in Gilgit region which is the largest producer of salajit in Pakistan.

It appears from the prevailing conditions that basically salajit is a bacteria-altered product of accumulated plant material. Possibly it develops at most of the coniferous forests of Northern Areas and elsewhere but comes out as seepages only under favourable conditions of rock and topography. In a hard and fractured or well-jointed but more or less non-porous rock like biotite granite it starts moving downwards along fracture/joint planes due to gravity and comes out at the surface as a seepage on encountering some opening which is invariably provided by some abrupt natural cutting. On the other hand, in porous sedimentary rocks or unfractured and inconspicuously jointed non-porous sedimentary and igneous rocks the salajit fluid is either completely absorbed by the underlying rock or is trapped down localised at or near the site of its origin thus disallowing any salajit seepage to occur. Absence of a steep cutting adjacently below the mother forest will also result in the absence of a salajit seepage despite a suitable host rock.

The slow moving thick acidic salajit fluid along with the still undigested plant material in the form of the fibrous woody pallets etc. and of course with out army of bacteria, apparently attacks the biotite and orthoclase feldspar of the biotite granite and partly dissolves and carries the same on its way downwards and laterally.

Key words: Salajit, Gilgit, Northern areas.

F/79. Faruqi, S.H., 1997c. The graphitized coal deposits of Chapursan valley, upper Hunza valley. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A number of characteristics, partially graphitised coal seams have been found to occur in a thick formation of brown weathered, grey-black, thick bedded, hard and compact carbonaceous limestone of possibly Permian age in the Reshit area of Chapursan valley north of Gilgit. The vertically trending coal seams are variable in thickness over short distances apparently due to lateral stresses but are persistent for several kilometers in strike at both flanks of Reshit Nala. Normal range of thickness is from a few inches to 25 feet. At places, specially at the thicker coal/graphite seams, the amorphous to flaky "secondary" graphite has been found to show tendency of migration to relatively low stress areas and give rise to graphite pockets of considerable sizes. At least at one locality ejection of graphite has apparently taken place from a graphite bed consisting of partially graphitised coal with alternating bands of carbonaceous limestone. This ejection of graphite, apparently from some of the rich graphite pockets of the otherwise lean graphite bed, has given rise to a 'graphite glacier' a unique object in the geological realm of the earth. The said graphite glacier maintains a length of about 500 feet and a breadth of 15 to 50 feet. However it seems to be the result of apparently a one-time migration phenomenon rather a still continuous process.

Key words: Coal deposits, Chapursan valley, Hunza.

F/80. Faruqi, S.H., 2000. Feasibility Report Henzal White Granite, Gilgit. A joint report of ETL, GMC and ENFI China, prepared for Zaver Mining Co. Pvt Ltd Islamabad.

So far Nagar Parkar in the south (Sindh) and Mansehra in the north (NWFP) were known to be the only sources of workable granites in Pakistan. But the recent investigations by Eastern Technique for Zaver Mining in Gilgit have resulted in the discovery of a number of workable granite deposits at accessible localities and with inexhaustible reserves. Of these the Farphui's Black Granite deposit of Bagrot Valley occurring at a road distance of 37 km NE of Gilgit and the unique White Granite Deposits of Henzal Area located 20 km NW of Gilgit are most outstanding and promise to fetch good local and foreign markets. The Basin's massive grey granite deposits occurring under ideal conditions of working next door to Gilgit to the west show promise of being able to snatch a considerable part of the existing vast market of marble in Pakistan by making available abundant and cheap granite to the masses.

Two schemes of underground mining and open pit quarrying are recommended in this report:-

Total capital cost of the modest Underground Mining Scheme of the Henzal White Granite Deposits for a production of 5000 cubic meters or 100,000 m² of squared slabs of granite per annum is Rs. 420 million which is expected to be fully paid back within a period of 6 years.

For surface quarrying or open pit mining, around 930 million rupees would be required for the targeted production and a period of ten years would be required to bring the project into profit.

Key words: Granites, mineral resources, KKH, Nagarparker, Mansehra.

F/81. Fatima, E., Ahmad, N., Siddiqi, F.A. & Khan, A.H., 1983. Chemistry and mineralogy of some Eocene and associated limestones of Kohat District, North West Frontier Province, Pakistan Journal of Scientific and Industrial Research 26, 212-219.

Key words: Chemistry, mineralogy, limestone, Eocene, Kohat.

F/82. Fatmi, A.N., 1968. The palaeontology and stratigraphy of the Mesozoic rocks of Western Kohat, Kalachitta, Hazara and Trans-Indus Salt Ranges, West Pakistan. Ph.D. Thesis, University of Wales, Aberystwyth, 409p.

Key words: Palaeontology, stratigraphy, Mesozoic, Kohat, Kalachitta, Hazara.

F/83. Fatmi, A.N., 1969. Diamorphisms in some Jurassic and Lower Cretaceous ammonites from West Pakistan. GSP, Geonews 1(2), 6-13.

Key words: Ammonites, Jurassic, Cretaceous.

F/84. Fatmi, A.N., 1971. Late Jurassic and Early Cretaceous (Berriasian) ammonites from Sheikh Budin Hills, Dera Ismail Khan District, North West Frontier Province, Pakistan. GSP, Record 21 (2), 38p.

Key words: Paleontology, Ammonites, Jurassic, Cretaceous, Sheikh Budin, Dera Ismail Khan.

F/85. Fatmi, A.N., 1972a. Lithostratigraphic units of the Kohat-Potwar region. GSP, Information Release 46, 139p.

Key words: Lithostratigraphy, Kohat-Potwar.

F/86. Fatmi, A.N., 1972b. Stratigraphy of the Jurassic and Lower Cretaceous rocks and Jurassic ammonites from northern areas of West Pakistan. British Museum of Natural History Bulletin (Geology) 20(7), 299-380.

The stratigraphy of the Jurassic and Lower Cretaceous formations and Jurassic ammonites from Hazara, Kala Chitta, Nizampur, Western Kohat (Samana range) and the Trans Indus ranges in Northern Pakistan are described.

A provisional zonal scheme is proposed and correlation is suggested with Spiti, Cutch, Madagascar, Mediterranean Province, Middle East, and East Africa. Failure to recognize certain ammonite zones in the area may be explained by non-deposition, slow deposition, unfavourable facies, failure of collection or some combination of these factors. Middle Calovian, Upper Oxfordian and Lower Kimmeridgian ammonites from the Trans Indus range, Upper Oxfordian-Tithonian ammonites from Nizampur, Lower Toarcian ammonites from Kala Chitta and Lower Tithonian ammonites from northern areas of Hazara are recorded and described for the first time. In addition, a definite Aptian ammonite fauna is recognized in parts of Western Kohat and the Kala Chitta range. The faunal studies indicate that the Jurassic passes into the Cretaceous without a break in most areas of northern West Pakistan. The major stratigraphical breaks are Pre-Toarcian, Intra-Jurassic (pre-upper Oxfordian, pre-Kimmeridgian or pre-Tithonian) and intra-Cretaceous (post-Lower-Middle Albian).

Key words: Stratigraphy, Jurassic, Cretaceous, Ammonites.

F/87. Fatmi, A.N., 1973. Lithostratigraphic units of the Kohat-Potwar Province Indus Basin, Pakistan. GSP, Memoir 10, 80p.

Key words: Lithostratigraphy, Kohat-Potwar, Indus Basin.

F/88. Fatmi, A.N., 1974. Some problems of Mesozoic stratigraphy in Hazara and Baluchistan. GSP, Geonews 4, 35-42.

Key words: Mesozoic, Stratigraphy, Hazara, Baluchistan.

F/89. Fatmi, A.N., 1977. Mesozoic. In: Shah, S.M.I. (Ed.), Stratigraphy of Pakistan. GSP, Memoir 12, 29-56.

Key words: Mesozoic.

F/90. Fatmi, A.N., 1992. Mesozoic history of the upper Indus Basin in relation to plate tectonics. Abstracts, First South Asia Geological Congress, Islamabad, 12-13.

Key words: Mesozoic, plate tectonics.

F/91. Fatmi, A.N., Anwar, M., Hussain, I., Saeed, G. & Latif, A., 1990. Stratigraphy of the Shinawari and Datta formations from the Shinawari Area (western Samana Range), Kohat District, Pakistan. Punjab University Geological Bulletin, 25, 47-55.

Stratigraphy of Shinawari Formation is described from the type area of Shinawari on the basis of newly described Boulcieras bed and the overlying maroon shale. Both these units show as key horizons indicating a Lower Toarcian transgression in most areas of Kohat-Potwar Province of the Upper Indus Basin and provide a facies basis of interregional correlation. The clastic shallow water marine sequence below the Boulcieras beds is placed in the Datta Formation. The Datta Formation in the Samana Range shows a facies change from the type area of Datta in the Surghar Range where the formation is mainly continental. In western Kohat (Samana Range) it is a shore-line to shallow marine sequence as is represented by the frequent carbonate beds with the molluscan and brachiopod fauna and closrics. The two Datta facie are comparable to the Lower Cretaceous Lumshiwai facies which show similar environmental change from continental in the south to marine in the north west of the Trans Indus Ranges.

Key words: Stratigraphy, Shinawari Formation, Datta Formation, Kohat.

F/92. Fatmi, A.N. & Cheema, M.R., 1972a. Late Jurassic and Early Cretaceous (Berriasian) Ammonites from Sheikh Budin Hills, D.I. Khan (N.W.F.P.), Pakistan. GSP, Record 48 (2).

Key words: Paleontology, Jurassic, Cretaceous, Ammonites, Sheikh Budin, Dera Ismail Khan.

F/93. Fatmi, A.N. & Cheema, M.R., 1972b. Early Jurassic cephalopod from Khisor-Marwat Ranges (Sheikh Budin Hills, Dera Ismail Khan District, North West Frontier Province, Pakistan). GSP, Record 21(2), 9p.

Key words: Cephalopod, Khisor-Marwat, Sheikh Budin, Dera Ismail Khan.

F/94. Fawad, M., 1986-88. The geology and petrology of Chilas ultramafic complex in the vicinity of Chilas (District Diamar) with special emphasis on petrogenesis of the rock units. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 113p.

The project area covers about 368 sq. Km. located in the vicinity of Chilas, District Diamar. The work has involved geological mapping of the area on a scale of 1:50,000. This thesis deals with the geology, petrography and petrogenesis of the Chilas complex and adjacent southern rock units. The possible relation of Chilas complex with the southern Jijal complex has also been discussed. The geological sequence of the area consists of metadiorite rocks of the Chilas complex and granodiorite. The rocks of the Chilas complex are divided into two main associations, the ultramafic-anorthosite association and the main norite/gabbro-norite association. Both the associations represent lower and upper cumulates respectively and are in a complicated contact possibly due to syndepositional folding-and faulting. Diorite is the most evolved unit of the Chilas complex.

Field evidences suggest that Chilas complex was intruded into an old pluton, the metadiorite which was included in Kamila amphibolite by Coward (1982). The relationship of Jijal with Kamila amphibolite also shows that the Jijal complex was accommodated in the rocks represented by Kamila amphibolites, suggesting an older age of Kamila rocks than Chilas and Jijal complexes. The Chilas complex is unmetamorphosed and is present in an anticlinal position with ultramafics chiefly restricted to the core of the anticline. The ultramafics are overlain by more evolved rocks i.e. gabbro-norite association and diorite capped on both limbs by metadiorite roof rock. On the southern limb, the metadiorite roof rock unit is intruded by a granodiorite pluton which seems to be younger in age than the Chilas complex. Whole of the stratigraphic sequence of Chilas complex is fractionation product of hydrous, magnesian, island arc basaltic magma and there is a strong possibility of finding economic metallic mineral deposits in the Chilas stratified complex.

Key words: Petrology, ultramafics, petrogenesis, Chilas.

F/95. Fayaz, A., 1988. A short note on movement of Dih Glacier causing blockage of the Karakoram Highway. GSP, Information Release, 329, 8p.

On 12th September 1987. Karakoram Highway was closed due to damming of Khunjerab River resulting in a lake about 1 /2 km long. This problem cropped up due to the movement of Dih glacier in the form of mud flow through Dih nulluh.

Dih glacier is a type of surging glacier which creates problems after lapse of many years. Reasons of movement of glaciers, its effects and possible solutions to reconstruct and to keep open the affected part of the Karakoram Highway is the subject of this report.

Out of the three options suggested in this report, the author is obliged to put emphasis on the one that the army engineers are already working on. The method calls for the construction of a new segment of the road along the bank of the lake by filling the available material.

Key words: Glacier, Glacier surge, Karakoram Highway.

F/96. Fayaz, A. & Hussain, H., 1998. Geotechnical report on the proposals for the future planning of Astor valley road, Northern Areas of Pakistan. GSP, Information Release 642, 17p.

During the course of rehabilitation and metalling of the Astore Valley Road, a geotechnical study was carried out on the request of Frontier Works Organization. The aim of this study was to discuss the various proposals under consideration for the improvement of this road.

During the last ten years, more than 250 Million rupees were spent on this project, without achieving its main objective to make it truckable upto Astore. The only hindrance in the fulfillment of this goal is the road portion between Mushkin and Dushkin,

These Slides are complex and a source of constant problem, a detailed study of these slides indicates that the problem is so severe that control of these slides are prohibitively expensive. Instead of repairing these

slide zones, new alignment proposals are taken into consideration by shifting the road in this portion to the other side of the river by the construction of two or four bridges, to avoid the unstable areas of both sides. Keeping in view, the three alternative a comparison was made from the Engineering geology point of view and recommended the realignment of the road on the right bank with two bridges on Astore River.

It is also recommended that before undertaking the project worth of 1032.680 million (Construction of road- Thelichi, KKH -Gorikot-Chilam choki-Minimarg 140 Km), a detailed evaluation from the engineering geology point of view must be undertaken to appreciate the latest techniques available in this field for the future safety of this project.

Key words: Geotechnical, Astore.

F/97. Fayaz, A. & Hussain, S.H., 1999a. Engineering geological studies for road alignment and slope stability along Gupis-Shandur Pass road, Ghizar valley, Northern Areas, Pakistan. GSP. Information Release. 682, 30p.

This report presents data, from Gupis to Shandur Pass which is about 107 km long. The whole strip is divided into 30 sections on the basis of material, topography and prominent bridge locations.

The study includes road alignment considerations, land slide investigations, river bed erosion problem and identification of plantation sites. At the end of each section recommendations are proposed for the improvement of the road and remedial measures (or the control and stabilization of slopes).

Presently the road condition from Gupis to Shandur Pass requires improvement as only jeeps can cross the Shandur Pass to reach upto Chitral. The widening and realignment proposed in this report will help a great deal for better road link between Gilgit and Chitral, which will ultimately attract more tourists in the country.

Key words: Engineering, slope stability, Gupis-Shandur, Ghizar valley, Northern areas.

F/98. Fayaz, A. & Hussain, S.H., 1999b. Reconnaissance survey of slope stability and river bed erosion control along Naltar valley road, Northern Areas of Pakistan. GSP, Information Release 674, 21p.

Naltar valley is very famous Tourist resort in Northern Areas. Pakistan Air force (PAF) also maintains a Skiing Resort in this area. The Ministry of tourism and Culture has also proposed to truckable metalled road from the Karakoram Highway by constructing a bridge on Hunza River in front of NomaI village and improving the existing road upto the PAF Skiing Point in this valley. They also planned a tourist resort (five star) to encourage Tourism in this area.

The whole strip is divided into 20 sections depending upon the nature of material/problem envisaged. These sections are of different lengths. A brief description of bridges encountered are also mentioned in this report.

Keeping in view, the type of material/deposits, river position with respect to road, present condition of the road existing gradient of the road, width of the road, suggestions are proposed to improve the gradient, slope stability, river bed erosion to gain the required width. Wherever realignment of the present road found suitable, its proposed and comparison has been given to justify this realignment.

Key words: Slope Stability, erosion, Naltar Valley, Northern areas.

F/99. Fayaz, A. & Khan, K.S.A., 1988. Study of cracks near the village Bara Khaplu subdivision, District Baltistan, Northern Area. GSP, Information Release 363, 12p.

Geological investigations were carried out at Bara village near Khaplu, Baltistan in February, 1988 on the development of a crack about 3 km long in the out-washed material on the western piedmont slope of Bara Pien hills. The crack is about 2 meter wide and has shown down-warping of talus material by 1.5 to 2 m due to creep movement.

The exposed rocks are of granitic composition and are hard, massive and well jointed. The hill slopes show thick accumulation of talus material derived from the adjacent rocks and comprise big boulders embedded in a heterogeneous mixture of coarse sand and fine clay.

Causes of appearance of this crack and land subsidence is apparently due to excessive infiltration of water from the channels called “Kouhls” and slow insipient seepage of snow-melt water into the ground. These channels are unlined and allow the escape of water into the ground which subsequently causes settlement of unconsolidated talus material.

Further development and enlargement of crack and creep of talus material may be checked by controlling the excessive inflow of water into the ground by cementing the irrigation channels. The soil creep may be checked by plantation of quick-growing species of plants along the slope.

Key words: Cracks, Khaplu, Baltistan, Northern areas.

F/100. Fayaz, A., Khan, K.S.A., & Latif, M., 1985. Mudflows and avalanches along the Karakorum Highway. GSP. Information Release 247, 28p.

Landslide investigations were carried out along the Karakoram Highway during the field season 1983-84 on the request of University Grants Commission and the Frontier Works Organization. The problems of the area were thoroughly investigated and classified according to their origin and mode of occurrence.

Mud flows and avalanches along the Karakoram Highway (KKH) from Thakot to Khunjerab pass are discussed in this report. Study of slides include type of rock/material involved in the affected area, reason of its occurrence and remedial measures to check the mass movement phenomenon.

Specific recommendations for each of the affected area are made. These remedial measures are of two types; first, those which can be immediately implemented to check further deterioration; the other ones are for long term measures which will involve more funds and also some restructuring of the KKH plans. However, the second set of remedial measures are very crucial for further safety of the KKH.

Jaglot Gah Mudflow and Harbon avalanche are studied in detail due to their critical position on the KKH as well as their magnitude and repeated occurrences involving large amount of material fall. The recommendations made for these areas should thus be implemented soon.

Continuous maintenance of the KKH requires considerable efforts in terms of time and money. Proper execution and implementation of the recommendations proposed in this report may help a great deal in reducing the manpower and maintenance cost of the KKH.

Key words: Mudflows, avalanches, Karakoram Highway.

F/101. Fayaz, A., Khan, K.S.A. & Latif, M., 1986. Study of landslide problems in rural and urban areas of Murree tehsil. . GSP, Information Release 270.

Fifteen landslides on the link-roads connecting rural areas of Murree Tehsil and the urban area of Murree Town were studied and described in this report. Study of slides include plotting the location of the slides on the maps, type of rocks and material involved in the sliding area, origin and mode of their occurrences and remedial measures. The lithological behaviour of Murree Formation, overloading of soils by constructing heavy structures and unscrupulous cutting of trees are mainly responsible for the generation of slides in Murree area.

Proper execution and implementation of the recommendations proposed in this report may help a great deal in the control and stabilization of slopes in the affected areas.

Key words: Landslides, Murree formation, Murree.

F/102. Fayaz, A., Khan, K.S.A., Hussain, S.H. & Latif, M., 2001. Landslides and their control along the Karakoram Highway (Hasanabdal to Gilgit), Vol-II, GSP. Special Publication.

Key words: Landslides, Karakoram Highway, Hasanabdal, Gilgit.

F/103. Fayaz, A. & Latif, M., 1984. Development of cracks in mountain around Sermik village Skardu Sub-division, Northern Area, Pakistan. GSP. Information Release 223.

On the request of Commissioner, Northern Areas, landslide investigations were carried out around Sermik village, Skardu Sub-Division, during the month of February, 1984. The work pertained to the development of cracks in the mountain terrace near Sermik village and probable danger to the life and property of the people of the area.

The affected terrace comprises heterogenous mixture of silt sand and gravel with large embedded boulders. The cracks have developed due to the subsidence of terrace material resting on a downthrown block of an intraformational fault in the granitic body. Excessive seepage and infiltration of rain and snow-melt water have added to the enlargement of these cracks.

The affected terrace may be stabilised by controlling the excessive infiltration of rain and snow-melt water by making catchwater drains, filling and tamping of all open cracks and by plantation of deep rooted and quick growing plants.

Key words: Landslide, Skardu.

F/104. Fayaz, A., & Latif, M., 1988. Rocks excavation problems along Gilgit–Gupis road, Northern Area, Pakistan. GSP. Information Release No. 364, 12p.

Rock Excavation studies along Gilgit Gupis road were carried out during the field season of 1986. The road is 110 Km long and is jeepable in fair weather conditions. Now the work is in progress to make it a metaled road. This report is based on identifying the geological structure and applying it for the excavation of major rock outcrops (locally called Pari). Four of them were measured on 1:200 scale and geological profile were prepared to know the distribution of joints, fractures, faults, shear zones, and other related structures and their impact on drilling and blasting. Based on the rock characteristic various drilling and blasting methods have been suggested for the future safety of the road and to minimize the hazards of land sliding after the construction of the road.

Key words: Excavation, Gilgit-Gupiz, Northern areas.

F/105. Fayaz, A., Latif, M., & Khan, K.S.A., 1985. Landslides evaluation and stabilization between Gilgit and Thakot along the Karakorum Highway. GSP. Information Release No. 253, 49p.

Ten major landslides and a few unstable zone s in a road strip of 350 km long from Thakot to Gilgit along the Karakoram Highway (KKH) are discussed in this report.

Study of slides include plotting of location of the landslide on road log map with respect to their distances from Thakot, types of rock/ material involved in the affected area, origin and mode of their occurrences and remedial measures.

Proper execution and implementation of the recommendations proposed in this report may help a great deal in reducing the man power and maintenance cost of the KKM.

Key words: Landslides, Gilgit, Thakot, Karakoram Highway.

F/106. Fayaz, A., Latif, M., & Khan, K.S.A., 1988. Geology and slope stability studies along Gilgit–Skardu road, Northern Area, Pakistan. Geological Survey of Pakistan. Information Release No. 379, 5p.

Engineering Geological investigations were carried out during 1987-88, along the Gilgit - Skardu Road. These studies included preparation of geological road log map, identification of landslide areas and evaluation of the suitability of various bridge sites under consideration. Contour plans already available were utilized as the base maps for further details of the proposed sites. In all 21 bridge sites and 6 landslide areas were studied and are described in this report.

Gilgit - Skardu road was started after the completion of Karakoram Highway, and the experiences gained at the KKH were effectively utilized during the construction of this road. It has greatly helped in limiting the landslide and slope stability problems on this road as compared to the KKH.

The recommendations proposed in this report may help a great deal in stabilizing the slopes and construction of safer bridges on the Gilgit - Skardu Road.

Key words: Slope stability, Gilgit-Skardu, Northern areas.

F/107. Fazali, A., 1969-70. Geological report on Dunga Gali-Kuldana Area, District Hazara. M.Sc. Thesis, Punjab University, Lahore, 90p.

This field report concerns about the findings of geological investigation carried out from Kuldana to Dunga Gali areas. Main emphasis has been placed on structural, stratigraphic and geomorphological aspects. The area shows high relief and for the most part covered with thick vegetation. The degree of exposures is low and the 'ground affords poor opportunity for geological mapping. The rocks exposed in the area range from Jurassic to Eocene in age. A study of the area shows that it has suffered strong tectonic disturbance. A number of folds with almost parallel axes were affected by numerous longitudinal and transverse faults. Different geological cross sections prepared are dealt in the descriptive geology along section C-D. Stratigraphic succession is established, and various formations have been correlated. The geological history of the area is made on the basis of their mineralogical enumerations and from the lithology, fossils and their sedimentary features and environment of the deposition are, also given in this chapter. Opinion is given about the regional tectonics of the Himalayan syntaxial bend on whose western limb area situated. Economically, the area contains a pure enough band of gypsum. Laterite, though economical in its composition, is very small in amount. Two main maps have been prepared by the author; one is lithological which is 3" = 1 mile, one part of the area from Changla Gali -Khaira Gali is enlarged by 9" = 1 mile. The other map is structural, showing main trends of folds and faults.

Key words: Geology, Dunga Gali, Kuldana, Hazara.

F/108. Featherstone, B.K., 1926. The Biafo Glacier. *Geographical Journal* 67, 351-354.

Key words: Glaciology, Biafo glacier, Baltistan.

F/109. Feistmanter, O., 1880. Notes on the fossil plants from Kathiawar, Sheikh Budin, and Srinagar. *Geological Survey of India, Records* 13 (1), 62-69.

Key words: Fossil plants, Kathiawar, Sheikh Budin, Srinagar.

F/110. Feistmanter, O., 1882. Note on remains of palm leaves from the (Tertiary) Murree and Kasauli beds in India. *Geological Survey of India, Record* 15, 51-53.

Key words: Tertiary, Murree, Kasauli, India.

F/111. Felix, G., Michael, S., Pierre, B.J., Bernard, C. & Munir, G., 1999. Kinematics and dynamics of the Himalayan fold-and-thrust belt in Pakistan. *Terra Nostra* 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 59.

The NW Himalayan fold-and-thrust belt in Pakistan runs from the Hazara-Kashmir Syntaxis to the Afghan border. It includes the southern part of the Lesser Himalaya and involves, in places, parts of the Sub Himalaya lying south of, the Main Boundary Thrust (MBT). The MBT and the Hazara-Kashmir Syntaxis dominate the tectonics of this region. The MBT, running all along the Himalayan arc, separates the Indus Basin from the West-Himalayan mountain chain. The Hazara-Kashmir Syntaxis is one of the West-Himalayan Syntaxes where the whole mountain system is sharply bent. The MBT loops around the Hazara-Kashmir Syntaxis, to the east of which no equivalent of the NW Himalayan fold-and-thrust-belt is identified.

Our study area is located in the foothills of the Western Himalaya, 50-km NE of Islamabad, focused on the region between Murree and Nathia Gali (Figure 1). Obviously the development of the MBT and Hazara-Kashmir Syntaxis dominated the deformation of the fold-and-thrust belt, whose understanding required

more dynamic and kinematic arguments. Previous work had given evidence for an imbrication of several thrust sheets in a standard thin-skinned tectonic framework. However, complex models were proposed for the evolution of the Hazara-Kashmir Syntaxis. The area was thus suitable to study the tectonic relationship between thrusting and folding in this part of the Himalayas.

Our study included:

Detailed mapping: A new map with cross-sections will be presented (scale 1:25000).

Describing the lithologies by field observations and thin sections. The belt consists of Jurassic to Eocene low grade metasediments lying unconformably on a basement of Precambrian slates and limestones.

Evaluating the deformational character of the series involved: Imbrication is associated with strike-slip faulting. Carrying out a fault striation analysis using computer aided methods: Various tensors will be integrated in the deformation history. The map and sections show that the fold-and-thrust belt has developed in a multilayered system with layers having contrasting rheologies (e.g. thick limestones interlayered with shales). Lithologies were derived from a passive margin whose sequence is summarized in the following mega-sequences:

Precambrian Hazara slates and limestones (basement).

Unconformable lower Jurassic to upper Cretaceous shallow water marine shelf carbonates and clastics.

Unconformable Paleocene to middle Eocene shallow water limestones and shales, with an upper series of evaporitic marls and mudstones.

Late Eocene to Miocene sediments were deposited in the Himalayan foreland basin and are of shallow marine to continental origin.

Generally steep faults were found. Along the MBT, thrusting and wrenching occurred, but also normal faulting. Combined wrenching and thrusting resulted in positive flower structures well displayed on the map and sections. Folding shows a broad range of styles with most hinges being rather angular. Folds with opposite vergence are seen in several segments of the section. In Mesozoic and Tertiary Formations, synsedimentary normal faults were often reactivated.

The analysis of fault slip data revealed the importance of sinistral strike slip movements along SW-NE-faults. The structural data fit a transpressional regime that has involved the basement. Stress calculations from striations yield a dominant NNW-SSE compression, which, however, cannot explain the whole deformation pattern. A second tensor, with a principal WSW-ENE-compression, was obtained. These two tensors do not have to belong to different phases but instead are the result from a swap between σ_1 , and σ_2 in a constriction-dominated stress field. The two tensors were measured at different places, and no clear superposition was found in the field. In addition a constrictional stress ellipsoid was measured in several sites. Shortening across the anticlinal Hazara-Kashmir Syntaxis led to WSW-ENE-compression, which has influenced the region lying west of the syntaxis. The interaction with the SSE-ward Himalayan transport direction produced the regionally complex deformation pattern. This interpretation simplifies previous ones that proposed rotations in compression directions during the Syntaxis formation. The MBT was bent to its present shape under the influence of the multiple horizontal shortening induced by the constrictional regime. In the core of the syntaxis, shallow marine to continental sediments of the Subhimalaya were folded by an anticline growing vertically, parallel to the extensional axis of the constrictional regime.

Recent seismic activity, neotectonics and geomorphological observations point to the ongoing activity along the frontal Himalayan ranges. Landslides close to the MBT are frequent, and deeply incised valleys with fluvial terraces in a steep topography are common.

Our new maps, sections and structural information point out new features: normal faulting and wrenching along the MBT, inversion tectonics, consistent steep dips and positive flower structures due to combined wrenching and low-angle thrusting. Similar features were recently found in the nearby Kohat plateau by Sercombe et al. (1998).

Key words: Fold and thrust belt, Himalaya.

F/112. Ferguson, R.I., 1984. Sediment load of the Hunza River. In: Miller, K.J. (Ed.), The International Karakoram Project 2, 581-598. Cambridge University Press.

The Hunza River drains 13200-km² of the western Karakoram Mountains, in which heavily-glaciated mountains rise 5-6000m above arid incised valleys. Measurements by the Pakistan Water and Power Development Authority show the Hunza contributes 22% of the runoff and 39% of the suspended sediment load of the upper 143,000 km² of the Indus basin. Its sediment yield of 4,800 t km⁻²a⁻¹, equivalent to a

denudation rate of 1.8mm a^{-1} , is amongst the highest in the world but the precise rate is uncertain because of infrequent sampling, considerable short-term and seasonal scatter about sediments rating curves, and big year-to-year variations in load. Ninety-nine percent of annual suspended load is carried in June-September when melt water discharge is maximum and concentrations exceed 10 kg m^{-3} . IKP measurements in summer 1980 showed sediment concentrations in a major proglacial tributary averaged only 12% of those at the basin mouth. This downstream increase, and the pronounced seasonal hysteresis in sediment rating curves, suggest fresh sediment stores are flushed and then depleted not only as melting extends to higher elevations but subsequently as swollen river overtop unvegetated valley floors and undercut terraces. Solute concentrations estimated from electrical conductivity also increase downstream but less so. At the downstream site annual solute yield is estimated as $90\text{ t km}^{-2}\text{ a}^{-1}$, three times the world average but only 2% of the solid load. Hydraulic properties calculated from gauging data suggest bedload transport could exceed $100,000\text{ t/day}$ in summer and forms 2-10% of total annual load.

Key words: Sediment, Hunza River,

F/113. Ferguson, R.I., Collins, D.N. & Valley, W.D., 1984. Techniques for investigating melt-water runoff and erosion. In: Miller, K.J. (Ed.), *The International Karakoram Project 1*, Cambridge University Press.

Meltwater runoff from glaciers and snow fields varies seasonally, with day to day hydrometeorological conditions, and diurnally. Suspended sediment transport is high in Meltwater Rivers but does not have a simple relationship with discharge, and solute concentrations depend on the englacial or subglacial path of the meltwater as well as on rock type. Quantitative understanding of meltwater runoff, solid load and hydro- chemistry in the Alps, Scandinavia, and North America has been improved by continuous monitoring of river conductivity and turbidity as well as stage, automatic water sampling at frequent intervals, and use of atomic absorption spectroscopy and ion-selective electrodes. The sediment removed by meltwater runoff may come from beneath, above or downstream from the glacier. Sources of suspended and dissolved sediment can be inferred crudely from changes in turbidity and conductivity along meltwater routes. They can also be investigated at the microscale by laboratory analysis of rock samples and weathered debris from different altitudes using scanning electron microscopy, X-ray diffraction, microprobe analysis and other techniques already applied to rock debris from the Alps and Hindu Kush. Rockfall contributions can be assessed by time-lapse photography, and bedload transport in meltwater rivers, may be predictable from hydraulic properties obtained during gauging by the velocity-area or dilution methods.

Key words: Glaciology, meltwater runoff, XRD-EPMA data.

F/114. Fernandez, A., 1983. Strain analysis of a typical granite of the Lesser Himalayan cordierite granite belt: The Mansehra pluton, northern Pakistan. In: Shams, F.A. (ed.), *Granites of the Himalayas Karakoram and Hindu Kush*. Institute of Geology, Punjab University, Lahore, 183-199.

Mansehra pluton is a granite - gneiss complex that has been affected by a markedly heterogeneous deformation. From South to North, a general evolution from granite to thinly laminated gneisses is observed, the bulk strain being highest near the base of the M.M.T.

Three main structural domains have been recognised. In the Southern one, granite predominates over some scarce gneissic zones. Preferred orientation analysis of feldspar megacrysts in the granite reveals that an important flattening component was locally active during intrusion. The Central domain is characterized by coarse grained gneisses which frequently present a well-developed schistosity (s) and a flow cleavage (e), as well as a marked stretching lineation. The gneissification bulk strain evaluated from enclaves and quartz crystals in typical gneisses of this zone, gives a $\lambda_1 : \lambda_2 : \lambda_3$ ratio=75. In the Northern domain, the gneisses are thinly laminated and contain scarce feldspar relics. Bulk strain evaluated from enclaves shape data gives $\lambda_1 : \lambda_2 : \lambda_3$ ratios as high as 300.

Key words: Mansehra pluton, cordierite, granite, Lesser Himalayan, Mansehra.

F/115. Fielding, E.J., Burbank, D.W., Leland, J., Duncan, C.C. & Isacks, B.L., 1995. Geomorphic Responses of Rapid Denudation Rates in the NW Himalaya and Karakoram. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Analysis of high-resolution digital topography for the Kohistan-Karakoram Himalaya area near Nanga Parbat provides new information on the geomorphic response to some of the fastest cooling and denudation rates on the earth. Apatite cooling ages (Zeitler, 1985) and cosmogenic strath terrace ages (Leland et al., 1994; Burbank et al., 1994) both indicate rapid rates of erosion in this area. Measured incision rates range from ~2 mm/yr east of the Nanga Parbat-Haramosh Massif (NPHM) to 6-9 mm/yr where the NPHM is cut by the Indus River gorge. The present topography presumably represents a balance between the tectonic and erosion processes, and the latter have been affected by Quaternary climate changes. Geometric arguments suggest that incision rates are approximately equal to bedrock uplift rates and that these rates have been sustained for ≥ 0.5 my.

Several quantitative geomorphic measurements have been derived from the digital elevation model (DEM-three arc-second or ~90 m grid), including hillslope angles, local relief, valley widths, and hypsometry. The hillslope angles and local relief were calculated with analysis windows of varying sizes from (~250 m to ~4 km across) to characterize their dependence on scale. The slope of a given window size is defined as the slope of the best-fitting plane to all of the points of that window, while the relief is defined as the difference between the maximum and minimum elevations within the window. Statistics such as slope histograms and hypsometry (elevation histograms) were determined for the studied regions.

Hillslope angles measured with ~250 m windows (the highest resolution reliably determined from this DEM) appear to reflect the dominance of landsliding in hillslope erosion, but not the variations in rock uplift rates in this area. There are no significant differences in slope histograms between the areas of very rapid (6-9 mm/yr) and rapid (~2 mm/yr) denudation. There is a small difference between the slopes in the non-glaciated valleys where slope histograms are narrowly peaked between 30~45° and the generally higher elevation glaciated areas where the slopes have a bimodal histogram with shallow slopes in the valley bottoms and steep slopes along the valley walls. Even in the glaciated zones, there are still only small areas with slopes greater than about 45°. This suggests that the rock-strength limitation on slope is perhaps 45-50° in this region where all of the units are medium- to high-grade crystalline rocks. The relatively narrow range of slopes may reflect a state of self-organized criticality where the rocks are everywhere close to slope failure as in sandbox experiments.

There are also some other areas with shallow slopes that appear to be remnants of low-relief surfaces now at elevations of 4000-5000 m. The most outstanding example is the Deosai plateau, but there are other surfaces with more subtle appearances. These surfaces are expressed as shallow-slope, low-relief areas with large peaks in their hypsometry at an elevation between 4000 m and 5000 m. To the west of the Indus River and NPHM and south of the Hunza and Gilgit Rivers is a low-relief surface at an elevation of about 4300 m, called the Gamugah or Kohistan surface. This surface is remarkably level in its more than 50 km east-west extension. If it is a remnant of a previous regional plateau, it would indicate little or no warping of that surface has occurred since it was formed.

Key words: Topography, geomorphology, denudation, Nanga Parbat.

F/116. Filippi, F.de, 1913-14. The Italian Expedition to Himalaya, Karakoram and Eastern Turkestan. Arnold, London.

Key words: Italian expedition, Himalaya, Karakoram, Turkistan.

F/117. Filippelli, G.M. 1997. Intensification of the Asian monsoon and a chemical weathering event in the late Miocene – early Pliocene: Implications for the Neogene climate change. *Geology*, 25, 27-30.

Several sedimentary, geochemical, and isotopic records indicate that the hypothesized intensification of the Asian monsoon at about 8 Ma triggered a physical and chemical weathering event in the Himalayan-

Tibetan Plateau. Records of sediment input and clay composition from the northern Indian Ocean reveal clear weathering changes in the plateau at this time, and Ge/Si ratios of opaline silica as well as biogenic sedimentation rates indicate that increased dissolved element fluxes from this weathering event had an ocean wide effect. It is likely that weathering intensity also increased in the Andes and Amazon Basin in this interval as well. Perhaps the most important impact of this weathering event was to increase the net flux of the biolimiting nutrient phosphorus to the ocean, as evidenced by a peak in phosphorus accumulation rates at this time. The temporary increase in nutrient inputs to the ocean triggered increased oceanic productivity and organic carbon burial (recorded in carbon isotopic records and paleoxygen concentrations). The net result of this weathering event may have been an increase in the rate of drawdown of atmospheric CO₂ through the late Miocene–early Pliocene, via direct silicate weathering reactions and increased burial of organic carbon in the ocean. This increased rate of atmospheric CO₂ drawdown may have destabilized the climate system by the late Pliocene, thus initiating a period of intense cooling and ice buildup leading to the present.

Key words: Monsoon, Chemical Weathering, Miocene, Pliocene.

F/118. Finetti, I., Giorgetti, F. & Poretti, G., 1979. The Pakistani segment of the DSS-profile, Nanga Parbat - Karakul (1974-75). *Bollettino di Geofisica Teorica ed Applicata* 21, 159-169.

Key words: DSS profile, Nanga Parbat.

F/119. Finetti, I., Poretti, G. & Mirza, M.A., 1983. Crustal structure of the Karakorum Range along the DSS Profile Nanga Parbat-Karakul. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* XXV, n99-100, 195-209.

Key words: Crustal structure, Karakoram Range, Nanga Parbat.

F/120. Finsterwalder, R., 1936. Die Formen der Nanga Parbat-Cruppe, Topografische-morphologische Begleitworte zu den Karten der Nanga Parbat-Cruppe, *Zeitschrift der Gesellschaft für Erdkunde zu Berlin* 71, 321-341.

Key words: Topography, Nanga Parbat.

F/121. Finsterwalder, R., 1937a. Parbat-Cruppe, Topografisch-morphologische Begleitwerte zu den Karten der Nanga Parbat-Cruppe, *Ges, Erdk Berlin*, zs. H. 9-10.

Key words: Topography, Nanga Parbat.

F/122. Finsterwalder, R., 1937b. Die geodatischen und topographischen arbeiten bei der Nanga Parbat-Expedition 1934 und ihr Ergebnisse. *Zeitschrift für Vermessungswesen* 66, 33-62.

Key words: Topography, Expedition, Nanga Parbat.

F/123. Finsterwalder, R., 1937c. Die Gletscher des Nanga Parbat, Glaziologische Arbeiten der Deutschen Himalaya Expedition 1934 und ihre Ergebnisse. *Zeitschrift für Gletscherkunde* 25, 57-108.

Key words: Glaciology, Expedition, Nanga Parbat, Himalaya.

F/124. Finsterwalder, R., 1938. Die geodatischen, gletscherkundlichen und geographischen Ergebnisse der Deutschen, Himalaja-Expedition 34, zum Nanga Parbat. Deutschen Forschungsgemeinschaft, N. F. 2.

Key words: Geodesy, geography, Expedition, Himalaya.

F/125. Finsterwalder, R., 1959. Recent German expeditions to Batura Mustagh and Rakaposhi. Jour. Glaciology, 3, 787-788.

In 1954 a German expedition under the scientific leadership of W. Pillewizer worked in the Batura Mustagh (Hunza-Karakoram) as far as the Rakaposhi Range. Extremely steep mountains are characteristic of this region, also very narrow valleys and gorges. The numerous glaciers have steep icefalls and their tongues are covered with debris except that of the Batura Glacier in the north. The Batura is the largest glacier; it is about 50 km. long. A photogrammetric survey of the whole area of about 3,000 km² was carried out. On several glacial tongues, especially on the Batura, ice velocities and ablation were also measured. However, owing to the great difficulties caused by the steep and high mountains the survey remained uncompleted. At the end of the expedition a disaster occurred. The geodesist K. Heckler fell to his death into the Hunza Gorge. The preliminary results of the expedition were published in *Erdkunde* by the geographer, K. Paffen, the glaciologist and photogrammetrist, W. Pillewizer, and the geologist, H. J. Schneider.

In 1959 another expedition, under the leadership of Schneider of Munich, worked in the same region in order to complete the work of 1954. The northern side of the Batura Mustagh could not be visited as an English mountaineering expedition, under the leadership of Dr. Warburton, was at work there. The surveyor of the German 1959 expedition was H. Baumeri of the photogrammetric institute at Munich. He completed the photogrammetric surveys of all the valleys, mountains and glaciers between the Batura Mustagh and the Rakaposhi Range, and again carried out ice velocity measurements in order to determine the mass balance of the glaciers.

Two remarkable events with tragic consequences must be reported. The first was the fact that the monsoon crossed the Himalaya on 2-5 July and reached the Batura Mustagh. This happens about once in 50 years according to the meteorological authorities in Pakistan. As a result there was very heavy precipitation in the valleys for three days and nights. Normally these valleys are very dry and practically without rain for years at a time. At high levels furious snowstorms raged. The Warburton expedition was then probably working on the highest peak of the Batura Mustagh. It must be assumed that Dr. Warburton with his four companions, two Germans among them, was buried by snow and avalanches. The German rescue party of the Schneider expedition could not find any sign of the mountaineers nor even of the four high camps. They had been installed by them on the same glacier which the German mountaineers of the Pillewizer expedition had tried to climb in 1954. The second tragic event took place on 21 August with the sudden burst of a lake dammed by the tongue of one of the big glaciers in the very remote Shimsal Valley, which is an eastern tributary of the Hunza River. It is assumed that it was the Malangutti or the Yazgil Glacier, first found by the Vissers in 1925 and surveyed by K. Mason some years later. The flood caused by the burst had a depth of about 30 m. at the junction of the Shimsal with the Hunza, about 40 km from the assumed position of the lake. The flood destroyed the village of Pasu near this junction, and further on the bridges over the Hunza River were swept away, causing heavy losses. The bursting of the lake had been expected three months before. Perhaps the bursting of the lake was caused by the extraordinary precipitation which had occurred seven weeks earlier. The glaciers of Batura Mustagh are very important for agriculture in the valleys and Alps many kilometres away from the glacier snouts. Irrigation channels lead run-off water to the very dry valley bottoms. These channels begin as near as possible to the end of the glaciers.

Fluctuations of the glaciers have therefore considerable influence on cultivation, but the most critical influence is caused by the damming up of lakes which occurs from time to time and was reported as recently as 1925 by Visser.

Key words: Glaciology, Photogrammetry, Batura, Mustagh, Rakaposhi.

F/126. Finsterwalder, R., 1989. Seit 100 Jahren Beobachtungen am minapin gletscher im Hunza karakorum. Zeitschrift fur Gletscherkunde und glazialgeologie 25, 209-216.

Key words: Hunza, Karakoram.

F/127. Finsterwalder, R. & Pillewizer, W., 1939. Photogrammetric studies of glaciers in High Asia. *The Himalayan Journal* 11, 107-113.

Key words: Photogrammetry, Glaciers, Asia.

F/128. Finsterwalder, R., Raechal, W. & Misch, P., 1935a. The scientific work of the German Himalayan Expedition to Nanga Parbat, 1934. *The Himalayan Journal* 7, 44-52.

Key words: Himalayan Expedition, Nanga Parbat.

F/129. Finsterwalder, R., Raechal, W. & Misch, P., 1935b. Die wissenschaftlichen Arbeiten der Nanga-Parbat-Expiations 1934. *Petermanns Geographische Mitteilungen* 81, 1-6.

Key words: Nanga Parbat, Expeditions.

F/130. Finsterwalder, R., & others, 1935. Forschung Am Nanga Parbat. Deutsche Himalaya Expedition 1934, (Verlauf. Bericht unver d wissenschaft, Anbeiten). *Sounderoffentlichung der Geologische Gesellschaft, Hannover*, vol. 24.

Key words: Nanga Parbat, Himalaya, Expedition.

F/131. Fiori, G., 1957. Una nuova specie de *Seminolus muls.* Et Rey dell Karakorum. *Atti dell Museo Civico di Storia Naturale de Trieste* 21 (2).

Key words: Paleontology, Karakoram.

F/132. Fischer, G., 1932. Petrographische unter suchungen an den won Dr. De Terra im Kun-Lun und Karakorum gesammelten Gesteinen. In: Trinkler, E. (ed.), *Wissenschaftliche Ergebnisse der Trinkler'schen Zentralasien-Expidition*, Bd. 2. Reimer & Vohsen, Berlin.

Key words: Petrography, Karakoram, Kun Lun.

F/133. Fitch, T.J., 1970. Earthquake mechanisms in the Himalayan, Burmese and Andaman regions and continental tectonics in Central Asia, *Journal of Geophysics Rec.* 75(14), 2699-2709.

Focal mechanisms are presented for thirteen earthquakes between Hindu Kush and Sumatra, including four shallow-focus events along the Himalayan mountain front and two events at intermediate depth beneath the Burmese mountains. All mechanisms are based on first-motion P- and S-wave data recorded by long-period instruments. The mechanisms along the Himalayan front confirm the existence of thrust faulting for which there is post-Mesozoic geologic evidence. Additional evidence for thrust faulting in central Asia comes from focal mechanisms based on other seismic data published recently by Russian investigators. The axis of minimum compression (the T axis) at intermediate depths beneath the Burmese mountains is oriented approximately down the dip of the seismic zone, as are T axes at intermediate depths in several other

seismic zones. A mechanism solution consistent with strike-slip faulting and another consistent with normal faulting were derived from two shallow earthquakes in western China. One shallow earthquake within the Himalayas yielded a normal faulting mechanism, as did one event from the western margin and two events near the northern border of the Andaman Sea. Slip vectors consistent with under thrusting beneath the Himalayas have a nearly uniform north to northeasterly strike. This evidence, as well as the frequency of occurrence of large-magnitude earthquakes, suggests that seismic slip at shallow depths may account for the convergence between the Indian Ocean and the Eurasian plates along the Himalayan mountain front.

Key words: Tectonics, earthquakes, seismology, structure, Himalaya.

F/134. Fleming, A., 1848. Report on the Salt Range and on its coal and other minerals. Journal and proc Asiatic Society of Bengal, 17, 500-526.

As a member of the Indian Geological Survey, Dr. Andrew Fleming (1822-1901) executed exploration and analysis of the Salt Range in the Punjab reporting on its height, course, and its physical and stratigraphic aspects. He also searched for coal and wood in support of the needs of steamers on the Indus and also sought out gold, copper and other minerals. From his investigations he published Report on the Geology and mineral wealth of the Salt Range in the Punjab.

Key words: Coal, Salt Range.

F/135. Fleming, A., 1852. On the rocks of upper Punjab. British Association for Advancement of Science 22, p.43.

Key words: Geology, lithology, Punjab.

F/136. Fletcher, C.J.N., 1985. Copper mineralization in the Kohistan complex near Dir and Drosh, NWFP. British Geological Survey Circular, 1-65.

Key words: Copper mineralization, Dir, Kohistan.

F/137. Fletcher, C.J.N., Leake, R.C. & Haslam, H.W., 1986. Tectonic setting mineralogy and chemistry of a metamorphosed, stratiform base metal deposit within Himalayas of Pakistan. Journal of Geological Society, London 143, 521-536.

Stratiform Zn-Pb mineralization of probable Proterozoic age occurs in a structurally complex area near the northern margin of the Indian plate around Besham in the North West Frontier Province of Pakistan. The sphalerite and galena mineralization is associated with a well-defined stratigraphy of carbonate, layered calc-silicate quartzite, garnet-bearing quartz-feldspathic gneiss, feldspathic granulite and albite gneiss. Associated with the ore are varying proportions of pyrrhotite, pyrite, baryte, clinopyroxene, quartz, garnet, actinolite, pyroxmangite, feldspar, carbonate and magnetite. The Mn-rich composition of the silicate minerals and the widespread enrichment of Ba in the rocks associated with the ore form a distinctive signature of the mineralization recognizable in reconnaissance exploration. This signature is distinct from that of skarn minerals formed later in carbonate rocks as a result of the intrusion of pegmatites. The recognition of the stratiform nature of the deposits within a well-defined stratigraphy enhances the exploration potential of the mineralization over a much wider area.

Key words: Mineralogy, chemistry, metamorphism, tectonics, Besham, Himalaya.

F/138. Flohn, H., 1969. About climate and hydrology of the Hindu Kush and the neighbouring high mountains. Erdkunde, Bonn, 23(3), 205-215.

Key words: Climate, hydrology, Hindukush.

F/139. Fluegel, H.W., 1989. Rugosa aus dem Perm des N-Karakorum und der Aghil-Kette. *Geologische Paleontologische Mitteilungen* (Innsbruck), 17, 101-117.

From the upper Artinskian and/or lower Kungurian of the Hunza region (Pakistan) and the Shaksgam valley (China) coral fauna with genera *Ufimia*, *Paracaninia*, *Duplocarinia*, *Yatsengia*, *Verbeekiella*, *Euophyllum*, *Lophophyllidium* (*Lophillidium*), *allotropiochisma* (?A) and *Amandophyllum* (?) are described. In addition two new species of the new genus *Petraphyllum* are named *P. hunzaianum* and *P. columnum*. *Petraphyllum* is characterized by a fanlike arrangement of their septa of naostyp and a septobasal columella. The genus belongs to the new family *Petraphyllidae*.

The coral fauna shows very close similarities to the cold water "Lytvolasma"-fauna of the Lower Permian of the lhasa- and the Kunlun-Terrane and the Permian corals faunas of the Himalaya-Timor zone, but no affinity to the *Waagenophyllum*-fauna of the Maokou of the Qiangtang and Lhasa Terrane of Tibet.

Key words: Palaeontology, Permian rugosa, Karakoram.

F/140. Fluegel, H., 1995a. *Aphyllum* n.sp. (Rugosa) aus der Gircha-Formation des Pakistanischen Karakorum. *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, 166-172.

Key words: Paleontology, Gircha Formation, Karakoram.

F/141. Fluegel, H., 1995b. Permian corals from Chitral (N.W.-Pakistan). *Rivista Italiana di Paleontologia e Stratigrafia* 101, 153-164.

Key words: Paleontology, corals, Permian, Chitral.

F/142. Fluegel H.W. & Gaetani M., 1991. Permian Rugosa from Northern Karakorum and Aghil Ranges. *Rivista Italiana di Paleontologia e Stratigrafia* 97, 35-48.

Key words: Paleontology, Permian, Karakoram.

F/143. Flynn, L.J., 1981. Biostratigraphy and systematic of Siwalik Rhizomyidae (Rodentia). Ph.D. Thesis, University of Arizona, Tucson, 246p.

Key words: Biostratigraphy, Paleontology, Siwaliks.

F/144. Flynn, L.J., 1982. A revision of fossil rhizomyid rodents from northern Indian and their correlation to rhizomyid biochronology of Pakistan. *Geobios* 15, 583-488.

Key words: Paleontology, rodents, India, Pakistan.

F/145. Flynn, L.J., Barry, J.C., Morgan, M.E., Pilbeam, D., Jacobs, L.L. & Lindsay, E.H., 1995. Neogene Siwalik mammalian lineages--species longevities, rates of change and modes of speciation. *Palaeogeography, Palaeoclimatology, Palaeoecology* 115(1-4), 249-264.

A long depositional sequence from northern Pakistan provides a good fossil record of terrestrial vertebrates for the interval of 18-7 Ma. Making allowances for possible range extensions, we use this record as a direct measure of species longevities. There is a correlation between body size and longevity, smaller mammals frequently being short-lived and larger taxa showing durations up to ca. 10 m.y. The distribution of small mammal longevities indicates an exponential decrease in frequency from a high modal value in the smallest

increment measured (0–200,000 yrs). The most frequent value for large mammals is also the smallest increment measured (1 m.y.), but that distribution may not be unimodal. Small mammal taxa of short duration are concentrated late in the sequence, after 9 Ma especially. The middle Miocene fauna is more stable, with species showing longer durations. The contrast in longevities corresponds with hypothesized greater environmental stability in the middle Miocene. For comparison, the Paleogene sequence of Wyoming indicates short median species durations, with few surveyed taxa lasting over 2 m.y. Siwalik mammals show diverse modes of evolution, but stasis in at least some features is usual, with species boundaries corresponding to morphological breaks. Up to half of the Siwalik rodent and artiodactyl species surveyed likely immigrated from outside the biogeographic province, and for a few, historical data are sufficient to stipulate when and by what route they came to the Indian subcontinent.

Key words: Paleontology, Neogene, Siwaliks

F/146. Flynn, L.J., Pilbeam, D., Jacobs, L.L., Barry, J.C., Behrensmeyer, A.K. & Kappelman, J.W., 1990. The Siwaliks of Pakistan: time and faunas in a Miocene terrestrial setting. *Journal of Geology*, 98 (4), 589-604.

Magnetostratigraphy provides unparalleled chronologic precision for long terrestrial sedimentary records. The Siwaliks of the Potwar Plateau, northern Pakistan, present perhaps the best example of a sequence of well dated faunal horizons spanning most of the Neogene in a single terrestrial biogeographic province. Temporal control on fossil localities tied to multiple paleomagnetic sections is ca. 0.1 m.y., less given special conditions of short magnetozone duration or superpositional relationships. New correlations are presented for two long sections in the lower Siwaliks showing the power and the limitations of magnetostratigraphic correlation within the Siwalik depositional setting. Correlation of Potwar fossil localities to those of an East African section, also dated paleomagnetically, are established with fossil localities from those two biogeographic provinces shown to be coeval on a scale of 105 yr. The composite biostratigraphy rendered by the thick, well exposed, well dated Potwar Siwaliks enables definition of sequential bio-chronologic units without gaps. Utility of the biochronology lies in correlating isolated deposits to the Potwar composite; for studies within the Potwar, locality relationships and the biostratigraphy itself are the operational units. The history of the Siwalik fauna shows turnover episodes, but they differ in intensity, diversity of groups affected, and coincidence of first and last occurrences, probably reflecting different causes. Studies on the evolution of lineages are rendered more powerful by magnetostratigraphy: temporal control tests patterns of speciation, yields confident estimates on true temporal ranges of fossil taxa, and shows that rodent species longevities exceeded 2 m.y. on average.

Key words: Faunas, Miocene, Potwar, Siwaliks

F/147. Fontan, D., 1998. Regional geologic mapping, metamorphic P-T-t paths evaluations and ore potential assessment in Neelum Valley (Azad Kashmir, NE Pakistan). Ph.D. thesis, Univsite' de Louvain, 182p.

Key words: Metamorphism, geology, tectonics, economic geology, Neelum Valley, Azad Kashmir.

F/148. Fontan, D., Cosca, M.A., Schoupe, M., Gourirane, A., Hunziker, J.C., Kervyn, F., Martinotti, G. & Verkaeren, J., 1995. Geology and Tectonometamorphic Evolution of Neelum Valley (Azad Kashmir, NE Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

This study is focused on the stratigraphy and the tectono-metamorphic history of the Higher Himalayan Crystalline (HHC) and the Lower Himalayan Crystalline (LHC) in the Neelum Valley. Over 20 samples of phengite white mica, biotite and phlogopite have been analysed by the ⁴⁰Ar/³⁹Ar method and help to constrain the tectonothermal history of the Neelum area.

The HHC and the LHC units have the same stratigraphic features. In both we have distinguished a cover overlying a basement. The basement is composed of an older granulitic complex stratigraphically overlain by a thick metasedimentary sequence; both are intruded by later granites. The granulitic complex mainly

consists of medium grained biotite, garnet-bearing gneisses with interlayers of amphibolite, interpreted as very old (Precambrian?) basic dykes. In accordance with Pognante & Lombardo (1989) we have distinguished between the basic dykes of type A, which are intruded only in the granulites (they are cross-cut by pegmatites referred to granites), and those of type B, which cross-cut the basement/cover regional banding and can be correlated with the Permian Panjal Traps. Acid granulites can presumably be correlated with the Iskhere Gneiss of Zeitler et al. (1989). The metasedimentary sequence (Salkhala Series) is represented by a thick flysch-like sequence that can be correlated with the Precambrian Hazara slate (Wadia, 1934; Wadia, 1952; Greco, 1989). The granites have been considered equivalent to the Mansehra Granite (516 ± 16 Ma, Le Fort et al., 1980) and to the Shengul Gneiss in the Nanga Parbat area (400 to 500 Ma, Zeitler et al. 1989), situated north of our area.

The cover (Upper Carboniferous ? - Jurassic?) unconformably overlies the basement and can be correlated with the Kaghan Burawai Fm. of Greco et al. (1989) and with the First and Second cover of Spencer (1993). We have distinguished, from the bottom to the top, a siliceous, a carbonatic and a pelitic units.

In the Salkhala Series, old andalusite blasts (now pseudomorphosed by white mica) have grown on an older foliation have been interpreted as relics of pre-Himalayan tectono-metamorphic events. The foliation was probably formed during the Hazaran orogenesis (Baig and Lawrence, 1987) while andalusite blast are related to intrusion of Mansehra-type granitoids.

The rocks forming the basement and the cover have been deformed and metamorphosed during the Himalayan Tertiary events. The HHC and LHC tectonic units are characterised by a metamorphic zoning: in the HHC unit the metamorphic grade increases toward NE from upper greenschist facies to kyanite and sillimanite amphibolite facies and in the LHC unit the metamorphic grade ranges from greenschist to lower amphibolite facies.

The Tertiary metamorphism can be divided into three thermobarometric stages: an early stage of high pressure conditions, well preserved in the basic rocks outcropping in the medium grade terrains, characterised by omphacite + garnet, with estimated temperature and pressure of $600 \pm 50^\circ\text{C}$ and 15-18 Kbar (Gourirane, 1993), and by muscovite-bearing pegmatites that give upper Cretaceous $40\text{Ar}/39\text{Ar}$ cooling ages. Analogous thermobarometric results and an Eocene age have been found in the adjacent Kaghan valley (Pognante & Spencer, 1991; Villa et al., 1992; Spencer, 1993).

The second stage is a Barrovian prograde sequence defining the main rock fabric. The metamorphic grade ranges from greenschist to upper amphibolite facies and is the result of the decompression coupled with increasing temperature. The greenschist event is responsible for the formation of biotite and garnet while the amphibolite facies event formed typical garnet, biotite, kyanite and staurolite assemblages. With the increasing temperature kyanite and staurolite are replaced by sillimanite and garnet and in the Palaeozoic granites incipient melting is visible along narrow shear zones.

$40\text{Ar}/39\text{Ar}$ cooling ages of muscovite and biotite yield middle Oligocene ages for the greenschist facies rocks and upper Oligocene to Lower Miocene cooling ages for the amphibolitic assemblages.

The third stage is characterised by further increasing temperature and drop pressure. It is responsible of formation of post-cinematic biotite in the greenschist facies rocks and coronitic rim (garnet around biotite) in the amphibolite terrain.

The structure of the basement and cover rocks of the Neelum Valley record the ductile nature of complex Himalayan deformation. Four successive phases of folding have been distinguished in the field.

A widespread penetrative schistosity (S1) associated with isoclinal folding (F1) is constrained by $40\text{Ar}/39\text{Ar}$ analyses on white mica present in shear zones as upper Eocene. A second isoclinal and asymmetrical phase (F2), associated with 100 meters wide shear zones north dipping is coeval with movement along the Main Central Thrust (MCT). This thrust crosscuts the previous mylonites as well as the isograds. $40\text{Ar}/39\text{Ar}$ data on these mylonites give a Middle Oligocene (≈ 30 Ma) ages. Later, a third phase developed a crenulation cleavage (S3) while the fourth folding phase produced open folds with a wavelength of several kilometres (F4).

Key words: Tectonics, metamorphism, Neelum valley, Azad Kashmir

F/149. Fontan, D. & Schoupe, M., 1994. Contribution to the Geology of Azad Kashmir (NE Pakistan): Mapping of the Neelum valley, recent geological results. *Journal of Nepal Geological Society* 10 (Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal), 42-44.

Because of its central position between the Hazara Kashmir Syntaxis (HKS) and the Nanga Parbat Syntaxis (NPS), the Neelum Valley represents a very attractive section through the major tectonic elements of the Western Himalayan mountain belt.

From 1991 to 1993, the NW flank of Neelum Valley has been systematically mapped at the scale 1:50,000 (from Tithwal to Kel: ± 1500 km²). From the HKS to the higher structural levels, we have distinguished three units separated by two main thrust faults. We have found successively the Sub Himalaya (SH) inside the HKS, the Main Boundary Thrust (MBT) near Nauseri, the Lesser Himalaya (LH) up to Luat, the Main Central Thrust (MCT) crossing Man Nala, Jagran Nala and Ghurial Nala, and further north, the Higher Himalaya (HH).

The 1993 fieldwork has made it possible to locate a very good pretender to be the MCT connection between the MCT identified near Batal in the Kaghan Valley by Ghazanfar and Chaudhry (1985), near Musa Gali by Greco (1989), and near Luat in the Neelum Valley (Ghazanfar, Baig and Chaudhry, 1984). The newly detected MCT portion is recognized on the field by a >100 m thick shear zone expressed by dark mylonites in the schists and by light schistose mylonites in the granites. From place to place, rocks close to the MCT enclose numerous traces of metasomatism (scheelite bearing skarns). In Neelum Valley, the MCT, which demarcates the LH from the HH, crosscuts a single stratigraphic sequence. Consequently, the HH and the LH units do show the same stratigraphic features.

The pre-Himalayan basement comprises an older migmatite complex (embrekites, agmatites, anatexites) unconformably overlain by a thick meta-sedimentary sequence (the Precambrian Salkhala series of Wadia, 1934). The metasediments consist of psammitic to pelitic schists, in alternance with minor intercalations of impure marbles. Both formation are intruded by later granitoids, presumably of the early Palaeozoic age (Manshera-type of granite of Le Fort, 1988). The Himalayan cover (Upper Carboniferous-Jurassic?) lies unconformably on the basement. From bottom to top, it mainly includes gneisses and micaschists (Unit A), marbles, amphibolites, and calcschists (Unit B) and garnet micaschists (Unit C).

In Neelum Valley, the prevalent Himalayan metamorphic zoning ranges from lower to upper greenschist facies to kyanite and sillimanite amphibolite facies. The metamorphic grade increases towards NE.

Data collected in Neelum Valley suggest the following succession of geological events:

A very old metamorphism associated to an early Proterozoic orogenic event (1900-1800 My) generated the migmatite complex of the Pre-Himalayan basement. The metasedimentary Salkhala series was deposited subsequently unconformably on the migmatites. The leucogranite (Manshera type) intruded the whole basement (migmatites+Salkhala series). After uplift and erosion of the basement, the deposition of the Himalayan cover started in the region (Upper Carboniferous?-Jurassic?).

Later (About 250-300 My), basic dykes were emplaced through the whole cover-basement sequence.

The Himalayan deformation and metamorphism affected the basement and the cover.

Two subparallel penetrative schistositys S₁ and S₁₋₂ were elaborated during the transposition of the basement-cover sequence and during the development of the MCT. The MCT brought to the north the LH as a hanging wall over the HH. This step marks the peak of the Himalayan deformation. A Barrovian-type stage of the Himalayan metamorphism follows an early stage in high-pressure conditions (eclogites discovered in Gumot Nala). Further strain generated tight to open folds (wavelength <1-km) associated with a crenulation cleavage S₃. It was followed by a third stage of Himalayan retrometamorphism (growth of post-kinematic chlorite basalts). The next phase, characterised by regional open folds with a wavelength of several km, disturbed regionally the geometry of all the previous structures. Brittle deformation started with a set of N500E trending subvertical faults.

Finally, late deformations, including kinks, fracture sets and subhorizontal local thrust planes, affected particularly the HH. The scientific and technical collaboration of J. Verkaeren and D. Daduron (Université Catholique de Louvain), G. Martinotti (Università di Torino), R. Malik and his collaborators (Azad Kashmir and Industrial Development Corporation), during this work (EEC Grant No C11-0571-M (GDF) is gratefully acknowledged.

Key words: Mapping, Neelum valley.

F/150. Fontan, D., Schoupe, M., Hunziker, C.J., Martinotti, G. & Verkaeren, J., 2000. Metamorphic evolution, ⁴⁰Ar-³⁹Ar chronology and tectonic model for the Neelum valley, Azad Kashmir, NE Pakistan. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 431-453.

This paper describes the geology, tectonometamorphic history and geochronology of part of the northern flank of the Neelum Valley in Azad Kashmir, NE Pakistan. Metamorphic crystalline rocks in this area belong to the Lesser and Higher Himalayan Crystalline complexes. Geological mapping of about 1500 km² confirms the presence of three main tectonic units characterized by similar lithostratigraphic sequences but with different tectonometamorphic histories. Whether these tectonic units belong to the Lesser or Higher Himalayan Crystalline depends on the, still controversial, position of the Main Central Thrust. A tectonic model, involving syn-convergent exhumation, is suggested that is consistent with new petrographic and geochronological data, and with a revised interpretation of the Main Central Thrust.

Key words: Metamorphism, geochronology, tectonic model, Neelum Valley, Azad Kashmir.

F/151. Forcella, F., 1978. Short notes on Trich Mir geology (Hindu Kush Range). *Rend. Accademia Nazionale dei Lincei* 65, 307-312.

Key words: Geology, Tirich Mir, Chitral.

F/152. Foster, D.A., Gleadow, A.J.W. & Mortimer, G., 1994. Rapid Pliocene exhumation in the Karakoram (Pakistan), revealed by fission-track thermochronology of the K2 gneiss. *Geology* 22, 19-22.

Rapid Pliocene denudation in the Karakoram, Pakistan, as revealed by fission-track dating of rocks from K2 (Godwin Austen) was probably caused by tectonic uplift. Apatite separated from samples collected from elevations of 5300 to 8611 yielded fission-track ages of 2.1 ± 0.6 to 4.3 ± 1.4 Ma, and suggest an initial, apparent denudation rate of 3-6 mm/yr commencing after 5 Ma. One zircon separate from 6600 m gave a mean fission-track age of 32 ± 6 Ma. The mid-Tertiary zircon age delimits the maximum amount of Pliocene denudation to ≤ 7000 m. The total amount of denudation at the present mean surface elevation of 6000 m was estimated to be 6000 m.

Key words: Exhumation, fission track, chronology, K2, Karakoram.

F/153. Foster, G., Kinny, P., Vance, D., Harris, N., Argles, T. & Whittington, A., 1999. The Pre-Tertiary metamorphic history of the Nanga Parbat Haramosh Massif, Pakistan Himalaya. *Terra Nostra* 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 44-45.

It is often assumed that within active orogenic zones, such as the Himalaya, metamorphic and tectonic fabrics exposed at the surface today relate to the most recent phase of orogenesis. However, for collision-related orogenesis this assumption is only valid for metasedimentary lithologies deposited immediately prior to the most recent event, e.g. sediments deposited on the continental margin of the now-closed ocean basin. The basement rocks on which these sediments were deposited, are almost inevitably polymetamorphic, and tight chronological controls on their thermal and deformation histories are required to avoid erroneous tectonic interpretations. The Nanga Parbat-Haramosh-Massif (NPHM), a basement terrain exposed by recent exhumation of the western Himalaya, is unique in the orogen in that it has experienced recent (2-10 Ma) and rapid (approaching 4 mm/yr.) exhumation with associated decompressive melting and leucogranite intrusion (Zeitler et al. 1993; Whittington, 1996). Approximately 90% of the rock exposed within the massif has been termed "basement" on the basis of zircon chronometry (Zeitler et al., 1989) and textural investigations (Wheeler et al., 1995), yet, due to the difficulty of unravelling polymetamorphic terrains, the Pre-Tertiary metamorphic history of the massif has yet to be established. Therefore, the true thermal significance of both the Himalayan (Foster et al., 1998) and the Neogene (Smith et al., 1992) metamorphic events cannot be accurately assessed until the pre-Himalayan fabrics and assemblages can be identified. Here we present the results of a systematic investigation into the thermal history of the basement rocks of the NPHM and draw important conclusions upon the nature of Pre-Tertiary events that affected this segment of the Himalayan orogen.

Our approach has been to combine detailed field and fabric studies with a range of chronometric approaches that include: (i) U-Pb SHRIMP chronometry of basic dykes that clearly cross cut migmatitic fabrics within basement gneisses; (ii) U-in-Pb SHRIMP analyses of monazites within granitic bodies; (iii) Sm-Nd garnet analyses of metamorphic assemblages coupled with a thermobarometric treatment of these assemblages; (iv) Sm-Nd whole rock analysis of critical lithologies. As a result of these investigations we are able to recognise the following chronologies within the basement lithologies of NPHM:

Iskere Gneiss (Madin, 1986). This unit is exposed generally on the western and central portions of the massif and has a source age of around 2.5 Ga (Nd model age) and $\epsilon(\text{Nd})$ of around -18 to -27 (Whittington et al., 1999). Migmatization occurred at 1852 ± 14 Ma (Zeitler et al. 1989), closely followed by basic dyke intrusion at 1824 ± 14 Ma as identified by the age of zircon cores within the dykes. Field relations suggest that in some cases, this intrusion occurred while the surrounding gneiss were still hot. A Sm-Nd whole rock-garnet investigation and further concordant zircon analyses also indicate a significant reactivation of this gneiss at around 1300-1000 Ma.

Shengus Gneiss (Madin, 1986). This unit is exposed generally in the eastern portions of the massif and has a similar source age (~ 2.7 Ga; Nd model age) to the Iskere Gneiss with inherited zircons of around 2.5 Ga (Zeitler et al., 1989). Intruding the metasediments of the Shengus Gneiss along the western margin (Schneider, pers. comm.), in the north along the Indus gorge (Zeitler et al., 1989) and on the eastern margin (this study), are 500 Ma granitic bodies. Of particular importance is a megacrystic intrusion along the eastern margin. Here field investigations and Th-Pb ages of concordant monazites indicate this body was intruded at 467 ± 6 Ma, around 40 Ma after the main intrusive phase, thus suggesting correlation with the Manshera granite dated at 468 ± 12 Ma (Zeitler et al., 1989).

Based on the above data it is clear that these two components of the Nanga Parbat Haramosh massif are geologically distinct. What is not clear however, is how (if at all) they correlate with the well-documented terranes of the main Himalayan orogen. It is often assumed that the majority of fabrics and assemblages exhibited by the gneisses of the NPHM formed during the recent syntaxis-related metamorphic event. However, this has been shown not to be the case for the garnet-grade cover sediments exposed along the margins of the massif (Foster et al., 1998) and the data presented here suggest that pre-Himalayan fabrics and assemblages are also present in the basement lithologies. Our results not only document the resilient nature of the ancient continental crust but also illustrates the necessity of a systematic and chronologically well constrained approach to the study of polymetamorphic terrains.

Key words: Metamorphic history, NPHM, Himalaya

F/154. Foster, G., Vance, D. & Harris, N., 1998. The prograde thermal history of the Nanga Parbat Haramosh Massif, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 64-65.

The Nanga Parbat Haramosh Massif, in Pakistan, is unique in the Himalaya in that it has experienced recent and rapid exhumation (approaching 4 mm/yr.; Whittington, 1996) with associated decompressive melting and leucogranite intrusion (Zeitler et al., 1993). Zircon rims and monazites recovered from high-grade basement gneisses have yielded young ages which have been interpreted by some workers (e.g. Smith et al., 1992) to indicate that a Neogene partial melting event was also related to this rapid uplift. However, it remains to be established whether the entire massif underwent this event, and whether there is any part that preserves the earlier metamorphic history of this polymetamorphic terrane. The discovery of relatively low-grade metasediments along the margins, in particular in the south-eastern corner of the massif, allows an investigation of this problem. The best exposure of these rocks occurs in the lower Rupal valley where they form a sequence of kyanite + staurolite + garnet mica schists with associated garnet amphibolites and calcsilicates. Nd model ages and $\epsilon(\text{Nd})$ values of these and other such metasediments cluster around 1.8 Ga and -14 respectively, allowing them to be correlated with the High Himalayan crystalline unit exposed elsewhere in the central Himalaya rather than with the basement gneisses of the massif, which are more readily correlated with the Lesser Himalayan Unit (Whittington et al., this volume). Here we present new garnet-whole rock Sm-Nd ages for these rocks and show that they experienced garnet - grade metamorphism at about 20-50 Ma. These data, together with P-T determinations, demonstrate that the assemblage has followed a "prograde" Himalayan P-T-t path significantly predating the recent exhumation-related event. This study illustrates the power of garnet Sm-Nd chronometry to see through late stage overprinting events, and the importance of a systematic approach to the study of polymetamorphic terranes.

Key words: Mountain Building, NPHM, Himalaya.

F/155. Fox, C.S., 1923. The bauxite and aluminous laterite occurrences of India. Geological Survey of India, Memoir 49, 287p.

Key words: Bauxite, Aluminous Laterite, India.

F/156. Fox, C.S., 1926a. Water supply near Landi Khana. Geological Survey of India, Record 59, p.64.

This report concerns the supply of water to Landi Khana on the Peshawar- Torkham (Khyber Agency) railway line (the Khyber Railway).

Key words: Water, Landi Khana, Khyber Agency.

F/157. Fox, C.S., 1926b. Geological consideration which appear to affect the safety of Khyber Railway. North-Western Railway Press publication, Lahore.

This report concerns the geological consideration for the safety and sustainability of the Khyber Railway. The rail tracks pass through a gently sloping level ground up to Jamrud, from where on there is a steady climb up to Landikotal, followed northward by a steep descent to Torkham on the Pak-Afghan border. There are several bends and tunnels on the way between Jamrud and Landikotal. The track passes through sedimentary rocks, comprising mostly slates, phyllites and limestones.

Key words: Geological safety, Khyber Railway.

F/158. Fox, C.S., 1944. India's mineral resources for war and the future, (Presidential address), Quarterly Journal of the Geology, Mining and Metallurgy Society of India, 16, 93-106.

This is a summarized compilation of the mineral resources of the subcontinental India, known by 1943, for use in war and sustainable development.

Key words: Mineral resources, war, India

F/159. Fox, C.S., 1950. The mineral resources of Kashmir. Mineralogical Magazine 23/83, 80-86.

Key words: Mineral resources, Kashmir.

F/160. Fox, C.S. et al., 1942. The mineral wealth of India. Geological Survey of India, Record 76.

This document gives a review of the then known mineral deposits of India, including the present day Pakistan.

Key words: Mineral deposits, India.

F/161. Fernandez Polo, J.A., 1970. Caracteres de algunas yacimientos uraniferos del Pakistan. Energia Nuclear, Madrid, 14, 19-29.

This account gives some details of uraniferous deposits of Pakistan. It contains nine figures and one map.

Key words: Radioactivity, nuclear energy.

F/162. Francis, M.R., Miller, K.J. & Dong, Zhi-Bin, 1984. Impulse radar ice-depth sounding of the Ghulkin Glacier. In: Miller, K. J. (Ed.). The International Karakoram Project 2, 111-123. Cambridge University Press.

The work carried out by a radio-echo sounding team on the Hispar glacier is described. Results of impulse radar depth-soundings at eleven different sites are given. The measurements are discussed in relation to the effects of surface moraine and melt-water upon the echo signal.

Key words: Glaciology, Ghulkin, Hunza.

F/163. Fraser, H., 1998. Structural and metamorphic evolution of the deep crust in the Hunza Karakoram, Pakistan. Geological Bulletin, University of Peshawar 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop), p.65.

The Karakoram Metamorphic Complex forms the southern most margin of the Asian Plate with the northern limit of the complex in Hunza being marked by a tectonic contact with the Hunza Plutonic Unit. (Desio, 1964; and Crawford and Searle, 1993). This granodiorite is a pre-collisional batholith that exhibits a strong foliation at its southern contact with the underlying metamorphic rocks. The southern margin of the complex is marked by the Shyok Suture Zone as described by Pudsey, 1986.

A detailed map of the middle Hunza valley has been produced that illustrates the principal lithologies, structural features and locations where detailed petrology and thermobarometry has been carried out.

Rocks ranging from staurolite through kyanite to sillimanite grade occur in the middle Hunza valley and exhibit an inverted metamorphic sequence with structurally higher units exhibiting the highest metamorphic grade. This is reflected not only in the mineral assemblages present, as previously noted by Broughton et al., 1985, but also in pressure and temperature estimates throughout the slab, extending previous work carried out by Okrusch et al., 1976. This inversion appears to be a consequence of south directed ductile and semi-ductile shear and later brittle thrusting which emplaced higher grade units over those of lower grade in agreement with earlier work of Crawford and Searle, 1993. P-T work shows a small variation in values for staurolite grade rocks, but those of sillimanite grade rocks show greater variation in pressure estimates. Retrograde reaction textures have been observed in those sillimanite grade samples that have yielded lower pressures of 5.8 ± 1.2 and 4.4 ± 1 Kb. Temperatures are typically 628 ± 41 to 674 ± 49 C. These P-T patterns may reflect those seen in the Baltoro, reference Searle and Tirrul, 1991; Allen and Chamberlain, 1991; and Lemennicier et al., 1996.

Key words: Structure, metamorphic evolution, Hunza.

F/164. Fraser, J., Searle, M., Parrish, R. & Noble, S., 1999. U-Pb geochronology on the timing of metamorphism and magmatism in the Hunza Karakoram. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 45-46.

U-Pb dating has been carried out on samples of regional metamorphic rocks and granites of the Hunza Karakoram in northern Pakistan with the aim of deciphering the thermal and magmatic evolution of the thickened Asian plate crust. The pre-collisional (India-Asia collision) origin of the Hunza plutonic unit granodiorites forming the main component of the Karakoram batholith in this part of the range has been confirmed by three concordant zircon analyses yielding a U-Pb crystallisation age of 105.7 ± 0.5 Ma. The Hunza dykes consist of a co-genetic suite of granodiorites, monzogranites and leucogranites, which intrude the early phase of the batholith, as the sillimanite grade rocks to the south. Zircon and uraninite from the early set of Hunza dykes parallel to the regional north-dipping schistosity have concordant U-Pb age of 51.5 ± 1.5 Ma.

One sample of a garnet + biotite leucogranite dyke from the later set of Hunza dykes which emanate from the southern part of the granite batholith and cross-cut sillimanite gneisses and phlogopite $\pm$ ruby corundum marbles, has been dated using zircon, monazite and uraninite at 35.1 ± 0.6 Ma, similar to the age of the Mango Gusar pluton (37.0 ± 0.8 Ma; U-Pb on zircon), south of the Baltoro plutonic unit to the east. Monazites from a sillimanite grade meta-pelite from Baltit gave a U-Pb age of 68 ± 0.5 Ma, which is

interpreted as the timing of sillimanite grade peak metamorphism and deformation in the Karakoram metamorphic complex south of the Karakoram batholith. Sillimanite grade metamorphic rocks in the Hunza valley structurally overlie kyanite and staurolite grade rocks which have been emplaced southwards over low-grade rocks of the Shyok suture zone forming an inverted metamorphic field gradient. Monazites were separated from these highly graphitic garnet-staurolite schists and yield an interpreted crystallisation age of 16.0 ± 1.0 Ma. The somewhat large error ellipses are due to the numerous inclusions in these monazites. All presently available U-Pb geochronological data from the Hunza and Baltoro Karakoram suggest that two metamorphic episodes are present: (1) a long-lasting latest Cretaceous to late Eocene sillimanite grade event south of the batholith in Hunza and (2) a mid- to late Miocene ~ 16 Ma staurolite -kyanite grade event along the southern part of the metamorphic complex. The youngest phase of crustal melting is dated at 9.2 ± 0.5 Ma from U-Pb ages of zircon, xenotime and uraninite from the Sumayar tourmaline leucogranite south of the Karakoram batholith.

Key words: Geochronology, metamorphism, magmatism, Hunza, Karakoram.

F/165. Fraser, J., Searle, M. Parrish, R.M. Noble, S. & Thimm, K., 1998. U-Pb geochronology on the timing of metamorphism and magmatism in the Hunza Karakoram. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 66-67.

U-Pb dating has been carried out on samples from the regional metamorphic rocks and leucogranites of the Hunza Karakoram with the aim of deciphering the thermal and magmatic evolution of the thickened Asian plate crust. The pre-collisional origin of the Hunza plutonic unit granodiorites forming the main component of the Karakoram batholith in this part of the range has been confirmed by three concordant zircon analyses yielding a U-Pb crystallisation age of 105.7 ± 0.5 Ma (sample K94-24). The Hunza dykes consist of a co-genetic suite of granodiorites, monzogranites and leucogranites, which intrude the early phase of the batholith, as well as the sillimanite grade rocks to the south. One sample (K 94-23) of a garnet+biotite leucogranite dyke emanating from the southern part of the granite batholith and cross-cutting sillimanite gneisses and phlogopite±ruby corundum marbles, has been dated using zircon, monazite and uraninite at 35.3 ± 0.4 Ma, similar to the age of the Mango Cusar pluton south of the Baltoro plutonic unit to the east (37.0 ± 0.8 Ma, U-Pb on zircon; R.Parrish data in [11]. These two ages put an upper time constraint on sillimanite grade peak metamorphism and deformation in the Karakoram metamorphic complex south of the Karakoram batholith.

The Sumayar leucogranite is a small isolated tourmaline leucogranite with minor biotite and garnet intruding staurolite grade schists south of the Karakoram batholith in the Nagar region east of Hunza. It is a water-saturated, minimum-melt leucogranite similar to many High Himalayan granites, probably derived from melting of a pelitic lower crustal source [21]. U-Pb dating of zircon and uraninite yields an age of 9.2 ± 0.1 Ma, whereas xenotime intergrown with zircon yields 8.55 ± 0.15 Ma. The apparently distinct ages of intergrown zircon and xenotime could be explained by two periods of mineral growth (and partial resorption?) or by Pb loss in xenotime. This shows that this is the youngest crustal melting event in the Karakoram, and it cannot therefore be linked temporally to the Mango Cusar or Chingkiang-Ia plutons, south of the Baltoro granite, as previously thought. Several phases of granitic dyke intrusion are present in the Hunza section and dykes emanating from the Sumayar pluton must be a younger phase than the Hunza dykes.

Metamorphic monazites were extracted from a staurolite+garnet mica schist (K94-20) from Nasirabad in the Hunza valley. The $206\text{Pb}/238\text{U}$ age of monazite is $15.5\text{--}16.5$ Ma and due to probable excess 206Pb , we interpret the crystallization age as $14\text{--}16$ Ma. This must date the timing of monazite growth during staurolite-grade metamorphism, and is considerably younger than the previous estimates of a pre-37 Ma age for metamorphism of all the southern Karakoram metamorphic complex [3]. All presently available U-Pb geochronology from the Hunza and Baltoro Karakoram suggest that two metamorphic episodes are present: (1) a pre-37 Ma late Eocene-Oligocene sillimanite grade event south of the batholith in Hunza and the Baltoro region, and (2) a mid- to late Miocene ~ 16 Ma staurolite - kyanite grade event along the southern part of the metamorphic complex.

Key words: Geochronology, metamorphism, magmatism, Hunza, Karakoram.

F/166. Friend, P.F. & Raza, S.M., 1991. Size and form of the fluvial sandstone bodies of the Lower Chinji Formation (Miocene, Siwalik Group), Northern Pakistan. Abstract Symposium on Characterization of Fluvial and Aeolian Reservoirs, Aberdeen University, Scotland.

Key words: Sandstone, Siwaliks, Chinji Formation, Miocene.

F/167. Friend, P.F., Raza, S.M., Baig, M.A.S. & Khan, I.A., 1994. Geological Evidence of the ancestral Indus from the Himalayan Foothills. In: Meadows, A. & Meadows, P., (Eds.), *The Indus River, Biodiversity, Resources, Humankind*. Linnean Society, Symposium on the River Indus. Proceedings, Burlington House, London, Oxford University Press 103-113.

Northern Pakistan contains classic outcrops of Himalaya-derived 'Siwalik' river sediments, rich in mammal fossils, and dating from between twenty million years ago and the present. The sediment logical analysis of local structures in these sediments has made it possible to reconstruct the flow directions of the depositing rivers. In outcrops west of the present Indus, the depositing rivers are seen to have flowed with Indus-like trend, towards the south. East of the present Indus they are seen to have flowed with a more Ganga-like trend, towards the south-east and east. The Sargodha 'high' of basement outcrops may represent a structure that caused the divergence between these two trends. From about eight million years ago, there is evidence that a particularly large river emerged from the mountain front in approximately the position of the present Indus, and this is identified as the ancestral Indus.

Key words: Geology, Siwaliks, Indus, Himalayan.

F/168. Friend, P.F., Raza, S.M., Geehan, G. & Sheikh, K.A., 2000. Intermediate-scale architectural features of the fluvial Chinji Formation (Miocene), Siwalik Group, northern Pakistan.

The Lower Siwalik, Chinji Formation (Late Miocene) of the Chinji Village area, northern Pakistan has provided remarkable material for the study of terrestrial fossil faunas, magnetic reversal stratigraphy and fluvial sedimentology. This paper considers patterns in the sedimentary stratigraphy, using magnetic reversals to constrain the time framework, and focusing on an intermediate (kilometre) horizontal length-scale. The project aimed to determine the architecture and time relationships of the channel sandstone bodies in a panel 300 m in stratigraphic thickness, and 11 km in horizontal length (along stratigraphic strike). This panel (the 1990 Fence) trends at a high angle to the flow direction of the Late Miocene river channels, and represents about 2 Ma of sediment accumulation. There is a continuous range in thickness of the sandstone bodies, but they can be usefully classified into (i) microbodies, (ii) minor sheets, (iii) thin mega-sheets and (iv) thick mega-sheets. The microbodies are probably mainly marginal features of the thicker bodies. The minor sheets were formed by small river channels, and the mega-sheets were formed as the deposits of the largest, generally braided, channel belts. Two aspects of the intermediate length-scale architecture of the Chinji Formation are analysed: (1) the presence in the Fence of three thick mega-sheets separated by two mudstone-dominated intervals that lasted for about 0.5 and 1.0 Ma, respectively and (2) the abrupt upwards increase in sandstone/mudstone proportions that defines the upper stratigraphic boundary of the Chinji Formation. We suggest that each of the three thick mega-sheet episodes resulted from avulsions into the area of large-channel belt complexes that formed central features of the Chinji river network and were each constrained by scarps or valley-side slopes during episodes of net deposition that lasted for about 100 ka, and may have resulted from climate and/or sea-level changes. The regional upward change from mudstone- to sandstone-domination at the top of the Chinji Formation resulted from a similar, but one-off, and more widespread, change in plan-view style of the river network, produced either by tectonic change in the mountain source area, or by climatic change.

Key words: Stratigraphy, fossils, Chinji Formation, Siwaliks.

F/169. Fuchs, G., 1970. The significance of Hazara to Himalayan geology. *Geological Bundes. Jahrd. Sondubd* 15, 21-23.

Key words: Hazara, Himalaya.

F/170. Fuchs, G., 1975. Contribution to the geology of the north western Himalayas. *Geologische Abhandlungen* 32, 1-59.

Key words: Geology, Himalaya.

F/171. Fuchs, G., 1999. The evolution of the Himalayan orogenesis. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 47-48.

Orogenesis is a complex process involving tectonics, sedimentation, magmatism, metamorphism etc. Many problems arise: When did orogenesis start; how did tectonisation propagate; what happened in different tectonic zones contemporaneously? We must come to a vivid picture of the growth of the mountain chain. I am giving such a picture-admittedly subjective and the number of aspects is certainly not complete-but I hope that it will invite discussion.

Research of the last two decades has shown that the orogenesis started already in the Maastrichtian: The blockflysch of the Tsangpo region (Burg, 1983) is an orogenic sediment formation, which documents that the northern margin of India was already close to the subduction zone. Overlap of the Lamayuru basin facies onto the Zaskar Shelf followed by folding of the Tethyan Zone indicates a short period of down bending in the Maastrichtian when the continental margin reached the subduction zone and collided with the Asian Plate (Fuchs, 1982). The overlapping euxinic sediments, however, are connected with the underlying Campanian Fotu La Formation and do not represent an early thrust sheet as proposed by Corfield et al. (1996). In Pakistan, Beck (1995) found Upper Paleocene beds transgressing the accretional wedge of the MMT.

This early collision of India was not with the Asian Continent but with trapped oceanic lithosphere of the Asian Plate (Dürr 1995; Fuchs and Linner 1996). The latter was consumed in the course of continued convergence in Maastrichtian-Early Eocene times along a second melange zone north of it.

Connections between Asia and India, as early as at the Cretaceous/Tertiary boundary, are also documented by floral and faunal exchange (Prasad et al., 1988; Jaeger et al., 1989). Palaeomagnetic research also suggests that collision occurred around the Cretaceous/Tertiary boundary in equatorial latitudes (Klootwijk et al., 1991) and that the extended northern margin of India reached the subduction zone earlier than assumed previously (Appel, 1989; Patzelt, 1996).

Thus pre-Eocene collisions are well-documented. The continent/continent collision along the whole suture, however, occurred in the Early Eocene. Then the MMT was sealed in Pakistan (Beck, 1995) and the Spontang thrust mass was emplaced on the Zaskar Shelf (Fuchs, 1982; Fuchs and Willems, 1990). That event put an end to the marine sedimentation and initiated the deposition of terrestrial molasse along the Indus-Tsangpo Suture Zone. Compressional phases with uplift and denudation alternated with extensional phases and molasse transgression. Rather late ultrabasic masses came to rest on the molasse, which was folded and imbricated with the underlying beds. It seems that the Miocene nappe tectonics in the southern Himalaya coincide with extensional tectonics in the north.

The Miocene age of the Lesser Himalayan nappe stacking is proved by the Dagshai Formation exposed in windows, the cooling ages of the Crystalline nappes and the start of Siwalik sedimentation in the foredeep. Later the Lesser Himalayan nappe pile was folded, which led to windows and outliers. The scene of thrusting shifted further south to the MBT. Siwalik sedimentation was accompanied by the formation of new thrusts, which became younger southwards (Heraïl et al. 1986).

In the Lesser Himalaya a mature relief was formed by denudation. Quaternary reactivation of older lineaments led to the steep southern flanks of the Great Himalaya, Panjal, Dhauldhara and Machabhat Ranges. This does not mean that the MCT is a young thrust, as suspected by Raiverman (1997).

Latest molasse deposits in the Tethyan Zone (Plio-Pleistocene) are non-folded but disturbed by faulting and tilting during the uplift of the Great Himalayan Range (e.g. Sutlej, Takkhola).

The above is a rough picture of the complex orogenic development commencing along the suture, propagating towards the south and thus involving more and more rock series of the Indian passive margin. This process spans a period of approximately 70 m.y. and has not yet ended.

Key words: Tectonics, orogeny, Himalayan.

F/172. Fuchs, G. & Gupta, V.J., 1979. The significance of the Tanol Formation of the western Himalaya. In: Gupta, V.P. (Ed.), Contribution to Himalayan Geology, Upper Paleozoics of the Himalaya 1, 154-161.

Key words: Tanol Formation, Himalaya.

F/173. Fuchs, G. & Mostler, H., 1972. Der erste Nachweis von fossilien (Kambrischen Alters) in der Hazira-Formation, Hazara, Pakistan. Geologische Palaontologische, Mitteilungen (Innsbruck) 2, 1-12.

Within the marly respectively calcareous dolomitic beds of the Hazira Formation there are sporadic phosphate airs rich in biogenic matter. Obviously they are replacement products, as all the organic remains are replaced by apatite.

The microfauna yielded by maceration indicates Cambrian age. The fossils cited below, according to present knowledge, point to Lower Cambrian age; porifera (*Archiasterella pentactina* SDZUY, *Allonnia tripodophora* DORE and REID and "stauractine" archiasters; *Calyptoptomatids* (*Hyolithes* EICHWALD and *orthothecides*) and forms of doubtful systematic position (*Hyolithellus* EICHWALD). Further there are forms probably belonging to the annelids (? *Lapworthella* COBBOLD, ? *Rushtonia* COBBOLD and *POCOCK*).

Key words: Paleontology, Hazira Formation, Hazara.

F/174. Fujii, N., 1995. Genesis of clay deposits and their exploration: Focusing on some clay deposits in Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 12, 23-40.

This paper discusses the mineralogical and chemical aspects of clay minerals and their genesis. The shahdheri china clay deposits have been described. It is concluded that this deposit is rather low in content and contains Ca rich feldspar. Such a raw material might not be suitable for the common ceramic products.

Key words: Clay deposits, exploration.

G/1. Gaetani, M., 1967a. Devonian of northern and eastern Iran, northern Afghanistan and northern Pakistan. In: Oswald, D.H. (ed.), International Symposium on Devonian System, Calgary 1967, Alberta. Society of Petroleum Geology 1, 519-528.

Key words: Biostratigraphy, Devonian, Iran, Afghanistan, Pakistan.

G/2. Gaetani, M., 1967b. Some Devonian brachiopods from Chitral (NW Pakistan). *Rivista Italiana di Paleontologia e Stratigrafia* 73, 3-22.

Key words: Devonian, Palaeontology, Chitral.

G/3. Gaetani, M., 1967c. Northern and Eastern Iran, Northern Afghanistan and Northern Pakistan. International Symposium on the Devonian System, Calgary, vol. 1, 519-528.

Key words: Geology, mapping, Iran, Afghanistan, Pakistan.

G/4. Gaetani, M., 1990. The sedimentary sequence of the Shaksam valley (Karakoram and Aghil Ranges). In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 14.

Sedimentary rocks of the Shaksam Valley (Karakoram and Aghil Ranges) are arranged in large south-west verging folds, disrupted by several thrusts and faults aligned NW-SE. Though field data are uncompleted, three different stratigraphic sequences may be described. Everywhere, the base of the succession is thrust.

The better documented is the northern eastern sequence. Above a clastic wedge, marine shallow water carbonates begun in the Arthinskian. Drowning, resulting in cherty carbonates occurred in the Late Permian, with huge resedimentations from active platforms during the Djulfian. Deep-water, thin-bedded carbonates persisted in the Early and possibly Middle Triassic. The re-sedimented calcirudites helped the recovering of the carbonate platform, which persisted to the Early Jurassic. Lateral Liassic equivalent are dark-gray bedded limestones, which continued up to the Middle Jurassic. Red conglomerates and sandstones spread over in Bathonian, followed by mostly terrigenous fine rocks, interpreted as distal turbidities. Yellow polymict conglomerates with mostly carbonate clasts, end the succession. In the middle, till the main fault of the Karakoram Fault Zone (KKFZ), black shales and sandstones, most probably of Permian age, represent the base of the sequence. Then, pelagic gray limestones constitute a relevant sheet, in which also Carnian conodonts were found. Finally, west of the main fault of the KKFS, black shales and several hundreds meters of the Urdok Conglomerate. Crop out. The conglomerate contains prevalent red sandstones, but also gneiss pebbles. The inferred age of the Urdok Conglomerate is Cretaceous or younger.

Key words: Sedimentology, stratigraphy, Shaksam valley, Karakoram.

G/5. Gaetani, M., 1992. The Karakoram plate during the Permo-Triassic. Abstracts, First South Asia Geological Congress, Islamabad, p.13.

Key words: Karakoram plate, Permo-Triassic.

G/6. Gaetani, M., 1994. The Karakoram Block from Ordovician to Jurassic: A progress report. Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal, 53-54.

The Karakoram Block was a part of the Peri-Gondwanian fringe during the Paleozoic. The most ancient unmetamorphosed sediments are of Early Ordovician (Arenig) age, consisting of sandstones and shales, transgressing over a crystalline basement. Rare carbonatic intercalations point the succession up to the Middle Devonian, when a wide peritidal platform spread over, temporally stopping the terrigenous deposition. Sedimentation rates were low, 10-20 m/Ma. The mixed terrigenous/calcareous sedimentation resumed in the Late

Devonian, with brachiopod shell lags and coral patches. The Early Carboniferous is poorly documented, probably still calcareous. No data instead on the Late Carboniferous.

Starting with Permian, sedimentation rate increases and thickness of Permian rocks is between 1 and 2.5-km. They record a variety of environments. The Larger differentiation occurred from the Late Permian to the Middle Triassic, when a peritidal carbonate flat developed at southwest, facing a deeper basin at northeast. With Carnian, the carbonate platform resumed everywhere. This evaluation is interpreted as the passive margin stage of the Karakoram Block, when it followed the fate of the Mega Lhasa continent, which drifted northwards on the Tethyan Transit Jurassic, the Eo-Cimmerian deformation, more severe in SE Pamir, is recorded also in Karakoram, mostly to northeast, with two arenaceous bodies. Below, Quartzo-lithic sandstones characterized by mafic volcanic detritus and serpentinite grains suggest the nearby presence of a collisional belt. They are sutured by red sandstones with sedimentary and metasedimentary clasts, feeded by an uplifted sedimentary succession. From the Aalenian, this orogenic episode was out and shallow water carbonates ramp aggraded onto the previously emerged area, probably developing for most of the Late Jurassic. This episode is interpreted as the first docking of the MegaLhasa spur represented by SE Pamir to the Eurasia margin, followed by an anticlockwise rotation.

The Karakoram Block is also characterized by a very wide occurrence of black slates, the "Karakoram", fringing externally to the range the previously recorded Paleozoic succession, from the Chitral, through Whakan and SE Pamir, to the W Qiang Tang in Tibet. They are considered as the alluvial and submarine fan of a large drainage system. Such a huge pile of terrigenous sediments may be fed only by a large continent and not by a small block, like the Karakoram. Consequently the "Karakoram" are considered as of Gondwanian origin. When the MegaLhasa continent was isolated by the Neo-Tethys opening, various carbonatic environments developed in Karakoram. The deeper basin starved, with cherty, nodular to platy limestones and shales, at low sedimentation rate, as are the rare occurrence of Triassic conodont bearing layers in Wakhan and SE Pamir. However, any paleogeographic reconstruction is severely hampered by Cretaceous to Cainozoic tectonics, which affected the area, causing also important lateral displacements.

Key words: Sedimentation, metamorphism, Karakoram block, Ordovician, Jurassic.

G/7. Gaetani, M., 1997. The Karakoram Block in Central Asia, from Ordovician to Cretaceous. *Sedimentary Geology* 109, 339-359.

For details consult the preceding account. More or less the similar, but with information of the Cretaceous period added in this one.

Key words: Karakoram block, Ordovician, Cretaceous.

G/8. Gaetani, M., Angiolini, L., Garzanti, E., Jadoul, F., Leven, E.Y., Nicora, A. & Sciunnach, D., 1995. Permian stratigraphy in the northern Karakorum, Pakistan. *Rivista Italiana di Paleontologia-i- Stratigrafia*, Melano, 101, 107-152.

Key words: Stratigraphy, Permian, Karakoram.

G/9. Gaetani, M., Erba, E., Jadoul, F. & Angiolini, L., 1992. Age constraints on Karakoram early deformation derived from sedimentary rocks. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.28.

The early deformations of Northern Karakorum have at least three age peaks. The older is Jurassic, spanning from Liassic to early Middle Jurassic, as evidenced by red and grey thin to coarse arenites, forming tens to hundreds m-thick multiple bodies. Petrographic composition indicates the orogenic character of these sandstones. The terrigenous bodies increase in thickness from west to east, and north to south, being mostly reddish with emersion evidence at west in Chapursan valley (Yashkuk Fm.) and exclusively gray with marine fauna intercalations south and eastwards (Kundil and the area between Shimshal to Shixnshal pass). More details are reported in the Jadoul et al. abstract (This Workshop). The occurrence of these arenites and shales is interpreted as connected to a nearby deformation and uplift, related to a first docking of Cimznerian microplates.

A strong deformation instead directly affected the whole sedimentary sequence in a time comprised between the Late Jurassic and the Late Cretaceous. The polymictic, mostly fluviatile, Tupos Conglomerate seals verticalized and

folded Triassic and Jurassic sedimentary rocks. Upper Paleozoic clasts were also detected. These were considered till now the youngest pre-India collision sediments of the Karakorum Range, and they were related to the final welding of the Karakorum microplate to the Asian continent, due to the Neothethys active subduction at south. The deformation was tentatively ascribed to a Mid Cretaceous time. It should be also considered the large occurrence of granitoids plutons, with 110-100 Ma age in Northern Karakorum.

During the 1991 expedition, we found a marine reddish to gray nodular limestone some hundred m thick, onlapping with angular unconformity (10 to 20m) the highly irregular surface of the Tupo Conglomerate. These scaglia-like deep-water sediments contain Inoceramid phosphatized particles and very rare Nannofossils. The identified species *Ceratolithoides verbekii* and *Calculites obscurus* till now are considered as coexisting only in the Early and Middle Campanian. This finding represents the youngest marine sediment so far detected in Karakoram, the only Late Cretaceous marine evidence and makes possible some connection with the Late Cretaceous evolution of Western Tibetan Plateau.

Key words: Deformation, sedimentary rocks, Karakoram.

G/10. Gaetani, M. & Garzanti, E., 1991. Multicycle history of the Northern India continental margin (Northwestern Himalayas). *American Association of Petroleum Geologists Bulletin* 75, 1427-1446.

The geologic evolution of northern India is best recorded in the stratigraphic succession of the Zaskar Range (northwestern Himalaya), which represents the most complete transect through this ancient continental margin. Sedimentary history began in the late Proterozoic, and recorded a late Pan-African orogenic event around the Cambrian-Ordovician boundary, when the Gondwana supercontinent was eventually assembled.

The following long period of epicontinental deposition in shallow seas linked to palaeo-Tethys lasted until the Early Permian, when a neo-Tethyan rift began to open between paleo-India and the Cimmerian microcontinents. Neo-Tethyan history can be subdivided into two sedimentary megasequences, both recording a major tectonic and magmatic event in the lower part. The first one began with breakup in the Late Permian and lasted until the end of the Jurassic. The second one started in the early Cretaceous with the final detachment of India from Gondwana and the opening of the Indian Ocean, and ended with the India-Eurasia collision in the Early Eocene. The two megasequences can be in turn subdivided into six transgressive/regressive supersequences bounded by tectonically enhanced unconformities.

Basal sandstone units of Early Permian, Late Permian, Norian, Callovian, Early Cretaceous, and Paleocene age are invariably associated with oolitic ironstones or reworked glauco-phosphorites, and mark the transgressive part of each supersequence. Next, condensed nodular carbonates or shales with pelagic fauna are typically overlain by thick shallowing-upward marly units capped by regressive platformal carbonates. The six tectono-eustatic supercycles reflect successive rifting episodes which punctuated the progressive separation of India from the rest of Gondwana, and document the combination of plate/microplate reorganizations and eustatic, climatic, and oceanographic changes in the Tethyan domain.

After the onset of collision between India and Asia close to the Paleocene/Eocene boundary, obduction of the remnants of the neo-Tethys ocean floor onto the Indian margin began, and the latter underwent multi-phase deformation with fold-thrust shortening followed by heating and extension. After the main metamorphic event, ophiolitic nappes were re-thrusted and finally emplaced with their sedimentary sole on top of the passive-margin succession.

Key words: Plate tectonics, Indian plate, Himalaya.

G/11. Gaetani, M., Garzanti, E., Jadoul, F., Nicora, A., Tintori, A., & Kanwar, S.A.K., 1987. Major structural elements in upper Hunza valley (Northern Pakistan). *EUG Strasbourg*, 112-113.

Key words: Structure, Hunza, Karakoram.

G/12. Gaetani, M., Garzanti, E., Jadoul, F., Nicora, A., Tintori, A., Pasini, M. & Khan, K.S.A., 1990. The north Karakoram side of the Central Asia geopuzzle. *Geological Society of America, Bulletin* 102, 54-62.

An Italian geological team visited a remote and in part never studied area in the northern Hunza region (Pakistan), which represents the link between the Karakorum and Pamir Ranges. The north Karakorum sequence commences in the Permian with terrigenous sediments, followed by shallow- to deep-marine carbonates deposited on a newly formed passive margin. Deep-water sedimentation continued till the end of the Middle Triassic, when carbonate platform conditions resumed. An episode of deltaic red sandstones with orogenic provenance is interbedded in the Liassic, and it is transgressed by a Middle to ?Upper Jurassic shallow water marine unit. Eventually, all of the sequence was faulted and folded, with weak metamorphic imprint, before fluvial red polygenic conglomerates sealed the succession, in a spectacular unconformity.

The north Karakorum provides an example of a microplate that rifted away from Gondwana in the Permian, reached deep-marine conditions in the Early Triassic, and marginally recorded compressive movements in the Liassic. A subsequent orogenic episode points to a reorganization of the southern Asian margin possibly around middle Cretaceous time. Finally, the north Karakorum was affected by strong fold-thrust deformation and low- to very low-grade metamorphism in the Cainozoic, related to the India-Asia collision.

Key words: Sedimentation, stratigraphy, Permian, Hunza, Karakoram.

G/13. Gaetani, M., Garzanti, E. & Tintori, A., 1990. Permo-Carboniferous stratigraphy in SE Zaskar and NW Lahul (NW Himalaya, India). *Eclogae Geologicae Helveticae* 83, 143-161.

Key words: Stratigraphy, Permo-Carboniferous, Zaskar, Lahul, Himalaya.

G/14. Gaetani, M., Gosso, G. & Pognante, U., 1990a. From Kunlun to Karakoram, the EV-K2 CNR 1988 Expedition. In: Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.15.

During September and October 1988, a geological and geophysical expedition, sponsored by the Consiglio Nazionale delle Ricerche (CNR) and assisted on the field by the Chinese Mountaineering Association (CMA), made a reconnaissance from Mazar (Yarkand Valley) to the north side of the Karakoram (K2 and Gasherbrum).

South of the Kun Lun Crystalline, six units, all bounded by tectonic contacts, have been detected. North to south, they are:

Bazar Dara Slates and related granitoids. Gray dark slates and fine litharenites, several thousand meter thick, intruded by km-sized granitoid bodies.

Surukwat Thrust Sheets. Non-metamorphic red sandstones and anhydrites thrust together with metadiorites, micaschists, orthogneisses, and metapelites. Aghil Dara Granodiorite. Large body of granodiorite, and subordinated porphyritic granites, quartzdiorites and gabbros. Shaksgam Sedimentary Belt. At least 3-km thick sedimentary sequence, with marine fossils from Permian to the Jurassic. Sughet Granodiorite. Granodiorites and tonalites.

Sarpo Lago-K2 Metamorphics. Ortho- and paragneisses, marbles and pegmatoids, with less metamorphosed sedimentary thrust sheets containing fusulinids. Unit 1 and 2 are attributed to the Kun Lun and Qiantang micro plates, separated by a great fault, interpreted as the W Kun Lun Fault. Units 5 and 6 belongs to the Karakoram microplate, whilst the correlation of the sediments of Shaksgam valley is uncertain. The Karakoram Fault Zone affect the Sughet Granodiorite and the sediments of the Shaksgam Valley.

Key words: Geophysics, Kunlun, Karakoram.

G/15. Gaetani, M., Gosso, G. & Pognante, U., 1990b. A geological transect from KunLun to Karakoram (Sinkyang), China: The western termination of the Tibetan Plateau. Preliminary note. *Terra Nova Research* 2, 23-30.

Consult the preceding account.

Key words: Geophysics, Kun Lun, Karakoram, Tibet Plateau.

G/16. Gaetani, M., Gosso, G. & Pognante, U., 1991. Geological report. In: *Geodesy, Geophysics and Geology of the Upper Shaksgam Valley (North-East Karakoram) and South*

Sinkiang. Scientific Report of the Italian Expedition to Karakoram 1988 (A. Desio leader). Consiglio Nazionale delle Ricerche-Milano, 99-179.

Key words: Geodesy, geophysics, Shaksam Valley, Sinkiang, Karakoram, Expedition.

G/17. Gaetani, M., Jadoul, F., Erba, E. & Garzanti, E., 1993. Jurassic and Cretaceous orogenic events in the N Karakoram: age constraints from sedimentary rocks. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonics*. Geological Society, London, Special Publications 74, 39-52.

At least two major episodes of tectonic deformation are recorded in the Mesozoic sedimentary succession of the North Karakoram. The older event took place between the Liassic and the early part of the Mid-Jurassic, as documented by tens to hundreds of metres thickness of dark grey litharenites (Ashtigar Fm.). The latter are sharply overlain by 35 m to 150 m thick red sandstones, interbedded with shales and siltstones (Yashkuk Fm.). Terrigenous bodies increase in thickness from west to east, and from north to south. Petrographic composition indicates the orogenic character of these quartzo-lithic sandstones, characterized by mafic volcanic and serpentinite detritus, being replaced upwards by sedimentary and subordinate metasedimentary clasts. The Ashtigar Fm. may have been deposited in a collisional basin close to a newly-formed suture belt. Contribution from allochthonous oceanic rocks was significant in the first stages of collision, whereas detritus was subsequently derived mainly from uplifted sedimentary successions. Terrigenous units were conformably transgressed by shallow-water limestones in the Aalenian, and later on marine conditions persisted until the earliest Cretaceous.

The second event of tectonic deformation occurred between the earliest and the Late Cretaceous, when the fan delta Tupo Conglomerate, mostly derived from uplifted carbonate and clastic rocks, sealed the strongly folded and faulted underlying succession. Mid-Cretaceous granitoid plutons are also widespread in the North Karakoram. This orogenic event is interpreted as related to the final welding of the Kohistan arc and Karakoram microplate to Asia.

The highly irregular topography of the Tupo Conglomerate is overlapped unconformably by reddish to grey nodular limestones, some hundred metres thick and containing phosphatized inoceramids and nannofossils of Campanian age (Darband Fm.). These are the youngest marine sediments detected in the Karakoram to date.

Key words: Deformation, tectonics, sedimentation, orogeny, Jurassic, Cretaceous, Karakoram.

G/18. Gaetani, M., Le Fort, P., Tanoli, S., Angiolini, L., Nicora, A., Sciunnach, D. & Khan, A., 1996. Reconnaissance geology in upper Chitral, Baroghil and Karambar districts (northern Karakoram, Pakistan). *Geologische Rundschau* 85, 683-704.

During the summer of 1992 a geological expedition crossed the northern Karakorum Range in northern Pakistan, from the Chitral to Karambar valleys, from the villages of Mastuj to Imit. Some of the areas visited were geologically unknown. A number of structural units were crossed, belonging to the Karakorum block or to other crustal blocks north of it. They are: (a) the axial batholith, in which three plutonic bodies have been identified, and (b) the northern sedimentary belt (NSB), in which three major tectonostratigraphic units form thrust stacks dipping to the north. Their internal stratigraphy and structural style are partly different. The most complete contains a crystalline basement, transgressed by a marine succession during the Early Ordovician. The youngest strata are represented by the Reshun conglomerate, of inferred Cretaceous age. The northernmost unit of the NSB is tightly folded, whereas the central one forms a monocline. Vertical faults, mainly strike-slip, dissect the thrust slabs. Metamorphic deformation is absent or reaches only the anchizone in the studied sector of the Karakorum NSB. To the north of the Karakorum proper there are several other tectonic units, separated by vertical faults. They are, from south to north: (a) the Taş Kupruk zone, with metavolcanics of basaltic to latibasaltic composition; (b) the Atark unit, mostly consisting of massive carbonate rocks of Mesozoic age; and (c) the Wakhan slates which consist of a thick widespread succession of dark slates, metasiltites and sandstones. The fine-grained elastic rocks are supposed to be Palaeozoic to Early Triassic in age. The Wakhan slates are intruded by plutons belonging to the East Hindu Kush batholith, from which a single K/Ar age on muscovite gave a Jurassic age.

Key words: Reconnaissance, Chitral, Karakoram.

G/19. Gaetani, M. & Leven, H., 1993. Permian stratigraphy and fusulinids from Rosh Gol (Chitral, Hindu Kush). *Rivista Italiana di Paleontologia e stratigrafia* 99, 307-326.

Chitral (Pakistan), geologically, includes the eastern termination of the Hindu Kush and its transition to the Karakorum. The position of the boundary is not precisely defined, and may be located provisionally at the Chitral Fault, or at the Tirich Mir Fault. Four main tectonostratigraphic units are identified. From SE to NW they are: 1) Lun Shales (shales and slates with Devonian calcareous intercalations) and Devonian to Permian carbonates. 2) Metabasites, consisting of amphibolites and green tuffs, locally associated with carbonates. 3) Atark Group, mostly metacarbonates in which Permian, Triassic and Cretaceous intervals have been detected. 4) Wakhan Slates, a very thick terrigenous succession of dark colour, partly of Paleozoic age. Huge granitoid bodies have been intruded into this unit. This 4-fold subdivision is here proposed for the first time.

A terrigenous-calcareous succession of Permian age has been measured and sampled in the Atark Group at Rosh Gol. Seven lithostratigraphic units have been identified. Six of them contain fossils, mostly fusulinids, allowing identification of Yahtashian, Bolorian, Kubergandian and Late Murgabian or Midian. The most significant species of fusulinids are illustrated; these have close affinities to the Central Pamir.

Key words: Stratigraphy, Fusulinids, Permian, Chitral, Hindukush.

G/20. Gaetani, M. & Muttoni, 1991. Preliminary notes on the high Chitral geology. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 43.

The High Chitral area, from Mastug to Tirich Gol and Morich Gol valleys, i.e. from SE to NW, consists of the following units.

Lavas and volcanoclastics of the topmost Kohistan arc.

Chitral Slates (gray phyllitic slates) and marbles possibly covered with angular unconformity by 500-m thick polymict conglomerate, including abundant volcanic pebbles.

Shogram-Kuragh Unit. It includes the classical Silurian to Cretaceous succession, sealed by the Reshun Conglomerate, described by Hayden (1915), Desio (1959) and Talent et al. (1981). Disrupted in several blocks, the more complete successions lie northwestwards. It is separated of the following units by the Mt. Shogram Fault.

Lun Slate Unit. Extremely thick unit of gray dark slates, with subordinated marls and marly limestones, with metamorphic grade increasing from SE to NW. In the Morich Valley, it reaches the low-grade with phyllites and micaschists. This belt, wide 15-20 km, was formerly considered as Carboniferous, but Talent et al. discovered in several places Devonian Conodonts.

Uzhnu Gol Metavolcanics. Bounded by regional faults, a metavolcanic body (amphibolites according to Buchroithner, 1980), some 20-km long and up to 1-km wide, has been observed. It disappears westwards.

Attak Sedimentary Unit. The term was introduced by the Austrian authors, Gamberith and Buchroithner. It forms a carbonate belt, from the upper reaches of the Rosh Gol to just south of the Tirich Mir. Its contact with unit 4 and 5 is due to a regional fault with significant sinistral component. The metamorphic deformation mostly hampers any detailed stratigraphy. However, in the Zundrangram area, along the Rosh Gol, a Permian sequence of about 600-m was measured. It consists of an arenite-carbonate to claystones sequence, very rich in Fusulinids in the central part that may be interpreted as passive margin succession, drawing during the Middle Permian. Moreover very thick shallow-water carbonates are testified by the presence of Megalodontids and Rudists. Previously considered only as Paleozoic, the age of this unit should be extended up to most of Mesozoic. The sedimentary sequence is crosscut by sills oriented NE-SE, subsequently penetrated by rarer NW-SE dykes.

Whakhan Slates. Separated from the previous unit by another regional fault, dark gray or black slates follow, with subordinated arenites, microconglomerates and rarer pebbly mudstones. Sure turbiditic sequences have not been observed. Along the Rosh Gol a horizon packed with Bryozoan possibly of Paleozoic age has been sampled, together with poorly preserved Brachiopods. The slate may be intruded by granitoid bodies.

Key words: Stratigraphy, structural geology, metasediments, metavolcanics, Chitral.

G/21. Gaetani, M., Nicora, A., Angiolini, L. & Le Fort, P., 1993. Geological traverse from Chitral to Karambar (E Hindu Kush to W Karakoram): Preliminary geological results. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 20-21.

In the easternmost Hindu Kush, Hindu Raj and W Karakoram, the following units may be recognized from south to north:

The Axial Batholith forms two distinct branches in this region. They are separated by a band of metasediments already described east of this zone as the Darkot Group, of Permian age *pro parte*. Possible Mesozoic fossils have been obtained. The Yarkhun river only cuts through the northern branch where two types of granitoid have been recognized: (i) a dark amphibole-biotite granodiorite to biotite, rich in mafic enclaves, often foliated, resembling the Hunza granodiorite of mid-Cretaceous age, (ii) a porphyritic biotite $\pm$ amphibolite granite, often strongly deformed, more abundant to the north of the section, where it intrudes into the metasedimentary formations with a diffuse contact. This second type, resembling the subalkaline mid-Cretaceous Darkot pass granite, is intimately associated with the first, a situation similar in some way to that of the Karambar section (see Debon & Khan Abstract).

North of the Axial Batholith mostly sedimentary rocks crop out, usually arranged in three stacks, thrust southwards. The crystalline basement of the middle stack has been discovered. It is made up of medium-grained biotite granite, largely eroded in a glacial basin, due to its very strong alteration and brittle deformation. To the south, the granite intrudes the dark metapelites of Chikar. The sedimentary succession is directly transgressive on the granite with conglomerates and siltites, in which Early Ordovician acritarchs have been detected (N. Tongiorgi, Pisa). The succession continues upwards with a terrigenous unit, hundreds m-thick, with rare dolomitic intercalations in which Talent et al. (1981) found Middle-Upper Ordovician conodonts. The first significant carbonate unit consists of about 150m of yellow well-bedded dolomites, with peritidal depositional characters. Supposed age: Devonian. A mixed terrigenous carbonate unit, locally extremely rich in corals, brachiopods and bryozoans follows. Field identification: Middle Devonian and Frasnian. Upwards about 100 m of grey wackestone-crinoidal packstones follow, with solitary corals. Supposed age: Carboniferous. The lower part of the Permian is terrigenous and it is correlatable with the Gircha Formation of the Hunza region. Then a mixed carbonate-terrigenous succession, several hundreds m-thick follows, locally crowded with brachiopods, corals, bryozoans, conodonts, gastropods, bivalves and especially fusulinids. For details refers to Angiolifli et al. (Poster Section). After an erosional surface, with local incursions and a thin terrigenous unit, a huge peritidal dolomitic formation, 700 m thick follows. The paleontological control is poor and we suppose it represents the Upper Permian and may be the Triassic up to the Early Jurassic. We have no information about most of the Mesozoic. The southernmost thrust slice may have at its top the Reshun Conglomerate with Orbitolina-bearing pebbles.

A system of sinistral strike-slip faults, SW-NE oriented, the Tirich Mir Fault, brings in contact gray pale dolomites, with low metamorphic grade. Phosphates of Devonian and Triassic fossils have been found. Most significant are mafic metatuffs and various detrital volcanogenic levels, dark red to dark green, interbedded with the sediments.

With faulted contact, the huge, several km-thick Wakhan Slates follows. They are intruded by granitoid bodies made up in general of biotite-amphibole porphyritic granite. A single granitoid pluton (Chatteboj), with a strong contact aureole, was found also intruded in the unit 2). All these granitoid bodies could pertain either to the northern granitoid belt running from Tirich Mir to Khunjerab, in which Cretaceous ages have been obtained, or to the Batura group of Eocene age.

Key words: Stratigraphy, structural geology, Hindukush, Karakoram, Chitral.

G/22. Gaetani, M., Nicora, A., Cirilli, S., Atudorei, V. & Lucia, A., 1999. The P/T boundary in Karakorum revisited. *Terra Nostra* 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 48-49.

The stratigraphic succession including the P/T boundary in Karakorum, Pakistan, may occur in two different settings: A) Carbonate platform; B) Pelagic, poorly oxygenated basin.

In Central Western Karakorum, within the carbonate platform of the Ailak Formation, the stratigraphic control is very poor and no details can be obtained. Instead, in the Eastern Karakorum, a pelagic succession spanning the interval from the Kundil Formation (Late Murgabian-Midian=Wordian according to Yin et al., 1997) to the Borom Formation (Olenekian-Ladinian) make possible to analyse the P/T boundary to some details. Unfortunately, the strongly tectonised setting hampered in the field a correct recognition of the stratigraphic sequence and hence the interpretation published in Gaetani et al. (1995) is here reconsidered. The type section, measured by MG and LA, is here reconsidered as far as conodont are concerned (AN). Palynostratigraphy (SC) and stable isotope stratigraphy (VA) are added. Particularly, the second hithozone has been reinterpreted and is now considered a tectonic slice of the underlying Kundil Fm., within tight isochinal folding. The search for radiolarians (P. De Wever, Paris) was unsuccessful.

The Wirokhun Fm. results now entirely made of 1 dark-grey marls and slates, with only occasional limestone intercalations. Due to the lithology and the thermal deformation (CAI of conodonts = 5.5-6; TAI of sporomorphs = 5-7, approximately corresponding to Ro of vitinite reflectance 1.35-5), most of the 60 samples collected (including

100 kg for conodonts) were barren. The Permian/Triassic boundary lies near the base of the Wirokhun Fm., being the sample KK1 12 the last Permian datum with *Neogondolella* ex gr. *Changxingensis* and *N. subcarinata*. In sample KK 115, (3.20 m above) the palynomorph assemblage contains *Cyclogranisporites varius*, *Polypodiisporites mutabilis*, *Polypodiisporites* sp., *Verrucosisporites* sp., *Densipollenites indicus*, *Calamospora* sp., *Dictyotrilletes* sp., *Lundbladisporella brevicula*, *Lundbladisporella* sp., *Eucommiidites* sp., *Thymospora lpsviciensis*, *Foveotrilletes* sp. The concurrent presence of a few Permian and dominating earliest Triassic palynomorphs, suggests that the very base of Triassic is here present. This interpretation is supported by sample KK127 (2 m above) in which a conodont assemblage characterised by transitional forms *Hindeodus latidentatus* - *H. parvus*, *H. praeparvus* and primitive *Neogondolella carinata* along with *Neogondolellids* cf. the *tulongensis-taylorae* group, was identified.

A fully Triassic palynomorph assemblage of Induan age is recorded in the following KK124 (6.8 m above) with *Cyclogranisporites varius*, *C. arenosus*, *Kraeuselisporites* sp., *Calamospora* sp., *Inaperturopollenites* sp., *Dictyotrilletes bireticulatus*, *Dictyotrilletes* sp., *Verrucosisporites* sp., *Densosporites* sp., *Baltisphaeridium* sp., *Grandispora jansonii*, *Prothoaploxypinus panaki*, *Thymospora ipsiviciensis*, *Lundbladisporella brevicula*, *Lundbladisporella* sp. This age assignment is reinforced by the following KK126 (1 m above) which contains *H. parvus* with more evolute morphotype and *Neogondolella carinata*. To be noted also the presence of fungal remains in the KK 124, which become abundant 2 m above (KK 129).

No significant data are further preserved in the next 10 m of the section. We suggest that this part is the tight core of an isoclinal syncline and the cherty limestone of the sample KK 149 and KK 150 represents the top of the Kundil Fm. Sample KK 150 interestingly contains a Changxingian fauna with *Hindeodus typicalis*, *Neogondolella* cf. *subcarinata* and *N. cf. changxingensis*. In sample KK 158 *Hiranognathus* cf. *unicostatus* along with several *Neogondolellids* is also present.

The carbon isotope profile displays a marked, gradual decrease in values from values higher than +2‰ recorded at the top of the Kundil Formation, to values as low as -4‰ which characterize the base of the Wirokhun Formation. Such low values are typically recorded in Lower Triassic carbonates and support the age assignment suggested by the palynomorph data. Moreover, the above-mentioned negative shift may correspond to the well-documented drop in values that marks the Permian-Triassic boundary worldwide. The relatively high $\delta^{13}C$ values (around +2‰) recorded in samples KK 150 to KK 159 support the interpretation that Upper Permian strata may be present in this part of the section (as a tectonic slice). $\delta^{13}C$ values from carbonates belonging to the Borom Formation show little variability upsection with an average value of -2.5‰. The strata examined for this study underwent severe thermal alteration and the primary carbon isotopic composition may be distorted; however, the general trends suggest correlations in agreement with the biostratigraphic data.

Key words: Stratigraphy, P/T boundary, Karakoram

G/23. Gaetani, M., Pognante, U. & Gosso, G. 1991. Geological Report. In: Desio, A. et al. - The Ev-K2 CNR Expedition to the southern Sinkiang (Kun Lun) and the Shaksam Valley. Italian Expedition Kun Lun Karakoram, 99-190, Milano.

Key words: Expedition, Karakoram.

G/24. Gaetani, M., Zanchi, A. & Angiolini, L., 1992. Geological Reconnaissance to Shimshal Pass, Karakoram. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 113.

A reconnaissance has been made from Pasu (Upper Hunza) to Shimshal and then up to Shimshal Pass. The rocks cropping out are mostly sedimentary, with feeble to low metamorphic imprint on the southern side of the Shimshal valley, reaching the maximum metamorphic deformation around Dut. On the right side of the valley, from Shimshal up to just NE of the Mai Dur River, the Permian to Cretaceous succession of the Sost Unit (sensu Gaetani et al., 1990) has been crossed. The Jurassic gray sandstone unit is here widely exposed. All the succession is disrupted by the strike-slip system of the Misgar Fault. Details of the structural analysis of this belt are reported in Zanchi's abstract (this Workshop).

With tectonic contact, granitoid bodies follow, intruding slightly metamorphosed slates (Misgar Slate) and carbonates. The granitoid plutons belong to the important intrusive belt developed northwards of the Karakoram Axial Batholith, which comprises amongst others Mintaka, Kunjerab, Gyraf, and Sughet plutons. They characterize the northern edge of the Karakoram Range, being separated by a sedimentary belt from the Axial Batholith complex.

Key words: Reconnaissance, sedimentary, Shimshal pass, Karakoram,

G/25. Gamerith, H., 1976. Preliminary Geological Map of Gilgit / Hunza / Yasin, Pakistan. Scale 1/250,000. Austromineral, Vienna.

As the title indicates, this is a preliminary map of the western Karakoram Range at a scale of 1: 250, 000 (1 cm = 5 km). All the principal lithologies, comprising (meta)sedimentary rocks, volcanics, granitic intrusions, and major structures are shown.

Key words: Geology, Gilgit, Hunza, Yasin.

G/26. Gamerith, H., 1982. Geologische Karte von Gilgit/Chitral/Whakhan (Nordpakistan und Ostafghanistan) 1:250 000. Graz, privately published.

This is the geological map of the Karakoram Hindukush region of Pakistan and northeast Afghanistan (Wakhan) at a scale 1 cm = 5 km. The rocks of this transitional eastern Hindukush-western Karakoram region range from Paleozoic to Holocene. Major structures are also shown on the map.

Key words: Geology, Gilgit, Chitral, Wakhan.

G/27. Gamerith, H. & Kolmer, H., 1973. Untersuchungen an intrusive gesteinen des ostlichen Hindukusch. Geologic Rundschau, 62, 161-171.

Key words: Stratigraphy, P/T boundary, Karakoram

G/28. Gansser, A., 1964a. Geology of the Himalaya. Wiley Interscience, London, 289p.

This is the first compilation on the geology of the Himalayan mountain range. This well illustrated book also contains a geological map and covers tectonics, structure, and other aspects of the range.

Key words: Books, geology, Himalaya.

G/29. Gansser, A., 1964b. Geologic and tectonic maps of the Himalayan region. London Wiley Interscience, London, (4 maps).

Key words: Geology, tectonics, Himalaya.

G/30. Gansser, A., 1964c. The Alps and the Himalayas. 22nd International Geological Congress, Part XI.

Key words: Alps, Himalayas.

G/31. Gansser, A., 1973. Ideas and problems on Himalayan geology. In Seminar on Geodynamics of the Himalayan Region, 97-103. National Geophysical Research Institute, Hyderabad.

Key words: Geodynamics, Himalayas.

G/32. Gansser, A., 1974a. The ophiolitic melange, a world-wide problem on Tethyan examples. Eclogae Geologiae Helvetiae 67, 459-507.

The ophiolitic mélange is defined as an olistostromal and tectonic mixture of ophiolitic material and sediments of oceanic origin with exotic blocks, reflecting areas which have subsequently disappeared. Being intimately related to

ophiolitic belts they indicate important suturelines connected to plate boundaries. Ophiolitic mélanges occur mostly where continental type plates are subducted with obduction of oceanic material. These fact are discussed on examples from the Middle East and the Himalayas, where the mélanges are particularly well exposed.

Key words: Ophiolite Melange, tectonics, Middle East, Himalaya.

G/33. Gansser, A., 1974b. Himalaya. In: Spencer, A.M. (ed.), Mesozoic-Cenozoic orogenic belts. Geological Society of London, Special Publication 4, 267-278.

Key words: Orogeny, Mesozoic, Cenozoic, Himalayas.

G/34. Gansser, A., 1976. The Great Suture Zone between Himalaya and Tibet: A preliminary account, Himalaya. Colloquium Science de la Terra, International 2nd Ed., C.N. Rech. Science, Paris. Himalaya Sciences De La Terre 268, 181–191.

Key words: Indus Suture, Himalaya, Tibet, Kailas, Ladakh.

G/35. Gansser, A., 1980a. The peri-Indian suture zone: Geology of the Alpine chains born of the Tethys. 26th International Geological Congress, Paris, 5, 140-148.

The 5.000 km long Peri-Indian Suture Zone is divided into the North Himalayan - the Arakan Yoma – and the Quetta belt. It consists of ophiolites with basic volcanics. Ultramafics and associated ophiolitic mélanges which suggest originally steep but narrow oceanic basins. The Himalayan belt is followed northwards by the 2.500 km long Transhimalayan batholith which originated from a mostly oceanic crust and is different from the Himalayan and Karakorum batholiths. On its south side, the batholith is transgressed by the paleogene Kailas molasse. All these elements are interrupted by younger north south directed cross highs and fault zones. In the Arakan Yoma and Quetta belts the ophiolitic associations are similar but the geological frame has partly changed.

Key words: Suture zone, Geology, India.

G/36. Gansser, A., 1980b. The significance of the Himalayan suture zone. Tectonophysics 62, 37-52.

The 2500 km long Himalayan Suture Zone is discussed within the widest structural frame, with new results obtained from a study of the Landsat pictures. The platform sediments from the Tethys or Tibetan Himalaya, north of the Main Central Thrust, Change northwards into a belt of Flysch sediments beginning in the Triassic and reaching the Paleocene. The belt is mixed with oceanic crust material such as volcanics, mélanges and ultrabasic slabs, and is strongly tectonized: the Suture Zone. It is followed to the north by a conspicuous belt of Kailas Molasse, of Paleogene age and transgressing the late Cretaceous Transhimalayan plutons. They consist of five bodies, predominantly tonalitic, separated by structural anomalies that also cut the Suture Zone. The plutons are structurally controlled and related to the Himalayan Suture (Subduction belt?). They are followed to the north by the south Tibetan Nyenchen Tangla belt, bordered by large fault zones and characterized by frequent Paleogene acid volcanics. The Central Tibetan Chang Thang area is structurally most complex, contains some ultrabasic rocks related to large fault zones, and exposes a large subrecent basaltic volcanism with no structural control but reminiscent of a “hot spot”. The northern Kun Lun — Astin Tagh Paleozoic orogenic belt displays 200 km of rejuvenated fault zones, some older mantle fragments and subrecent volcanism.

This structural aspect of Tibet, with internal older Suture Zones, younging southwards, contrasts with the Indian plate south of the Main Himalayan Suture. This Suture Zone is the only constant structural element all along the Alpine-Himalayan belt.

Key words: Suture Zone, landsat images, sediments, Himalayas.

G/37. Gansser, A., 1980c. The division between Himalaya and Karakoram. Geological Bulletin, University of Peshawar 13, 9-22.

The 5000 km long Peri-Indian Suture Zone has doubled in the western Himalaya and the northern branch forms the division between the Himalaya and the Karakorum. The northward directed Nanga Parbat-Haramosh crystalline spur controls structure and petrology of both the Suture Zone. It divides the over 2000 km long Trans-Himalayan batholith into the eastern Ladakh and the western Swat Batholith. Geology and petrology of the Karakorum north of the Northern Suture Zone strongly contrast with the Himalaya to the south of it.

Key words: Suture zone, Himalaya, Karakoram.

G/38. Gansser, A., 1981. The geodynamic history of the Himalaya. In: Gupta, H.K. & Delany, F.M., (Eds.), *Zaqro–Hindukush–Himalaya: Geodynamic Evolution*. American Geophysical Union, Geodynamics Series 3, 111-121.

Key words: Geodynamics, Himalaya.

G/39. Gansser, A., 1990. Fact and theories on the Himalayas. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 16-17.

Consult the following account

Key words: Orogeny, Himalayas.

G/40. Gansser, A., 1991. Facts and theories on the Himalayas. *Eclogae Geologi Helvetia*, 84, 33-59.

During the classical exploration in the 19th and early 20th centuries the ratio between facts and theories was 1:0.5. Plate tectonics changed it 1:3 and with geophysics, geochemistry and structural analysis the ratio became 1:5.

The backbone of the High Himalayas is a crystalline core, involving the Lesser Himalayas in the W. Exposed are Precambrian structures and metamorphism, overprinted by a Himalayan phase, its intensity still highly disputed. Cambrian non-orogenic granites cut discordantly rocks with preserved Precambrian structures. New age from 2000 to 900 may confirm this fact. Himalayan PT has not cancelled all the Precambrian elements and thrusting along the MCT has transported some relictic structures. The MCT forms a shuppen zone or can expose a sharp contact (Bhutan). Sediments of the Lesser Himalayas are now dated Late Precambrian to Cambrian, including most of the tillites. No real basement is yet known. Disputed is the fact of reversed metamorphism towards the MCT and above. The hot overthrust theory is contradicted by Jurassic palynomorphs just below the thrust. The Himalayan metamorphic overprint ends with the intrusion of leukogranites. They stress the 5000my intrusive gap from the Cambrian granites, a fact repeated in the North Himalayan crystalline, diapiric domes; a gap filled with nonorogenic Tethyan sediments. These follow above the crystallines with Late Precambrian argillaceous sediments where the high-grade metamorphism gradually decreases to anchi-phase in the Cambrian. Locally the crystalline/sediment contact can be downfaulted, negligible in the Garhwal Himalayas where basal sediments are over 5000m thick. The lesser Himalayas have a similar facies of Late Precambrian, (Dalings, Simla Slates). They suggest a more distal facies of the widespread Vindhyan, covering the northern Indian Shield.

Theories over facts increase when we approach the Indo/Yarlung suture (IYS), the obducted remnants of a large or small Tethyan ocean, outlining the collision between India and Tibet. Its timing, proven by intra-trappean Asian faunas of 67 my predates all previous assumptions, though collision was not synchronous and started earlier in the W Himalayas. The regional outline is surprisingly constant, but the details vary considerably: W Ladakh exposes 3 vertical ophiolitic melange belts. Eastwards they are capped by a large (40-km) ultramafic body, which retains a normal cover of gabbros and volcanics. Further E it is transported 50-km northwards to the tripple-junction at Tashigong, the most important but least known spot along the IYS. From here starts the Shyok suture and borders the Karakoram to the S as a deep fracture or a subduction. In a post-collision phase ophiolite nappes were thrust southwards. Remnants are seen in the Spongtag nappe (40-km thrust), the Amlang-La nappe (80-km) and Shigatse nappe (30-km). Similar nappes are even known along the suture on the West Side of the Indian shield (Quetta branch) with 30 to 50-km thrusts towards the E. In all nappes ophiolitic mélanges, frequently with exotic blocks, form the base and ultramafic bodies, often with primary textures, the top. Most of the nappes have been emplaced within the Lower Eocene.

North of the IYS follow the Andean-type Transhimalayan plutons, subdivided into Gangdese, Kailas, Ladakh and Swat plutons, the latter already W of the western syntaxis within the Kohistan complex, where facts and theories

show an abnormal high ratio. The Transhimalayan plutons, ranging from 100-40 my, the older ones often with a more basic composition, border the complex Tibetan continental margin, from which they have been more or less contaminated. This is documented by many xenoliths from the Tibetan "basement". However, in the western Ladakh pluton, between the Shyok suture and the IYS, NS aligned xenoliths seem to resemble the basement of the Nanga Parbat spur.

Subsequent to the intrusions the Transhimalayas were strongly uplifted and eroded, producing an Oligocene molasse, well preserved in the central Transhimalaya with 4000-m of clastic rocks, still nearly horizontal bedded and from which the spectacular Kailas has been carved, the most sacred mountain in Asia. All the greater rivers in the wider Himalayas originate from the Kailas region cut through the highest uplifts in the Himalayas and deposit their sediments in the Indus and Bengal fans, the largest submarine deltas known.

Key words: Orogeny, Himalayas.

G/41. Gardezi, A.H., 1957. Geology of Salt Range, Potwar, Hazara and Swat. M.Sc. Thesis Punjab University, Lahore, 74p.

Key words: Salt Range, Potwar, Hazara, Swat.

G/42. Gardezi, A.H., 1970a. Note on the Geology of the area around Nathiagali, District Hazara, West Pakistan. Geological Bulletin, Punjab University 7, 71-78.

The geological investigation around Nathiagali, District Hazara, West Pakistan, was initiated during the summer of 1963 in order to understand (a) the lithostructural features of the Hazara Slate Formation, (b) the nature and inter-relationships of calcareous bands that occur within the Hazara Slate Formation, (c) the nature of the base of post-Hazara slate rock sequence and (d) the tectonic style. During the subsequent years, as the emphasis shifted to other geological problems and to other areas as well, detailed and more extensive investigations were postponed. However, in the following paragraphs are summarised the few conclusions that were arrived at during the preliminary survey.

Key words: Geology, Nathiagali, Hazara.

G/43. Gardezi, A.H., 1970b. Stromatolite (agal reefs) in Hazara District, West Pakistan. 21st and 22nd All Pakistan Science Conference, Rajshahi, p.114.

Key words: Reefs, Hazara.

G/44. Gardezi, A.H. & Ghazanfar, M., 1965. A change of facies at the base of the Jurassic in District Hazara, West Pakistan. Geological Bulletin, Punjab University 5, 53-56.

During his mapping of Hazara District, Middle- miss (1896, p. 124, 125) observed the presence of some "yellow shales" below the so-called Trias limestone near Tarnawal, which he goes on to say might represent the upper part of his Infra-Trias formation. He, however, was not able to confirm their age.

Independent observations were made, in another locality, by Marks and Muhammad Ali (1961, p. 50), who noted the presence of some "brownish to greenish siltstones and shales apparently conformably overlying the cherty limestone of the Infra-Trias". These authors further observed that "higher on the western slopes of Sarbun Dhaka the same formation is developed as haematite breccias associated with red-spotted, yellow sandstones".

The junior writer had an opportunity to study the geological and structural position of the so-called yellow shales during the summer of 1964. He found them to form a distinct rock unit and in his M.Sc. Fieldwork Report referred to them as the Hazira shales, after the village Hazira. In the following year, a more detailed study was undertaken in collaboration with A. H. Gardezi. This work produced some very interesting structural and stratigraphical results, which have led to a useful clarification and elaboration of the observations already made. Their stratigraphic position and field relationships are now better understood than before. The results of this field-work are now summarised and should be considered in conjunction with the map.

The Hazira Formation consists mainly of dirty grey and yellowish brown, calcareous, shaly siltstones, containing earthy concretions and attaining a maximum thickness of some 1,000 ft. It conformably overlies the Abbottabad

formation and is itself overlain by the basal arenites of the Jurassic, which often form a thin band of whitish ironstained orthoquartzite. The yellowish brown colour of the Hazira formation is replaced by a red tinge at places, as at Banda Pir Khan where it also contains a few quartzite bands. Towards its base, the Hazira Formation is generally glauconitic; this is clearly noticeable in the hand specimens.

The following details of the Hazira Formation are given:-

(a) It replaces the Haematite formation in stratigraphic sequence.

(b) Its lower boundary is gradational.

(c) Wherever its upper boundary is preserved, it is followed by a thin band of iron-stained ortho-quartzite (belonging to the Maira Formation of Davies and Gardezi, 1965. p.), which is present at the base of the Jurassic limestone throughout Hazara. Whether the Abbottabad Formation and Haematite formation intervene between the Jurassic and the Hazara slates or not, this band of ortho- quartzite is never missing and, therefore, it must form the lower boundary of the Jurassic. Its presence in no way means the presence of the Haematite formation, even in a reduced form.

The boundary relationships and stratigraphic position, as mentioned above, make a strong case for believing that the Hazira Formation is at least partly equivalent to, and represents a facies change of the Haematite formation.

(d) In spite of the great difference in lithology, the close proximity of the two facies remained puzzling. Therefore, a detailed mapping of the relevant area was undertaken. It has led to the discovery of a major thrust-fault which may be called the Lagarban Fault. This fault, starting from near the Kunhar river in the northeast continues southwards to beyond Abbottabad. The Lagarban Fault has provided translation to such an extent as to eliminate the transitional zone between the two facies, except near Kihal, Abbottabad, where at the base of the Hazira Formation a part of the Haematite formation is developed in the form of haematitic quartzite and quartzite breccias.

(e) Since its lower boundary is gradational and since it lies below the orthoquartzite of the Maira Formation the Hazira Formation should succeed or represent the uppermost part of the so-called Abbottabad Formation. Its counterpart, the Haematite formation should also represent the same with, of course, some slight breaks in sedimentation represented by the volcanic flows. This stratigraphic conclusion is also supported by the way in which the Jurassic overlaps the Hazira and Abbottabad Formations lying below it. In part of the area, there is also evidence of their overstep by the Jurassic on to the Hazara slates. Further support for this regrouping comes from the observation of the cyclic deposition of the Abbottabad Formation itself. Such a grouping would, however, be in contrast with that presented by Marks and Muhammad Ali (1961, p. 50) and should lead to the renaming of the Abbottabad Formation as the Abbottabad Group, which would include the Abbottabad Formation of Marks and Muhammad Ali and the Haematite formation or the Hazira Formation, the last two being equivalent to and interchangeable with each other.

(f) Near Jaster the lower part of the Jurassic limestone formation is very well developed and is underlain by the calcareous fossiliferous shales of the Maira Formation (Upper Liassic). These shales are lithologically quite different from the Hazira shales and have at their base the iron- stained orthoquartzite which always overlies the latter.

(g) No fossils have so far been recorded from the Hazira Formation and it can only be said that it is probably Pre-Jurassic and lies at the top of Middlemiss, "Infra-Trias", or of the Abbottabad Formation of Marks and Muhammad Ali (1962, p. 56) which has been assumed to be of Permo- Carboniferous age.

Key words: Facies change, Jurassic, Hazira, Abbottabad, Hazara.

G/45. Gardezi, A.H., Ghazanfar, M. & Shakoor, A., 1976. Geology of Darra Adam Khel area, District Kohat, Northwest Frontier Province, with observations on the facies changes and their tectonic implications. Geological Bulletin, University of Punjab 12, 97-102.

Pioneer work has been carried out in the geological unknown tribal territory of Darra Adam Khel. Stratigraphic column has been established. Facies changes of great structural significance have been discovered. Complicated local structure has been unraveled with important bearings on the tectonics of the outer Himalayas.

Key words: Stratigraphy, facies change, structure, Kohat.

G/46. Gardner, J.S., 1986. Recent fluctuation of Raikot Glacier, Nanga Parbat, Punjab Himalaya, Pakistan. Journal of Glaciology 32, 527-529.

Key words: Glaciers, Raikot, Nanga Parbat.

G/47. Gardner, J.S. & Jones, N.K., 1993. Sediment transport and yield at the Raikot Glacier, Nanga Parbat, Punjab Himalaya. In: Schroder, J.F.Jr. (Eds.), Himalaya to the Sea. Geology, Geomorphology, and the Quaternary. Routledge, 184-197.

Key words: Glaciology, sedimentology, Nanga Parbat.

G/48. Garrido, C.J., Bodnier, J.L., Hussain, S.S., Dawood, H., Burg, J.P. & Chaudhry, M.N., 1999. Geochemistry of the Jijal complex: a subarc mantle-crust transition at the base of the Mesozoic Kohistan arc. EU G. Meeting, Strasbourg, J. Conference Abstract 4, p.397.

Key words: Geochemistry, Jijal Complex, Kohistan.

G/49. Garwood, E.J., 1924. Himalayan glaciation. The Geographical Journal 63, 243-246.

Key words: Glaciology, Himalaya.

G/50. Garzanti, E., Critelli, S. & Ingersoll, R.V., 1996. Paleogeographic and paleotectonic evolution of the Himalayan Range as reflected by detrital modes of Tertiary sandstones and modern sands (Indus transect, India and Pakistan). Geological Society of America Bulletin 108, 631-642.

Detrital modes of sandstones derived from the Himalayan suture belt record the history of the mountain range since initial collision between India and Asia, which began in latest Paleocene time. Tertiary clastic wedges deposited in fore-arc, foreland, and remnant-ocean basins, and exposed along the Indus transect from northernmost India to the Arabian Sea, represent the best opportunity to study sedimentary responses to successive tectonic events during continental collision. Quartzose "continental-block" and feldspatholithic "magmatic-arc" sandstones were deposited, respectively, on the passive Indian (Tethys Himalayan succession) and active Asian (Indus Group) continental margins during Late Cretaceous–Paleocene time. Closure of the Neotethys was marked by sudden arrival of volcanic and ophiolitic detritus on the passive continental margin of the Indian plate during deposition of sediments dated at foraminiferal zones P6 (Pakistan) to P8 (India). Starting in early Eocene time (deposition of Chulung La Formation and Murree Supergroup), volcanic and ophiolitic to metasedimentary detritus was accumulated in rapidly subsiding "piggy-back" and foreland basins. Homogeneous petrographic composition within the Eocene–lower Miocene Murree Supergroup, with only slight progressive increase of detrital feldspars, suggests erosion of largely supracrustal rocks involved in thrusting in the north.

In middle Miocene time, marked enrichment in medium- to high-grade metamorphic detritus in foreland sandstones (Siwalik Group) reflects rapid uplift of a warm wedge of Indian crust, which was carried southward along the Main Central thrust. This major paleogeographic change was recorded also by quartzolitic remnant-ocean turbidites, which were fed great distances along transverse fracture zones and later accreted in the coastal Makran subduction complex (Panjgur association and Makran Group). Recycled-orogen detritus derived from the elevated Himalayan chain is still accumulating today in the Indus fan. Enrichment in feldspars with respect to ancient sandstones reflects deep erosion levels into mid-crustal rocks along the core of the growing orogen.

Key words: Fore-arc, foreland, paleotectonic, paleogeography, sandstone, sutures, Indus transect, Himalaya.

G/51. Gattinger, T.E., 1961. Geologischer querschnitt des Karakorum vom Indus zum Shaksgam. Jahrbuch der Geologischen Bundesanstalt, 6, 3-118.

Gattenburg took part in the Austrian Himalaya-Karakoram Expedition of 1956. He carried out an intensive field work in the Baltoro basin and its southwestern adjoining area as far as Skardu on the left bank of the Indus River. In this paper, he published the geological section between the Indus and Shaksgam, and provided information on the stratigraphy, lithology and structure of the (meta)sedimentary and granitic rocks.

Key words: Structure, stratigraphy, lithology, Shaksgam, Karakoram.

G/52. Gauhar, S.H., 1965. The geology and mineral potentialities of Azad Kashmir, Gilgit and Baltistan area. Geological Survey of Pakistan, Information Release 25, 15p.

Key words: Geology, mineral resources, Northern Areas, Azad Kashmir.

G/53. Gauhar, S.H., 1969. Exportable minerals of Pakistan. Geological Survey of Pakistan, Geonews 1(3), 34-41.

This compilation lists the exportable mineral deposits of Pakistan till the year 1968.

Key words: Mineral deposits.

G/54. Gauhar, S.H., 1976. Mineral resources of Pakistan. (Summary report for 1974) Geological Survey of Pakistan, Geonews V (1), 3-14.

A summary of the mineral resources of Pakistan upto the year 1974 is compiled in this report.

Key words: Mineral resources.

G/55. Gauhar, S.H., 1984. Interim note on manganese occurrences in North Waziristan Agency, FATA., NWFP. Geological Survey of Pakistan, Information Release 247.

An earlier report on the occurrence of manganese deposit in North Waziristan is given in this report. The report is accompanied by preliminary geological map of the area.

Key words: Mineral deposits, manganese, N. Waziristan.

G/56. Gauhar, S.H., 1992. Plate tectonics, crustal evolution, and metallogeny of Pakistan. Geological Survey of Pakistan. Information Release 525, 27p.

A study of the metallogenic zonation of different regions of Pakistan shows a close genetic and temporal relationship with various aspects of crustal dynamics and plate boundary features such as subduction, continental collision, rifting, and emplacement of ophiolites. In the perspective of delineating their exploration potential and priorities, these zones have been further classified into different 'metallotect' belts by combining the plate tectonic environment of each separately discernible geological region with its characteristic metallogenic imprints. Thus besides serving the general purpose of a review article of the state-of-art on the accumulated knowledge about the evolution of crust in this part of the world, the present paper also attempts to give a brief yet unified synthesis on the mineral potential of Pakistan as interpreted in terms of the current concepts of metallogenesis and plate tectonics. Based on mineral prognosis and plate tectonic interpretations, a number of new target areas have been identified for initiating scientific exploration. Some of the more important of these prospects include those of gold, copper, and other base metals in shield protrusions and shield derived sediments in the Punjab and Sin; copper & tin, in the hot spot brine and rift - related Paleozoic rocks in the Salt Range, Punjab; barite fluorite associated lead-zinc-silver deposits in shelf sediments in parts of Baluchistan and NWFP; porphyry type deposits of copper-gold-molybdenum and massive sulphides of copper-lead-zinc in the Chagai and Kohistan regions; epithermal gold in clay altered volcanic rocks in Chagai; lithium in pegmatites in Chitral and adjoining areas; chromite in northern ophiolites; copper and manganese in the Waziristan ophiolitic melanges; and tin & tungsten in Chagai porphyrites and in the granitoids and their contact Paleozoic carbonate rocks in NWFP and the Northern Areas.

Key Words: Plate tectonics, Metallogeny.

G/57. Gauhar, S.H., 1999. An overview of mineral resources of Pakistan. Geological Survey of Pakistan. Records, 127, 85p.

Key Words: Mineral resources,

G/58. Gauhar, S.H., 2000. Issues in the development of gems and precious stones in Pakistan. Geological Survey of Pakistan, Information Release, 751, 32p.

Key Words: Gemology, precious stones.

G/59. Gauhar, S.H. & Afridi, A.G.K., 1980. Preliminary report of geology and mineral prospects of the Kohistan region, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 127, 10p.

A summary of the economic mineral prospects of Kohistan region is given in the report.

Key words: Geology, minerals, Kohistan, NWFP

G/60. Gauhar, S.H., Asrarullah, & Farah, A., 1980. Some introductory remarks on the plate tectonic and metallogenic framework of Pakistan. Geological Survey of Pakistan, Information Release 125, 25p.

This contribution looks at the metallogenic framework of Pakistan in relation to the plate tectonic configuration of the country.

Key Words: Plate tectonics, metallogeny.

G/61. Gauhar, S.H., Khan, A.L., Abbas, S.G., Hussain, A., Tariq, M.A. & Khan, I.A., 1998. Geological Atlas of Pakistan. Geological Survey of Pakistan, Special Publication, 76p.

Key Words: Atlas, geology.

G/62. Gauhar, S.H., Mirza, M.A. & Jamiluddin, S., 1985. Map showing the status and strategy of geological mapping in Pakistan. Special Volume, Geological Survey of Pakistan, Map Series 1, scale 1:2000,000.

Key Words: Mapping, geology, Pakistan.

G/63. Gazis, C.A., Blum, J.D. & Chamberlain, C.P., 1995. The effect of hydrothermal activity on the Sr isotope systematics of gneisses from the Nanga Parbat-Haramosh Massif (Northwest Himalaya, Pakistan). EOS (Transaction, American Geophysical Union) 76, F704.

Key Words: Hydrothermal activity, Sr isotopes, NPHM gneisses, Himalaya.

G/64. Gazis, C.A., Blum, J.D., Chamberlain, C.P. & Poage, M., 1998. Isotope systematic of granites and gneiss of the Nanga Parbat massif, Pakistan Himalaya. American Journal of Science 298, 673-698.

Isotopic analyses of gneisses and anatectic granites from the Nanga Parbat-Haramosh Massif (Pakistan Himalaya), a zone of pronounced thermal activity and recent high-grade metamorphism in the Indian Plate, reveal information about the conditions of granite genesis and the nature of Sr exchange in high-grade gneisses and granites. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for both gneisses and granites are extremely high and heterogeneous (0.7721-1.0642), indicating that both granites and gneisses have an ancient metasedimentary crustal source. Whole rock Rb-Sr data for gneisses scatter around a reference isochron with an age of 1.8 Ga. Although the Nanga Parbat leucogranites have similar $^{87}\text{Sr}/^{86}\text{Sr}$ ratios to the surrounding gneisses, their Nd isotopic compositions ($\epsilon_{\text{Nd}} = -23$ to -25) are higher than those of the gneisses and migmatites ($\epsilon_{\text{Nd}} = -26$ to -29), indicating that the granites' source is not the presently exposed level of gneisses. This result is consistent with other studies that suggest these granites formed as a result of vapor-absent

melting during the recent, rapid uplift of Nanga Parbat. Biotite and feldspar mineral separate Rb-Sr data for six gneisses and one granite have near-horizontal or negative slopes (and ages) on a Rb-Sr isotopic evolution diagram. This behavior is best explained by: (1) a recent «5 Ma) local homogenization of Sr isotopes during the young metamorphism; and (2) after peak metamorphism, Sr isotope exchange occurred between biotite and carbonate minerals after feldspar became closed to Sr exchange. This exchange took place within the last 2 my and was mediated by metamorphic or magmatic fluids which augmented Sr exchange with carbonate/calcsilicate lenses and/or deposited secondary calcite veins in the granites and gneisses. This proposed Sr exchange between silicates and carbonates could have significant implications for the interpretation of the seawater Sr curve because it enables carbonate dissolution to contribute radiogenic Sr to the dissolved load in streams.

Key Words: Isotopes, granite gneiss, NPHM, Himalaya.

G/65. Gee, E.R., 1934. The saline series of Northwestern India. *Current Science*, Bangalore, 2, 460-463.

Key Words: Saline series, India.

G/66. Gee, E.R., 1935a. The Saline series (Lower Eocene) of northwestern India (abstract). *Proceedings 22nd Indian Science Congress*, Calcutta, 207p.

Key Words: Saline series, Eocene, India.

G/67. Gee, E.R., 1935b. Salt Range, Punjab and N.W.F.P. *Geological Survey of India*, 69(1), 64-72.

Key Words: Salt Range, NWFP, Punjab.

G/68. Gee, E.R., 1937. The occurrence of Cambrian beds in the Khasor Range, North-West Frontier Province (abs). *Proceedings 24th Indian Science Congress*, Hyderabad, 232-233.

Key Words: Cambrian, Khasor Range, NWFP.

G/69. Gee, E.R., 1938. The economic geology of the northern Punjab, with notes on adjoining portions of the North-West Frontier Province, India. *Mining Geology and Metallic Institute Transactions*, 33(3), 263-354.

Key Words: Economic geology, Punjab, NWFP, India.

G/70. Gee, E.R., 1940. Recent views on the salt-bearing formations of north-western India. *Proceedings*, 27th Indian Science Congress, Madras, pt.4, p.10.

Key Words: Salt bearing Formations, India.

G/71. Gee, E.R., 1945. The age of the Saline series of the Punjab and of Kohat. *Proceedings*, National Academy of Sciences, India, Section B, 14(6), 269-312.

Key Words: Saline series, Punjab, Kohat.

G/72. Gee, E.R., 1947. The mineral resources of Northwestern India. *National Institute of Sciences*, India 2(8), 20-32.

Key Words: Mineral resources.

G/73. Gee, E.R., 1949. The mineral resources of North West India. Geological Survey of Pakistan, Records, 1(1), 25p.

Key Words: Mineral resources, India.

G/74. Gee, E.R., 1950. Petroleum geology in Pakistan. 18th International Geological Congress, London, 6, 59-64.

Key Words: Petroleum geology, Pakistan.

G/75. Gee, E.R., 1957. Principal mineral resources of certain regions of West Pakistan. Geological Survey of Pakistan, Mineral Map, Sheet No. 20.

Key Words: Mineral map, West Pakistan.

G/76. Gee, E.R., 1962. Notes on Mesozoic/Tertiary stratigraphy of the (Former) Punjab, North West Frontier Province, Sulaiman Ranges. The Geologist, Geological Society, Karachi University I (1), 2-5.

Key Words: Stratigraphy, Mesozoic, Tertiary, Punjab, NWFP, Pakistan.

G/77. Gee, E.R., 1980. Pakistan Geological Map: Salt Range Series (6 sheets, scale 1:50,000). Directorate of Overseas Surveys (UK) for the Government of Pakistan and the Geological Survey of Pakistan.

This is the most detailed geological map of the Salt Range based on published data and many years of studies of E.R. Gee. It is produced on six sheets at a scale of 1:50,000. The map is essentially for the Salt Range, however, a small portion of the Trans Indus Salt Range around Kalabagh is also shown. Salt Range is not covered in our work, however, this map shows the distribution of the Siwalik sediments which we include in our work for the sake of completion of references on the Siwaliks.

Key Words: Mapping, Salt Range.

G/78. Gee, E.R., 1983. Tectonic Problems of the sub-Himalayan Region of Pakistan. Kashmir Journal of Geology 1, 11-18.

Key Words: Tectonics, Himalaya.

G/79. Gee, E.R., 1989. Geological map of the Salt Range, Pakistan.

This geological map at a scale of 1:250,000, is based on E.R. Gee, 1980, geological map (Sheets 1-6), scale 1:50,000. For more details consult Gee, 1980.

Key Words: Mapping, Salt Range.

G/80. Gee, E.R. (edited by Gee, D.G.), 1989. Overview of the geology and structure of the Salt Range, with observations on related areas of northern Pakistan. In: Malinconico, L.L. & Lillie, R.J. (eds.), Tectonics of the Western Himalayas. Geological Society of America, Special Paper 232, 95-112.

The Salt Range and its Trans-Indus extension bridges the reentrant between the outer ranges of the northwestern Himalaya and the Sulaiman Mountain arc. Upper Proterozoic to Recent successions occur in the range, which makes up the southern thrust front of the orogen. There are two regional features of particular interest. The first is the occurrence of thick saliferous deposits of Eocambrian age, overlying Precambrian basement in the Potwar Plateau and thrust southward in the Salt Range over the alluvial Cenozoic.

Thick, saliferous deposits also occur within the Eocene sequence of Kohat. These in-competent formations played a significant role in determining structure. The second feature is the presence of four major unconformities: between the marine Eocambrian to Cambrian sequence and the glacial, Lower Permian conglomerates, and below the Paleocene, the Miocene, and the late Pliocene-Pleistocene formations.

Metamorphic rocks, linking with the Precambrian crystalline basement of north-western India, crop out only in the Kirana Hills some 80 km south of the Salt Range. Within the Salt Range and related areas, unmetamorphosed sedimentary rocks compose the exposed succession, mainly shallow-water marine, until mid-Tertiary time, and lacustrine and fluvial from Miocene time onward.

Prior to Quaternary time, only epeirogenic forces affected the region, accompanied occasionally by local warping. In contrast, during Quaternary time, the effects of the Himalayan orogeny extended southward. Accentuated by movement within the Eocambrian saliferous formation, the Salt Range developed as a complex anticlinorium, emplaced southward along a major thrust, which has recently been determined by seismic reflection measurements to involve a decollement of at least 20 km. Complex fold and fault structures resulted elsewhere within the region.

Key words: Salt Range, orogeny, Potwar Plateau, Soan Basin, Himalaya.

G/81. Geological Survey of India, 1904. Quinquennial review of the mineral production of India. Geological Survey of India, Record 32(1), (For the period of 1898-1903).

Key words: GSI publication.

G/82. Geological Survey of India, 1907. Preliminary survey of certain glaciers in the northwest Himalaya. Geological Survey of India. Records, 35

Key words: GSI publication.

G/83. Geological Survey of India, 1931. Geological map of India and adjacent countries. Geological Survey of India, 5th edition.

Key words: GSI publication.

G/84. Geological Survey of India, 1943. Catalogue of publications and index of geological maps of the Geological Survey of India up to June 1941. Geological Survey of India. Memoirs, vol. 77, 114p.

All publications, up to 1940, by the geological Survey of India on the former NWFP, northern Punjab, Hindukush, Karakoram and Himalayan ranges are listed in this memoir.

Key words: GSI publication.

G/85. Geological Survey of India, 1947. Catalogue of publication of the Geological Survey of India and index of Geological maps. Up to March 1946. Memoirs of Geological Survey of India, 77.

This catalogue contains the index map on a scale of 50 miles to an inch, of the published and unpublished maps of India up to 1946, and publications of the GSI. These include the available publications on the areas of this compilation.

Key words: GSI publications, Maps.

G/86. Geological Survey of Pakistan, 1958. A preliminary geological map of Pakistan. Scale 1: 5,000,000, Geological Survey of Pakistan, Information Release 1.

This is one of the earliest efforts on preparing the geological map of Pakistan, following fragmentary information in compilations such as that of Wadia. It was revised in 1962.

Key words: Maps, geology.

G/87. George, M.T., 1993. Structural and Thermal Constraints on the Tectonic Evolution of the North-Western Margin of the Nanga Parbat-Haramosh Massif (Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 31-32.

In the Haramosh region of northern Pakistan, the Kohistan island arc is separated from the Indian crust of the Nanga Parbat-Haramosh massif (NPHM) by a 2.5 km-wide, steeply inclined ductile shear zone containing intercalated lithologies derived from both terranes. A combined structural, geochemical and geochronological study across this zone has helped to constrain the thermal and tectonic evolution of the region.

The youngest stage of magmatism within the eastern part of the Kohistan batholith is characterized by biotite granite sheets (Confluence granites) emplaced at 50-30 Ma and younger muscovite granite sheets (Patti granites) at ~26Ma. These are geochemically distinct, with the Confluence granites comprising a range of granitic compositions with high Sr and Ba abundances and the Parri granites comprising granite sheets enriched in Rb. Undeformed granites in both suites have ($^{87}\text{Sr}/^{86}\text{Sr}$)_i in the range (1.7045-0.7054 and $\epsilon\text{Nd}(\text{T})$ of +0.1 to +2.7, suggesting that both groups may be derived from juvenile arc sources.

The Kohistan granite sheets can be traced into the shear zone at Sassi, where they are generally intensely deformed and mylonitized, although locally the sheets cross-cut shear fabrics and intrude intercalations of Indian crust material. Whilst none of the sheets appear to have intruded far into the NPHM, these relationships indicate that the Kohistan granite sheets postdate the initial collision of the northern Kohistan terrane with the Indian continent. The isotopic evidence from the undeformed granite sheets suggests that significant underthrusting of northern Kohistan by the Indian continental crust may not have occurred until after 26 Ma. Within the shear zone, deformed granite sheets show a marked increase in ($^{87}\text{Sr}/^{86}\text{Sr}$)₁ (0.7075-0.7784), with decreased $\epsilon\text{Nd}(\text{T})$ (-13 to -26). These trends are thought to be due to a combination of sub-solidus fluid infiltration and assimilation of crustal material, with fluids or material derived from the adjacent, isotopically evolved NPHM crust.

Structural data were collected from a 24-km long section along the western margin of the NPHM. The main shear fabrics within the belt are at greenschist grade and rework the earlier amphibolite-grade metamorphic assemblages. Kinematic indicators demonstrate an east-side up movement sense, with a strong component of dextral-slip. Since the foliation dips moderately to steeply west, the shear zone has a normal fault geometry, characterized by a north-westerly motion of the Kohistan arc relative to the NPHM.

The timing of movements within the shear zone have been constrained using mica geochronology on deformed lithologies within the zone. Rb-Sr muscovite-WR ages lie in the range 12-28 Ma, and reflect variable post-metamorphic cooling through the 5000C closure temperature. Rb-Sr biotite-WR and biotite-feldspar ages are 11 and 24 Ma, and have locally been reset to 6 Ma, probably during the retrograde shearing within the zone. Interestingly, leucogranites and their metamorphic country-rocks within the adjacent part of the NPHM have Rb-Sr ages of 2.8-7.7 Ma (muscovite) and 1.4-3.4 Ma (biotite), related to recent uplift and Leucogranite intrusion within this part of the NPHM. The absence of such young mica ages within the shear zone bordering the Kohistan arc indicates that in the Haramosh area, the major, recent uplift of the NPHM was not accommodated along the western margin of the NPHM, as occurred further south. The disparity in mica ages between the shear zone and the NPHM, and the lack of any consistent age variation within the NPHM, may indicate a relatively passive uplift of this part of the massif.

Key words: Structure, thermal constraints, geochemistry, NPHM, Himalaya.

G/88. George, M.T., 1995a. The magmatic, thermal and exhumation history of contrasting granite magmatism between the Kohistan Island Arc and the Nanga Parbat-Haramosh massif, Western Himalaya. Ph.D. thesis, Open University, U.K.

Key words: Magmatism, Kohistan island arc, NPHM.

G/89. George, M.T., 1995b. Implication of Rb-Sr Mica Ages from the North Western Flank of the Nanga Parbat-Haramosh Massif. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

In the western Himalaya, formation of the Nanga Parbat-Haramosh Massif (NPHM) in late-Himalayan times led to the rapid exhumation of upper-amphibolite grade orthogneisses and paragneisses of the Indian continent. Monazite U-Pb ages suggest that these lithologies were locally still at metamorphic temperatures as late as 4-11 Ma(1). To the west, Indian continental rocks are separated from rocks of the upper part of the Kohistan island arc by a ductile shear zone which appears to have accommodated much of the relative uplift of the NPHM. Near Raikhot in the south (Fig. 1), fabrics within the shear zone indicate that Indian continental rocks have been thrust towards the north-west, over the Kohistan arc. Between Sassi and Darchan in the north, the shear zone dips moderately to steeply towards the west and contains lithologies derived from both the Indian continent and the Kohistan island arc. Greenschist-grade fabrics indicate dextral oblique-slip, with an extensional, west-side-down movement sense.

A detailed geochronological traverse across the shear zone in the Sassi-Darchan area has recently confirmed that exhumation-related cooling has occurred both more rapidly and more recently in the NPHM compared with the Kohistan arc. In this contribution, Rb-Sr mineral data are presented from lithologies collected from the shear zone itself, in an attempt to resolve the timing of cooling and deformation along the flanks of the NPHM in relation to present tectonic models. The well-constrained regional cooling history allows an assessment to be made of the relative importance of shear strain, mineral assemblage and grain-size in controlling cooling ages through variation in closure temperature. Mica ages obtained from several mylonitic granite sheets are similar to ages obtained from both their proximal and distal wall-rocks, and do not reflect cooling following granite intrusion. Mica ages from both igneous and metamorphic lithologies are therefore considered together. All mica ages were calculated by regression to the whole-rock.

Biotite ages mostly lie in the range 5.5-10.8 Ma. However, two amphibolites have yielded ages of 16.7 and 23.7 Ma. The majority of muscovite ages lie in the range 9.5-21 .0. However, four pelitic lithologies from Sassi yield anomalously old muscovite ages of 26, 49, 64 and 293 Ma. In addition, two samples collected from the core of the NPHM in the Astor gorge, 40 km to the south (Fig. 1), have yielded muscovite ages of 36.4 and 21.9 Ma.

The majority of biotite ages lie between those earlier obtained from proximal parts of the NPHM (2-3 Ma) and the Kohistan island arc (13-17 Ma), and they therefore probably reflect simple cooling through ~300 °C, rather than late-stage recrystallisation during shearing. The transtensional movements mentioned above occurred at >300 °C, and these movements therefore accommodated uplift of the NPHM prior to 6 Ma. Only brittle movements were occurring in the shear zone during the late-stage exhumation of the northern part of the NPHM.

Several muscovite ages are anomalously old, and indicate that resetting of muscovite during Himalayan processes was locally incomplete, whilst coexisting biotite, intergrown with the muscovite, was fully reset due to the lower closure temperature of biotite relative to muscovite. A cluster of muscovite ages lies in the range 17-21 Ma, and probably reflects cooling of many shear zone samples through ~500 °C in this period. The youngest muscovite ages obtained from metamorphic samples are 9.5 and 11.9 Ma, respectively. Such a wide range in muscovite ages (21.0-9.5 Ma) may reflect the following:

Maintenance of temperature gradients (>200 °C) due to differential shearing during slow cooling, with the result that different imbricates followed different cooling histories.

Closure temperature variations (>200 °C) due to varying fluid content, grain size or mineral assemblage, with the result that different samples yield different mica ages despite cooling along the same pathway.

Isotopic resetting of the majority of biotite samples, and some of the muscovite samples, due to leucogranite intrusion, sub-solidus fluid activity, or deformation occurring at ~6 Ma, at least 11 Ma after the regional 500 °C isotherm had reached the surface.

The latter hypothesis is considered to be unlikely, since it would also have to account for even younger muscovite ages (4-8 Ma) obtained from samples collected from right across the NPHM. Furthermore, the majority of biotite ages are younger than the youngest muscovite age determined, an observation which suggests that the ages are dominantly controlled by diffusion during cooling rather than resetting during shearing. No correlation can be found between either lithology and grain-size and mica age, and therefore there is no evidence for significant variation in closure temperature existing between the studied samples, although it should be remembered that the grain-size is probably not equivalent to the effective diffusion distance.

In summary, this study shows that:

Closely-spaced lithologies that have been sheared along the north-western flank of the NPHM yield variable mineral cooling ages due to real variations in cooling histories followed by proximal sample, possibly combined with variations in closure temperatures. Relatively old (and variable) ages have also been obtained from the core of the NPHM further to the south, indicating that lithologies lying within the NPHM structure have also been strongly affected by differential cooling since Himalayan collision. Muscovite may not be fully isotopically homogenized during upper amphibolite-grade metamorphism. Temperatures in the Sassi-Darchan shear zone probably remained close to 500°C for 11 Ma, whilst cooling through 300°C occurred in the period 5.5–10.8 Ma. Uplift of the northern part of the NPHM was accommodated by brittle movements occurring along the western margin.

Key words: Geochronology, Rb-Sr mica ages, NPHM.

G/90. George, M.T. & Barlett, J., 1996. Rejuvenation of Rb-Sr mica ages during shearing on the northwestern margin of the Nanga Parbat-Haramosh massif. *Tectonophysics* 260, 167–185.

The shear zone bordering the western margin of the Nanga Parbat-Haramosh massif (NPHM) separates terranes with distinct but well-documented cooling histories. This study was undertaken in order to examine isotopic behaviour and if possible to date deformation or cooling within the contact zone itself. Rb/Sr muscovite and biotite ages and petrographic descriptions are presented for a range of metamorphic lithologies and granite sheets which have been affected to varying degrees by greenschist-facies extensional crenulation. This deformation has been kinematically linked to the differential uplift of the NPHM. Ages for metamorphic lithologies and granite sheets are similar and are considered together. Determined muscovite ages mostly lie in the range 9–22 Ma, whilst the majority of biotite ages lie in the range 2–11 Ma. Mica ages from the shear zone are significantly more variable than ages determined for unsheared lithologies from outside the shear zone. Even closely spaced samples yield variable mica ages, and in some cases there is a significant difference between muscovite and biotite ages determined for the same sample. Muscovite ages yield a bimodal distribution, with groups of ages in the range 17–21 Ma and 8–12 Ma. The older group is thought to reflect the original, purely thermostatic cooling of lithologies through the muscovite closure temperature, prior to formation of the NPHM structure. In contrast, the younger group of muscovite ages reflects variable degrees of isotopic resetting during shearing at temperatures below the muscovite closure temperature, associated with the relative uplift of the NPHM. The majority of biotite ages also reflect partial to complete resetting during shearing. However, biotite samples from structurally competent amphibolite horizons preserve older (>16 Ma) ages, indicating that there was locally a strong lithological or fluid control on the degree of resetting. The flanks of the NPHM cooled through the muscovite closure temperature significantly earlier than the deeper structural levels presently exposed within the core of the NPHM. Greenschist-grade deformation was occurring within the shear zone at the same time that deeper levels of Indian crust were passing through the muscovite closure temperature, suggesting that the shearing reflects the relatively passive extensional movement of rocks sliding off the flank of the actively growing Nanga Parbat structure. The results highlight the isotopic complexities of long-lived shear zones present in orogenic belts, but show that useful radiometric age information may be obtained if the regional tectonic history is well understood and if the samples for dating come from well-constrained structural settings.

Key words: Geochronology, Rb-Sr mica ages, NPHM.

G/91. George, M.T., Harris, N.W.B. & Butler, R.W.H., 1993. The tectonic implications of contrasting granite magmatism between the Kohistan Island Arc and the Nanga Parbat-Haramosh massif. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonics*. Geological Society, London, Special Publications 74, 173–191.

In northern Pakistan, an integrated structural and geochemical study across the contact between the Cretaceous-Tertiary Kohistan island arc and Indian crust of the Nanga Parbat-Haramosh massif (NPHM) has identified strongly contrasting source regions contributing to post-50 Ma magmatism, which constrains the tectonic evolution of the region. Nd-model ages of Tertiary intrusives increase dramatically across the contact from c. 700 Ma in the Kohistan terrane to c. 2500 Ma in the NPHM.

Following collision between the Indian continent and the Kohistan island arc terrane at c. 50 Ma, biotite granite sheets (Confluence granites) were emplaced into the Kohistan batholith at 50–30 Ma, followed by muscovite granite sheets (Parri granites) at c. 26 Ma. These are geochemically distinct, with the Confluence granites comprising a range of granitic compositions with high Sr and Ba abundances and the Parri granites forming granite sheets enriched in Rb. Undeformed granites in both suites have ($^{87}\text{Sr}/^{86}\text{Sr}$)_i in the range 0.7045–0.7054 and $\epsilon\text{Nd}(\text{T})$ of +0.1

to +2.7, suggesting that both groups may be derived from juvenile arc sources. Detailed structural studies verify that the Kohistan granite sheets postdate the initial collision of the Kohistan terrane with the Indian continent, but are pre- or syntectonic with respect to continued underthrusting of the Indian continent below the Kohistan arc. These results, together with isotopic evidence from the undeformed granite sheets, suggest that significant underthrusting of northern Kohistan by the Indian continental crust could not have occurred until after 26 Ma.

Along the western margin of the NPHM, deformed granite sheets show a marked increase in $(^{87}\text{Sr}/^{86}\text{Sr})_i$ (0.7075–0.7784), with decreased $\epsilon\text{Nd}(T)$ (–13 to –26). These trends are thought to be due to a combination of sub-solidus fluid infiltration and assimilation of crustal material, with fluids or material derived from the adjacent, isotopically evolved NPHM crust.

The NPHM (Indian continent) has been intruded by a series of tourmaline leucogranite dykes and plutons at 2–12 Ma. These intrusives have trace-element signatures consistent with generation by vapour-absent melting of a pelitic source. Sr-Nd isotope systematics indicate derivation from metasediments such as are currently exposed in the basement rocks of the massif, although melting at the present exposure level is generally precluded by subsolidus metamorphic grades in the country rock. Extreme heterogeneities in radiogenic Sr ($(^{87}\text{Sr}/^{86}\text{Sr})_i > 0.9$) are observed in leucogranite dykes from the Liachar thrust zone, probably indicating subsolidus fluid infiltration. In general the NPHM leucogranites result from rapid exhumation of metasediments characterised by unusually high heat productivity.

Key words: Geochronology, Tectonics, Magmatism, NPHM, MMT.

G/92. George, M.T., Harris, N.W.B. & Keynes, M., 1992. Granite Magmatism and Thermochronology across the Main Mantle Thrust, NW Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 32.

In NW Pakistan, the Kohistan Arc is separated from the west margin of the Nanga Parbat Massif (NPM) by a major ductile shear zone. Interpretation of assemblages and structures from either side of this suture suggest contrasting thermal and magmatic histories that help constrain the regional tectonic evolution.

Metamorphic assemblages from the arc record lower amphibolite facies conditions of 500–600°C and 5–7 Kb. Garnets from the arc show strong compositional zoning with X_{Ca} increasing and X_{Mg}/X_{Mg+Fe} decreasing towards the rims, suggesting garnet growth during increasing pressure but decreasing temperature. In contrast, the Precambrian ortho and paragneisses of the NPM lie in the upper amphibolite facies (kyanite grade) and show peak conditions of metamorphism of 600–700°C and 7–8 Kb. Most garnets are unzoned. Mineral growth cannot be directly correlated with thrust tectonics associated with the Main Mantle Thrust.

Lithologies from both terranes are imbricated in a steeply inclined ductile shear zone which operated at lower amphibolite facies conditions. Mineral stretching lineations on the foliation plunge steeply to the NW and shear-sense indicators suggest a dextral-normal movement, presumably related to the post-tectonic uplift of the NPM. This movement has steepened and overprinted earlier fabrics related to underthrusting of the Indian plate beneath the arc. The youngest magmatic rocks in the arc are cross-cutting granite sheets with a poorly constrained age of 20–50 Ma (1). These sheets can be divided into early biotite granites, which are cross-cut by younger muscovite-garnet-sheets, each type characterized by a distinct trace element and isotope geochemistry. Since both suites are strongly deformed in the shear zone, these granite sheets place an important constraint on the age of shearing. The timing of deformation is being further constrained by ongoing laser Ar-Ar microstructural studies of hornblende within the zone.

The NPM basement is intruded by dykes and sheets of leucogranite. A substantial two-mica body (the Jutial leucogranite) cross-cuts the regional fabric of the NPM and is being studied in more detail. Trace element and highly radiogenic ^{87}Sr – ^{86}Sr (0.874–0.891) indicate an origin by crustal melting of NPM basement rocks. Elsewhere in the NPM, the cross-cutting musc-tourm.(±bi) leucogranite sheets, dated at 2.3–7 Ma (2), show a comparable but more scattered trace element and isotopic composition ($^{87}\text{Sr}/^{86}\text{Sr}$ 10.806–1.061) and probably share the same source.

NPM basement rocks have wide-ranging $(^{87}\text{Sr}/^{86}\text{Sr})_i$ of 0.786–0.963, and variable trace element compositions. The metamorphic grade of these suggest that melting occurred at deeper levels in the NPM than those currently exposed. The heterogeneous isotopic compositions are a common feature of Himalayan leucogranites and reflect a variable source, poor magma mixing or late fluid circulation. In addition to its unusually radiogenic Sr-isotope composition, the Jutial granite contains high concentrations of Th (22 ± 9 ppm) compared to other Himalayan leucogranites, a feature which may have contributed to the thermal budget that caused crustal melting.

The thermochronology of the granites in both the arc and the NPM relative to their country rocks is being investigated by both Rb-Sr dating of micas and laser Ar-Ar dating of micas and amphiboles, in order to constrain the time of granite emplacement and the post-magmatic thermal and tectonic evolution of the region.

Key words: Granite, thermochronology, magmatism, MMT.

G/93. George, M.T., & Reddy, S.M., 1994. Differential unroofing and inherited radiogenic strontium in the Western Himalaya. *Mineralogical Magazine*, 58A, 325-326.

In the western Himalaya, the Nanga Parbat- Haramosh massif (NPHM; Indian continental crust) has been differentially exhumed relative to the adjacent Kohistan island arc terrane (Zeitler 1985). This study aims to constrain the detailed cooling history of the region by using both Rb-Sr and laser probe $^{40}\text{Ar}/^{39}\text{Ar}$ dating of muscovite and biotite from closely-spaced samples. Such a study should also help to evaluate the resolution of mineral ages in determining cooling rates in regions of rapid exhumation. Samples dated include granite sheets and their metamorphic country rocks, and come from the NPHM, the Kohistan arc, and from the intervening steeply dipping, high-grade shear zone.

Key words: Exhumation, NPHM, Kohistan island arc, Chronology.

G/94. George, M.T., Reddy, S.M. & Harris, N.W.B., 1995. Isotopic constraints on the cooling history of the Nanga Parbat-Haramosh massif and Kohistan Arc, Western Himalaya. *Tectonic* 14, 237-252.

Nineteen $^{40}\text{Ar}/^{39}\text{Ar}$ and 22 Rb-Sr mineral ages are presented for metamorphic rocks and granites collected from the northern part of the Nanga Parbat-Haramosh Massif (NPHM) and adjacent parts of the Kohistan arc, western Himalaya. The majority of these ages are interpreted as exhumation-related cooling ages, and they therefore place important constraints on the exhumation history of the region. The $^{40}\text{Ar}/^{39}\text{Ar}$ and Rb-Sr mica cooling ages for areas of the NPHM to the north of the Indus River lie in the range 2–8 Ma and are similar to previously published ages from the Indus gorge itself. Cooling histories for these areas show little systematic variation from east to west, suggesting that the basement may have been exhumed as a relatively rigid block, after the main stages of folding. Mica ages increase dramatically from the NPHM westward into the Kohistan arc, where ages lie in the range 13–30 Ma. The contrast in both cooling ages and the age differential between mineral pairs between the two terranes indicates rapid cooling of the NPHM in the last 10 m.y. compared with the Kohistan arc. The relationship between rates of cooling and exhumation is poorly constrained in regions of rapid uplift, where the characteristics of the evolving geotherm are not well understood. However, the results are consistent with an anomalously rapid exhumation history of the NPHM during the last 10 m.y. compared with the adjacent Kohistan arc. The interpretation of some of the ages documented in this study is problematical. Two biotite samples from contrasting lithologies within the NPHM have yielded higher $^{87}\text{Sr}/^{86}\text{Sr}$ ratios than the corresponding whole rocks, but the cause of this isotopic disequilibrium remains unclear. Other biotite samples from the region have consistently yielded younger Rb-Sr ages than $^{40}\text{Ar}/^{39}\text{Ar}$ ages, which may be a reflection of either preferential leaching of ^{87}Sr during fluid infiltration on a regional scale or the presence of excess argon. Alternatively, the relative ages indicate slightly lower closure temperature for strontium diffusion in biotite than for argon diffusion in biotite where samples have undergone rapid cooling.

Key words: Isotopes, cooling history, NPHM, Kohistan arc.

G/95. Gerth, H., 1938. Perm korallen aus dem östlichen Karakorum and Trias Korallen aus dem nordwestlicher Himalaya. *Paleontologica Geographica*, bd., 88, Abst. A, Lf, 4–6., 230–237.

Key words: Corals, Permian, Triassic, Karakoram, Himalaya.

G/96. Ghani, A. & Nasreen, S., 1990. Ultramafic decorative stones of N.W.F.P. and adjoining areas. Abstracts, First SEGMITE Conference on Industrial Minerals, Peshawar, p.7.

Decorative stones of ultramafic composition in different shades of green occur in various parts of the province and adjacent areas such as Malakand and Mohmand agencies [also Waziristan]. These include rodingite and serpentine.

Internationally, such ultramafic stones are replacing marble (the most widely used decorative stones) due to better colour, hardness, lower porosity, etc.

Key words: Decorative stones, serpentinite, Malakand, Mohmand, Alpuri.

G/97. Ghani, A., Nasreen, S. & Qureshi, K., 1994a. Geology and industrial applications of talc of Juragh area, District Swat, Pakistan. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, p.21.

Good quality talc occurs in the Juragh area of district Swat. The deposits lie in the western part of the suture (Lesser Himalayas, exposed in Pakistan) of the Indo-Pak plate in tectonic interaction with Eurasia in the north. The deposits are developed by secondary processes undertaken by the action of hydrothermal solutions on metamorphosed calcareous sediments and impure marbles as well as retrogression during the Himalayan Orogeny. The talc is suitable for utilization in a range of industries, including sensitive ones like automobile, pharmaceuticals, electroceramics and glazes etc.

Key words: Minerals, talc, Swat.

G/98. Ghani, A., Nasreen, S. & Qureshi, K., 1994b. Talc deposits of Juragh area, District Swat, Pakistan. Pakistan Journal of Scientific and Industrial Research 37(11), 462.

Good quality talc occur in the Juragh area of district Swat. The deposits lie in the western part of the suture (Lesser Himalayas, exposed in Pakistan) of the Indo -Pak plate in tectonic interaction with Eurasia in the north. The deposit is comprised of talc and antigorite while the country rocks are quartz-mica and dolomitic schists. The talc may have been developed by secondary processes undertaken by the action of hydrothermal solutions on metamorphosed calcareous sediments and impure marbles as well as retrogression during the Himalayan orogeny. The talc is suitable for utilization in a range of industries.

Key words: Economic geology, Talc, Swat.

G/99. Ghani, A., Nasreen, S. & Qureshi, K., 1994c. Geology and industrial applications of talc of Juragh area, Swat, NWFP. Proceedings, Second SEGMITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, 23-25.

Consult the previous account for further details.

Key words: Economic Geology, Talc, Swat.

G/100. Ghani, M.A., 1962. Cement industry in Pakistan. CENTO Symposium on Industrial Rocks and Minerals, Lahore, 235-245.

Key words: Industrial minerals, cement.

G/101. Ghauri, A.A.K., 1962. Geology of the Lowari Tunnel area. M.Sc. Thesis, Punjab University, 30p.

Key words: Geology, Lowari Pass.

G/102. Ghauri, A.A.K., 1977. The pebble petrology and the stratigraphy of Tanaki conglomerate in Hazara, North West Frontier Province, Pakistan. Journal of Science and Technology 1 (1), 48-53.

Key words: Petrology, stratigraphy, Tanaki conglomerate, Hazara.

G/103. Ghauri, A.A.K, 1984. Tectonics of western Indus suture in Pakistan. EOS., 65(45), 1094.

Key words: Tectonics, Indus suture.

G/104. Ghauri, A.A.K., Lawrence, R.D., Jadoon, I.A.K. & Saeed, T., 1987. Structure and the history of Yasin group of rocks in Hunza valley, Northern Pakistan. Kashmir Journal of Geology 5, 11-116.

Yasin Group of metasedimentary rocks lies on the northern extremity of Kohistan Island Arc. F1 (minor folds), F2 (upright fold), F3 (intrafolial and kink folds), F4 (minor folds) and F5 (crenulation observed in oriented hand specimens) are the type of folds that can be studied in addition of slickensides, veins, dykes, foliation, lineation and shear zones. Average trend of dominant axial plane foliation of F2 folds is WNW and the inclination is almost vertical. Veins of different age and origin had been of substantial help in this study. The most recent deposit travertine probably relates to a major fault.

Key Words: Structure, deformation, Yasin Group, Hunza.

G/105. Ghauri, A.A.K., Pervez, M.K., Riaz, M., Rehman, O., Ahmad, I. & Ahmad, S., 1991. The Structure and tectonic setting of Attock-Cherat and Kala-Chitta Ranges in Nizampur area, NWFP, Pakistan. Kashmir Journal of Geology 8 & 9, 99-110.

The southern belt of Paleozoic strata of Attock-Cherat Range comprising of limestone, argillite and quartzite, constitutes a major overturned south-verging fold. The southern limb of this fold is truncated by north dipping Hissartang thrust, which is the part of late, Tertiary imbricate thrust system in this area. This fault has emplaced the Paleozoic rocks of Attock-Cherat Range over the Mesozoic sequence of Kala-Chitta Range. From the town Nizampur in the east, the Hissartang fault runs at the foot of Attock-Cherat Range but near the Indus River it swings northeast and a low-angle Hissartang backthrust appears. The tectonically emplaced patches of Jurassic limestone over the Paleozoic rocks of Attock-Cherat Range are quite common east of Indus. The emplacement of Jurassic limestone over the Paleozoic rocks is the result of back thrusting of Hissartang thrust. The north dipping listric normal faults marks the late extensional phase in the area.

Key Words: Structure, tectonics, Paleozoic, Attock-Cherat Range.

G/106. Ghauri, A.A.K., Rehman, O. & Rehman, S., 1983. A new structural model of the southern slopes of Kohat pass, District Kohat, NWFP, Pakistan. Geological Bulletin, University of Peshawar 16, 97-104.

The Darra Adam Khel area has been affected by at least three phases of deformation from Cretaceous onwards. The central block was elevated by an early Cenozoic revolution and has since remained a positive area. Miocene rocks were deposited in linear depressions towards north and south of the block. A central problem in this area is north-verging folds that are anomalous to the regional structural pattern.

The chain of repetitions of Samana Suk and Chichali Formation towards the southern part of the area are neither due to tight folding nor repeated fault slicing, as is generally believed. Instead, there are relatively small, open and somewhat overturned folds developed within the southernmost limb of the main fold, during the last deformational episode, with Chichali Formation being preserved in the synclinal troughs only.

Key Words: Structure, deformation, Cretaceous, Kohat.

G/107. Ghaus, N., 1980-82. Geology of Jabri Pesar Bhajura Area, Abbottabad. M.Sc. Thesis, Institute of Geology, Punjab University, Lahore.

Key words: Geology, Abbottabad.

G/108. Ghazanfar, M., 1987-89. Geology and structure of Harno Area, District Abbottabad. M.Sc. Thesis, Institute of Geology, Punjab University, Lahore, 247p.

Key words: Structure, Geology, Abbottabad, Hazara.

G/109. Ghazanfar, M., 1994. Petrotectonic elements and plate tectonic framework of North West Himalaya. Institute of Geology, Punjab University, Lahore, Ph.D. Thesis, 380p.

Key words: Plate tectonics, stratigraphy, Neelum valley, Azad Kashmir, NW Himalaya.

G/110. Ghazanfer, M., Baig, S. & Chaudhry, M.N., 1983. Geology of Tithwal Kel area Neelum valley, Azad Jammu and Kashmir. *Kashmir Journal of Geology* 1, 1-10.

More than three hundred and eighty five square km area between Tithwal and Kel in the Neelum Valley on the right bank of river Neelum has been mapped for the first time. However, of the section between Doarian and Kel only a reconnaissance sketch was prepared. A detailed description and a preliminary petrography of rock unit between Tithwal and Kel is presented. The rocks between Tithwal and Loat comprise a psammatic-pelitic sequence which resemble the Tanol Formation as found further north in Neelum Valley, north of Jared in Kaghan and elsewhere in the region. The rocks found in the vicinity of Authmuqam have also been considered as part of same psammite pelitic sequence and not Dogra Slates as proposed by Wadia (1928). The extensive pelitic-calcareous sequence found north of Loat has been named as Sharda Group. We suggest the term Sharda Group should be replace the term Salkhala Formation as type of rocks described in literature as Salkhala Formation are nowhere to be found around Salkhala village. Three different granite batholiths have been described. The two southern one Jura and Neelum granites are possibly Tertiary while the Kel granite in the north is Palaeozoic or older. The whole sequence of country rock has been regionally metamorphosed. Very broadly speaking the grade of metamorphism increases from south to north (biotite grade at Authmuqam and kyanite grade at Gamot). Two major structures have been detected. The major synclinal structure in the south has been called Salkhala syncline and the major anticlinal structure in the north has been called as the Kel anticline. The Neelum granite appears to be post-tectonic while the Kel granite is pre-tectonic.

Key words: Geology, structure, metamorphism, Neelum valley, Azad Kashmir.

G/111. Ghazanfar, M. & Chaudhry, M.N., 1984a. A Palaeozoic ophiolite and island arc sequence of Hazara-Kashmir Pakistan syntaxis, District Mansehra. Abstracts, First Pakistan Geological Congress, Lahore, 37-38.

For details consult the following account.

Key words: Paleozoic, ophiolites, Island arc, Panjal volcanics, Hazara-Kashmir syntaxis.

G/112. Ghazanfar, M. & Chaudhry, M.N., 1984b. A Palaeozoic ophiolite and island arc sequence of Hazara-Kashmir Syntaxis, District Mansehra. *Kashmir Journal of Geology* 2, 37-38.

Detailed mapping and field relationships of the rocks in Paras-Jared-Sharan area in Kaghan Valley have revealed the presence of an ophiolite-arc derived metasedimentary suit of Palaeozoic age. The ophiolite-sequence is represented by basic lavas of Panjal Trap abundant between the villages of Malakand and Shinu on the Kaghan valley roadside. North and east of the ophiolite sequence a sedimentary-volcanic sequence is represented by agglomeratic slates and arc derived metasediments. The likely age of this sequence of Hazara-Kashmir Syntaxis is between Devonian and Triassic. The sequence continues around the syntaxis, the eastern limb extending over the Kaghan ridge across Neelum Valley and beyond and the western limb turning south of Nadi Bungalow to Balakot and further south and southwest.

Key words: Ophiolites, Island arc, Paleozoic, Hazara-Kashmir syntaxis.

G/113. Ghazanfar, M. & Chaudhry, M.N., 1985a. A Third suture in Northern Himalaya. *Kashmir Journal of Geology* 3, 103-108.

The MKT and MMT are two sutures so far identified in NW Himalayas and Northern Area. In the region of Kaghan and Neelum Valleys the Main Boundary Thrust (MBT) constitutes an older Upper Paleozoic Panjal Suture. The Panjal Volcanics-Agglomeratic Slate-Tanol sequence in this area may together mark the opening and closure of a basin developed on a rifted continental margin possibly associated with an arc. Stratigraphy along the MBT point to the existence of an Upper Paleozoic Panjal Sea in the area of Northwest Himalaya separating the Indian Main land from its rifted tectonic slice, the Kashmir Hazara Continent Slice.

Key words: Sutures, MMT, MKT, MBT, Himalaya.

G/114. Ghazanfar, M. & Chaudhry, M.N., 1985b. Geology of Bhunja-Batakundi area, Kaghan Valley, District Mansehra, Pakistan. *Geological Bulletin, Punjab University* 20, 76-105.

The part of Kaghan Valley between Mahandari and Batakundi has been geologically surveyed and mapped, at 1:17,000 for the first time. Besides a detailed field description of rock units, brief description of structure and comments on metamorphism, stratigraphic correlation and geomorphology are included. The rocks range from limestones, greenstones, tillites. Pelites, calcareous pelites to psammities in the biotite to silliminite grade. Some locally produced granites and a beautifully developed migmatite unit are also present. Stratigraphically the sequence becomes older towards north. A tentative correlation of the rock units has been attempted with Panjal series, Tanol Formation, Hazara slates and Precambrian Sharda Group (Salkhalas) successively to the north. Major structures consist of a number of asymmetric and at places, overturned folds separated in the form of blocks by high angle north dipping thrusts. Graphite, gypsum and marble are potential economic deposits.

Key words: Geology, Bhunja-Batakundi, Kaghan Valley.

G/115. Ghazanfar, M. & Chaudhry, M.N., 1986. Reporting MCT in northwest Himalaya, Pakistan. *Geological Bulletin, Punjab University* 21, 10-18.

Work in Neelum valley, Azad Kashmir and Kaghan valley has now made it possible to locate the Main Central Thrust (MCT) in northwest Himalaya. Geological mapping and investigations in the two valleys indicate that the MCT extends in a NE-SW direction between Luat in Neelum valley and Batal (south of Naran) in Kaghan valley crossing the Kaghan watershed near Thod Bhaik. There is a marked difference in the tectonic style, stratigraphy and metamorphism north and south of this line. This difference compares well with that reported from India. This discovery of MCT in Pakistan now, for the first time, enables us to compare and tentatively extend the tectonic zones of Central Himalaya in India into northwest Himalaya in Pakistan.

Key words: Structure, Maps, MCT, Himalaya.

G/116. Ghazanfar, M. & Chaudhry, M.N., 1992. Four phase deformation in Murree-Abbottabad of Attock-Hazara fold and thrust belt, Northwest Himalaya, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 55-56.

Key words: Deformation, Attock-Hazara, Himalaya.

G/117. Ghazanfar, M. & Chaudhry, M.N., 1996a. The Tethys Himalaya of Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 49-50.

Of the four major tectonic subdivisions of the Himalaya, the two northern ones, the Higher Himalaya Crystalline (HHC) and the Tethyan Himalaya, were neither identified nor delineated in Northwest Himalaya of Pakistan until quit recently. The demarcation of MCT in Pakistan and Azad Kashmir (Ghazanfar & Chaudhry, 1986) finally settled the character and boundary of the HHC in Pakistan. This work aims at defining and setting limits and presenting a map of the Tethyan Himalaya in Pakistan.

To the south of Indus Suture in Pakistan a belt of low grade sediments extends all along from Babusar Pass in the east to Swat in the west of these sediments have been largely ignored in the tectonic setting of the NW Himalaya. These were first mapped and described from near Babusar and later westwards to Ledi grade rocks of Banna, Allai, and Swat. In Swat low grade rocks have been described from a number of locations including Sassoi, Karora and Mingora. The presence of these rocks at the head of the high grade HHC terrain below the MMT has been variously explained as a back thrust slice of the Cambrian Abbottabad Formation which occurs far to the south (Coward et al., 1988) or as retrogressed part of the high grade upper Kaghan metasediments which were considered Permo-Triassic (Greco et al. 1989; Spencer, 1993).

These workers thus considered the high grade gneisses of the Burawai Group of the Higher Himalaya of Upper Kaghan as the Tethys Himalaya. Such a suggestion remains highly debatable. The huge Burawai group everywhere in Kaghan and Swat is in the kyanite-sillimanite grade and is an integral part of the HHC. Field observations disprove both the back thrust as well as the retrogression hypothesis.

As opposed to this Chaudhry and Ghazanfar (1992) suggested that the only Tethyan sequence were the low grade metasediments exposed along the MMT north of the HHC. Low grade sediments below MMT were first described from Upper Kaghan by Chaudhry and Ghazanfar in 1987 where they were named as the calcareous Bachh Formation and the graphitic Richpar Formation.

Low grade metasediments are also exposed further west south of the MMT in Banna, Besham and Swat areas. The sequence is best developed in Banna, Allai area east of Besham. Preliminary mapping reveals it can be subdivided into a lower graphitic phyllite (Chiran Formation) an upper thin bedded limestone/ marble (Banna Formation) and an intervening unit comprising intercalations (Palang Formation). The whole sequence is nearly one km thick.

Further west in Swat the low sediments are represented mainly by graphitic pelites which have been called Dargai Formation (Saidu Formation). Structurally they form synclinal inliers with a faulted base.

Geological mapping has revealed that the much attenuated sequence of Upper Kaghan more or less physically continues into the Banna area. Although the units are very thin in Upper Kaghan their continuation from Babusar through Lohyalul and Ledi to Dila is remarkable.

In the Karora area of Besham the lithologies are similar to Banna area except that this is the only area where the unit instead of being faulted at the base is underlain by a boulder bed which rest on the high grade slab of HHC.

In the Kashmir Basin the Tethyan sequence discontinuously continues across the HHC to the south. A somewhat similar situation is present in Lower Swat where the Tethyan sequence occurs as synclinal inliers in the high grade terrain and possibly correlates southwards with the low grade basal rocks of the Peshawar Basin.

Although fossils are likely to be present no fossils have been reported anywhere in Pakistan from this suite far and their age is mainly a matter of correlation. Near Besham the Karora Group rocks have been cut some granite bodies which were dated Precambrian by Baig (1990).

Key words: Structure, tectonics, MMT, MCT, Himalaya.

G/118. Ghazanfar, M. & Chaudhry, M.N., 1996b. Structure and Tectonic style in Sedimentary Lesser Himalaya, south Hazara, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 51-52.

The Attock Hazara Fold and Thrust Belt, AHFTB, is mainly a shelf sedimentary sequence extending in east-west direction for some 250 kilometers from Garhi Habibullah in the northeast to Parachinar in the west.

A thick sedimentary sequence ranging in age from Cambrian to Neogene and overlying the slightly metamorphosed Hazara slate is present in the form of arcuate megasynclinalorium which closes into the Hazara Kashmir Syntaxis in the northeast near Garhi Habibullah and complicates to the west. To the north it is separated from an extensive zone of igneous and metamorphic rocks by the Panjal Fault. This is the Main Boundary Thrust, MBT, coming from east in India. The real throw of MBT in Pakistan is distributed along a number of parallel faults passing through this belt, the chief among these being the Nathia Gali Thrust, NGT. The AHFTB is essentially a westward continuation of the parautochthonous fold belt of Pir Panjal Himalaya over the Hazara Kashmir Syntaxis. Important stratigraphic differences in the belt exist from place to place. The stratigraphic sequences of Kashmir, Hazara and Muzaffarabad constitute three different stratigraphic provinces, which juxtapose in the area of Balakot. The AHFTB constitutes the southern sedimentary fringe of the mainly metamorphosed Lesser Himalaya. West of the HKS the metasediments of Mansehra-Oghi area and the Peshawar Basin lie the north of AHFTB. This study pertains to the Abbottabad-Murree section of northeast AHFTB.

Three major phases of deformation are clearly discernible. The first phase D1 is pre-Himalayan when the Hazara slates were metamorphosed. These Precambrian slates are now overlain by a thick shelf sedimentary Phanerozoic

sequence with an angular unconformity at the base. From the metamorphosed clasts of Hazara Formation in the basal Tannaki boulder bed of the overlying Cambrian Abbottabad Formation. This orogeny has been dated Precambrian (Baig et al., 1987; Chaudhry, 1964; Chaudhry et al. 1989). During the Himalayan orogeny the entire sequence underwent two major phases of brittle deformation. The main phase Himalayan deformation, D2, is now represented by the NE-SW outcrop trends of structures. These megafolds are generally overturned and isoclinal and interrupted by numerous dip slip and oblique slip faults. The vergence of these structures is enigmatic. Apart from the southeast vergence major blocks show northwest vergence of both folds and faults. The southeast vergence is clearly explainable as being in line with the Himalayan direction of transport in this area. The northwest vergence, however, has been explained as later overturning and back thrusting (Coward et al. 1988; Ghazanfar et al. 1990) pertaining to a later phase. Large scale geological mapping of this section (this study), however, indicates box folding and fan folding during D2. A number of normal faults were formed following relaxation of stress. The final Himalayan phase of deformation D3 relates to the formation of Hazara Kashmir Syntaxis, HKS, and a major re-entrant of the Northwest Himalaya. The NE-SE trend of syntaxial phase of folds is at right angles to the NE-SW trends of D2 structures. These folds are generally intraformational and only faintly seen on the map scale where they generally appear as broad flexures and broad bends. Many of these folds are SW vergent and are not accompanied by related faults.

Key words: Structure, tectonics, sedimentation, Attock-Hazara, Himalaya.

G/119. Ghazanfar, M., Chaudhry, M.N. & Hussain, M.S., 1991. Geology and petrotectonics of southeast Kohistan, Northwest Himalaya, Pakistan. *Kashmir Journal of Geology* 8 & 9, 67-97.

About 2200 km² of southeast Kohistan has been geologically mapped and the stratigraphy of the area established. A possible sequence of events has been listed. Detailed field relations and lithologic descriptions of many units have been reported for the first time. The predominantly plutonic arc set represents a relatively older much-eroded terrane where volcanic cover stands largely removed. The relatively smaller volcano-hypabyssal suite appears to be the latest magmatic event. Most of the amphibolite mass, tholeiitic greenstones and ultramafics represent obducted masses and shreds of oceanic affinities. The hanging wall sole rocks of MMT as well as foot wall rocks along minor syntaxis do contain deeper level obducted slices and shreds of eclogites and high-pressure granulites.

The Chilas norite complex is sandwiched between northern and southern arc masses. The field and petrographic data suggest that the Chilas norite complex appear to have been formed under a spreading center. The MMT suture zone ultramafics are divided into part cumulate and part mantle tectonic. The carbonaceous-argillaceous, argillaceous and calc-pelitic phyllites and associated low-grade carbonates represent Tethyan shelf sediments, sandwiched between the Higher Himalaya and southern suture ophiolites.

Structurally the area is characterized by a number of northwest dipping high-angle imbricate thrusts, which converge into and are terminated by the Raikot fault in the east. Polyphase folding is seen in the Kamila amphibolites while the norites appear to have been folded into tight isoclinal antiform.

Key words: Structure, mapping, stratigraphy, ophiolite, Island arc, MMT, Kohistan.

G/120. Ghazanfar, M., Chaudhry, M.N. & Hussain, M.S., 1992. Geology, tectonics and structure of northeast Kohistan and Kaghan. Abstracts, First South Asia Geological Congress, Islamabad, p.14.

Key words: Structure, Tectonics, Kaghan, Kohistan.

G/121. Ghazanfar, M., Chaudhry, M.N. & Latif, M.A., 1987. Three stratigraphic provinces at Hazara-Kashmir boundary, Pakistan. *Kashmir Journal of Geology* 5, 65-74.

A stratigraphic study of Hazara-Kashmir boundary in the region of Kaghan, Garhi Habibullah and Muzaffarabad indicates presence of three different stratigraphic sequences now tectonically juxtaposed. Two different stratigraphic levels are indicated for Tanols/Tanawal of Hazara and Kashmir.

Key words: Stratigraphy, tectonics, Hazara-Kashmir.

G/122. Ghazanfar, M., Chaudhry, M.N. & Mirza, S.B., 1984. Geology of Tithwal-Kel area, Neelum valley, State of Azad Jammu and Kashmir. Abstracts, First Pakistan Geological Congress, Lahore, 29-30.

For further details consult Ghazanfar et al., 1983.

Key words: Geology, Neelum valley, Azad Kashmir.

G/123. Ghazanfar, M., Chaudhry, M.N., Pervaiz, K. & Qayyum, M., 1990. Geology and structure of a section of Attock-Hazara fold and thrust belt around Ayubia, District Abbottabad, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.4.

Detailed geologic mapping of Kuza Gali - Dunga Gali - Ayubia area has been carried out at a scale 1:9560. Lithostratigraphy, structure and regional geology of the area has been discussed and described in relation to the larger tectonic framework. Stratigraphically the area shows exposures of rock units from Middle Jurassic to Eocene and belongs to the so-called Kohat-Potwar Basin. The overall structure is an anticlinorium bounded by the two synclinoria to its north and south. The whole being a small section of the Attock Hazara fold and Thrust belt of Pakistan.

Key words: Structure, Maps, Attock-Hazara.

G/124. Ghazanfar, M., Chaudhry, M.N., Pervaiz, K., Qayyum, M. & Ahmed, R., 1990. Geology and structure of Kuza Gali-Dunga Gali-Ayubia area, Hazara-Potwar basin with a reference to hydrocarbon prospects of Attock-Hazara fold and thrust belt, Pakistan. Journal of Hydrocarbon Research 2, 43-56.

Key words: Structure, maps, hydrocarbons, Hazara Potwar basin, Attock-Hazara.

G/125. Ghazanfar, M., Chaudhry, M.N. & Qayyum, M., 1990. The stratigraphic framework of Northwest Himalayas along the Kaghan valley section, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.34.

This paper is a first time attempt at systematizing the stratigraphy between the Main Boundary Thrust (MBT) and the southern Suture zone (SSZ) as exposed in Kaghan valley. The sequence in the Kaghan valley between Para and Naran is mainly inverted and becomes successively older towards the north. From south to north the rocks may be subdivided into three main groups: 1) the Kashmir sequence, Mid-Paleozoic to Miocene, which represents, by and large, tectono-stratigraphy of the Pir Panjal (Kashmir) to the east; (2) the Kaghan Group, possibly Late Proterozoic, which occurs between Mahandri and Naran; and 3) the Sharda Group, possibly Archean to Mid-Proterozoic, which occurs north of Naran and represents a continuation of the Higher Himalaya to the east. The Kaghan valley section also traverses important tectonic scars, including from south to north the Murree Fault, the Panjal Fault, the Main Central Thrust (MCT) and the Main Mantle Thrust (MMT).

Key words: Stratigraphy, MCT, MMT, Kaghan valley, Himalaya.

G/126. Ghazanfar, M., Chaudhry, M.N. & Qayyum, M., 1992. The stratigraphic framework of Northwest Himalayas along the Kaghan valley section, Pakistan. In: Sinha, A.K. (ed.). Himalayan Orogeny and Global Tectonics. Wadia Institute of Himalayan Geology, Dehra Dun, India, 307-327.

Consult the preceding account for further information.

Key words: Stratigraphy, MCT, MMT, Kaghan valley, Himalaya.

G/127. Ghazanfar, M., Chaudhry, M.N. & Spencer, D.A., 1995. The geological character and problems of Lesser Himalaya in Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

With the delineation of the Main Central Thrust (MCT) in the Northwest Himalaya of Azad Kashmir and Pakistan, the Lesser Himalaya slab can now be defined. The Lesser Himalaya of Pakistan and Kashmir is divided into a northern metamorphic zone and a southern sedimentary zone. The northern metamorphic zone is represented by the mutually analogous Kashmir Basin in the east and the Peshawar Basin in the west separated by Kaghan and Northern Hazara in between. Whilst the Lesser Himalaya of Kashmir and Peshawar basins are characterized by simple fold structures, the intervening Kaghan and Northern Hazara are marked by schuppen structures. The Kashmir and Peshawar basins are limited to the south by the sedimentary zones of Pir Panjal in the east and the Attock Hazara Fold and Thrust Belt in the west. Both these sedimentary belts are again marked by numerous closely spaced ramp faults. In the area of Balakot these two zones along with the sedimentary sequences of Muzaffarabad comprise three stratigraphic provinces on the boundary of Hazara and Kashmir. Southeast Hazara is characterised by a four phase sequence of deformation. The first phase is Pan-African while the other three phases are Himalayan in age. The earliest Himalayan phase of deformation is marked by south verging folds and thrusts, the second by north verging structures and finally the third by open north-south cross folds related to the formation of HKS. Evidence of pre-Himalayan metamorphism is now well documented in the Lesser Himalaya of Pakistan. The pre-Himalayan phases start in the Proterozoic and end in the Hercynian. The Tanol-Tanawal controversy, regarding the age and correlation of these formations in Kashmir and Hazara, can now be finally settled. The Tanawals of Kashmir are Devonian to Carboniferous while the Tanols of Hazara are Precambrian in age and are older than the Hazara slate to which they have always been considered younger.

Key words: Geology, metamorphism, MCT, Himalaya.

G/128. Ghazanfar, M., Chaudhry, M.N. & Spencer, D.A., 1999. The geological character and problems of the Lesser Himalaya in NE Pakistan. Geological Bulletin, Punjab University 33 & 34, 9-42.

With the delineation of the Main Central Thrust in the Northwest Himalaya of Azad Kashmir and Pakistan, the Lesser Himalayan slab stands defined. The Lesser Himalaya of Pakistan and Kashmir are divided into a Northern Metamorphic Zone and a Southern Sedimentary Zone. The Northern Metamorphic Zone is overlain by the Peshawar Basin in the west of Pakistan and also includes Northern Hazara and the middle parts of Kaghan and Neelum valleys to the east.

Whilst the Kashmir and Peshawar Basins are characterized by a Tethyan stratigraphic sequence deformed by simple folding, the intervening middle Kaghan and Northern Hazara areas are highly deformed schuppen structures on the limbs of the Hazara-Kashmir Syntaxis. The Kashmir and Peshawar Basins are limited to the south by the sedimentary zones of the Pir Panjal in the east and the Attock-Hazara Fold-and-Thrust Belt in the west. Both these sedimentary belts are marked by numerous closely spaced ramp faults. The Attock-Hazara Fold-and-Thrust Belt is marked by a polyphase sequence of deformation. At least one phase is Precambrian. The occurrence of Pre-Himalayan/Pre-Cambrian metamorphism in the Lesser Himalaya is now well established. The Himalayan overprint is missing or at best limited. The Tanol-Tanawal controversy regarding age and correlation of these formations in Kashmir and Hazara is discussed and it is here suggested that among the Pre-cambrian formations the Tanawals of Hazara are in fact older than the Hazara slates.

Key words: Geology, tectonics, metamorphism, MCT, Himalaya.

G/129. Ghazanfar, M., Chaudhry, M.N., Spencer, D.A., Hussain, S.S. & Dawood, H., 1999. The nature and problems of the Tethyan Himalaya in Pakistan and western Kashmir. Geological Bulletin, Punjab University 33 & 34, 43-69.

This paper aims to define, describe and discuss the occurrence of the tectonic subdivision of the Tethyan Himalaya in northern Pakistan and western Kashmir. With the demarcation of the Main Central Thrust in the Neelum and Kaghan valleys (western Kashmir and Pakistan), the Higher Himalaya and the Lesser Himalaya have now been differentiated in these areas. In the NW Himalaya, two domains of the Tethyan sedimentary rocks have been

recognised, both north and south of the Main Central Thrust. To the south, the Lesser Himalaya in Pakistan and Kashmir is overlain by a sedimentary sequence of Tethyan affinity. The relationship of this Southern Tethyan Sequence, incorporated as part of the Lesser Himalaya, is interpreted to be analogous to that of the cover sediments in Kashmir and the autochthonous fold belt of Pir Panjal. To the north of the Higher Himalaya and directly underneath of the Indus Suture, the 'Northern Tethyan Sequence' possibly consists of low grade sediments which are found in Upper Kaghan, Banna, Karapa and Lower Swat. These sediments can be interpreted to be analogous to the Tethyan Himalaya. Other interpretations of these sediments (i.e., their suture zone affiliation) are also discussed. Finally, the high grade metasedimentary cover of Higher Himalaya is also regarded as being the equivalent of the Tethyan Himalaya in the 'Northern Tethyan Sequence'. The role and significance of these Tethyan sequences, in the subdivision terminology of the Himalaya, is assessed with the other known subdivisions of the Pakistani Himalaya and western Kashmir.

Key words: Tectonics, MCT, Kaghan valley, Neelum valley, Tethyan Himalaya.

G/130. Ghazanfar, M., Chaudhry, M.N., Zaka, K.J. & Baig, M.S., 1986. The geology and structure of Balakot area, District Mansehra, Pakistan. Geological Bulletin, University of Punjab 21, 30-49.

Nearly 65-km² area in the vicinity of Balakot has been mapped at 1:10,000. The stratigraphy and major structures are described and discussed. The stratigraphy of Balakot brings out three separate stratigraphic sequences of rocks east and west of the river Kunhar. A new stratigraphic interpretation of the metamorphics is presented. The small but interesting Bamphora structure is explained. The Muzaffarabad fault is correlated with the Riasi fault and with the Great boundary fault, passing through Potwar. Jhelum fault is the youngest major structure, which has displaced the western limb of the Hazara-Kashmir Syntaxis.

Key words: Geology, structure, Balakot, Mansehra.

G/131. Ghaznavi, M.I., 1981. Graphite deposit of Mohriwali, upper Azad Kashmir. Geological Survey of Pakistan, Information Release 167.

Key words: Mineral Deposits, Graphite, Kashmir.

G/132. Ghaznavi, M.I., 1988. The petrographic properties of the coals of Pakistan. M.S. Thesis, southern Illinois University, Carbondale, 175p.

Key words: Petrography, coal.

G/133. Ghaznavi, M.I., & Karim, T., 1978a. A note on phosphorite deposits of Lagharban and Kalu-di-Bandi areas, Hazara District, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 103, 31p.

Phosphorite deposits have been discovered in Kalu-di-Bandi and Lagharban areas (toposheet. 43 F/7) of Hazara district. The phosphorite is found in the upper cherty dolomitic part of Abbottabad Formation. The phosphate beds are present along both the western and eastern limbs of an overturned syncline.

The phosphorite zone found in the western limb is more promising because of its quantity. It is lenticular in shape with average thickness of 18 feet and lateral extension 8500 feet. The P₂₀₅ percentage varies from 24 to 31%. The reserves of this zone upto 500 feet dip depth are about 5.00 million tons.

The eastern limb deposit is not as extensive as that of western limb. The phosphate zone has 14 feet average thickness and the lateral extension is about 3500 feet. The P₂₀₅ percentage of this zone is very good and varies from 30 to 38%. The reserves of this zone are about 2.00 million tons.

The total probable estimated reserves of Kalu -di-Bandi area are about 7.00 million tons upto dip depth of 500 feet.

Key words: Mineral deposits, phosphorites, Hazara.

G/134. Ghaznavi, M.I., & Karim, T., 1978b. Phosphorite deposits of Dalola–Daulatmar area, Hazara District, NWFP. Pakistan. Geological Survey of Pakistan, Information Release 104, 31p.

The phosphorite deposits have been discovered in Dalola-Daulatmar areas (toposheet No.43F/7) of Hazara district. The phosphorite is found only in the middle silty beds of Galdanian Formation. Three different phosphorite zones in the same stratigraphic horizon have been discovered in this area. The zone No 1 is 5580 feet long and has 28 feet average thickness. The zone No 2 is 2700 feet long with 48 feet average thickness. While the third zone No 3 is further divided into A and B with 3630 feet and 2300 feet respective lengths. The average thickness of former is 29 feet and of later 18 feet. The P205 percentage varies from zone to zone and within the same zone. The best and richest zone is No 2 and the poorest is zone No 3. The P205 percentage of phosphorite deposits of this area varies from 8 to 39%. On the whole the phosphate is low grade and needs beneficiation to upgrade. The total probable estimated phosphorite reserves of this area are about 9 million tons upto a dip depth of 300 feet.

Key words: Phosphorites, Hazara.

G/135. Ghaznavi, M.I., Karim, T. & Maynard, J.B., 1983. A bauxitic paleosol in phosphorite-bearing strata of Northern Pakistan. *Economic Geology* 78, 344-347.

The area around Abbottabad contains commercial grade phosphate in several localities. The stratigraphy of the phosphate-bearing units is of great interest. This report documents the position of a major unconformity which can be used to improve stratigraphic correlation and which may shed some light on the genesis of the phosphate beds. The phosphate deposits are contained in stratigraphic sequence comprising the Abbottabad formation, a cherty dolomite; the Hazira formation, a complex unit, mostly silt stone; and the Samana Suk limestone, which is of Jurassic age.

Key words: Stratigraphy, phosphate deposits, mineralization, Indian plate, Abbottabad.

G/136. Ghazi, B., 1987-89. Geotechnical study of proposed Ghazi-Gariala Hydropower Project and material testing of District Hazara and Attock. M.Sc. Thesis, Punjab University, Lahore, 140p.

Key words: Hydropower, geotechnical, Ghazi, Hazara.

G/137. Ghazi, S., 1992. Environmental hazards along the Mansehra-Duber segment of the Karakorum Highway. *Mountnews* 5, 65-72.

Key words: Environmental hazards, KKH.

G/138. Ghigliione, P., 1946. Himalaya: Karakorum. 1st Geogr. De Agostini, Novara.

Key words: Geography, Karakoram.

G/139. Ghumman, M.A., 1976-78. Detailed Geology, Petrology and Economic Geology of Toposheet No. 43 B/9. M.Sc. Thesis, Punjab University, Lahore.

The Shangla Par-Alpurai Area is composed mainly of schist and phyllites containing volcanics at some horizons. These rocks were originally deposited in eugeosynclinal conditions or argillaceous sediments and have subsequently been metamorphosed to schists and Phyllis. These rocks are probably Cambrian in age. They have been intruded by the ophiolites, which have now been metamorphosed to amphibolites. These are the southern amphiboles which are ortho in character. Subsequently the area has been strongly folded and intruded by Basi granite and then by the ultramafic body. This body was originally a complex peridotite-pyroxenite-amphibole-pyroxene etc. rock which has been altered first to serpentinite and then further metasomatised at places to talc-carbonate rock. The area lies on the Northwestern Limb of the syntaxis and therefore, the prominent strike is NW+SW. Almost all major contacts are faulted. The folding pattern is isoclinal.

Key words: Mapping, petrology, economic geology, ophiolites, Swat.

G/140. Giaradino, J.R., Shroder, J.F. & Vitek, J.D. (Eds.), 1987. Rock Glaciers. Allen and Unwin, London, 355p.

Key words: Glaciology, glaciers.

G/141. Gilani, T.M., 1984-85. Geology of Nauseri-Reshian area with special emphasis on the structure of the area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, 119p.

The project area covers about 307 square kilometers, located between Reshian and Jura to the ESE and NE of Muzaffarabad, Azad Kashmir. The work has involved geological mapping of the area on a scale of 1:25,000. In this thesis an attempt has been made to introduce the detailed geology of the area. Bulk geological sequence of the area consists of sedimentary, volcanic, metamorphic and granitic rocks. The area is tectonically, highly disturbed being involved in Himalayan orogeny. Major and minor structures of the area are described with the help of figures and maps. For Petrographic analysis sixty thin sections were studied microscopically. Tectonic setting and stratigraphy of the area are described briefly. Economic rocks and minerals found in the area have been described in detail to some extent.

Key words: Structure, geology, Azad Kashmir.

G/142. Gilani, T.M., Baig, M.S., Ashraf, M., Khan, M.S., Raja, M.K.K., Rashid, A., Aziz, M. & Lucky, M.H., 1991. Geology of Reshian-Nauseri Area, Azad Jammu and Kashmir, Pakistan. Kashmir Journal of Geology 8 & 9, 191-192.

The area lies in the Pir Panjal Range of the lesser Himalaya, a pre Cambrian to late Paleozoic sequence of the Northern margin of Gondwana is imbricated by NE dipping thrust faults. The major thrust faults from south to north are the Murree thrust and the Panjal thrust. The former emplaces the late Paleozoic Panjal formation on to the Oligocene to Miocene molasses of the Murree formation. The Panjal thrust emplaces the Precambrian tanol formation and early Paleozoic granitoids on to the Panjal formation. Petrography of the rocks is given and comments are made on regional metamorphism,

Key words: Structure geology, stratigraphy, Pir Panjal Range, Azad Kashmir.

G/143. Gill, W.D., 1951. The tectonics of the Sub-Himalayan fault zone in the northern Potwar region and in the Kangra district of Punjab. Quarterly Journal Geological Society of London 107, 112-121.

The paper defines three major zones of deformation across the Nimadric (Tertiary freshwater) geosyncline between the foreland and the autochthonous folded belt in the North-West Himalaya:-

- (1) A zone of open folding, affected to a varying degree by fold-faulting.
- (2) A fault zone, displaying a number of reversed faults of steep northerly hade and great lateral extent with open folds between them in the west and, in places, gently dipping monoclines in the east.
- (3) A zone with closely spaced strike-faults and severely compressed folds, referred to in the Potwar area as the isoclinal zone, terminating at the main boundary fault which forms the general northern limit of Nimadric rocks.

This succession of structural zones has a superficial resemblance to progressive deformation of the Jura type towards the nappe zone, and previous workers have regarded the tectonic pattern as reflecting tangential pressures from the north.

The author seeks to demonstrate that such an interpretation is denied by the evidence of the structures themselves. Two areas are chosen to illustrate in adequate detail the tectonics of all three zones, and in particular the crucial fault zone. In the west, the Jhamat-Khushalgar area of western Potwar typifies the fault zone of the area between the Indus and the Jhelum rivers. In this area there is clear evidence of the steep hade of the great strike-faults at the surface, and also important evidence of their continued steep hade in depth from the results of boreholes drilled by the Attock Oil Company. Analysis of the relationship of the faults to the fold structures leads to the conclusion that

the faults have no genetic relationship to the fold axes. They are considered to be fractures due to shearing stresses principally with a vertical orientation, whilst the folding reflects the subsidiary compressive force. The Nadaun Dun area of Kangra district is some 200 miles to the southeast of the Potwar area, but lies across similar structural zones and typifies the relationships of the anticlinal zone and the fault zone in the region east of the Jhelum River. In this area the Gumber fault is seen to present all the features of the great strike-faults of the fault zone in the Potwar and is an upthrust structure produced by quasi-vertical movement. A feature not present in the Potwar is the marked contrast between the gently dipping monocline to the north of the fault and the strongly folded country to the south, providing a clearer distinction between the influence of tangential and vertical forces. It appears that the fault movement provided a block-line against which tangential forces from the south were directed. Important evidence of tangential pressure from the south is provided by the Barsa fault, which typifies the most common form of fold-fault in the anticlinal zone throughout the region. Gravity collapse structures are recorded in the form of severely overturned "flaps" of sandstone on the south side of the Sola Singhi ridge.

Key words: Tectonics, structure, deformation, Kangra, Potwar,

G/144. Gill, W.D., 1952. The stratigraphy of the Siwalik series northern Potwar, Punjab, Pakistan. *Quarterly Journal of the Geological Society of London* 107, 375-394.

Detailed mapping of the Jhamat area in the west and of the Soan syncline in the east forms the basis of revision of the stratigraphy of the Siwalik Series in the northern Potwar region. The succession is here affected by facies changes of regional significance: -

1. Near the Indus River the uppermost 3000 feet of the Middle Siwalik sequence (Upper Nagri and Dhok Pathan stages) contain thick beds of conglomerate which die out eastwards and south-eastwards into sandstones and clays. Farther eastwards, across the Soan syncline, a clay facies develops at progressively lower horizons in the Nagri Stage, replacing a considerable portion of the massive sandstones of the type area. The facies change is accompanied by a reduction in thickness. The facies variation in the Middle Siwalik rocks is indicative of a channel environment in the west at Jhamat, clearly coinciding with the line of the present Indus River and grading eastwards into deposits of "flood plain" type.

2. The Lower Siwalik rocks show a development of coarser facies in the opposite direction to that noted in the Middle Siwalik. At the eastern end of the Soan syncline the lowest 1500 feet of the Chinji Stage, which in the west is almost entirely of clay-shale facies, contain thick beds of hard sandstone and the sequence is very similar to that of the underlying Kamli Stage.

In the Soan area, the complete Siwalik succession from the Kamli Stage to the Pinjor Stage (Villafranchian) is free from any marked unconformities but is overlain with strong unconformity by post-Siwalik Pleistocene beds—the Lei Conglomerates. This interpretation differs greatly from that of de Terra (1936, 1939), who placed the first great unconformity of the area at the base of the Tatrot Stage. The revision explains Pilgrim's reluctance to include the Villafranchian in the Pleistocene, since in the Indian Siwalik belt this stage forms the highest member of a conformable succession which was intensely folded and subjected to peneplanation before the next deposition took place. The decision at the International Congress in 1948 to adopt the Villafranchian as the base of the Pleistocene places the Siwalik phase of Himalayan orogenesis within the Pleistocene System.

Key words: Stratigraphy, Siwaliks, Foreland basin, Potwar.

G/145. Gill, W.D., 1953. The genus *Assilina* in the Laki series (Lower Eocene) of the Kohat Potwar Basin, North West Pakistan. *Cushman Foundation Foraminiferal Research Centre* 4(2), 76-84.

Key words: Palaeontology, Laki beds, Kohat-Potwar basin.

G/146. Gingerich, P.D., 1977. A small collection of fossil vertebrates from the middle Eocene Kuldana and Kohat Formations of Punjab (Pakistan). *Contributions from the Museum of Paleontology, University of Michigan* 24(18), 190-203.

1975 the author made a new collection of fossil vertebrates from the Middle Eocene Kuldana and Kohat Formations in the Kala Chitta mountains of the Punjab Province in Pakistan. Vertebrates were found at twelve localities in the

vicinity of Lammidhan and Chharat. All of the identifiable mammals came from Lammidhan. Two additional mammal specimens from Lammidhan in the British Museum (Natural History) are also described and illustrated for the first time. It is suggested that Gandakasia may be a primitive cetacean rather than a mesonychid condylarth. The new artiodactyl genus Lammidhanina is proposed for the anthracothere species 'Anthracobune' wardi Pilgrim, 1940. Discovery of a small concentration of mammal specimens at one locality suggests that there is very good potential for the discovery of additional middle Eocene mammals in the Kuldana Formation and its lateral equivalents.

Key words: Vertebrates, Eocene, Kuldana Formation, Kohat Formation.

G/147. Gingerich, P.D. & Gunnell, G.F., 1995. Rates of evolution in Paleocene mammals of the Clarks Fork Basin of Wyoming, and a comparison with the Neogene Siwalik lineages of Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 115, 227-247.

Rates of size change are quantified in 19 species-level evolutionary lineages of Clarks Fork Basin Paleocene and early Eocene mammals. Intrinsic rates of change in Clarks Fork Basin lineages range from about $10^{-0.1}$ to $10^{-3.4}$ haldanes (standard deviations per generation), with a median rate of about $10^{-1.1}$ haldanes. These values are in the usual range of intrinsic rates commonly seen in other settings. Temporal scaling slopes indicate that seven of the 19 Clarks Fork Basin lineages were stable over time (37%), five were stable with a random component (26%), four were indistinguishable from random (21%), two were directional with a random component (11%), and one lineage cannot be classified. Clarks Fork Basin mammalian species have mean durations of about 0.95 m.y. and median durations of about 0.76 m.y. Intrinsic rates of size change are similar to those for Miocene Siwalik mammals, but the average species duration is less than one-half the average for Siwalik mammals.

Key words: Paleontology, mammals, vertebrates, Paleocene, Siwaliks, Wyoming.

G/148. Gingerich, P.D., Raza, S.M., Arif, M., Anwar, M. & Zhou, X., 1994. New whale from the Eocene of Pakistan and the origin of cetacean swimming. *Nature*, 368, 844-847.

Modern whales (order Cetacea) are marine mammals that evolved from a land-mammal ancestor, probably a cursorial Palaeocene–Eocene mesonychid. Living whales are streamlined, lack external hind limbs, and all swim by dorsoventral oscillation of a heavily muscled tail. A streamlined rigid body minimizes resistance, while thrust is provided by a lunate horizontal fluke attached to the tail at a narrow base or pedicle. We describe here a new 46–47-million-year-old archaeocete intermediate between land mammals and later whales. It has short cervical vertebrae, a reduced femur, and the flexible sacrum, robust tail and high neural spines on lumbar and caudal vertebrae required for dorsoventral oscillation of a heavily muscled tail. This is the oldest fossil whale described from deep-sea shelf deposits, and it shows that tail swimming evolved early in the history of cetaceans.

Key words: Palaeontology, marine mammals, Eocene.

G/149. Gingerich, P.D. & Russell, D.E., 1981. *Pakicetus inachus*, a new archaeocete (Mammalia, Cetacea) from the early-middle Eocene Kuldana Formation of Kohat (Pakistan). *Contributions from the Museum of Paleontology, University of Michigan*, 25, 235-246.

A new genus and species of primitive protocetid whale, *Pakicetus inachus*, is described from the early-middle Eocene Kuldana Formation at Chorlakkhi, Kohat District, North-West Frontier Province, Pakistan. The holotype is a nearly perfectly preserved posterior portion of a cranium. *Pakicetus* is distinctive among whales in retaining an extremely primitive auditory region. The auditory bulla articulates with the squamosal, basioccipital, and paroccipital in addition to a normal cetacean articulation with the posterior process of the petrotic. The cochlear part of the petrotic articulates with both the squamosal and the basioccipital. Three genera of early-middle Eocene whales are now known from Pakistan. *Pakicetus* is intermediate in size between *Ichthyolestes* and *Gandakasia*, and it resembles both to some degree in dental morphology. "*Protocetus*" *atocki* from Ganda Kas is here referred to *Pakicetus*.

Key words: Paleontology, mammals, Eocene, Kuldana Formation, Kohat.

G/150. Gingerich, P.D. & Russell, D.E., 1990. Dentition of Early Eocene *Pakicetus* (Mammalia, Cetacean). *Contrib. Museum of Paleontology, University of Michigan*, 28(1), 1-20.

Thirty deciduous and permanent teeth of *Pakicetus inachus* are described from Chorlakkhi in Pakistan. Geological sequence stratigraphy indicates that *Pakicetus* is latest early Eocene (latest Ypresian) in age. Incisors of *Pakicetus* are simple high-crowned sharply-pointed teeth. The upper canine may have been double-rooted. Lower canines vary in size and may have been dimorphic. Premolars have simple narrow crowns with coarse serrations on some anterior and posterior crests. Upper molars retain three roots and distinct protocones. Lower molars have simple pyramidal trigonids and narrow trenchant talonids. These teeth are combined in a model based on the type braincase-basiscranium showing that all represent a single species. *Pakicetus inachus* may prove to be a junior synonym of *P. attocki* when the latter is better known, but restudy of contemporary *Ichthyolestes* and *Gandakasia* confirms that these genera are distinct. The three early Eocene genera are placed in a new subfamily Pakicetinae of the Archaeocete family Protocetidae. Teeth of *Pakicetus* have several distinctively archaeocete characteristics. Upper and lower cheek teeth have wear facets on apices of pointed cusps indicating that the lower jaw was retracted when food was punctured. Buccal phase shearing and lingual phase grinding wear facets are also mesent. Deciduous teeth at Chorlakkhi indicate that juveniles and adults were present in approximately equal proportions, suggesting that juveniles, like adults, spent a significant amount of time on land.

Key words: Paleontology, Eocene, mammals, Kohat.

G/151. Gingerich, P.D., Russell, D.E., Hurtenberger, J.L., Shah, S.M.I., Hassan, M., Rose, K.D. & Ardrey, R.H., 1979. Reconnaissance survey and vertebrate paleontology of some Paleocene and Eocene formations in Pakistan: Contribution Museum of Paleontology, The University of Michigan, 25(5), 105-116.

In 1977 we spent approximately two months in the field in Pakistan studying three geological formations to assess their potential to yield identifiable fossil mammals. The middle Eocene Domanda Formation was examined at six localities spanning a 100 km distance along the east side of the Sulairnan Range in southwestern Punjab. This formation yielded abundant fish remains, including skulls and skeletons, and some reptilian bone. Mammalian remains included a poorly preserved skull fragment and postcranial elements of cetaceans. Land mammals may also be represented, but they are too poorly preserved to be useful for study. The Domanda Formation appears to be entirely a shallow water marine formation, with little potential to yield land mammals unless localized deltaic facies can be found.

The Paleocene Bara Formation was examined at five localities in the Lakhi Range in Sind. This formation yielded only fragmentary remains of crocodilians and turtles, but the middle part of the formation appears to be fluvial in origin, and with further work it could eventually yield mammals. The early-middle Eocene Kuldana Formation was examined at six localities in Kohat District, North-West Frontier Province. All of these localities yielded reptilian and mammalian bone and tooth fragments, and one locality near Chorlakkhi village yielded a diverse assemblage of mammals. The vertebrate fauna of the Kuldana Formation is becoming increasingly well known in Punjab and Jammu-Kashmir on the east side of the river Indus, and our work indicates that good collections can also be made west of the Indus as much as 100 km west of previously known localities.

Key words: Reconnaissance, Palaeontology, Vertebrate, Paleocene, Eocene, Kohat.

G/152. Gingerich, P.D., Russell, D.E., Singogneau-Russell, D. & Hartenberger, J.L., 1979. *Chorlakkia Hassani*, A new middle Eocene Dichobunid (Mammalia Artiodactyla) from the Kuladana Formation of Kohat (Pakistan). Contributions to the Museum of Paleontology, The University of Michigan 25 (6), 117-124.

A new genus and species of artiodactyl, *Chorlakkia Hassani*, is described from the middle Eocene Kuldana Formation in the Kohat District of Pakistan. This is the smallest artiodactyl described from the Paleogene of Asia, and it is one of the smallest artiodactyls yet known. The familial position of *Chorlakkia* is somewhat uncertain, but it appears to belong to the family Dichobunidae (s.l.).

Key words: Vertebrates, Eocene, Kuldana Formation, Kohat.

G/153. Gingerich, P.D. & Sahni, A., 1979. *Indraloris* and *Sivaladapis*: Miocene adapid primates from the Siwaliks of India and Pakistan. Nature 279, 415-416.

The primate family Adapidae underwent a major radiation during the Eocene in Europe and North America. Asian and African Eocene mammalian faunas are still poorly known, but there is sufficient evidence to indicate at least a modest radiation of Eocene adapids in Asia and probably also in Africa. Apart from possible lemuriform and anthropoid primate derivatives, the family Adapidae was thought to have become extinct at the end of the Eocene (middle Tongrian, approximately 37 Myr). We present here new evidence which indicates that at least two genera of adapid primates, *Indraloris* and *Sivaladapis* (gen. nov.), survived into the late Miocene of India and Pakistan. These genera are little advanced over Eocene Adapidae in terms of dental adaptations and are apparently south Asian relicts of a much earlier radiation.

Key words: Vertebrates, *Indraloris* and *Sivaladapis*, Eocene, Miocene, Siwaliks.

G/154. Glennie, E.A. (ed.), 1932. Gravity, the depth of the Indus alluvium. In: *Geodetic Reports of the Geological Survey of India* 7, 79.

Key words: Gravity, Indus alluvium, Geodesy.

G/155. Glennie, E.A., 1956. Gravity data and crustal warping in Northwest Pakistan and adjacent parts of India. *Royal Astronomical Society, Monthly Notices, Geophysics Supplement* 7(4), 162-175.

Gravity data are used to investigate the geological structure of an area of about 160000 square miles in the light of the crustal warping hypothesis. The region is in N.W. Pakistan and India, and includes the whole of the alluvial plains of Sind and Punjab, the Salt Range and the Potwar Plateau.

A new gravity anomaly is introduced and used by an original method, which leads automatically to the detailed contouring of the basement rock below the region, the basement being assumed to be the upper surface of the Earth's crust. The standard crustal section employed is a two-layer crust with a total thickness of thirty kilometres but a table permits direct comparison with other sections of a six-layer crust, two of which have increased thickness.

The basement contours show a ridge about 300 miles long separating the Indus Basin from the Lahore Basin. It is hidden by alluvium except for a few outcrops near its northern end. This ridge has apparently suffered sub-aerial erosion under typical S.W. monsoon conditions, extending in places to a depth of over 3000 feet below sea level. This modification of the basement requires a revision of the contours over the ridge, and two contoured charts show firstly the simple crustal upwarp underlying the ridge and secondly the eroded surface of the basement. A deep valley with its bottom far below sea level cuts through the ridge connecting the Indus and Lahore Basins. In Sind a similar valley leads from the direction of the sea to the Indus Basin, but here interpretation is uncertain.

It is concluded that the hypothesis yields results giving depths to the basement of the right order in deeply downwarped areas, but in upwarped areas the possibility of erosion, or other concealing factors, leads to uncertainty of interpretation unless the area is wide enough to include a complete section of the upwarp.

Key words: Gravity, structure, Potwar, Salt Range, northern Pakistan, NW India.

G/156. Godwin-Austen, H.H., 1863-1864. On the glaciers of the Mustagh Range. *Proceedings, Royal Geographical Society* 34, 19-56.

Godwin-Austen, after whom is named the 2nd highest peak in the world, K2, describes the large glaciers of upper Baltistan, and provides evidence showing that they were formerly much more extensive.

Key words: Glaciation, Mustagh Range, Baltistan.

G/157. Godwin-Austen, H.H., 1864. Geological notes on part of the North-Western Himalayas: with notes on the fossils by Davidson, T., Etheridge, R. and Woodward, S.P. *Quarter Journal Geological Society* 20, 383-387.

The paper describes (1st) the fluvio-lacustrine series of the Kashmir valley and Baltistan; (2nd) the Siwalik series of the Outer Hills; (3rd) the [so-called] Nummulitic [really secondary] series of the outer Pir-Panjal; (4th) the Jurassic

series of Zaskar; (5th) the carboniferous of the Kashmir valley; and (6th) the older rocks of these districts. The Carboniferous fossils described are all of from the Kashmir valley, and not, as stated, from Shigar, in Baltistan. A list of terrestrial shells is given from the lacustrine deposits.

Key words: Lithology, paleontology, fossils, NW Himalayas.

G/158. Godwin-Austen, H. H., 1966. Corrigenda to the Abstract. Capt. Godwin Austen's paper; Geological Notes on the Northwestern Himalayas. Quaternary Journal of Geological Society London, 22, p.35.

Key words: Fossils, Himalayas.

G/159. Godwin-Austen, H.H., 1894. Peak K2 (Godwin-Austen). The Geographical Journal 5, 431-432.

Godwin-Austen was the first to produce a geographic map with location of the K2 and the neighbouring peaks.

Key words: K2, geography.

G/160. Gohar, A., 1999. Concrete feasibility for the limestone of the Kohat formation, District Kohat. M.Phil. Thesis, University of Peshawar, 99p.

Limestone is a valuable raw material, which is widely used in the chemical and construction industries throughout the world. With huge deposits of limestone in Pakistan, it is immensely used as concrete aggregates. The Eocene limestone of the Kohat Formation is generally exposed in the Kohat, Hangu and Bannu districts. It is cream to gray in color, hard, compact, well-bedded and fossiliferous. The limestone of Kohat Formation has been evaluated mineralogically, chemically and physically, for its use as concrete aggregates during present study.

Mineralogically, the studied limestone is dominantly calcite with abundant fossil shells. Fine-grained quartz, chalcedony, clay, dolomite and opaque phases are present in minor amount. The limestone generally has fine to medium-grained granular mosaic with bioturbated microfossils. Deleterious minerals to concrete are generally foliated in the argillaceous variety of the studied limestone.

Chemically, the studied limestone (by weight) is classified as high-calcium limestone, with CaCO_3 between 81.23 and 98.93%. The SiO_2 varies from 0.50 to 13.90 wt %, Al_2O_3 from 0.47 to 0.74 wt %, Fe_2O_3 from 0.05 to 0.30 wt %, CaO from 46.07 to 57.03 wt %, Na_2O from 0.35 to 0.45 wt % and K_2O from 0.01 to 0.05 wt %. MnO and MgO are up to 0.25 and 2.69 wt %, respectively. The average chemical compositions of various cements manufactured in N.W.F.P. are within the ASTM limits. The alkali-silica reactivity graph for the limestone aggregates based upon ASTM C 289-90 also verify the petrographic observations. Physical properties (i.e., soundness, water absorption, Los Angeles abrasion and specific gravity) are generally in accordance with the ASTM standards for aggregates to be used in concrete. The studied limestone of the Kohat Formation except its argillaceous variety found in the eastern part of the study area, is generally free of dolomitization and has no other deleterious substances as far as the durability of concrete is concerned. This Eocene limestone of the Kohat Formation is therefore, recommended for its use as concrete aggregates.

Key words: Limestone, concrete, Kohat.

G/161. Gohar, S., 1962. Geology of Bagnotar, Nathiagali and Kohala, Hazara. M.Sc. Thesis, Punjab University, 25p.

Key words: Geology, structure, Hazara.

G/162. Gohar, S.H.U., 1985-87. Lithostructural mapping and geology of Bara Gali-Kunola Area, District Abbottabad, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 95p.

This report gives an account of geological studies and lithostructural mapping carried out in Kuldana-Bara Gali area. The prescribed area lies on both side of the road leading from Murree to Abbottabad. It is a mountaneous region with fairly high relief.

Lithostructural mapping of approximately 20 sq.Km was carried out. The stratigraphic succession ranges from Hazara Formation (pre-Cambrian) to Kuldana Formation (Eocene) with absence of Cambrian to Jurassic rocks. The lithology is mainly limestone, sandstone and shale. Extensive sampling was carried out and micro structural studies along with petrography of the various rock units under the microscope from thin section of certain rock samples was also carried out in the laboratory. A geological map is prepared on a scale of 1:7060 and two cross section (AA' and BB') were also drawn in order to interpret the regional structure and tectonic history of the area. This report also included the brief study of the rock units exposed in the project area. Major structures (folds and faults) lies in the project area are also discussed. Finally there is a general discussion about the source rocks, reservoir rocks (Hydrocarbons) and the economic importance of the rock units present in the project area.

Key words: Lithostructure, mapping, Abbottabad.

G/163. Gondal, M.M.I., 1982-84. Economic geology and petrology of graphite and other minerals in Naran-Paludaran Area, middle northern Kaghan valley, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 138p.

Key words: Petrology, economic geology, Kaghan valley, Mansehra.

G/164. Goraya, M.A., 1976. Report on Lithostructural mapping of Paras area, Kaghan valley with special emphasis on petrography and petrogenesis. M.Sc. Thesis, Punjab University, Lahore, 53p.

Key words: Lithostructure, mapping, petrography, Kaghan valley.

G/165. Gormov, A.V. & Zeb, Z., 1992. On the mineralogy of pink topazes from Katlang deposit (Pakistan). (Russian with English abstract). Zapiski Vsesoyuznogo Mineralogicheskogo Obshchestva 121, 72-79.

In addition to the relatively recent discovery of significant amount of emerald, aquamarine, and ruby, Pakistan has also begun to produce fine gem quality pink topaz. In a small hillock of recrystallized limestone north of Katlang, narrow calcite veins encase pink topaz crystals up to 3 cm long accompanied by larger amounts of reddish brown, tan and colourless topaz crystals. More than 70000 ct of gem quality pink topaz has been reported to date. The refractive indices, optic axial angle, unit-cell dimensions, and density of the topaz are influenced by a partial replacement of fluorine by hydroxyl ions. The color is due to trace elements – principally chromium (Cr^{3+}). Treatment experiments reveal that the color of the brown, tan, and colorless topaz from this source may be improved by irradiation and heat.

Key words: Mineral deposits, topaz, gemstone, Mardan.

G/166. Gornitz, V. & Seeber, L., 1981. Morphotectonic analysis of the Hazara arc region of the Himalayas, North Pakistan and North West India. Tectonophysics 74, 263-282.

In the Hazara arc region of northern Pakistan, some of the active basements structures buried below a thick, detached sedimentary layer are inferred from the distribution of lineaments and the drainage patterns, as viewed in Landsat satellite imagery and from river profiles.

A prominent set of NW-trending lineaments seen on satellite imagery, coincides approximately with the southwest or updip side of the Indus—Kohistan seismic zone (IKSZ) —the most active basement structure of the region, even though this structure is buried beneath and decoupled from a 12 km thick sedimentary layer. The IKSZ has been interpreted as an extension of the Himalayan Basement Thrust, and is also associated with a prominent topographic “step”.

Knickpoints on major rivers in the region lie on or north of the IKSZ. All Indus River tributaries, examined north of the IKSZ, show prominent knickpoints, while two tributaries draining south of the IKSZ have no knickpoints. These

results suggest ongoing uplift above and north of the IKSZ, and are consistent with the tectonic model obtained from the seismic data. Another prominent lineament set is detected along the north—south section of the Indus River. This set is probably related to the Indus River horst—anticline and associated reentrant. One of the two highest lineament concentrations occurs at the intersection between the NW-trending IKSZ lineament and the N-trending Indus River lineament. The other is along the west bank of the Indus Valley, 25 km north of Tarbela Dam. A topographic ridge (Swabi—Nowshera ridge) appears to be forming along the west side of the Indus River, in the Peshawar Basin. The rising ridge is ponding the Kabul River upstream of Nowshera, where the drainage is braided.

Key words: Tectonics, Hazara arc, Himalaya.

G/167. Gortani, M., 1920. Permocarboneifero e Permiano nella catena del Caracorum. *Rendicanti Accad. Lincei, Ser. II* (29), 53-55.

Key words: Paleontology, Permocarboneiferous, Karakoram.

G/168. Gortani, M., 1921. L'Ordoviciano nell Caracorum orientale. *Rendiconti della Reale Accademia dei Lincei, Series 5*(30), 183-185.

Key words: Ordovician, fossils, Karakoram.

G/169. Gortani, M., 1928. Fossili Ordoviciani dell Caracorum. In: *Realizzazioni Scientifiche della Spedizione Italiana de Filippi nel'Himalaia, Caracorum e Turchestan Cinese (1913-1914)*, Series 2(5), 3-97. Zanichelli Bologna.

Key words: Paleontology, Ordovician, Karakoram.

G/170. Gortani, M. & Merla, G., 1934. I fossili del Paleozoico. In: *Relazioni Scientifiche della Spedizione Italiana de Filippi nel'Himalaia, Caracorum e Turchestan Cinese (1913-1914)*, Series 2(5), Zanichelli Bologna.

Key words: Paleontology, Paleozoic, fossils, Karakoram.

G/171. Goudie, A.S., 1981. Fearful landscape of the Karakoram. *The Geographical Magazine* 53, 306-312.

Key words: Paleontology, Paleozoic, Fossils, Karakoram.

G/172. Goudie, A.S., 1984. Salt efflorescences and salt weathering in the Hunza Valley, Karakoram Mountains, Pakistan. In: Miller, K.J. (Eds.), *The International Karakoram Project 2*, Cambridge University Press.

In the Karakoram Mountains, Pakistan, rainfall levels are low in the village, and under conditions of high evaporation salt efflorescences form, composed largely of magnesium sulphate (hexahydrate) and gypsum. Moraines and rock fall debris of the twentieth century have been severely weathered by salt attack.

Key words: Salt efflorescence, weathering, Hunza, Karakoram.

G/173. Goudie, A.S., Brunsden, D., Collins, D.N., Derbyshire, E., Ferguson, R.I., Hashmet, Z., Jones, D.K.C., Perrott, F.A., Said, M., Waters, R.S. & Whalley, W.B., 1984. The geomorphology of the Hunza valley, Karakoram Mountains, Pakistan. In: Miller, K.J. (Eds.), *The International Karakoram Project 2*, 359-410. Cambridge University Press.

The Hunza Valley in northern Pakistan shows greater relative relief than any other place on Earth. It cuts through the diverse structural and lithological elements of the Karakoram Mountains. At low altitudes it flows through an area of aridity and of desert vegetation. The slopes in the area are highly unstable, weathering by salt and frost is active, glaciers are active and large, discharge is highly seasonal, channels are subject to marked changes, and sediment and solute loads are high. The overall denudation rate is approximately 5000 t km⁻² yr⁻¹.

Key words: Geomorphology, glaciers, denudation, Hunza, Karakoram.

G/174. Goudie, A.S., Jones, D.K.C. & Brunsden, D., 1984. Recent fluctuations in some glaciers of the Western Karakoram Mountains, Hunza, Pakistan. In: Miller, K. J. (Ed.), *The International Karakoram Project 2*, 411-455. Cambridge University Press.

During the International Karakoram Project, 1980, the snout positions of the Minapin, Ghulmet, Hasanabad, Ghulkin, Pasu and Batura glaciers were surveyed, and their positions related to previous investigations over the last century. They have shown considerable fluctuations, including major advances at the turn of the century, and general retreat from the 1930s to the 1979s.

Key words: Glaciers, fluctuation, Hunza, Karakoram.

G/175. Gough, S.J., Searle, M.P., Waters, D.J. & Khan, M.A., 2001. Igneous crystallisation, high pressure metamorphism and subsequent tectonic exhumation of the Jijal and Kamila complexes, Kohistan. *Journal of Asian Earth Sciences* 19, p.23.

Key words: Metamorphism, tectonic exhumation, ultramafics, Jijal, Kamila, Kohistan.

G/176. Gourirane, A., 1993. Étude pétrologique et géothermobarométrie des eclogites de la haute-vallée du Neelum (Himalaya, Pakistan). Faculte des Science, Laboratoire de Geologie et mineralogie, UCL, Louvan-La-Neuve (Belgium).

This account describes the Petrological study of eclogites and geothermobarometry in the high-valley of Neelum (Himalaya, Pakistan).

Key words: Geothermobarometry, eclogites, HP metamorphism, Neelum, Azad Kashmir.

G/177. Government of NWFP, 1975. Outline development plan for reconstruction and rehabilitation of earthquake affected area in Swat and Hazara districts. Planning and Development Department Govt. NWFP, Pakistan.

This document concerns the government plan for rehabilitation of the population of Swat and Hazara areas affected by the Pattan Earthquake. There is also a strategy outlined for reconstruction and development of the area.

Key words: Pattan earthquake, rehabilitation, reconstruction, Swat, Hazara

G/178. Government of NWFP, 1983. Mineral directory of North West Frontier Province. Directorate of Industries, Commerce and Mineral Development, Peshawar, Publication, 211p.

This exhaustive work gives information on the geological framework and available mineral resources, along with production data, of the Province. It also gives information on the concerned directorate, Mineral Coordination Committee/Board, licenses and leases. The document contains tables and a map showing location of the minerals.

Key words: Mineral resources, NWFP.

G/179. Grazaoli, Lante Della Rovere, G., 1881. Brevi recordi di un viaggio nelle montagne dell Kashmir. *Bollitin del Club Alkpino Italiano*, 15, 227-250.

This is a travelogue of a journey to the mountains of Kashmir.

Key words: Geography, travelogue, Kashmir

G/180. Greco, A., 1986. Geological Investigation in the Reshian Area (Jhelum valley, State of Azad Jammu and Kashmir). *Kashmir Journal of Geology* 4, 51-66.

Petrographical and structural geology investigations have been carried out in the Panjal Volcanics, Triassic Limestone, and Salkhala Series exposed in the Reshian area. The study of the microstructures shows a complex relationship between deformation and metamorphism. The highest metamorphic grade-greenschist in the volcanics and amphibolitic in the Salkhala- has been reached before the main deformation phase. Retrograde mineral paragenesis is pre- to synkinematic. Only in the upper part of the investigated area the highest metamorphic conditions seem to persist during the deformation. Shear was the most important. Due to the thrusting of the Salkhala over the Panjal and over the Murree Formation a penetrative, continuous schistosity has been developed. Its trend is sub-parallel to the bedding and the thrust planes, and it is accompanied by an intense stretching lineation, showing the NE-SW direction of tectonic transport. In a later phase the crenulation cleavage, which cuts the previous structures, has been developed in the less competent rocks. All these events agree with the tectonic model elaborated by Bossari et al. (1984).

Key words: Petrography, structure, Panjal volcanics, Salkhalas, Kashmir.

G/181. Greco, A., 1988. Tectonic and metamorphism in the Himalayas of NE Pakistan (Kaghan Valley and Azad Kashmir). Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, 24-15.

Key words: Tectonics, metamorphism, Kaghan valley, Azad Kashmir.

G/182. Greco, A., 1989. Tectonics and metamorphism in the western Himalayan syntaxis area (Azad Kashmir, NE Pakistan). Ph.D. Thesis. ETH Zurich, Switzerland, 194p.

Key words: Tectonics, Metamorphism, Kaghan valley.

G/183. Greco, A., 1991. Stratigraphy, metamorphism and tectonics of the Hazara-Kashmir syntaxis area. *Kashmir Journal of Geology*, 8 & 9, 39-65.

Key words: Stratigraphy, metamorphism, tectonics, Hazara Kashmir.

G/184. Greco, A., Martinotti, G., Papritz, K., Ramsay, J.G. & Rey, R., 1989. The Himalayan crystalline nappes of the Kaghan valley (NE Pakistan). *Eclogae Geologicae Helvetiae* 82, 629-653.

Key words: Structure, Kaghan valley, Himalaya.

G/185. Greco, A. & Spencer, D.A., 1993. A section through the Indian Plate, Kaghan valley, Northwestern Himalaya, Pakistan. In: Treloar, P.J. & Searle, M.P. (eds.), *Himalayan Tectonics*. Geological Society of London, Special Publication 74, 221-236.

A map is presented which summarizes the work of the ETH Himalayan Group in the Kaghan Valley and adjacent areas of the NW Himalaya in Pakistan. The stratigraphical, structural and metamorphic features of the lithologies belonging to a virtually complete section through the Indian plate are described. Evidence is presented which shows a stratigraphic range in ages from the Precambrian Salkhala Formation to the Eocene Murree Formation which have been metamorphosed at various metamorphic grades ranging from very low grades/unmetamorphosed to eclogite facies. An inverse metamorphism, associated with the Main Central Thrust is also described. A large-scale tectonic

subdivision of the area into the classical Sub-, Lesser and Higher Himalayan elements can be correlated with the Kashmir Himalaya to the east. A tectonic model is presented which suggests that an anticlockwise rotation of the transport direction caused the refolding and stacking of the nappe piles in the Paleogene.

Key words: Structure, tectonics, plate tectonics, Kaghan valley, Himalaya.

G/186. Gregory, C.E., 1932. The Shyok Ice-barrier in 1931. *The Himalayan Journal* 4, 64-74.

My original intention was to spend some time shooting in the Hanle district of Ladakh and then go on to Phobrang and cross into Chinese Turkistan by way of the Aksai Chin. With this object I left Srinagar on the 12th April, and when passing through Leh arranged with Bishop Peter of the Moravian Mission to send my porters and supplies for the Changchenmo-Aksai-Chin crossing, to Phobrang. On arrival at the latter place I received word that my passport for Central Asia had not arrived, and it looked possible that I might not get one at all. I therefore went off to shoot round Dakpo Karpo and the Changchenmo; on my return again to Phobrang I learnt by wire that the passport had been despatched from Nanking on the 29th May and I judged that it should reach Leh by the 5th July at the latest. I now decided to return to Leh and travel by the shorter and quicker route by the Karakoram pass. I left Leh on the 23rd June, having given instructions for the passport to be forwarded to me by special runner, and spent some time mapping the Chong Kumdan glacier and the Shyok lake. Having completed this work I pushed on to Daulat-Beg-oldi, close to the Karakoram pass, but after waiting some time for the passport, my supplies began to run short, and, though I tried to persuade my caravanbashi to go on to Suget for more, he refused to do so and I was forced to return. This short paper therefore is merely a brief summary of my observations of the Chong Kumdan glacier-dam. It was on the 28th June that I left Takshai, the last village in the Nubra valley. Up till that date no one had crossed the Saser pass that year and the inhabitants of Nubra stated that it was still deep in snow and unfit for pony-transport. I had three permanent porters with me and collected six more at Takshai (pay Re. 1/- a day). In the Thulan-buti defile I met the first of the Yarkandi caravans. Their news was not very hopeful; they had stayed at Saser Brangsa, north of the pass, till their food was almost exhausted, and had then tried to force it, with the result that they had had to abandon their baggage on the pass after losing two ponies and three asses. I therefore left my own animals at Skyangpo-che and moved up towards the pass with my coolies only, halting that evening at the first of the lakes. I intended to start at 5 a.m. the next morning, cross the pass and reach Saser Brangsa that day, but at midnight, when I looked out, the snow was frozen hard and the moon full, so that I felt it was an ideal opportunity to cross. I went over to the porters, but they were not for it, saying that it was too cold and that in their local boots they would get frostbitten, but that they would start at five. At five the next morning it was snowing hard and we were forced to remain there all day. It was again snowing at 5 a.m. on the 3rd July, but an hour later the sky looked better, the snow had stopped and the porters agreed to make a move. Fortunately for us the sun hardly came out all day and the eight miles to Saser Brangsa were covered in eight hours. On the 4th July I moved the camp up the Shyok valley to the Kichik Kumdan glacier, from the terminal moraine of which I could see the snout of the Chong Kumdan glacier lying across the valley like a bar of silver. There was very little water in the Shyok, and at the Saser Brangsa ford it was only about a foot deep. On the 5th I went up to the Chong Kumdan. The point from which the best view can be obtained is about a thousand feet above the main valley bottom on the right bank of the Shyok. From here the Shyok lake can be seen stretching away to the north, beyond the three miles of glittering ice-pinnacles of the Chong Kumdan glacier almost immediately below. The panorama published with this paper gives some idea of the magnificence of the spectacle. The lake at that time was ten miles long and varied from a mile to a mile and a half wide. Later when I went round and camped at the north end of it, I found that its level was rising at a rate of from six to seven inches a day. Above the surface-level on the hillsides at the edge of the lake were to be seen previous marks caused by water-erosion. In July the lake was from thirty-five to forty feet below the highest erosion-mark from which fact I concluded that by the beginning of the winter of 1931 the surface would be at its high-water level. As regards percolation through the ice-barrier, three hundred yards downstream of the snout of the glacier the Shyok river-bed was dry. On the 5th July there was very little water coming off the Chong Kumdan, and though on the 6th there was more, there was still less here than was issuing from the Kichik Kumdan glacier.

The Chong Kumdan glacier descends from a broad trough in the mountains. Standing at the snout it is up the Chong Kumdan valley and not up the main Shyok valley that one looks. The Chong Kumdan glacier and lake, in fact, form the upper branches of a "Y", the tail of which is the Shyok valley below the snout. Unless this is realized, the map, which shows a "T" lying on its side, is misleading. At the time of my visit the width of glacier against which the waters of the lake were resting was about 1500 yards, the same as that of the valley bottom immediately below the snout. The ice of Chong Kumdan, or left branch of the "Y", extended for a distance of 1100 yards below the point where the eastern edge of the lake met the ice.

The height of the ice at the snout was about ninety feet; where it was holding up the lake it might be as much as two hundred. Here it was a mass of pinnacles and it was difficult to judge the height. These pinnacles extend for a distance of three miles up the glacier and are due, I think, to the effect of the warm dry wind blowing up the main valley. They and their attendant ice-walls make climbing on the glacier difficult and crampons, ice-axe and rope are essential. I did not come across any bad crevasses, but the surface was badly cracked, and there would have been danger of an accident with laden or inexperienced men. The height of the pinnacles was from sixty to eighty feet. Once the sun reached the glacier surface, stones and ice started to fall; for this reason it was unsafe to be on the glacier after eight o'clock. A curious feature of the Chong Kumdan glacier was the complete absence of dead lateral moraine. The valley out of which the glacier emerges has steep cliffs on either side or the glacier ice reached right up to these cliffs. The terminal moraine consisted of a small pile of stones, out of all proportion to the size of the glacier. The channel cut in the ice by the escaping waters in 1929 could be clearly seen and acted as a central drain for the surface ablation of the glacier. Should the lake overtop the glacier, its waters would use this channel and probably open it up so rapidly that a flood would follow. If the barrier actually breaks, it seems to me probable that it will do so in August 1932, this being the month that it has usually burst before. With the water up to the high-water level and the old scar in the glacier, with the almost complete absence of percolation, I consider that the lake is almost certain to overtop the barrier or burst it in 1932. Should anyone think of going up to the ice-barrier in 1932, I would suggest that, after halting at Saser Brangsa, they move up the right bank of the Shyok to just short of Kichik Kumdan, using porters only from Saser Brangsa onwards. The next camp should be pitched near the snout and the party should start the next morning very early, pass the two side glaciers on the right bank of the Chong Kumdan, and cross the main glacier just above where it is joined by the lake. Should there be a break, in all probability this route will be above it and will remain. On the north side of the glacier a camp could be pitched on the spur on the west edge of the lake, just above the point where the lake meets the ice. This would save the long detour by the Depsang plains. Also, the two metal boats left by Gunn in 1929 at the mouth of the Chip-chap have now been removed. I ought perhaps to warn people against attempting to climb the cliffs on the left bank of the Shyok just below the glacier. Though it is possible to do so and to reach the lake by this route, the chimneys that have to be traversed form dangerous stone-shoots. I would also recommend that any party moving on the glacier itself should be clear of it by 8 a.m., when the sun may get on to it and render it dangerous from falling ice and stones.

Note by the Editor. Thanks to the courtesy of Captain Gregory and Messrs. Ludlow and Gunn, we have now some forty photographs of this glacier, taken from various points during the last four years. Much as I should like to do so, it is not possible to publish all these, though a careful examination makes clear some very interesting conclusions. In addition to the photographs and accounts of these observers, we also have a report by Mr. P. C. Yisser of his observations in July 1930. The photographs taken in 1928 and 1929 from below the snout are very similar. The larger series of 1929 show some definite features that led me then, in spite of Gunn's report, to doubt whether the glacier had begun to retreat, and I then foretold that the channel cut by the lake would heal during the winter of 1929-30, and that another lake would be impounded. These features are very marked when the 1929 photographs are compared with Captain Gregory's beautiful series taken in 1931.

In 1929 the upstream photographs show a vertical, and in places an overhanging, dam face holding the lake. The ice at the edges of the lake showed cracks and the ice-pinnacles emerged almost directly from the water's edge. The ice itself showed intensely white in the photographs, and even from a distance little englacial or medial moraine could be observed. These features may be seen to some extent in the two photographs in the *Himalayan Journal*, vol. ii, opposite pages 38 and 46. A complete series of fourteen photographs by Ludlow emphasizes them.

In 1931 there was a marked change. The lateral pinnacles were much reduced in size and became more degenerate; masses of medial moraine were being carried to the edge of the ice and were falling into the lake. In 1929 the lake edge of the dam had a marked convex bulge into the lake, probably owing to pressure against the rock wall opposite. The 1931 dam showed a straight, almost a concave, edge to the lake. Downstream of the glacier, the 1928 photographs show a protuberant tongue, possibly due to snout-spread, in the centre of the Shyok valley. There is little difference in 1929, both before and after the burst. The edges in both 1928 and 1929 were vertical (slightly more so in 1928 than after the burst in 1929, probably due to seasonal ablation in August). In 1931, as shown in the illustrations in this volume, not only the snout-tongue, but the whole snout-face was breaking up into detached ice-pinnacles very much interspersed with englacial and surface moraine. In pinnacled glaciers such as this, moraine-banks are only left as isolated terminal moraines when the ice-pinnacles are dead. 'Retreat' is most irregular, and, as could be seen in the neighbourhood of the Kichik Kumdan glacier in 1928, much dead ice is left below the living snout. If further proof were required that 'retreat' and degeneration has now set in, it is to be found in the pictures of 1929 and 1931 which give a longitudinal profile of the glacier surface. Ludlow's and Gunn's photographs of 1928 and 1929 show that of the portion of the glacier lying across the Shyok valley, the highest point lay then towards the left bank of the Shyok, which indicates that the ice had been forced up by pressure against the wall. The panorama

looking up the Shyok across the glacier, published in the present volume, shows that the highest point in 1931 was where the glacier enters the Shyok valley. From here the height tailed off towards the left bank, indicating a relief from pressure. This panorama also shows very distinct signs of pinnacle degeneration, particularly towards both edges and the opposing wall.

In 1929 the waters of the lake cut a channel approximately five hundred feet wide. The channel apparently commenced from near the right or western shore of the lake, took a course towards the centre of the glacier and emerged near the left or eastern side of the Shyok valley. In July 1930 the Vissers reported that the channel had completely healed and that there was no sign of it, though traces of the burst were still to be seen below the snout. In the same month, in 1931, though there was still no percolation through the glacier and no water issuing from beneath the ice, the channel had again opened out and acted as a central drain for surface water from the glacier. These facts again point conclusively to a release from pressure.

Estimates of the height of the ice at the snout and of the depth of the water at the dam are difficult to compare. In the snout observations we do not know whether the observations were made at the same spot. Ludlow's estimate in 1928, from some distance away was, "at its snout it could hardly have been less than 200 feet high". Gunn gives the height in August 1929 as "about 500 feet". Visser does not mention it, but in July 1931, Gregory gives it at about 90 feet. A few days before the burst in 1929 Gunn gives the depth of the lake at the dam as about four hundred feet; in July 1930, when the reformed lake had reached a length of three miles, Visser calculated the depth at the dam to be 133 feet; in July 1931, Gregory thought that it might be as much as 200 feet. Too much reliance must not be placed on these figures; it is notoriously difficult to make such estimates. But even assuming that Ludlow was liberal, that Gunn was radical, and that Gregory was conservative, these figures do bear out the conclusions given above from examination of the ice-formation in the photographs.

The two points of human interest are: Will the dam burst catastrophically? And if so, when? The second question may be answered first. There can only be a catastrophe if the dam bursts when the river is at or near normal high summer-level. This is between mid- July and October, inclusive. Damage from scour and isolated accidents from drowning may occur at other periods, but villages and grazing should be above the flood level. The point is: Will the dam hold till then? In my opinion, though there was no percolation in July last year, degeneration had set in to such an extent that in all probability there was a good deal of leakage before the winter. By October I believe the glacier may have been too degenerate for any substantial recuperation during the winter, and that spring and summer ablation in 1932 with normal periodic decline will relieve the lake of much of its water. It is an opinion that I hesitate to put forward, for observations of the little glaciers of other parts of the world are of no value for comparison. Of one thing I feel certain. I still maintain that after 1932, there will be no further danger of a block for over thirty years.

The above Note was sent to Captain Gregory, who comments as follows:

Now that I have had time to examine carefully the state of the glacier snout as shown in Gunn's photographs, I too think that degeneration has set in ; but at the same time, though I do not know very much about the subject, I shall be very astonished if so great a volume of water can be carried away by percolation. It may be of interest to mention the following facts which may affect the percolation question. In 1931 on the 7th and 8th July there was no percolation at the snout when I was there. On the 12th July I crossed the Shyok at Saser Brangsa; the water was then knee-high as against about eight inches on the 4th July, say ten inches higher. On the 17th and 18th July I was at Yapchan when the lake was rising at the rate of six or seven inches a day. On the 22nd I again crossed the Shyok at Saser Brangsa; the water was now -up to the men's hips, say 2 feet 10 inches at midday. The crossings on the 12th and 22nd were made at the same time of day, and the difference of level may have been merely seasonal. When I crossed the Shyok at Khalsar, about 135 miles downstream of the barrier, there was a good deal of water and a Yarkandi had been drowned the day before, but the men at the ferry did not say anything about the water being particularly high. I wonder whether percolation set in just after I left the Chip-chap.

In my opinion the normal seasonal advance and regeneration in the coming winter will almost certainly close the narrow transverse channel that has been cut, and by next spring this should have completely healed. I believe that another lake will almost certainly form next spring, but since the seasonal retreat next summer will now be assisted by periodic retreat, the dam will definitely degenerate in height and strength. It may be that the lake so formed will drain away by percolation, or it may gradually wear away a channel, taking several days to drain (as happened in the last of a similar series with the Khurdopin glacier). If the healing is so complete as to prevent either of these two courses, I believe the dam will break again in August 1931, the month of maximum inflow to the lake, and the month of maximum degeneration of the ice. Under no circumstances can the dam impound a lake in the next few years* of the same magnitude as that liberated in 1929. In my opinion there is no danger of a serious flood for many years to come, while the present danger of a complete block and a minor flood will be over at latest in 1932, after which there will be nothing to worry about till 1969. There will then be 100 year scare-period".—Himalayan

Journal, vol. ii, p. 46. With the exception that I did not foresee a healing so complete that the dam would hold throughout 1931, this forecast has been accurate and I see no reason to modify the prediction for the future. The terminal moraines left by the Chong Kumdan when the pinnacles have melted cover a very wide area, as may be seen in the photographs opposite pp. 200, 202, Chap. xx, vol. ii, of Professor Giotto Dainelli's *Pxri e Qenti del Caracorum* (Firenze : 1924). These photographs were taken in 1914, about thirty years after the previous year of maximum advance. It appears to have been impossible then to determine how much of this moraine was on ice. It is well worth while comparing Dainelli's photographs of this glacier in its degeneracy with those of the last few years taken since its rejuvenation.

Key words: Glacier surge, Shyoke dam, Himalaya.

G/187. Gregory, J.W., 1930. The fossil fauna of the Samana Range and some neighbouring areas; Part 7, The Lower Eocene corals. Geological Survey of India, Memoir Palaeontologica Indica, New Series 15(7), 81-128.

Key words: Paleontology, corals, Eocene, Samana Range, Hangu.

G/188. Griesbach, C.L., 1880. Geological notes. Geological Survey of India, Records, 13(2), 83-93.

This might be one of the earliest accounts on the geology of Indian subcontinent, including the present day Pakistan.

Key words: Geology, India.

G/189. Griesbach, C.L., 1880. Paleontological notes on the lower Trias of the Himalayas. Geological Survey of India, Records 13(2), 1-94.

This paper, although treating of rocks beyond the area under consideration, yet has some observations regarding the age of rock-groups within that area.

Key words: Palaeontology, Lower Trias, Himalaya.

G/190. Griesbach, C.L. 1886. Field-Notes from Afghanistan (no. 3) Turkistan. Records of the Geological Survey of India, 19(4), 235-267.

Key words: Field geology, Afghanistan, Turkistan, India.

G/191. Griesbach, C.L., 1887. Field notes from Afghanistan; (no.4) from Turkistan to India. Geological Survey of India, Records, 20 (1), 17-26.

Key words: Field geology, Afghanistan, Turkistan, India.

G/192. Griesbach, C.L., 1892. The Geology of the Safed Koh. Geological Survey of India, Records 25, 59-109.

Key words: Geology, Safed Koh, India.

G/193. Grinlinton, J.L., 1928. The former glaciation of the east Liddar Valley, Kashmir. Geological Survey of India, Memoir 49(2), 289-388.

Key words: Glaciation, Kashmir.

G/194. Griffiths, J.B., 1987. Pakistan's Mineral Potential: Prince or Pauper. *Industrial Minerals*, July, 1987, No.238.

The paper describes the economic geology of Pakistan. It gives detail information about the production of different mineral from Baluchistan, Punjab Province, Sind, and North-West Frontier Province and their economic importance for Pakistan.

Key words: Industrial minerals.

G/195. Grote, A., 1958. Notes on the fossils from Kohat. *Journal, Asiatic Society of Bengal* 27, 77-78.

Key words: Paleontology, Fossils, Kohat.

G/196. Gruber, G., 1970. The Buni Zom Group in Chitral. *The Himalayan Journal* 30, 305-311.

Key words: Geology, stratigraphy, Chitral.

G/197. Gruber, G., 1977. Glaciers and snow-line in Chitral. *Franfurter Wirtschafts und sozialageographische schriften* 26.

Key words: Glaciers, Snow line, Chitral.

G/198. Grujic, D. & Wosnitza, E., 1999. Thermomechanical analogue modelling of Himalayan collision processes. Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 63-64.

To simulate crustal rheological stratification in physical models, it is necessary to take into account the variations in mechanical properties induced by temperature. So far this has been done by using different materials, such as sand and silicone putty, for brittle and ductile behaviour respectively (e.g. Davy and Cobbold, 1991). Major advances have been made in understanding the Himalayan collision processes in this way (e.g. Chemenda et al., 1995). However, the major drawback with such models is that the material points within the model crust retain their physical properties throughout the experiment regardless of their changing position within the crust. The second approach to model the crustal layering is to use a single material with temperature-sensitive viscosity. This design has the advantage to reproduce the mechanical consequences of thermal readjustment during the model run. In our opinion this is the most important direction in improvement of modelling technique for plate tectonic processes. For example, it has been shown that the changing rheology of subducted sediments is an important phenomenon governing the material balance in the subduction zones (e.g. Mancktelow, 1995). This concept has been also applied to the exhumation of the Greater Himalayan Sequence (GHS) in the Bhutan Himalaya by ductile extrusion (Grujic et al., 1996).

Channel flow model

The process of extrusive flow can be approximated quantitatively by channel flow models that have been used to describe subduction zone processes. Such model characterises a thrust system as a viscous material-filled channel lying between two rigid sheets that deform the viscous material between them through induced shear and pressure gradients within the channel. The exact result depends on the geometry of the channel, but the simplest qualitative characteristic of these models is that the velocity field is a hybrid between two end-members (e.g. Turcotte and Schubert, 1982): (1) induced shear applied at the boundaries which produces a uniform vorticity across the channel; and (2) induced pressure gradients which produce a “pipe-flow” effect with highest velocities in the centre of the channel and opposite vorticity at the top and bottom of the channel. In these channel flow models the transition from uniform simple shear to “extrusive flow” is highly sensitive to viscosity and to lateral pressure gradients.

In a parallel-sided channel, the driving force for reverse flow at the top of the channel—the buoyancy of subducted material—is compensated by lithostatic pressure. In situations where the channel walls are non-parallel the (nonlithostatic) pressure gradient might cause high rates of buoyant return flow of the channel fill provided that the

viscosity is low enough (Mancktelow, 1995). In a thrust system such as the Himalayan Main Central Thrust (MCT), a lateral pressure gradient would develop due to building of topography during collisional tectonics. Similarly, major changes in viscosity also accompanied motion on the MeT. Swapp and Hollister (1991) and Davidson et al. (1997) presented evidence of early heating of the GHS followed by rapid high-T decompression. This early heating history may have been aided by heat advection due to the leucogranite intrusions into the GHS (e.g. Hollister et al., 1999). The related temperature increase would result in a drop in viscosity within the “channel” at the same time as the creation of orogenic topography produced a lateral pressure gradient within the channel.

In the GHS the main history of the system apparently records a hybrid process with a major influence of the pipe-flow effect. In particular, the reverse shear sense at the top of the channel is exactly the flow-pattern inferred across the top of the GHS along the South Tibetan Detachment system whereas south-direct ductile thrusting dominates at the base of the GHS belt.

Thermomechanical analogue models

In order to investigate the extrusion processes, in particular the role of rheology in distribution and propagation of deformation, we have constructed a deformation rig specially designed for thermomechanical modelling. We use analogue materials with temperature-sensitive viscosity to properly simulate the change in mechanical properties with depth. By inducing a vertical thermal gradient in the model, by precisely heating the bottom and cooling the top, one can produce a viscosity gradient. As the material points in the model change their depth by deformation they consequently change their material properties. The thermal perturbation is monitored by a series of resistance temperature detectors and by infrared camera. Correlating the thermal with physical field in the model one can deduce its rheological structure. As the differential stress, strain and temperature can be accurately measured during the experiment the onset of the instability can be easily defined. It also means that the rheology of the materials and the bulk rheology of the model can be characterised under exactly the same conditions as hold in the experiments themselves. Using all the informations together the dynamics of the structures formed can be investigated.

Key words: Collision, thermomechanical, Himalaya.

G/199. Gubelin, E.J., 1968. Gemmologische beobachtungen an neuen smaragden aus Pakistan. Der Aufschluss Sonderheft 28, 110-116.

Key words: Gems, Emerald, Pakistan.

G/200. Gubelin, E.J., 1981. Geological observations on new Emeralds from Pakistan. Gemology, 7.

Only during the last few years have the gem riches of Pakistan become known to the rest of the world. This article reports on three gem materials currently being mined: emerald, corundum (most importantly, ruby), and spinel. Intensely colored emerald crystals occur in dolomitic talc schists in the Swat Valley. Unusually high optical properties and density serve to distinguish these emeralds from those found elsewhere. Numerous gas-liquid inclusions are also typical. In the Hunza Valley, specimen and gem-quality crystals of corundum and spinel occur in beds of marble enclosed in gneisses and mica schists. The gemological properties of the Pakistan rubies and sapphires vary only slightly within normal limits.

Key words: Gemstones, ruby, emerald.

G/201. Gubelin, E.J., 1982. Die edelsteinvorkommen Pakistan-I. Teil: Die rubine aus dem Hunza tal. Lapis 7(5), 19-31.

Consult the following account for further info.

Key words: Gems, ruby, Hunza.

G/202. Gubelin, E.J., 1982. Die edelsteinvorkommen Pakistan. II. Teil: Die smaragd-vorkommen im Swat-tal. Lapis 7(6), 19-26, 1 fig. 18 photos, 1 map.

Emerald is found with quartz and dolomite in the Swat Valley of Pakistan, near Mingora in the area of Hindu-Kush. Stones of a fine colour have a n_D 1.588 and n_W 1.596 with a birefringence of 0.007. Strong bands occur in the

absorption spectrum at 683 and 680 nm with weaker bands at 662, 646, 637, 477.4 and 472.5 nm. The stones appear an orange red through the Chelsea colour filter. Specific gravity is 2.77. Inclusions of calcite and dolomite crystals have been noted, with various patterns of liquid droplets. A table of constants of emerald from various localities is given.

Key words: Gems, emerald, Swat

G/203. Gubelin, E.J., 1982. Gemstones of Pakistan: Emerald, ruby and spinel. *Gems and Gemology* 18, 123-139.

Three gem materials are currently mined – emerald from dolomitic talc schists in the Swat Valley, and corundum (especially ruby) and spinel from marble enclosed in gneisses and schists in the Hunza Valley. The geology, mining, recovery and properties of each gem are given. Optical data and chemical analyses (by M. Weibel) are also given in a table.

Key words: Gems, emerald, ruby, spinels, Swat.

G/204. Gubelin, E.J., 1984. Rosa topas aus Pakistan. *Lapis* 1(9), 23-28.

Consult Gubelin et al., 1986 for further information.

Key words: Topaz, gems, Pakistan.

G/205. Gubelin, E.J., 1990. Gemological characteristics of Pakistani emeralds. In: Kazmi, A.H. & Snee, L.W. (ed.), *Emeralds of Pakistan: Geology, Gemology and Genesis*, 75-91. Van Nostrand Reinhold, New York.

The gemmologically ascertainable diagnostic properties of emeralds from Khaltaro, Gujar killi, Makhad, Charbagh and Swat mines 1, 2 (5-8 specimens from each) together with 70 specimens from the Mingora area are given. All of the emeralds have mean constants of E 1.583 and W 1.590, rather high for gem-quality emerald but in agreement with emeralds containing appreciable Fe: D ranges 2.66 – 2.78 with a median of 2.71 g/cm³. There is a broad absorption band in the blue from 420 for E to 430 for W , with an absorption maximum at 427 nm. This absorption band is consistently present in the Pakistani emeralds tested and is an additional means of identification. Primary fluid inclusions are of two types; narrow rectilinear filaments in parallel alignment along and pronged three-phase inclusions reminiscent of those in Columbian emeralds. The second fluid inclusions are also of two kinds, finger print inclusions and flat film-like, two-phase inclusions. Mineral inclusions found are actinolite, chromite, dolomite, enstatite, feldspar, gerdorffite, magnesite, mica and pyrrhoites: 321 colour photographs of the inclusions are presented.

Key Words: Gemology, emerald, Gujar Killi, Swat.

G/206. Gubelin, E.J., Graziani, G. & Kazmi, A.H., 1986. Pink topaz of Pakistan. *Gems and Gemology*, vol. 18, pp. 123–139.

The occurrence of pink topaz in Pakistan was discovered less than 20 years ago. This attractive material has been reported on several occasions in the gemological literature [Afridi et al., 1973; Bank, 1976a and b; Petrov et al.; 1977a, b, and c; Jan, 1979], but details of the deposit itself have only recently become available. In this article, the authors report on their investigation of the geology and mineralogy of the pink topaz deposit near Katlang, and on the chemistry and the gemmologically ascertainable properties of this material. As part of this study, the authors also investigated the other color varieties of topaz found at the deposit and their reaction to treatment.

The topaz is found in one of two hills that rise abruptly from the fertile agricultural plain of the Mardan District in the neighborhood of a small village. This settlement of farmers and the topaz hillock both bear the same name—Ghundao—and are located about 4 Km (2.5 mi.) north of the small town of Katlang (figure 2). The geographic coordinates of the topaz-bearing hill of Ghundao are latitude 34°24'N longitude 72°06'E which places it about 63 km (40 mi.) northeast of Peshawar and about 20 km north of the district capital Mardan "as the crow flies" (approximately 50 km southeast of the Swat Valley emerald deposits; see Gubelin, 1982). The hill is easily reached by automobile. The other hill, which contains no topaz deposits, lies about 1 Km northwest of the Ghundao hill.

The summit of Ghundao, the topaz hill, is approximately 80 m higher than the village, and the two hills are conspicuous features of an otherwise unbroken plain

Key Words: Gemology, topaz, Mardan.

G/207. Guerra, I., Luongo, G., Maistrello, M. & Scarascia, S., 1983. Deep seismic sounding along the profile Lawrencepur-Sango Sar (Nanga Parbat). *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 211-219.

Key words: Seismic profile, Lawrencepur, Nanga Parbat.

G/208. Guex, P.J., 1978. Le Trias en fer vient des Salt Ranges (Pakistan); Problems biochronologiques. *Ecologiae Geologiae Helveticae* 71, 105-141.

Key Words: Triassic, Salt range.

G/209. Guillot, S., Cosca, M., Allemand, P. & Le Fort, P., 1999. Contrasting metamorphic and geochronologic evolution along the Himalayan belt. In: Macfarlane, A., Sorkhabi, R. & Quade, J., (Eds.), *Himalaya and Tibet: Mountain roots to mountain tops*. Geological Society of America Special Papers 328, 117-128.

Systematic different pressure-temperature-time paths are recorded along the internal zone of the Himalayan orogen. High-pressure rocks rapidly exhumed during the Eocene and Oligocene are restricted to the western part of the Himalayan belt. Farther to the east, both in the North Himalayan Crystalline massif and in the High Himalayan Crystalline slab, there are upper amphibolite facies rocks, which were unroofed during the Miocene. In the High Himalayan Crystalline slab, a systematic decrease in mica $40\text{Ar}/49\text{Ar}$ cooling ages can be correlated with the degree of low-pressure anatexis to the east. The observed contrasts in both the metamorphic and geochronologic evolution along the Himalayan belt can be related to the counterclockwise rotation of the Indian plate during the India-Asia collision. Such rotation, together with a shallower dip of the intracontinental subduction plane to the east, would explain the delay in nappe stacking, a warmer thickened upper crust, and the observed decrease in ages from west to east.

Key Words: P-T-t paths, metamorphism, geochronology, Himalaya.

G/210. Guiraud, M., 1982. *Geothermobarometrie du facies schiste vert a glaucophane. Modélisation et applications (Afghanistan, Pakistan, Corse, Bohème)*. Ph.D. Thesis, University of Montpellier, France, 86p + annexures.

Key Words: Geothermobarometry, glaucophane, Shangla, Khost, Afghanistan, Pakistan.

G/211. Gul, A., 1983-85. *Geology and petrology of Burawai Area, upper Kaghan valley, District Mansehra, Pakistan*. M.Sc. Thesis, Punjab University, Lahore, 125p.

The project area lies in the upper Kaghan valley on both sides of the river Kunhar and along its adjoining tributaries. The Kaghan valley administratively is a part of the district Mansehra, province of Sarhad, Pakistan. Within the Kaghan valley the area starts at Battakundi in the south and goes upto Babun near Jalkhad in the north and covers about 114 square kilometers (nearly 70 square miles) and is covered by the Survey of Pakistan, toposheet No. 43 F/13, at the scale 1:50,000. The area lies between;

Latitude; $34^{\circ}53'38''$ to $35^{\circ}00'00''$

Longitudes $73^{\circ}45'00''$ to $73^{\circ}58'30''$

Battakundi, Dabukan, Dunga, Bans Bandi, Rakhan, Burawai, Wetar and Seri are the main villages on the roadside, in the project area. This report represents partial fulfilment of the requirements for the M.Sc. Applied Geology Examination at the Institute of Geology, University of the Punjab. The field work for this field

Key Words: Petrology, petrography, Kaghan valley, Mansehra.

G/212. Gul, A., Rehman, S.S. & Hamidullah, S., 2001. Hydrological studies of Panjkora River system and its tributaries Dir District, NWFP, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 64-65.

The North West Frontier Province (NWFP) is primarily drained by the Indus River along with a tributary network of perennial streams including the Kabul, Swat, Chitral, Kunhar, Bara, Kurram, Gambila, Gomal and Haro. Among these, River Panjkora, a snow fed tributary of Swat River which originates from the mountains of Dir Kohistan near Thal and drains Dir District and part of the Malakand Agency. The confluence of Panjkora and Swat rivers lies northwest of Kolangai village near the border of Malakand and Bajaur agencies. The catchments area of this river is mostly forested. This river is important for its high head and great discharge even in winters. Sarhad Hydel Development Organization (SHYDO) has selected a number of sites on this river and its tributaries for high head power production. This study is planned to carry out hydrological investigations of the water samples of Panjkora River for better management. Water samples were collected from eleven sites, Rashai dub/Thal down to Bussaq/Sharbati village and were analyzed for pH, alkalinity, hardness, TDS and suspended sediments concentration. Chemical analysis are under process and there data together with other parameters will be compared with generally accepted water quality standards for the maintenance of human and aquatic life and also for agricultural growth of the region. Various recommendations are suggest for better use of this natural gift, on the basis of data obtained during the current investigations.

Key Words: Hydrology, Panjkora River, hydropower.

G/213. Gul, A., Shoaib, M., 1995. Geochemistry of oil field water of Sadkal Oil Field (OGDC), Fatehjang, Attock District, Punjab, Pakistan. M.Sc. Thesis, University of Peshawar, 41p.

Key Words: Geochemistry, oilfields, Fatehjang, Attock.

G/214. Gul, J. & Rehman, N., 1999. Structure and stratigraphy of a part of N. Waziristan, south of Mir Ali and Miran Shah Road, N.W.F.P., Pakistan. M.Sc. Thesis, University of Peshawar, 78p.

Key Words: Structure, stratigraphy, North Waziristan.

G/215. Gupta, H. & Delany, F. (eds.), 1981. Zagros-HinduKush-Himalaya, Geodynamic Evolution. Am. Geophys. Union, Geodyn. Ser. 3, 323p.

This is a compilation of many papers by Gupta and Delany dealing with the three mountain systems. Papers of interest to the present work are individually annotated.

Key Words: Geodynamics, tectonics, Himalaya, Hindukush, Zagross.

G/216. Guraya, M.A. & Khizr, K., 1981. Geology of Swani–Sheringal region, Kohistan, District Dir, North West Frontier Province with special emphasis on Mineralogy and Petrology. M.Sc. Thesis. Institute of Geology, Punjab University, Lahore.

Swani-Sheringal Area is part of Hindu Kush range and is included in Northwest Himalayas. The area is mainly composed of metamorphic rocks of sedimentary origin, with igneous intrusions. The main rock units in the area are calcareous quartzites, chlorite schists, biotite schists and amphibolites. Calcareous quartzites are believed to be the oldest rock unit of the area. Chlorite schists, biotite schistose and amphibolites have formed as a result of progressive regional metamorphism of calcareous quartzites. The contacts of calcareous quartzites with the schistose and the contacts between chlorite and biotite schistose are gradational. Amphibolites are developed as formless patches in the schistose. The area is tectonically highly disturbed being involved in Himalayan Orogeny. The report

presents a detailed geological and petrological investigation of about 40-km² area. A detailed map of the investigated area on a scale of 1:10,000 are presented, along with its cross-section along X-Y line. Succession of Rocks of the area has been worked out. Detailed petrography of all the major units of the area is described.

Key Words: Mineralogy, petrology, Dir, Kohistan.

H/1. Habib, M., Pervez, J. & Rehman, S., 1982-83. Petrography of the Thor and Thorly mafic ultramafics association Chilas complex, Northern Pakistan. M.Sc. Thesis, University of Peshawar, 116p.

The huge Chilas complex is predominantly occupied by rather uniform gabbro-noritic rocks locally amphibolized along shear zones. In the Chilas, Thorly and Thor area, there are many small bodies of mafic-ultramafic rocks showing complex relations with the host gabbro-norites. This is a detailed account of the geology, field relationships, and petrography some bodies in Thorly-Thor area, together with a carefully prepared geological map.

Key Words: Petrography, Mafic-ultramafic rocks, Chilas complex, Kohistan.

H/2. Haddle, J.F., 1855. Memoir on the River Indus. Bombay Government Sel., Record New Series 17.

Key Words: Indus River, India.

H/3. Hadi, S., Abbasi, I.A., Khan, M.A. & Shah, M.R., 2000. Structure and stratigraphy of the collision related Main Boundary Zone, Thal area, Western Kohat. Late Abstracts, Third South Asia Geological Congress, Lahore, p.8.

For further details consult the following account.

Key Words: Structure, stratigraphy, MBZ, tectonic mélange, Thal, Hangu.

H/4. Hadi, S., Abbasi, I.A., Khan, M.A. & Shah, M.R., 2001. Tectonostratigraphy along the western collision zone Thal area, western Kohat, NW Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 26-27.

The mélange zone and carbonate sequence exposed around Thal area defines the western most intersection of the Main Boundary Thrust (MBT) and the Kuram Boundary Zone (KBZ) that records the imprints of the western oblique collision of the Indian Plate with Afghan block. The associated deformation due to these structures in the area has bimodal nature. The first phase is syn-ophiolite obduction, which brings the Shahur Tangi-Kahi Group over the Indian shelf sequence as a thrust sheet with large aerial extent, and is contemporary to Paleocene as constrained by the highly brecciated and attenuated Lockhart Formation. The younger phase of deformation associated with Main Boundary Thrust (MBT) and uplift of the Kuram Boundary Zone (KBZ) caused the Indian shelf sequence (Isha Group) to breach out along the high angle south verging structures e.g. Kiliadii-nak & Darsamand structures. This phase is believed to be post-Pliocene as it deforms the young conglomeratic deposits of the molasse sequence.

The Isha Group (Jurassic-Paleocene) is comprised of Sainanasuk/Chiltan, Chichali/Lumshiwal, Kawagarh and Lockhart formations. The Shahur Tangi-Kahi Group represents a sub-CCD flysch olistostromal sequence and is subdivided into Ahni Tangi, Shinki Post and Khajuri Post formations of the Late Cretaceous age. The Eocene rocks are represented by shale/limestone sequence (Panoba Shale & Kohat Limestone) that unconformably overlies the post-ophiolite obduction thrust stack and marks the western extremities of the Eocene Kohat Basin where most of the Eocene rock taper out. Thick molasse sequence of the Kohat foreland basin unconformably overlies the Eocene rocks and is represented by Kamlial, Chinji & Nagri formations.

Key Words: Tectonics, stratigraphy, collision, Thal, Kohat.

H/5. Hafeez, M.A. & Ahmad, S.A., 1992. Status of geological mapping on 1:50,000 scale in Pakistan. Geological Survey of Pakistan, Information Release 535.

Information is provided on status of mapping by the Geological survey of Pakistan at a scale of 1: 50,000 in various areas of the country.

Key Words: Geological mapping.

H/6. Hallam, A. & Maynard, J.B., 1987. The iron ores and associated sediments of the Chichali Formation (Oxfordian to Valanginian) of the Trans-Indus Salt Range, Pakistan. *Journal of Geological Society*, London 144, 107-114.

A distinctive and widespread belemnite-bearing shale of the Tethyan region is well exposed in the Trans-Indus Salt Range as the Chichali Formation, where it contains two workable ironstone seams. Facies analysis indicates a pronounced deepening in the Upper Oxfordian and Kimmeridgian followed by two regressive cycles marked by a transition from glauconitic-phosphatic shales to glauconitic silts and sands and finally to winnowed and oxidized glauconitic sandy ironstones. The first cycle ends in Berriasian belemnite-rich beds; the second cycle, which has few belemnites, extends into the Valanginian, and is followed by deltaic sediments of the Lumshiwal Formation.

Comparison with other areas indicates that the source area for the clastic components was the Indian Shield to the east and south. The increased clastic supply in the Upper Jurassic-Lower Cretaceous is thought to result from tectonic uplift in this source area rather than from climatic change.

The ironstone beds are distinctive in being pelletal glauconites compared with the oolitic chamosite and goethite so typical of the Jurassic elsewhere. Enrichment of the glauconite to commercial grade was by winnowing and oxidation on the seafloor. The absence of oolitic chamosite and goethite could be related to generally deeper water and an overall Eh in the environment too high to allow iron to migrate in appreciable quantities as Fe²⁺.

Key words: Economic geology, iron ore, sedimentary rocks, Chichali Formation, Trans-Indus Salt Range.

H/7. Haller, H., 1937. Ein relief der Nanga Parbat-gruppe. *Mitteilungen des Deutschen und Österreichischen Alpenvereins* 11, 168-170.

Key words: Geomorphology, Nanga Parbat.

H/8. Hameed, A., 1992-94. Sedimentary petrology/sedimentology of Early Cretaceous Lumshiwal Formation and Early Palaeocene Lockhart limestone and lithostructural mapping of Sirgah area, southern Hazara, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 150p.

A comprehensive study of Geology and structure of Dhamtaur area is represented along with special constraints on the sedimentology of Lumshiwal Formation of Early Cretaceous and Margalla Hill Limestone of Early Eocene. Large scale (1:10000) Geological mapping of a small segment of the Lesser Himalaya in the Dhamtaur area is presented. The lithostratigraphic unit range from upper Paleocene to Pre-Cambrian, Hazara Formation being the oldest. Structurally the area comprises NW-SE trending major anticlinorium. The folds are tight to isoclinal and opposing southeast and North West vergence on the two sides of the core formation. Some anticlines show plunge to the southeast direction. Almost all faults have vergence parallel to the folds developed in the core on the two sides of the main anticlinorium. Most are reverse faults although some may be of the normal type. Faulting appears to be dip-slip to oblique slip and in general involves a maximum displacement of few hundred meters.

A detailed study of sedimentary petrology/sedimentology of Lumshiwal Formation of Early Cretaceous and Lockhart Limestone of Early Paleocene has been carried out. The object was to study the petrography environment of deposition and diagenesis of the above said formations.

The section of Lumshiwal Formation from Jhamiri village between Haripur-Jabrian Road is medium to thick bedded glauconite sandstone. This formation is divided into nineteen microfacies. The microfacies overlying Chichali formation is glauconite, iron oxides and quartz cemented, quartz arenite. The other microfacies are mainly quartz, glauconite and carbonate cemented, and mature to super mature quartz arenites. The maximum development of glauconite is from central to upper part. Upper horizons are selectively cemented with flint.

The Lumshiwal Formation indicates low energy conditions in the subtidal zone. The formation of glauconite itself reveals slow rate of sedimentation and mildly reducing conditions. Diagenetic history indicates the formation of glauconite, secondary quartz, feldspar and flint earlier and ferroan calcite and dolomite at a later stage. The last stage involves the formation of ferroan dolomitization which occurred during final uplift with parts convening into dedolomites.

The section of Lockhart Limestone near Ghumawan is medium to thick bedded. The Lower contact of Lockhart is disconformable with Hangu Formation and upper contact of Lockhart Limestone with Patala Formation is sharp and

conformable. This section is comprise of 25 microfacies and 4 facies ranging from mudstone, wackestone and packstone; have been defined on the basis of field observation and petrographic studies.

The deposition of Lockhart Limestone took place in open marine shallow shelf conditions. Neomorphism of syndepositional micrite has taken place under various conditions during different phases of tectonic activity. Mechanical and chemical compaction are present in the forms of aligned fauna and stylolites. The porosity is generally low. The type of porosities are fracture and vug.

Key words: Iron ore, sediments, Chichali Formation, Salt Range.

H/9. Hamid, K.A., Ahmad, K.S. & Shah, M.S., 1980. Geology of Muzaffarabad area, Azad Kashmir. M.Sc. Thesis, University of Peshawar, 86p.

Key words: Geology, Muzaffarabad.

H/10. Hamidullah, S., 1984. Asbestos occurrence in Mohmand Agency: Genesis, economics, and related health hazards. Geological Bulletin, University of Peshawar 17, 69-73.

Two new localities of asbestos are reported from Mohmand Agency. It is considered that the asbestos development is associated with shearing and circulation of water and some CO₂ in ultramafic rocks. The asbestos is of considerable economic significance, however, there is strong circumstantial evidence that its related health hazards have already started affecting the local miners.

Key Words: Minerals, asbestos, ultramafics, Mohmand Agency.

H/11. Hamidullah, S., 1991. Chemistry of clinopyroxene from the Deosai volcanics, Baltistan, N. Pakistan. Geological Bulletin, University of Peshawar 24, 161-176.

Seventy analyses of clinopyroxene phenocrysts from the Deosai volcanics were obtained and tested for substitutions and other petrogenetic characters. The data shown an overall core-margin substitution of $x\text{Ca}+x\text{Na}+x\text{Fe}^{3+} + x\text{Al}+x\text{Ti} = x\text{Si}+x\text{Mg}+x\text{Fe}^{2+}+x\text{Mn}$ type in the phenocrysts, with "x" representing the actual amount of a cation entered or replaced, and which can be determined precisely from its variation along with unit variation of Si. The data also indicate crystallization in a temperature range of 1100 – 1200°C, under highly variable pressure, from a basaltic magma of alkaline (but transitional to non-alkaline) characters.

Key Words: Mineralogy, chemistry, pyroxene, Deosai, Baltistan.

H/12. Hamidullah, S., 1994a. Chemistry of hornblendes from the Deosai volcanics, Baltistan, northern Pakistan. Geological Bulletin, University of Peshawar 27, 1-8.

Seventy eight core to margin spot analyses of 8 hornblende phenocrysts from an andesitic basalt of Deosai plateau, Baltistan. N. Pakistan, are presented in the form of means and standard deviations. The data show an igneous parentage for these hornblendes. Chemical variations do not agree with commonly accepted substitutions for igneous hornblendes and an overall core to margin substitution of $[x\text{Fe}^{3+}x^{\text{iv}}\text{Al}+x\text{Ti}+x\text{Mg}+x\text{NaB} = x^{\text{iv}}\text{Al}+x\text{Fe}^{2+}(\pm x\text{Mn})+x\text{Ca}+x\text{Si}+x\text{A-site}]$ type is suggested with the former set of cations higher in cores and the latter in margins. A tentative temperature range of 875-700°C and a PH₂O range of 6-4.2 kb are suggested for the crystallization of these hornblendes. It is also suggested that like clinopyroxene the Deosai hornblendes carry unusual chemical features which may be related to variations in physio-chemical environment of the magmata chamber, and for that reason, possibly, of the source region.

Key Words: Chemistry, hornblende, volcanics, Deosai, Baltistan

H/13. Hamidullah, S., 1994b. The Waziristan complex: some more chemical data and their interpretation. Geological Bulletin, University of Peshawar 27, 69-79.

Tholeiitic and cal-alkaline affinities are reflected by two different rocks from the Waziristan island arc in 22 major element rock analyses. Previously published clinopyroxene analyses are used for comparison. The data confirms the existence of a fossil island arc in Waziristan.

Key Words: Geochemistry, Island arc, Waziristan.

H/14. Hamidullah, S., 2000. Geology and mineral chemistry of the Deosai volcanic, Baltistan, N Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, p.416.

The westerly extension of the Dras volcanics in the Deosai plateau of Baltistan, northern Pakistan, lying east of the Nanga Parbat-Haramosh Massif, is comprised of agglomerates and tuffs together with flows consisting of basalt, andesite and some rhyolite. In the field these volcanics are overlying the Ladakh batholith and both these basic and acidic suites of rocks carry the signatures of the Nanga Parbat-related orogeny. The flows appear to have evolved from a basaltic magma, with opaque oxide, clinopyroxene, hornblende and plagioclase, respectively appearing on the liquidus. These have been metamorphosed under greenschist facies conditions and may contain abundant epidote, chlorite and secondary amphibole. Metamorphic impact seems to be stronger in the west, i.e., in the vicinity of Nanga Parbat-Haramosh Massif, than in the east. An $^{40}\text{Ar}/^{39}\text{Ar}$ age of 125.4 ± 6 Ma on hornblende phenocrysts in an andesite is in agreement with the Late Jurassic to Cretaceous age of the Dras volcanics, in India, and indicates that Nanga Parbat related tectonics may have played a part in the growth of lower green schist facies assemblage of the volcanic rocks.

Though the various chemical discrimination plots of the clinopyroxene phenocrysts show them as representing igneous parentage, with crystallization in a temperature range of 1100-1200°C, under highly variable pressure, from a basaltic magma of alkaline (but transitional to non-alkaline) characters, these data however, show substitutions which do not agree with the commonly accepted ones for clinopyroxenes from igneous rocks. Therefore, an overall core-margin $v\text{Ca}+v\text{Va}+v\text{Fe}^{3+}+vt\text{Al}+v\text{Ti} \rightarrow v\text{Si}+v\text{Mg}+v\text{Fe}^{2+}+v\text{Mn}$ type substitution has been suggested for these phenocrysts, with 'v' representing the actual amount of a cations entered or replaced, and which can be determined precisely from its variation along with unit variation of Si. Similarly the hornblende phenocryst chemical data also show igneous characters but with variations which do not agree with commonly accepted substitutions for igneous hornblendes. Therefore an overall core to margin substitution of $[\text{Fe}^{3+}+iv\text{Al}+\text{Ti}+\text{Mg}+\text{NaB} = vi\text{Al}+\text{Fe}^{2+}(\pm\text{Mn})+\text{Ca}+\text{Si}+\text{A-site}]$ type is suggested with the former set of cations higher in cores and the latter in margins. A tentative temperature range of 875-700°C and a PH_2O range of 6-4.2kb are suggested for the crystallization of these hornblendes. It is also suggested that like clinopyroxene the Deosai hornblendes carry unusual chemical features which may be related to variations in physio-chemical environment of the magmatic chamber, and for that reason, possibly of the source region triggered by subduction along the main Mantle Thrust.

Key Words: Geology, mineral chemistry, Deosai, Baltistan.

H/15. Hamidullah, S. & Ahmad, A., 1992. Pseudo-amphibolites in the southern amphibolite belt, Kohistan arc, N. Pakistan. Geological Bulletin, University of Peshawar 25, 73-76.

More evidences strengthening the view of the existence of (a) pseudo-amphibolite forming as a result of reaction between pre-granitic hornblendite or amphibolite and the granitic magma and (b) of certain hornblendites forming as a result of reaction between pre-granitic amphibolite and the granitic magma, in the southern amphibolite belt of the Kohistan island arc, are presented in this paper.

Key Words: Amphibolites, Kohistan, Island arc.

H/16. Hamidullah, S., Bangash, I.H. & Reuber, I., 1990. Petrology of the southern amphibolite belt rocks from Mahak and surrounding area, Kohistan arc, north Pakistan. Geological Bulletin, University of Peshawar 23, 27-43.

The various rock types of Mahak are medium- to coarse -grained amphibolites, hornblendites, hornblende pegmatite, diorites, meta-gabbro, metapyroxenite and quartzo-feldspathic veins and dykes. Amphibolites are most abundant rocks of the area. These are distinguished into epidote amphibolite and plagioclase amphibolite. The major element chemistry of the amphibolites suggests their derivation from a basic igneous parent of tholeiitic character,

but field data also indicate some of them to be hybrids having been developed as a result of reaction between hornblendites and the granitic magma. The true amphibolites contain mineral assemblages indicating amphibolite grade metamorphism followed by the prevalence of epidote amphibolite facies and a minor phase of green schist facies environments. Hornblendites are usually monomineralic. Two types of hornblendite occur, i.e. (a) pre-granitic and the common ones and (b) sys-granitic. Field and laboratory data show that the former types may be representing early cumulate for the basic amphibolites or rocks having been formed in the loci of fluid phases during the amphibolite grade metamorphism. However, field evidence show that the sys-granitic hornblendites are the product of reaction between amphibolites and the granitic magma.

Key Words: Petrology, amphibolites, Mahak, Kohistan Arc.

H/17. Hamidullah, S. & Hussain, I., 1990. Geochemistry and petrology of the southern amphibolite belt rocks from Mahak and surrounding area, Swat, North Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.24.

Part of the amphibolite belt rocks around Mahak area in upper Swat has been investigated for petrogenetic interpretation. The petrology of the rocks indicates their production as a result of the combined igneous, metamorphic and metasomatic activity. The major igneous activity was followed by amphibolite facies and green schist facies metamorphism, indicating retrogression. Limited metasomatic and/or igneous activity took place together with or followed by the major metamorphic episode.

Key Words: Petrology, Amphibolites, Mahak, Kohistan Arc.

H/18. Hamidullah, S. & Ihsan, M., 1977. Mineralogy and petrology of the Shergarh Sar complex, Allai Kohistan, Hazara. M.Sc. Thesis, Peshawar University, 32p.

Key Words: Petrology, Shergarh, Kohistan, Island Arc.

H/19. Hamidullah, S., Islam, F. & Farooq, M., 1991. Petrology and geochemistry of the western part of Kalam-Dir igneous complex, Kohistan arc, northern Pakistan. Physics and Chemistry of the Earth, 17, 31-46.

Key Words: Petrology, Geochemistry, Kalam, Dir, Kohistan, Island Arc.

H/20. Hamidullah, S., Jabeen, N., Bilquees, R. & Jamil, K., 1986. Geology and petrology of the Malakand granite, gneiss and metasedimentary complex. Geological Bulletin, University of Peshawar 19, 61-76.

The Malakand granite intrudes a series of low-grade metasediments and granitic gneisses. It appears to be Calc-alkaline in characters. A temperature range of c. > 875-6500C and PH_2O of c. 5 <5 kb has been suggested for the development of various phases in the granite. The chemical features and age relationship also indicate that the Malakand granite is not genetically related to the alkaline igneous complex of the Peshawar Plain.

Three types of gneisses have been distinguished; a) siliceous gneiss, b) silica-rich granitic gneiss and c) normal granite gneiss. Among these only the normal granitic gneiss seems to be genetically related to the Malakand granite. The metasediments indicate several episodes of regional metamorphism ranging from lower green-schist facies to upper green-schist facies environments. The presence of garnet in schist at the contacts of granite has been related to the thermal effects of the intruding granitic magma.

Key Words: Petrology, granite, gneiss, Malakand.

H/21. Hamidullah, S. & Jan, M.Q., 1986. Preliminary petrochemical study of the Chilas complex, Kohistan island arc, northern Pakistan. Geological Bulletin, Univ. Peshawar 19, 157-182.

The Chilas complex, stretching more than 300 km and reaching 40 km in width, consist predominantly of gabbro-norites with minor pyroxenites, anorthosites and quartz diorites containing labradorites / andesine. Within these are found upto 4 km², seemingly intrusive, masses of dunite-peridotite-troctolite-anorthosite association characterised by the presence of bytownite / anorthite. Sixty four new chemical analyses reflect a genetic relationship among the various rock types. The data suggest crystallization from an arc-related parent magma of calcalkaline character. The oxides vs. D. I. And CMAS plots indicate olivine, orthopyroxene, and plagioclase as the dominant liquidus phases for the development of rocks varying from ultramafic through mafic to intermediate compositions. It is concluded that crystallization occurred possibly at a depth of < 25 km followed by pyroxene granulite facies metamorphism. This was followed by widespread amphibolitisation during uplift. The masses of ultramafic and related rocks appear to be early cumulates that were remobilized and emplaced into the main gabbro-norite association.

Key Words: Petrology, geochemistry, Chilas complex, Kohistan.

H/22. Hamidullah, S., Jan, M.Q. & Khan, Barkatullah, 1992. Petrography of the Deosai volcanics, N, Pakistan. Geological Bulletin, University of Peshawar 25, 17-22.

The western extension of the Dras volcanics in the Deosai plateau is made up of agglomerates and tuffs together with flows comprising basalt, andesite and some rhyolite. The flows appear to have evolved from a basaltic magma, with opaque oxide, clinopyroxene, hornblende and plagioclase, respectively appearing on the liquidus. These have been metamorphosed under greenschist facies conditions and may contain abundant epidote, chlorite and secondary amphibole. An ⁴⁰Ar / ³⁹Ar age of 1125.4 ± 6 Ma on hornblende phenocrysts in an andesite is in agreement with the Late Jurassic to Cretaceous age of the Dras volcanics.

Key Words: Petrography, volcanics, Deosai, Baltistan.

H/23. Hamidullah, S. & Jehan, N., 1999. From asbestoses to silicosis: a new turn in the story of the disease-causing mineral industry of Northern Pakistan. Abstracts, International Conference on Sustainable Management of Natural Resources, Department of Geology, University of Peshawar-UNESCO, p.49.

Key Words: Asbestosis, silicosis, mineral industry, Mohmand Agency.

H/24. Hamidullah, S. & Jehan, N., 2001. Further data on environmental impacts of silica industry in Mohmand Agency, N. Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.65.

Key Words: Silica industry, environmental hazard, Mohmand Agency.

H/25. Hamidullah, S., Jehan, N. & Arshad, J., 1999. Asbestos in northern Pakistan and its possible role in malignant mesothelioma. Souvenir and Abstracts, 4th Biennial International Conference on Chest Diseases and Tuberculosis, Organized by Pakistan Chest Society, 35-36.

Key Words: Asbestos, health hazard.

H/26. Hamidullah, S., Khan, M.S. & Shah, M.T., 1998. Heavy metal pollution in the western part of Peshawar Metropolis, north Pakistan. Journal of Nepal Geological Society 18, 379-394.

Key Words: Heavy metals, pollution, Peshawar.

H/27. Hamidullah, S. & Khan, M.J., 1993. Two clinopyroxenes from Upper Swat: Their chemistry and its petrogenetic implications. Geological Bulletin, University of Peshawar 26, 35-43.

Two sets of clinopyroxene analyses, one from the andesites of Utror volcanics and other from a troctolite patch in diorite from Deshai, Upper Swat, are used to ascertain the magmatic affinity and tectonic setting of their host rocks. Both the sets indicate igneous crystallization in island arc-related orogenic environments. Clinopyroxene data from the volcanic rock indicate calcalkaline affinities, while, those from troctolite appear to have grown from tholeiitic magma.

Key Words: Chemistry, petrogenesis, clinopyroxenes, Swat.

H/28. Hamidullah, S. & Onstot, T.C., 1992. $^{40}\text{Ar}/^{39}\text{Ar}$ evidence for late Cretaceous Formation of the Kohistan Island Arc, NW, Pakistan. Kashmir Journal of Geology 10, 105-122.

Hornblende, biotite and plagioclase separates from Kalam-Dir igneous complex, Kohistan Island Arc, NW Pakistan, have been analyzed by the $^{40}\text{Ar}/^{39}\text{Ar}$ technique. Hornblende from the volcanics and diorite plutons of Gabral (near Kalam) and Dir areas and biotite from tonalite at Matiltan yield dates ranging from 74 to 54 Ma, whereas other biotite and one of the plagioclase separates from the diorite plutons at Gabral yield 44 to 39 Ma plateau dates. Plagioclase from another diorite of Gabral and one from the ultramafic rock unit of Mahodand are contaminated by excess argon.

These date indicate that the Late Cretaceous to Early Eocene period was dominated by calc-alkaline plutonic magmatism (represented by diorites) accompanied by a short span of calc-alkaline volcanism (Kalam-Dir volcanics) at about 70 Ma, in the northern Swat and Dir areas. The ages increase progressively southward. Each major magmatism and/ or volcanism has caused high-grade metamorphism of already crystalline rocks in the south. The culmination of magmatism in the Kalam-Dir area at 54 Ma probably resulted from the collision of the Kohistan Island Arc with India.

The 45-39 Ma dates of the biotite and plagioclase from the diorites of Gabral reflect a middle Miocene to Oligocene metamorphism followed by cooling due to uplift and erosion in the area, and may represent the after-effects (extensional environments) of collision of Kohistan Island Arc with India. Alternatively, they may reflect the collision of the combined Indian and Kohistan Arc plates with that of Eurasia (along the MKT).

Key Words: Geochronology, Ar/Ar dates, Gabral diorite, Utror volcanics, Kohistan island arc.

H/29. Hamidullah, S., Saifullah, M. & Shah, M.T., 1997. Heavy metals concentrations in the soils of Peshawar metropolis. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.16.

Part of the information is given in Hamidullah et al., 2000.

Key Words: Heavy metals, soil, Peshawar.

H/30. Hamidullah, S., Saifullah, M. & Shah, M.T., 1997. Heavy metal pollution in the eastern part of Peshawar, metropolis, Environ. Pollut. 3rd National Symposium, Abstract No.111.

Consult the following account for further information.

Key Words: Heavy metals, pollution, Peshawar.

H/31. Hamidullah, S., Saifullah, M. & Shah, M.T., 2000. Heavy metal pollution in soils of Peshawar city, NWFP, Pakistan. Geological Bulletin, University of Peshawar 33, 1-9.

Soil samples from 10 locations in Peshawar city have been analyzed for heavy metals including Cr, Co, Ni, Cu, Zn, Fe and Pb in order to evaluate the impact of heavy metals pollution reported earlier in the air, surface clay and sewerage system of Peshawar city by Hamidullah et al., (1997). It is concluded that heavy metals found in the dust fall of the city 012 the roadsides have so far not reached the soil horizon. The relative enriched Cr in the soils

compared to the heavy metals data of the corresponding air samples, reported earlier, has been attributed to the source material including the rock of the Main Mantle Thrust and Kohistan Island Arc. Higher Fe in these soils has been attributed to the process of soil formation. It has been warned that though heavy metals do not directly percolate into the soil horizon within the city at an alarming rate, these metals make their way from surface through the sewerage system of the city and via Budni Canal to Kabul River which is the feeder of the underground water system in Peshawar Basin. The indirect potential threat of heavy metals pollution to the subsurface strata of the basin does exist and needs to be blocked.

Key Words: Heavy metal, pollution, Peshawar.

H/32. Hamidullah, S. & Shah, M.T. 1993. Textural and minerachemical significance of hornblendes from an andesite at Dir, Kohistan arc, N, Pakistan. Geological Bulletin, University of Peshawar 26, 45-58.

Petrography and minerachemical features of a hornblende andesite from Gira Khwar, northeast of Dir proper, are studied to envisage the crystallization mode of hornblende phenocrysts, in the rock. It is determined that the cores of the hornblende phenocrysts are primary igneous. On the other hand the bluish green rims of these phenocrysts and probably the groundmass hornblende are a product of subsolidus re-equilibrium and or metamorphic recrystallization. The very tips of the hornblende phenocrysts appear to have recrystallized during shearing and cataclasis at a latter stage.

Key Words: Petrography, mineral chemistry, andesite, Dir, Kohistan arc.

H/33. Hamidullah, S., Shah, M.T. & Khan, M.A., 1996. Identification and characterization of the quality of silica sand resources from Munda Gucha, district Mansehra, in glass making. Geological Bulletin, University of Peshawar 29, 59-68.

The silica sand deposit of Munda Gucha area occurring in the quartzose rock of Tannawal Formation, district Mansehra, has been mapped and sampled for identification and characterization of its quality for glass making. Petrographic, geochemical and field studies show that the Munda Gucha silica sand deposit has tremendous potentials as a source of silica sand for glass, steel, soap and ceramic industries. With previous studies suggesting inferred reserves of 70 million metric tones and an average SiO₂ between 90-95 %, the present data has enhanced the average SiO₂ to 95.21%. Samples collected from the snow white zone of Bela Sukian block along Munda Gucha-Jacha road have maximum SiO₂ content of 99.7 % and those from Mohri have 98.84 %, providing to be useful in manufacturing of first quality optical glass. On the basis of grain size (0.3-0.5 mm in diameter) the Munda Gucha silica sand stands the best standard known in Pakistan. It is concluded that the deposit has tremendous potential as source of silica sand for glass, steel, soap and ceramic industries. Simple or very dilute acidic washing is suggested for the removal of tFe₂O₃ because of its occurrence as surfacial iron leaching.

Key Words: Economic geology, Silica sand, Munda Gucha, Mansehra.

H/34. Hamidullah, S., Tariq, S., Saifullah, Khan, M.S., 1999. Environmental studies in and around Peshawar Metropolis with special reference to heavy metals pollution. Souvenir and Abstracts, 4th Biennial International Conference on Chest Diseases and Tuberculosis, Organized by Pakistan Chest Society, p.33.

Consult Hamidullah et al., 2000, for information.

Key Words: Heavy metal pollution, Peshawar.

H/35. Hamidullah, S., Tariq, S. & Shah, M.T., 2001. Soil pollution in the western part of Peshawar basin. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.45.

Nineteen samples from horizon A (0-20 cm depth) and 18 samples from horizon B (20-45cm depth) of the soils from various spots of the western part of Peshawar basin were analysed for major elements, certain trace elements and heavy metals in order to (a) compare these soils with soils from other parts of the world, (b) determine if any

contamination is existing and (c) to identify the source of such a contamination. The data show that SiO_2 , Al_2O_3 and Fe_2O_3 stand normal in these soils. MgO , CaO , Na_2O , K_2O , and P_2O_5 of these soils are however, higher than the limits given for normal soils by the United States Department of Agriculture (USDA, 1957). Similarly, heavy metals including Cu, Pb, Ni and Cr are high in these soils when compared with international limit. The reasons for high concentrations of CaO , Na_2O , K_2O are water logging and salinity arid for high MgO , Cu, Ni and Cr, the availability of source material in the nearby Skhakot Qua ultramafic complex. Similarly, the high concentration of P_2O_5 may also be due to the presence of this element in the P_2O_5 bearing rocks at the northern extremities of the basin at Selai Patai (Malakand - Mohmand junction) or the overuse of phosphate-bearing fertilizers in the agricultural practices. The source of Pb in soils at certain locations may be both i.e. source rocks and industry.

Key Words: Soil pollution, Peshawar.

H/36. Hamidullah, S., Zahid, M. & Majid, M., 1991. Mineralogy and mineral chemistry of the amphibolite belt and Main Mantle Thrust Rocks from Gantar area, Allai Kohistan, north Pakistan. Geological Bulletin, University of Peshawar 24, 133-146.

Petrographic and mineralogical studies are performed for the Kohistan island arc, MMT mélange zone and Indian plate lithologies at Gantar village and in its surroundings, in Allai Kohistan, Hazara. Petrographic studies reveal that locally, the Kohistan island arc lithology is exclusively comprised of amphibolites and epidote amphibolites with certain patches of hornblende pegmatites. The MMT mélange zone includes greenschist and blueschist whereas the Indian plate sequence is made up of a variety of schistose rocks and siliceous marble. Petrography and mineral chemistry indicate that amphibolites have an igneous parentage and have undergone successive metamorphic episodes of amphibolite facies, epidote-amphibolites facies and greenschist facies, in a temperature range of $530 \leq 500^\circ\text{C}$ and a pressure range of $6 \leq 4.5 \text{ kb}$, whereas the MMT mélange zone rocks show signature of amphibolite facies, blueschist facies (7kb) and greenschist facies metamorphic episodes. The hornblende pegmatite patches in amphibolites are interpreted as products of low pressure metasomatism, on the basis of lower viAl content in hornblende as compared to that in amphibolites. Small outcrops of metagabbro and metanorite found in the area are regarded as part of the island arc system, on the basis of their clinopyroxene chemistry. Structural, petrographic and mineral-chemical features indicate a subduction-obduction related petrogenesis for these rocks.

Key words: Mineralogy, chemistry, amphibolite, MMT, Allai Kohistan.

H/37. Hamidullah, S., Zahid, M. & Majid, M., 1992. Petrology and geochemistry of the mélange zone and southern amphibolite belt rocks from Gantar area, Allai Kohistan, Hazara, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.15.

Consult the preceding account.

Key Words: Petrology, geochemistry, Mélange, amphibolite, gantar, Allai, Kohistan.

H/38. Hammarstrom, J.M., 1989. Chemistry of emeralds and some associated minerals from Pakistan and Afghanistan; An electron microprobe study. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 125-150. Van Nostrand Reinhold, New York.

An electron microprobe was used to study a suite of nine emerald samples representing four separate occurrences of gem-quality emeralds from northwestern Pakistan and neighboring Afghanistan. The study was undertaken to characterize the chemistry of the emeralds of the region, to compare the emeralds with emeralds from other locations, and to investigate local variations in composition. The results of the study could help unravel the complex and unusual parageneses of these deposits, and ultimately could aid in refinement of exploration techniques. The study also includes data for (1) green vanadian beryls from the Mohmand emerald district, (2) green chromium-rich tourmalines from the Swat emerald district, and (3) minerals in the carbonate host rock at Mingora. The electron microprobe technique allows nondestructive chemical analysis of discrete spots across a single crystal and is useful in the study of minerals.

This technique can determine transition metals responsible for color and can identify compositional zoning within single grains. The principal disadvantages of the technique are that elements lighter than fluorine (atomic number 9)

cannot be determined and that different oxidation states of elements such as iron cannot be distinguished. Thus, we do not report data for beryllium, a major constituent of emerald; lithium and water, which can occur in emeralds in amounts up to several weight percent; and boron, a major constituent of tourmaline.

Key words: Mineralogy, Gemstone, Emerald, Mingora, Gilgit, Panjsher.

H/39. Hammarstrom, J.M., Snee, L.W. & Kazmi, A.H., 1988. Mineral chemistry of emeralds from N.W. Pakistan: Geologic setting, chemical signature, and zoning. Abstract with Programs, Geological Society of America 20, p.102.

Key words: Emerald, Mingora, Gilgit, Panjsher.

H/40. Hammer, V.M.F., 1999. Tiefgrüner lazulith. *Lapis* 24(5), 33-34.

Key words: Gemology, Lazulith.

H/41. Hamood, O., 1992-93. Tectonics and structure of Timargara-Lal Qila-Wari areas District Dir N.W.F.P. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 265p.

The structural geological mapping of 673 sq. km area of Timargara, Lal Qila and Wari areas District Dir N.W.F.P was conducted along with structural, petrographical economic geological studies. The area lies in the western extremity of Kohistan Island Arc where the Mesozoic amphibolitized ocean floor Kohistan Island arc are sutured to the Shamoza Green schist mélange which is under thrust by gneisses of Indian plate.

The amphibolites exposed in the southern and northern extreme of the mapped area were the parts of a single ocean floor under which the arc was built. These amphibolites were formed by the metamorphism of basic volcanics and pillow lavas of tholeiitic affinities, and subordinate interlayered sediments of argillaceous, arenaceous and carbonate composition. The sediments were deposited on ocean floor along with lavas at mid oceanic ridge (MOR). The concentration of metasediments in the southern exposure is relatively less and thin as compare to northern part of amphibolite where thick piles of these sediments were evident. The amphibolites exposed in the project area are different from Kamila amphibolites which were formed by the metamorphism of basic plutonic rocks. The Kamila amphibolites represent the base of Kohistan Island Arc and are exposed near or, around Nangaparbat syntaxis due to uplifting and uncovering of base rocks. Whereas Dir amphibolites represent the supra crustal material of Kohistan Island Arc under which the arc was built. The southern part of Dir amphibolites are dominantly composed of fresh and altered plagioclase 20 to 38 % (altered to seracite, koalinite, epidote and chlorite) amphibolites hornblende 10 to 61 %, actinolite 15 to 15.5 %, tremolite 1 to 5 %, cummingtonite 1 to 6 % but in shear zones its amount is 17 to 30 %, and athophylitic 1 to 5 % and quartz 2 to 50 %. Carbonate metasedimentary layers with in these amphibolites contain calcite 10 to 25 % and siderite 18 %. Whereas biotite 18 % and garnet 6 % is found in meta argillaceous and arenaceous layers. The northern part of Dir amphibolites are mainly composed of fresh and altered plagioclase 3 to 47 % (altered to seracite, kaolinite, epidote and chlorite), amphibolites (dominantly hornblende 1 to 68 %, actinolite 2 to 52.5 % and quartz 3 to 65 %). The carbonate metasediments in these amphibolites contain 8 to 20 % calcite, whereas biotite is 0.52 to 31 % and garnet is 30 to 33 % (in two samples) in meta argillaceous and arenaceous part of these amphibolites.

From the geochemical studies of Dir amphibolites the major elements which were determined are SiO₂ (38.06 to 64.26 wt%), TiO₂ (0.07 to 1.3), Al₂O₃ (3.34 to 19.54), Fe₂O₃ (5.25 to 12.56), MnO (0.16 to 0.28), MgO (0.84 to 15.50), CaO (5.58 to 20.70), Na₂O (0.03 to 5.0), K₂O (0.17 to 1.44), P₂O₅ (0.01 to 0.20) and Cr₂O₃ (0.01 to 0.41 wt%). The trace elements are Ba (38 to 120 ppm), Ni (42 to 138), Sr (116 to 182), Zr (25 to 66), Y (12 to 20), Nb (10 to 24) and Sc (24 to 31 ppm).

The plutonic rocks exposed in the area consist of norite, gabbro-norite, diorite, tonalite, trondhjemite, granite/adamellite and quartz porphyries/aplites/ pegmatites are intruded in the Dir amphibolites and were exposed due to uplifting and uncovering of amphibolites. But the presence of small and large roof pendant of amphibolite in these plutonic rocks (which previously called xenoliths and screens of amphibolites) evident the presence of amphibolites over there.

The petrographic studies of plutonic rocks show that there is gradational change in mineralogy from norite/gabbro-norite towards diorite. The amount of quartz increases further from diorite (13.40%), tonalite (20%), trondhjemite (51.5%) to granite (54.1%) and adamellite (59.3%).

The amount of major elements determined from chemical analysis varies from norite/gabbro-norite to acidic bodies as SiO_2 (52.78 to 70.54 wt%), Fe_2O_3 (9.62 to 1.53), MgO (6.08 to 0.59), CaO (8.06 to 2.7), Na_2O (3.11 to 3.34), and K_2O (0.51 to 3.82 wt%). Whereas TiO_2 , Al_2O_3 , Cr_2O_3 does not show any remarkable variation. MgO , Fe_2O_3 , CaO and Al_2O_3 decreases with increase of SiO_2 towards tonalite and acidic bodies.

Generally three types of ultramafic rocks are exposed in the mapped area. The first type of ultramafic are highly altered and metamorphosed. These ultramafic rocks are present as exotic blocks in amphibolites. The second type which are present as roof pendant over the surface of some plutonic rocks (i.e. granite adamellite and diorite). These ultramafic were emplaced in oceanic crust (amphibolites) during its development at MOR. The third type of ultramafic which are mostly hornblendites and schelites are exposed both in amphibolites and plutonic rocks, were probably fractionated from the hydrous magma produced due to the partial melting of Indian plate and ascended to higher levels due to buoyancy acquired by their magmas as a result of residual liquid enrichment. Structural studies show that the rocks of Kohistan Island Arc exposed in the area are folded into northward dipping southward verging tight folds in the south (near MMT) which opens up northwards. The amphibolites have undergone at least two phases of isoclinal folding. In the first phase of recumbent or isoclinal folding S_1 axial planar foliation was developed in these rocks. The first phase of deformation is probably related to the subduction of Kohistan Island Arc under Eurasian plate. In the second phase these rocks were again folded. The second phase is probably related to the subduction of Indian plate under Kohistan. The rocks of Kohistan Island Arc have undergone a third phase of deformation which produced in the shear zones and a retrograde metamorphism of chlorite grade along shear zone which is most probably related to the collision of Indian plate with Kohistan Island Arc.

The southern part of Dir amphibolites near MMT mostly trend EW and dips 65° to 80° northwards, which is almost parallel to the trend of MMT. In the central portion of the mapped area, the plutonic rocks trend NE to SW and their dip varies from 40° to 70° NW and SE most of the fold axes in plutonic sequence are parallel to each other which mostly trend NE to SW and plunges from 12° to 50° . The northern part of Dir amphibolites mostly trend NE and dips 15° to 60° SE.

The economic significance of rocks of the project area was also studied. Geotechnical properties of Balambat norite, Panjkora diorite and hornblendite were analyzed and found that these rocks could be used as dimension stones as well as aggregates and building material.

Key words: Tectonics, structure, Dir.

H/42. Haneef, M., Jan, M.Q. & Rabbi, F., 1986. Fracture fills or "sedimentary dykes" in the lake sediments of Jalala, NWFP. A preliminary report. Geological Bulletin, University of Peshawar 19, 151-156.

Quaternary lake sediments of Jalala in Mardan District are intersected by discordant structures which have been described as clastic dykes by Allen (1964). These sediments consist of horizontal, alternate beds of clay, silt and sand with local pockets of erratics. Poor sorting, angular to subangular shapes of the grains, and varied mineralogy indicate short distance of transport. Metasediments, amphibolite and granitoids are among the possible source rocks. Field evidences indicate that episodic tectonic activity produced fracture in the sediments which were filled by the plastic flow of clayey material from the overlying beds.

Key words: Lake Sediments, Quaternary, sedimentary dykes, Jalala, Mardan.

H/43. Hanif, M., 1980-82. Geology and Petrology of Sher Qila Gulapur, Bargu and Dalnati Area, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore, 84p.

Key words: Petrology, Gilgit.

H/44. Hanif, M., 1999-2000. Structure, stratigraphy and petrography of Aghar, Gulpur and Nar areas, District Kotli, Azad Jammu & Kashmir, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 134p.

The geological and the structural mapping of Aghar, Gulpur and Nar areas of about 200 square kilometers was carried on the scale 1: 50,000 using the Toposheet No.43 G/15 of Survey of Pakistan. Then it was enlarged to the present scale 1: 18750. The lithostratigraphic units exposed in the area are mainly sedimentary in nature and range in age from Upper Miocene to Pliocene. These units are the Nagri Formation (Upper Miocene) and the Dhok Pathan Formation (Pliocene) of Siwalik Group of rocks. The Siwaliks are the molasse sediments which were derived from the upthrust mountain ranges of the Himalayas and adjoining foredeep area. The rocks of the area have been deformed during the two phases of deformation named as D1 and D2. D1 deformational event is related to F1 folds. F1 folds are the major anticlines and synclines of the area. These are Barali Anticline, Gulpur Syncline and Nar Anticline. F2 folds are formed during the second phase of deformation D2 due to change in plunge of F1 folds. About fifty rock samples were collected from different localities of the project area out of which twenty samples were selected for the petrographic studies. Tectonically, the Siwaliks lie in Sub-Himalayas and the project area is situated on the southern side of the Himalayan region, where the Siwaliks are deposited in the foreland basin. This foreland basin was formed in association with the collision of the Indian and Eurasian plates.

Key words: Structure, stratigraphy, petrography, Kotli, Azad Kashmir.

H/45. Hanif, S.M. & Khan, I.S., 1968. Petrology and structure of Khaki area, Hazara. M.Sc. Thesis, Punjab University, 75p.

Key words: Petrology, Structure, Mansehra.

H/46. Hanni, H.A., 1982. A contribution to the separability synthetic and natural emeralds. Journal of Gemmology 18, 138-144.

Gives chemical features of the two groups of emeralds. Two chemical analyses of emerald from Pakistan are also given.

Key words: Gemology, emerald, Swat.

H/47. Hansen, R., 1997. Remembering hazards as “Coping Strategy”. Local perception of the disastrous snowfalls and rainfalls of September 1992 in Astor valley, Northwestern Himalayas. In: Stellrecht, I. & Winiger, M. (Eds.), Perspectives on History and Change in the Karakorum, Hindukush, and Himalaya. Culture Area Karakorum, Scientific Studies 3, 203-215. Rudiger Koppe, Koln.

Key words: Hazards, snowfall, rainfall, Astor valley, Himalaya.

H/48. Hanson, C.R., 1986. Bed rock geology of the Shigar valley area, Skardu, Northern Pakistan. M.S. Thesis, Dartmouth College, Hanover, New Hampshire, 124p.

For further details consult Hanson, 1989.

Key words: Geology, Shigar, Skardu.

H/49. Hanson, C.R., 1989. The northern suture in Shigar valley, Baltistan, northern Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), Tectonics of the Western Himalaya. Geological Society of America, Special Paper 232, 203-216.

The Shigar Valley is crossed by a large, southwest-verging reverse fault containing pods of serpentized ultramafic rock; the fault is correlated with the Northern Suture, which separates Paleozoic shelf-type sedimentary rocks of the Asian plate from Cretaceous volcanic rocks of the Ladakh-Kohistan arc. In the Shigar valley, the Asian plate is represented by a series of folded schists and marbles (the Daltumbore Formation) that is faulted southward over metasedimentary rocks and volcanoclastics (the Bauma-Harel Formation) belonging to the volcanic arc. Cretaceous turritellid gastropod fossils were found in the Bauma-Harel Formation. Metamorphism on both sides of the suture

occurred in a regime of high temperature but only low to moderate pressure. Metamorphic isograds are cut by the suture, so metamorphism must have occurred before faulting along the suture. Two main phases of igneous intrusion are exposed in the arc terrane: a pre-tectonic, possibly tholeiitic phase about 100 m.y. old, and a post-tectonic, calc-alkaline to subalkaline phase 40 to 60 m.y. old. The Northern Suture does not have the appearance of a major suture, but the Ladakh-Kohistan Arc seems to have been a separate plate from the Asian continent. The suture probably marks the closure of a small ocean basin in late Cretaceous to early Eocene time.

Key words: Tectonics, Northern Suture, Shigar, Baltistan.

H/50. Hanson, C.R. & Lyons, J.B., 1986. Bedrock geology of the Shigar Valley area, Skardu, Northeast Pakistan. Abstracts with Programs, Geological Society of America 18(6), p.627.

For further details consult Hanson, 1989 above.

Key words: Northern Suture, Shigar, Baltistan.

H/51. Haq, A. & Faruqi, F.A., 1962. Ceramic qualities of West Pakistan feldspar, quartz and talc. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 142-147.

Key Words: Feldspar, quartz, clay, ceramics.

H/52. Haq, I., 1999. Geology and geochemical investigation of the part of Ushiri valley, Distt. Dir, Northern Pakistan. M.Phil. Thesis, University of Peshawar, 215p.

The study area is lying in the north-western portion of the Kohistan arc terrane. This terrane is bounded by two suture zones of regional extent at its northern and southern sides, believed to be formed by obliteration of ancient oceanic basin. The Kohistan arc consists of a series of east-west trending geological units, which are:

1) Jijal Ultramafic Complex, 2) Kamila Amphibolite, 3) Chilas Complex, 4) Chalt Volcanic Group, 5) Yasin Group and 6) Kohistan Batholith. This arc experienced its first collision at its northern margin with the Karakorum plate at 90-80 Ma, and its second collision at the southern margin during Early Eocene with the Indian plate. Rocks of the area are distinguished into two main lithological units: (1) Amphibolites and (2) Metadiorites/Metagranodiorites. The amphibolites occupy the southern part of the studied area while metadiorite/ granodiorites are exposed in the northern part of the area. Both these rock units have intrusive contact and exhibit local faulting and shearing. The amphibolites also host small patches of gabbro-norites which are less metamorphosed. The amphibolites are generally massive but also exhibit banding at places. These amphibolites are intruded by quartz and quartzofeldspathic veins especially in areas where the shearing and faulting are intense. The amphibolites are also intruded by the metadiorite/granodiorite in the form of small plugs. The metadiorites/granodiorites are medium to coarse-grained, massive in character and have xenoliths of amphibolites. Copper mineralization in the form of disseminated grains of tetrahydrite and chalcopyrite and supergene enriched in the form of malachite and azurite occur within quartz veins in limited areas. Petrographically the amphibolites are mainly composed of hornblende and plagioclase with subordinate amount of quartz and alkali feldspar. Biotite, muscovite, chlorite, epidote, apatite, sphene, rutile, calcite and opaque occur as accessories. The metagabbro-norites contain plagioclase, orthopyroxene and clinopyroxene, as the dominant mineral constituents. Quartz, sphene, apatite, chlorite, epidote and opaque are present as minor constituents. The metadiorite, quartz-diorite and metagranodiorite are dominantly composed of plagioclase with variable proportion of quartz and alkali feldspar. The other minor constituents include biotite, hornblende, muscovite, apatite, sphene, zircon, garnet and opaque. Chemically the amphibolites and metagabbro-norites are comagmatic. Their chemical characteristics favour the igneous parentage (i.e., host gabbro-norite) for the studied amphibolites. Both the amphibolites and gabbro-norites could be related to either Kamila amphibolites belt or Chilas Complex. The major and trace elements study of these rocks suggests that these are of calc-alkaline nature and are formed by the arc magma within the subduction related environment. The chemical characteristics of the granitoid rocks (metadiorite/granodiorite) suggest that these are comagmatic and have close affinity towards the calc-alkaline rocks, developed in island arc type of set up. The mineralogical and geochemical studies of the stream sediments (both pan concentrate and -80 mesh) suggest that the area has no anomalous zone of base and precious metals which could be attributed to the specific mineralization in the area.

Key Words: Petrography, mineralization, base metals, Kohistan arc, Dir.

H/53. Haq, I. & Nowshervi, A.R., 1966? Chemical studies of iron ores of North western region of Pakistan. Pakistan Journal of Scientific and Industrial Research 18 (2&3)?, 106-108.

Key Words: Chemistry, mineral deposits, Iron ore.

H/54. Haq, M.F., 1962. Mineral development in Pakistan. Natural Resources 1 (3), 43-46.

Key Words: Chemistry, Iron ore.

H/55. Haq, S.S.B. & Davies, D.M., 1997. Oblique convergence and lobate mountain belts of western Pakistan. Geology 25, 23-26.

The thin-skinned structures of the Pakistani convergent margin have formed as a consequence of the relative motion between India and Eurasia. Most of the resultant motion is being accommodated along or near the current edge of the Eurasian plate: the southwest-northeast striking Chaman fault zone. It has been observed at oblique margins that the total plate motion is resolved into a component parallel to the margin, accommodated through strike-slip faulting, and a component normal to the margin taken up as contraction. However, the orientations of structures along the Pakistani convergent margin in and around the Sulaiman lobe and Sulaiman Range cannot be explained simply by resolving the plate motion vector into components normal and parallel to the plate boundary. Our modeling suggests that the complex juxtaposition of strike-slip faults with thrust faults of various orientations can be explained by the presence of a block centered upon the Katawaz basin that translates along the southwest-northeast structural barrier of the Chaman fault zone, moving with respect to both Eurasia and India. As this relatively rigid block moves northeastward relative to Asia, it causes deformation of the sedimentary cover and is responsible for much of the structural complexity in the Pakistani foreland. Our simple model explains several first-order features of this oblique margin, such as the eastward-facing Sulaiman Range, the strike-slip Kingri fault (located between the Sulaiman lobe and Sulaiman Range), and the reentrant at Sibi. This leads us to conclude that very complex structural and geometric relationships at oblique convergent plate boundaries can result from the accommodation of strain with simple initial geometric constraints.

Key Words: Tectonics, structure.

H/56. Haq, Z., 1990-91. Geology and petrography of Kundal Shahi, Thunian, Thod and Balkand area Neelum valley, District Muzaffarabad (A.K.). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 92p.

The Project area is located in district Muzaffarabad (A.K), it covers about 200 Sq. Km the part of topographic sheet-No. 43 F/I3 and 43 F /14 published by survey of Pakistan.

Geological map at a scale 1:15000 from Kundal Shahi to Balkand area is presented. The area includes Salkhala Formation/Tanol Formation. On the basis of field observation and Petrographic studies the rock units are interpreted accordingly. The rock units exposed are the metasediments of the Precambrian age with sheet intrusives. These intrusives are from granite to pegmatitic in nature and composition, pelitic to psammitic and furthermore calc silicates are also present in the northern side of area. The metasediments are under normally prograde metamorphism towards north. While some effects of retrogressive metamorphism are also observed. The mineral assemblage lies from green schist to lower amphibolite facies.

Key Words: Geology, petrography, Neelum valley, Azad Kashmir.

H/57. Haque, A.F.M.M., 1956. Shorter contributions to the geology of Pakistan. Geological Survey of Pakistan, Record 8 (2), 60p.

Key Words: Geology, Pakistan.

H/58. Haque, A.F.M.M., 1962. Some Upper Cretaceous smaller foraminifera from West Pakistan. Geological Survey of Pakistan, Memoir 2(3).

Key Words: Cretaceous, Paleontology, foraminifera.

H/59. Haque, A.F.M.M., Ivanac, J.E., Traves, D.M. & King, D., 1956. The geology of the NW portion of the Gilgit Agency. Geological Survey of Pakistan Records, 8(2), (Containing 6 Rep.).

For further details consult Ivanac et al., 1954.

Key Words: Geology, Gilgit.

H/60. Haque, A.F.M.M. & Wood, A., 1956. The genus *Cyclodooulina* (foraminifera) with a description of the new species from Pakistan. Geological Survey of Pakistan, Records 8(2).

Key Words: Paleontology, foraminifera.

H/61. Haque, S.M., 1974. Geology of the Balambat quadrangle (Toposheet No. 38 N/13), District, Dir, West Pakistan. Geological Survey of Pakistan. Information Release No. 81, 34p.

The Balambat quadrangle (38 N/13) covers about 250 square miles of mountainous terrain in Dir state in the north western part of West Pakistan.

The quadrangle is underlain by metamorphic and igneous rocks, comprising four main rock types, i) quartz-feldspar-biotite schist with interlayers of metamorphosed limestone, ii) amphibolite, iii) rocks of diorite group and iv) series of pegmatite-aplite dykes cutting the amphibolite and the diorite group rocks.

The amphibolite is well foliated and has quartzite and gneissic interlayers and inclusions of granitic rocks. It is conformable and gradational with the quartz-feldspar-biotite schists. The diorite group of rocks intrusive into the amphibolite consists of varieties of diorite and granodiorite and hornblendite. Bulk of this group has been metamorphosed. The amphibolite has been folded into a major syncline trending east-northeast. Foliation and mineral lineation form very characteristic structural features of the rocks. Foliation is well developed in the schist and the amphibolite, and weakly developed in the diorite.

Few folds, observed, are small and partially exposed. They are similar folds moderately open to tightly appressed and appear to belong to a single fold system. Microfolds and ptygmatic folds, which commonly characterize the amphibolite, have presumably resulted from the effect of metamorphic flowage. Very few faults have been observed. They are in part parallel with foliation, which are shear faults, and in part transverse to the foliation.

A structural analysis by plotting the recorded foliation, and lineation has been attempted. The results in general confirm the field observation and lead to the following conclusion.

1. The quadrangle area is occupied by a large syncline trending ENE-WSW.
2. The preexisting structure has not been substantially affected by particular deformation producing
3. In a large part the folds are more or less isoclinal
4. In part of the area the folds are reclined type.

Showings of pyrite chalcopyrite and bornite? As disseminated in quartz-feldspar dykes and at a place beryl in a pegmatite dyke were noted. Small occurrences of kaoline resulting from weathering of feldspar rich portions of pegmatite are common in some parts. No pattern of mineralization could be established.

Key Words: Geology, Balambat.

H/62. Harding, R.R. & Wall, F., 1987. Blue spinel from Hunza valley, Pakistan. Journal of Gemmology 20, 403-405.

The spectral features of the blue spinel from Hunza valley are described. The crystals occur as single or twinned octahedral. The mean of nine probe analyses is SiO₂ 0.05, TiO₂ 0.18, Al₂O₃ 69.3, Cr₂O₃ 0.73, V₂O₃ 0.05, FeO 3.75, MnO <0.05, MgO 24.6, ZnO 0.35, CaO < 0.05, NiO < 0.05, = 99.01. The presence of Ti and Cr in addition to Fe is probably responsible for the colour.

Key Words: Gemstones, spinels, Hunza.

H/63. Hartmann, H., Hepp, G. & Luft, U., 1941. Physiologische beobachtungen am Nanga Parbat 1937/1938. *Luftfahrtmedizin* 6, 1-48.

Key Words: Geography, Nanga Parbat, Himalaya.

H/64. Hasan, B., 1962. Utilization and exploration of indigenous constructions material by WAPDA, West Pakistan. *CENTO Symposium on Industrial Rocks and Minerals*, Lahore, 375-389.

Key Words: Construction material, WAPDA.

H/65. Hasan, B., 1987. Surface water storages in mountainous regions of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), *Resources Potential of Mountainous Regions of Pakistan*. Centre for Integrated Mountain Research, Punjab University, Lahore, 60-65.

Key Words: Hydrogeology, Pakistan.

H/66. Hasan, B. & Khan, S.A., 1986. Possible impact of plate tectonics on Basha Dam Site. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 26-27.

The Basha Damsite is proposed on the Indus River 314 km upstream of Tarbela and 40 km downstream of the town of Chilas. It will be a 660 feet (200m) high Dam, constructed of earth and rock with a central core and concrete cut off to bedrock. It will store 7.3 MAF (9.3 km³) of water and would generate 2400 MW of power. Rocks exposed at site are predominantly igneous complex, comprised mostly of Norite with subordinate Peridotite and Hornblendite.

The Main Mantle Thrust, which forms the Northern boundary of Indian Plate, is located at a distance of about 30 Km to the south of Basha Dam Site and dips towards Basha. The Northern Megashear passes East to West at the Southern boundary of Eurasian plate. The plate tectonics and associated structures could possibly affect the design of the dam seriously. In the present state of the art the seismic factors are evaluated for maximum credible earthquake (MCE) and operation basis earthquake (OBE). The structure which could create great hazards to human life on their failure are designed on the MCE, while others are designed for OBE. For this purpose it is pertinent to evaluate all the major fault of the area including the plate tectonics.

The Indus river occupies a broad valley between Raikot and the dams site which is filled with sediments upto a considerable depth. Faults could also be present under the alluvium, Raikot fault on which several hot springs are present, is located in the upstream area of the reservoir. The Raikot fault and possible buried faults could get activated under Basha reservoir water load and seepage water penetrating into the fault planes and induce higher seismicity.

Any storage project on the main stem of Indus cannot be constructed unless all the aspects having bearing on the safety of the dam are evaluated. For this purpose it has to be ascertained that no major event of catastrophic nature will occur during the life of the project or if so, correct provisions are made in the design. The paper details broadly the possible effect of the plate tectonics and associated geologic features on the proposed dam-site.

Key Words: Plate tectonics, structural geology, Bhasha dam, MMT.

H/67. Hasan, M.T., 1986. Proterozoic and Cambrian phosphorites deposits: Hazara, Pakistan. In: Cook, P.J. & Shergold, J.J. (Eds.), *Phosphate Deposits of the World* 1, 190-201.

Marine phosphorite deposits of Cambrian age are located in the NW of Pakistan on the flanks of the structurally complex Hazara-Kashmir syntaxis. Phosphorite deposits are developed at two horizons within the bedded cherty dolomite of the Abbottabad formation and a horizon within the shale and siltstone of the overlying Hazira formation.

The phosphorite is partly siliceous, generally granular, but also dense and laminated, and dark in colour. The Phosphate content ranges 10-30% P₂O₅ and reserves of phosphate rock are estimated at 22.9 million tones. The deposits will be difficult to mine because of extensive faulting and folding.

Key words: Cambrian, phosphorite, Hazara.

H/68. Hasan M.T., 1989. Cambrian phosphorite deposits of the Hazara Division, North West Frontier Province, Pakistan. In: Notholt, A.J.G., Sheldon, R.P. & Davidson, D.F. (Eds.), Phosphate Deposits of the World: Volume 2, Phosphate Rock Resources. Cambridge University Press, 449-454.

For further details consult the preceding account.

Key words: Cambrian, phosphorite, Hazara.

H/69. Hasan, M.T. & Aslam, M., 1974. Reconnaissance geology of the Indus valley road, Pakistan. Geological Survey of Pakistan. Information Release 78, 8p.

This is a broad description of the Karakoram Highway. The road passes through the northern part of the Indian plate, followed northward by mafic to granitic rocks (now termed the Kohistan arc), and then sedimentary rocks and granites of the Karakoram plate.

Key words: Reconnaissance, geology, Indus Valley road.

H/70. Hasan, M.T. & Asrarullah, 1989. Phosphate (apatite) resources in the Loi Shilman carbonatite, Khyber Agency, North West Frontier Province, Pakistan. In: Notholt, A.J.G., Sheldon, R.P. & Davidson, D.F., (Eds.), Phosphate Deposits of the World: Volume 2, Phosphate Rock Resources. Cambridge University Press, 455-457.

This paper deals with some of the carbonatite body at Loe Shilman. This carbonatite body contains large amounts of apatite.

Key words: Economic geology, apatite, carbonatite, Loe Shilman.

H/71. Hasan, M.T. & Ghaznavi, M.I., 1980. Phosphate deposits of Hazara Division, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Records 50, 1-18

Key words: Phosphate, Hazara.

H/72. Hasan, M.T. & Ghaznavi, M.I., 1995. An over view of Hazara phosphate deposits, NWFP, Pakistan. Abstracts, International Symposium and Field Workshop on Phosphate and Other Industrial Minerals, Abbottabad, p.31.

Key words: Phosphate, Hazara.

H/73. Hasan, M.T., Ghaznavi, M.I., Karim, T. & Turi, A.A., 1991. Phosphorite deposits of Barkot, Sherwan area, Abbottabad, Hazara Division. Geological Survey of Pakistan, Misc. 6, 12p.

The investigated area lies in the toposheet No.43 F/4, 30 km west of Abbottabad town. The work was undertaken for studying and firming up the phosphorite deposits in the area. Phosphorite is developed in the basal beds of Hazira and upper most part of Abbottabad Formation. The lateral extension of phosphorite is about 750 meters with a variable thickness of 2-3 meters. The total probable reserves of low to medium grade are estimated at 4050 million metric tonnes with P₂O₅ ranging from 7 to 25 percent.

Key words: Phosphorite, Abbottabad.

H/74. Haserodt, K., 1982. The Quaternary glaciation of the Pakistan Hindukush (Chitral). Sitzungsbericht u. Mitteilungen der Braunschweiger Wissenschaftlichen Gesellschaft, Sonderband 6.

Key Words: Glaciation, Hindukush.

H/75. Haserodt, K., 1984. Aspects of present climatic conditions and historic fluctuation of glacier in Western Karakorum. In: International Conference on Karakorum Culture, Gilgit 1983.

Key Words: Climate, glaciology, western Karakoram.

H/76. Haserodt, K., 1989a. Chitral (Pakistanischer Hindukusch). Strukturen, wandel und probleme eines lebensraumes im Hochgebirge Zwischen gletschern und wüste. In: Haserodt, K. (Ed.), Hochgebirgsraume nord-Pakistans im Hindukusch, Karakorum und Westhimalaya. Beitrage und Materialien zur Regionalen Geographie 2, 43-180.

Key Words: Structure, glaciers, Chitral.

H/77. Haserodt, K., 1989b. Zur pleistozanen und postglazialen vergletscherung zwischen Hindukusch, Karakorum und Westhimalaya. In: Haserodt, K. (Ed.), Hochgebirgsraume nord-Pakistans im Hindukusch, Karakorum und Westhimalaya. Beitrage und Materialien zur Regionalen Geographie 2, 181-233.

Key Words: Glaciation, Pleistocene, Hindukush, Karakoram, Himalaya.

H/78. Haserodt, K., 1994. Lawinenfußgruben und lawinenfußschuttwälle im oberen Kaghan-Tal (Westhimalaya, Pakistan). In: Haserodt, K. (Ed.), Physisch-Geographische Beitrage zu hochgebirgsraumen Nordpakistans und der Alpin. Beitrage und Materialien zur Regionalen Geographie 7, 115-127.

Key Words: Kaghan valley, Himalaya.

H/79. Haserodt, K., 1995. Change of climate in the Hindukush region – facts, trends and necessary observations of the environment. IIIrd international Hindukush conference, Chitral, Pakistan. 20p.

This is a detailed report on climate change in Chitral and adjuscent areas, supported by many figures. Data for mean annual precipitation of Drosh, Chitral, Gilgit and other places for 1965 – 1982 is given. Graphical presentations of mean air temperature and of the amount of river discharge at Chitral town are also given.

Key Words: Climate change, environment, Chitral.

H/80. Haserodt, K., 1996. The geographical features and problems of Chitral: A short introduction. In: Bashir, E. & Israr-ud-Din (Eds.), Proceedings of the Second International Hindukush Cultural Conference, September 19-23, 1990, Chitral, 3-18. Oxford University Press, Karachi.

Key Words: Geography, Chitral.

H/81. Hashmat, Z., 1970-72. Geology of Manarai Band area (Upper Swat). Institute of Geology, Punjab University, Lahore, M.Sc. Thesis, 57p.

Rocks of Manarai Banda area comprise metamorphic rocks making buttress of Himalayas. They are known to extend to form Dir and extend to Kalam.

Three different rock types are exposed within 50 miles² of area mapped.

Amphibolites have been metamorphosed to amphibolite grade; hornblende, epidote and in some garnet are very common. The group has a thrust faulted contact with the rocks of lower Swat-Buner schistose group. Ultramafic body is formed by the complete alteration of Peridotite bodies occurring in the surrounding area. The area is of some economic importance because of the occurrence of magnetite and corundum.

Key Words: Petrology, metamorphic rocks, ultramafics, Swat, Himalaya.

H/82. Hashmi, F.A.S., Khan, S.A. & Haq, I., 1984a. Geology, geotechnique and construction of Khanpur dam project. Abstract, First Pakistan Geological Congress, Lahore, 9-11.

Key Words: Geotechnical, dams, Khanpur.

H/83. Hashmi, F.A.S., Khan, S.A. & Haq, I., 1984b. Geology, geotechnique and construction of Simly Dam Project. Abstracts, First Pakistan Geological Congress, Lahore, 13-14.

Key Words: Geotechnics, dams, Simly dam.

H/84. Hashmi, M.A., 1982-84. Geotechnical studies of land slides along Karakoram Highway; from Batgram to Thakot, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 90p.

Key Words: Geotechnical, landslides, KKH, Batgram, Thakot, Mansehra.

H/85. Hassan, B., 1984. Geo-technical problems for Kohala tunnelling. Abstracts, First Geological Congress, Lahore, 40-42.

The Jhelum River runs in a gorge throughout its journey in Azad Kashmir territory. It flows in North/Westerly direction while entering the area and follows the same direction upto Domel where it takes a very sharp turn to the South and continues in rapids towards Mangla where it debouches into the plains. Enroute it is joined by the waters of the Neelum and Kunhar. The river, in the upper arm of bend has a steep gradient of about 31 feet per mile which flattens to 13 feet per mile along its lower reach. Depending upon the respective locations on either side of the syntaxial bend a drop of 200 feet to 950 feet can be created and utilized for power generation, by linking both arms through 2 miles to 11 miles long transmountain tunnels.

As a result of preliminary design studies, four different alignments for topographic survey and geological investigations work were picked up. Further studies and field investigations narrowed to the most attractive choice for Barrage and Tunnel alignment near Dhani Village.

The scheme recently investigated envisages a low height diversion dam of 72 feet, about 9 miles Upstream of Muzaffarabad. The water would be diverted through two six mile long 24 feet finished diameter tunnels outfalling into Jhelum river, 13 miles downstream of Muzaffarabad. Natural drop of above 570 feet would thus be available and utilized to install 500 MW capacity. The project configuration also offers the possibility of integration with the upstream Neelum/Jhelum, diversion hydel project, which would substantially increase its power potential.

Regional Geological Framework

The project area occupies the axial zone of the "North Western Syntaxis". River Jhelum also takes almost 90° turn at Muzaffarabad shown by the change in its course from westerly direction upstream of Muzaffarabad to the south (downstream of Muzaffarabad). There are two more or less parallel thrust faults that warp around the syntaxis. These have been named as Punjab thrust and the Jhelum/ Murree faults. The syntaxis contains the youngest rocks

i.e. Murree formation in its core, successively older rock warp around the periphery. South of Muzaffarabad the Jhelum/Murree fault, passes at a short distance from Kohala power house area but has a steep dip ($70^{\circ} - 80^{\circ}$) towards east. The fault strikes N $30-50^{\circ}$ East. The area lying within the sharp bend of river Jhelum is a big synclinal structure with an anticlinal structure within it. This highly complex geology might have considerable influence on various engineering structures, particularly in the power tunnels area.

Geological Features along Tunnels Alignment; About 6 mile long, two tunnels are proposed for Kohala power generation. It is very difficult and expensive to do any sub-surface investigations in these tunnel alignments due to high relief and rough terrain. Hence only strip surface geological mapping has been conducted. It is difficult to project the geology at the tunnel level from the strip surface geological maps due to complex geology of the area. On the basis of the strip and regional geological mapping, it is interpreted that the major rock units of sandstone and shale will be encountered during the excavation of the tunnels. The physical & structural characteristics of sandstone and shale along tunnels have been inferred from the extensive drilling done, on nearby other projects in Murree formation. Number of adits have been done on similar rock units at Abassian Dam site. A number of rock mechanical in situ tests were also conducted in the adits, which would help in evaluating the design parameters for the proposed tunnels. However, it is very difficult to assess the proportion of the sandstone and shale which shall be encountered and its structural characteristics along the tunnel alignment. The study of aerial photographs and surface geological feature, it has been evaluated that tunnel alignment area is highly folded and faulted. Due to tight folding and faulting, it is difficult to predict the geological features of the area at tunnel elevation. Due to high rainfall, Snow cover in part of that area and the geological structure acute ground water problem is expected during tunnel excavation.

Anticipated Geological Problems

It is anticipated that foundation rock, particularly the sandstone shall be highly jointed and fractured due to tight folding in the area. Proper precaution and controlled blasting would have to be undertaken to reduce the excessive breakage during the excavation particularly in the jointed sandstone. It may also be necessary that the shale whenever excavated be immediately provided with supported and protective cover to protect against surface weathering. Acute ground water problem may be encountered during the excavation of the tunnel. As sandstone has interbeds of shale, the tunnel inlet and outlet areas should be excavated with care to avoid any possible slips along the weaker planes. The above problems will be explained during presentation of the paper with the help of maps/charts/photographs to elicit useful discussions.

Key Words: Engineering geology, Jhelum River, Kohala, Azad Kashmir.

H/86. Hassan, C.S., 1981-83. Geology and Petrology of Lower Yasin Valley Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore, 85p.

This field report described the results of geological studies in area, extending Sher Qila to Gahkuch, in Lower Yasin Valley, Gilgit Agency. The enlargement from toposheet was prepared. On this map different units are shown as granite, diorite, amphibolite and paragneiss. The mineralogical description and petrographic analysis of these rock units are reported in detail. The petrogenesis of these rock units has been discussed as well.

The granite is considered to be a part of Karakoram axial granite, which is emplaced as partially fused and mobile mass rich in alkali feldspar during synthetic phase of orogeny. The diorite is probably tholeiitic basaltic magma injected into the pre-existing rocks, which were partially melted and assimilated. Decrease of calcic contents produced granodiorite during cooling. Green stone is product of regional metamorphism of basic igneous rocks.

Intense tectonic disturbance is evident from the frequent occurrences of strained and crushing effect on minerals. The area shows evidence of extensive mountain glaciation in the quaternary and glacial deposits are common. The economic mineral potential of the area is also discussed.

Key Words: Petrology, petrography, granites, diorites, Yasin valley, Gilgit.

H/87. Hassan, M., 1977. Oil and gas prospects of the basins of Pakistan. Geological Bulletin, Punjab University 14, 91-94.

The history of petroleum investigations in Pakistan is very old and can be traced back to the middle of 19th century. However, oil in commercial quantities was found in 1914 at Khaur, by the Attock oil company. Since then, several companies have carried out extensive survey of the country and exhaustive information on petroleum geology has been accumulated, though most of this work is not open to the public. Some of the works available are those of

Rahman (1963), Movshovitch (1968) Sokolov (1971) and others. Classification of areas of Pakistan into oil and gas and possible oil and gas basins has been worked out by these authors. Before proceeding further it will be plausible to understand the term "basin" and the sense in which it is being used in the present work. Olenin (1977) defines oil and gas basin as a geological body within the limits of a large element of the stratisphere which is structurally immersed as a whole relative to its limiting elements. Thickness, form and composition of the sediments forming this body and its hydrogeological characteristics guarantee in its generation and accumulating of dispersed hydrocarbons and conservation of pools of oil and gas.

Key Words: Hydrocarbon, oil, Pakistan.

H/88. Hassan, M., 1996. Late-Quaternary terrace sequence in the piedmont zone, tectonics and palaeoclimatics in Peshawar vale, Pakistan. Programme and Abstracts, 8th All Pakistan Geographic Conference, Peshawar, p.20.

Key Words: Quaternary deposits, Paleoclimate, Peshawar.

H/89. Hassan, M., 1997. Little Ice Age in Pakistan. Abstracts, 9th All Pakistan Geographic Conference, Islamabad, 16-17.

Key Words: Glaciation, ice age.

H/90. Hassan, S., 1990-92. Geological mapping and evaluation of geotechnical and deformability, characteristics of building materials, Neelum valley, Azad Kashmir. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 62p.

Granitic gneisses, schists, Hazara slates, dolomite, marble, Panjal volcanics, Margalla Hill limestone exposed in various parts of Neelum valley Azad Kashmir have been investigated for geotechnical properties, chemical and petrographic characters to evaluate these rocks as building material. The physical properties like compressive strength, crushing strength, soundness, absorption, porosity and specific gravity observed in the rock samples of various localities have been found within the range of ASTM specification with few exceptions.

A modified classification has also been proposed on the basis of porosity and absorption percentages. Various grades of building materials have been made for economic exploitation of the rocks taking into consideration the accessibility, cheap labour and geographical control of the area. It is suggested that the marbles are presently being used as roadstone is not rational. The Panjal volcanics are still to be investigated as building material or roadstones, the gneisses are good decorative stones. The dolomites can be rationally exploited for steel manufacture. The rational use of limestones is in cement industry.

Key Words: Mapping, building material, Neelum valley, Azad Kashmir.

H/91. Hattori, K. & Shirahase, T., 1998. Platinum group element signatures of ultramafic-mafic rocks of the Kohistan block: evidence for crustal cumulate origin. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 76-77.

The Kohistan block in northern Pakistan near the India-China border is bounded by the Main Karakoram Thrust to the Eurasian continent and by the Main Mantle Thrust to the Indian continent, The east-trending, crescent-shaped block is interpreted to be a 100 Ma island arc within the Tethys ocean, which was accreted and uplifted during the Himalayan orogeny. The block consists of four units; ultramafic Jijal complex, Kamila amphibolite, gabbroic Chilas complex and volcanic rocks of Chalt complex in ascending order to the north. The Chalt complex is predominantly basaltic-andesitic volcanic rocks with intercalated sedimentary rocks. The Chilas complex consists of gabbro, gabbro-norite, norite and minor troctolite and dunite. The igneous rocks in the complexes show low concentrations of high field strength elements (HFSE) compared to large ion lithophile elements (LILE) indicating arc origin [1]. High ϵ_{Nd} (100 Ma; +5 to +6) and mildly low initial $^{87}\text{Sr}/^{86}\text{Sr}$ (≈ 0.70400 at 100 Ma; [2]) suggest derivation from a depleted mantle wedge. The Jijal complex consists of dunite, pyroxenite and websterite. The lithology and the

relationship with other units have suggested an origin as cumulates of arc magmas. However, there has been no geochemical evidence to support this interpretation because the incompatible elements that might have been useful for petrogenetic study have low contents in the ultramafic rocks. Also, alteration-metamorphism may have modified their trace element compositions. Thus the usual geochemical tools are not likely to be useful for identifying the origin of the ultramafic rocks. Ultramafic rocks, however, contain significant concentrations of platinum group elements (PGE; ruthenium, palladium, osmium, iridium, platinum, rhodium), which are diagnostic for the origins of the rocks.

Here, we report the concentrations of Re and PGE for the ultramafic and mafic rocks from the Kohistan block.

The concentration of PGE in Kohistan rocks are highly fractionated with low Os, Ru and Ir and high Pt, Pd and Re. Gabbroic rocks contain very low Ir-type PGE (Ir, Ru, and Os): less than 10 ppt Os and 50 ppt Ir. Even ultramafic rocks of the Jijal complex with high MgO (<30 wt.%) and Ni (<800 ppm) contain low Os (<0.13 ppb), Ir (<0.79 ppb) and Ru (<0.9 ppb). They are much lower than mantle rocks, which contain ~4 ppb Os, ~3 ppb Ir, and ~5 ppb Ru. The patterns of PGE, which are normalized to primitive mantle composition, show a deep concave shape: moderately high Ni, deep lows at Os, Ir and Ru and steep positive slope towards Pt (<0.5 times PM), Pd (<3 times PM) and Re. The total PGE contents show a broad correlation with the concentrations of Sr. Because Sr is an incompatible lithophile element, the correlation with siderophile and chalcophile PGE indicates a low sulphur concentration in the parental magmas. The results indicate that the ultramafic rocks in the Kohistan block are indeed cumulates of arc magmas, which formed by partial melting of a depleted mantle, under sulphur-unsaturated condition. The parental magmas did not reach sulphur saturation during cumulate crystallization. The PGE concentrations and patterns from the Kohistan ultramafic rocks are identical to websterite and dunite from the cumulates of the Jurassic Talkeetna arc in Southern Alaska [3]. Similar patterns of PGE and covariation with other lithophile elements from the two arcs appear to suggest that arc magmas are generally sulphur unsaturated during the partial melting in the mantle source and during crystallization in the lower crust.

To evaluate the Os isotope ratios of the arc magma, $^{187}\text{Os}/^{186}\text{Os}$ ratios were determined. They range from 1.19 to 1.55 ($^{187}\text{Os}/^{186}\text{Os} = 0.143\text{--}0.187$). The values are low, although higher than the depleted mantle value, $^{187}\text{Os}/^{186}\text{Os} = \sim 1$ ($^{187}\text{Os}/^{186}\text{Os} = \sim 0.120$). Although the precise initial ratios are difficult to determine due to probable mobility of Re, the data suggest that the subduction-related mantle metasomatism was accompanied by little enrichment of radiogenic Os.

Key Words: Ultramafics, PGE, MKT, Himalaya.

H/92. Hayase, I., 1965. Age determination of a Karakorum rock. In: Matsushita, S & Huzita, K. (eds.), *Geology of the Karakoram and Hindukush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindukush, 1955*, Vol. VII, 149-150. Nippon Printing & Publishing Co., Ltd., Japan.

In Dusso area, granitic pegmatites commonly intrude granitic gneisses. This is a study of age determination on the whole rock sample of a pegmatite by Rb/Sr method and on its muscovite by K/Ar method. The Rb/Sr date is distinctly older (28 Ma) than the K/Ar date (4 Ma).

Key words: Geochronology, pegmatite, Dusso, Nanga Parbat.

H/93. Hayat, A.M.S., 1968. *Geology of Balakot and Dadar Area*. M.Sc. Thesis, Punjab University, Lahore, 83p.

An attempt has been made to map the area in detail and as such, apart from drawing isogrades in different metamorphic units, their grades and types of metamorphism have been studied thoroughly. Contacts have been traced, followed and plotted in the case of the sedimentaries and their environmental conditions, correlation and age have been discussed and, structure pointed out. Granite, which occupies about one third of the area concerned, has been assigned a magmatic origin, due to certain definite field evidences (explained under granite). Great emphasis has been placed on structure, as the area lies at the tip of the Syntaxial bend, one of the greatest controversies of all times (Geological). Five stereographic projections have been provided in order to show the types of stresses prevailing in the area, clarified further by the two geological sections attached to the map and a special structural map included. Fifty thin sections have been studied under microscope, of which thirteen have been included in the report. Four faunas have also been described.

Key Words: Geology, Balakot, Mansehra.

H/94. Hayat, M.N., Afridi, G.S., Tariq, M. & Faqir, G., 1977. Geology of southwest of Kotal Post, Kohat, N.W.F.P. M.Sc. Thesis, University of Peshawar, 105p.

Key Words: Geology, Kohat

H/95. Hayden, H.H., 1896. On some igneous rocks from the Tochi valley. Records of the Geological Survey of India 29(3), 63-69.

Key Words: Igneous rocks, Tochi valley.

H/96. Hayden, H.H., 1898. On the geology of Tirah and the Bazar Valley. Geological Survey of India, Memoirs 28(1), 96-117.

This paper is compiled from notes made by me while attached to the Tirah Expeditionary Force, during the months of October to December, 1897. The area examined consists of parts of the country lying between the Samana range and the southern slopes of the Area examined portions of Khaibar) Chura and the Bazar Valley. Of this area, the geology was in part known from the survey made by Mr. Griesbach¹ in Previous observers. 1891, yet there still remained a considerable portion the geology of which could only be conjectured, and although the nature of the late expedition was such as to preclude the possibility of an exhaustive examination of the still unmapped country, yet the route followed by the troops crossing the strike of the strata at right angles-opportunity was afforded for an examination of almost the entire sequence of beds between the Samana range and the southern slopes of the Safed Koh. I propose to divide this paper into two sections: the first dealing with the country south of the Safed Koh and its eastern extension, the Surghar range, and the second dealing with the area lying north of those ranges. I.--The Area South of the Safed Koh. Orographically this area consists of four main mountain ranges parallel to one another and running almost due Orography. These ranges are separated by longitudinal troughs, but locally connected with one another by spurs trend 1 Vide his paper on "The Geology of the Safed Koh." Rec. G. S. I., Vol. XXV, p. 59. In the same paper will be found a list of the most important literature bearing on the subject.

Key Words: Geology, Tirah valley.

H/97. Hayden, H.H., 1907. Notes on certain glaciers in Northwest Kashmir. Geological Survey of India Records, 35, 127-137.

Key Words: Glaciers, Kashmir.

H/98. Hayden, H.H., 1910. The Hasanabad glacier in Hunza. Geological Survey of India Records. 40(4), 339-340.

Key Words: Glaciers, Hasanabad, Hunza.

H/99. Hayden, H.H., 1914. Notes on the geology of Chitral. Records geological Survey of India, 65, P.271-.

Hayden made the first important geological traverse through northern Pakistan. He followed the route through Chitral, over darkot pass, down the Yasin valley, east to Gilgit, then north along the Hunza River valley. This traverse, though hurried, gave two cross-sections approximately normal to the regional trend. His notes contain valuable descriptions and correlation including those of the darkot group, Chalt volcanics, Yasin group, and the granitic batholiths.

Key words: Stratigraphy, geology, Hindukush, Karakoram, Kohistan.

H/100. Hayden, H.H., 1916. Notes on the geology of Chitral, Gilgit and the Pamirs. Geological Survey of India, Records 45(4), 271-335.

Hayden performed reconnaissance survey of the area from Mastuj, via Darkot, Yasin, Gupis, Gilgit, Hunza onward, to Pamir. The traverse, though hurried, gave two cross-sections approximately normal to the regional trend. He provided valuable information on the region, and established the geological concept of the areas of Western Karakoram and Eastern Hindu Kush. One of his contributions in this work was the discovery of Cretaceous molluscan and coral fossils at Yasin “in the cliffs behind the Rest House on the right bank of the river...” in 1914. He also made a sketch of the stratigraphic succession there. He found fossiliferous shaly limestone containing large number of Fusulinae and Bryozoa near Darband that appeared to be underlain by massive limestones and shales, often calcareous. Although not studied in situ because of bad weather, he correctly inferred that the hills on either side of the glacier at Darkot were granitic.

Key Words: Geology, Chitral, Gilgit, Pamirs, Hindukush.

H/101. Hayden, H.H., 1918. Notes on the relationship of Himalaya to the Indo-Gangetic Plain and the Indian Peninsula. Geological Survey of India, Record 43(2), 138-167.

Key Words: Himalaya, Indian Peninsula.

H/102. Hayland, F.D., 1957. Mineral resources of Pakistan. Mineral Trade Notes (US Bureau of Mines) 45(6), Special Supplement, 49-50.

This account gives a brief on the mineral resources of Pakistan including those of the Northern Punjab and N.W.F.P.

Key Words: Mineral resources.

H/103. Head, J.J., 1995. Two new trionychids (Reptilia: Testudines) from the Miocene of Pakistan: evolution of Aspideretini. Journal of Vertebrate Paleontology, 15 (supplement 3), 33A.

Two skulls from the middle and late Miocene Chinje Formation of the Siwaliks deposits of the Potwar Plateau, Pakistan, represent two new species of trionychid turtle. The first specimen is a member of the tribe Aspideretini, based on several morphological characteristics: the basisphenoid is medially constricted and the quadrate is separated by the trigeminal foramen by contact between the pterygoid and the prootic. The specimen is dated at 14 MYA, and is the oldest known member of Aspideretini. The second specimen is a member of the tribe Ulutrionychini, and is the most complete skull known for the tribe. This assignment is based on: shortened facial region with downturned prefrontals and weakened maxillary-prefrontal contact. Medial constriction of the basisphenoid in this specimen is shared with Aspideretini. The specimen is dated at 12 MYA, and is the youngest member of the tribe.

This new material supports the hypothesis that Aspideretini are derived from Ulutrionychini. In addition, the presence of an ulutrionychid in younger strata than an aspideretid suggests that Ulutrionychini persisted for a minimum of 2 MYA after the derivation of Aspideretini.

Key Words: Paleontology, Miocene, Chinji formation, Potwar, Siwaliks.

H/104. Head, J.J., 1997. Reptile palaeontology of Dhok Pathan Formation, Siwalik Group, Pakistan: Preliminary results. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 58-62.

Mammalian paleontology of the Siwalik Group of Pakistan has been heavily studied in regards to taphonomy, paleoecology, and phylogenetics, however, reptile fossils from the Siwaliks have received much less attention. The majority of reptile studies have been taxonomic depositions (e.g. Lydekker, 1885), and brief paleoclimatic reconstructions based on reptile occurrences from the Siwaliks of Nepal (West et al., 1991). Presented here are the preliminary results of what is intended to be an extensive survey of the Siwaliks herpetofaunas, emphasizing changes in ecology and phylogenetics through time.

Reptile fossils were surface collected at 31 localities throughout the middle and upper Dhok Pathan Formation in the Padhri-Hasnot region during March, 1996. These localities comprise a timespan of approximately 7.92-6.3 Ma (J.C. Barry, pers. comm.). Reptile taphonomy of these localities is similar to conditions described for mammals from the Dhok Pathan Formation (Badgley et al, 1995), with the exception of skeletal element frequencies; turtles are predominantly represented by shells, and snakes exclusively by vertebrae. These differences are due to the unique morphologies of the reptile groups. No complete specimens were recovered, and articulation of skeletal elements was nearly absent with the exception of several snake vertebrae and a partial trionychid turtle carapace. The incomplete nature of the specimens, combined with difficulties in phylogenetic assignment of represented taxa (e.g. Gardner and Russell, 1994) prevents species-level assignments at this time.

Due to both their scarcity in preservation and difficulties in phylogenetic determinations, squamate fossils are only briefly discussed here. Remains were recovered from only five localities, with the majority of remains recovered from a single locality, Yale 935, which contained vertebrae of possibly two partially complete snake specimens. Snakes are the most abundant squamate remains, and several specimens are nearly identical to, *Acrochordus*, a taxon known only from the Siwaliks and modern Indonesia/Australia (West et al., 1991). Lizards are poorly represented, with only several vertebrae from locality Yale 457, questionably referable as varanoid.

Historically, there have been at least five named crocodilian species from the Siwaliks: *Crocodylus palaeindicus*, *C. sivalensis*, *C. bugtiensis*, *Gavialis hysudricus*, and *Rhamphosuchus crassidens* (Lydekker, 1885; C. Brochu, pers. comm.). Remains from the Padhri Hasnot region consist of *Crocodylus* sp., *Gavialis* sp., and single tooth, possibly referable to *Rhamphosuchus*. (West et al., 1993) tentatively described *Tomistoma* sp. from the Siwaliks of Nepal, however, no definitive evidence of this taxon was recovered from the Dhok Pathan Formation. Size ranges of crocodilians include extremely small (tooth crown height .75 cm: neonate/juvenile) to extremely large (tooth crown height 4.2 cm: *Rhamphosuchus*?), with no apparent pattern of size increase or decrease through time. Turtle remains are the most abundant reptile fossils. All recovered specimens can be grouped into two main lineages, Trionychoidea (aquatic turtles) and Testudinoidea (semi-aquatic and terrestrial turtles). There is no definite evidence of pleurodiran turtles. Trionychoids are the most common reptile fossils, and their diversity includes carretocheyids and both cyclanorbine and trionychine trionychids. Carretocheyid specimens are diagnosed on the basis of punctate shell sculpturing; lack of acute sulci combined with the presence of peripheral bones; and the extension of sculpturing to the internal surfaces of the shell (Meylan, 1987; W. Bartels, pers. comm.). Among trionychids, the presence of cyclanorbinines is indicated by partial epiplastra, similar to the extant Asian species *Lissemys punctata* (Meylan, 1987). Trionychines are diagnosed by fragmentary plastra. At least one trionychine specimen may be referable to a specific genus; a partial carapace from locality Yale 933 retains a preneural element, a characteristic of the genus *Aspideretes* (Meylan, 1987). The taxonomic utility of this characteristic has been argued as being undiagnostic (Meylan, 1987; Gardner and Russell, 1994), however, the tentative assignment to this genus is corroborated by the endemism of modern aspideretids to Asia, and the occurrence of earlier members of this lineage in the Chinji Formation (Head, 1995). Size ranges for aquatic turtles range from diminutive (carapace length less than 15 cm) to extremely large, with localities, Dartmouth-Peshawar 13 and 28, containing remains of trionychid carapaces longer than 100 cm.

Testudoideans include emydid, batagmine, and testudinid turtles. Emydids are recognized on the basis of low-domed carapaces, lack of extensive shell ornamentation, and the presence of a plastral hinge (Emydid morph "A", Fig. 1) in adult specimens. Six forms of batagrine turtles have been recognized from the Siwaliks of Nepal (West et al., 1991), on the basis of shell fragments. Similar fragments have been recovered from the Dhok Pathan, however, differentiating between testudinids and batagrine remains from the Padhri-Hasnot region is tenuous at best. Among definitive testudinids, the species *Geochelone* is recognized by an epiplastron possessing a prominent cranial buttress. The distribution of this genus in Pakistan and India spans the Oligocene to Plio-Pleistocene of Pakistan to present of India (Auffenberg, 1974). An additional testudine taxon is represented by neural elements possessing extremely high, transverse crests. As with trionychids, emydid specimens recovered at locality Dartmouth-Peshawar 13 are extremely large, with carapace lengths approaching 100 cm. Large size testudinids (greater than 50 cm carapace length) were recovered from localities dated at 7.3 Ma and younger. The presence of these large testudinids indicates a mean cold month temperature of warmer than 20° C (Hutchison, 1982). An increased aridity in the Siwaliks at 7 Ma has been reported, based on Dhok Pathan rodent faunas (Jacobs and Flynn, 1981) and a transition from C3 to C4 photosynthesis (Quade and Cerling, 1995). The expected results of increased aridity on the reptile faunas would consist of an increase in diversity and abundance of taxa adapted for more xeric environments, and a decline in aquatic forms due to the reduction of surface water area. The occurrence of large testudinids from 7.3 Ma on may represent an influx of xeric (though not exclusively so) species. Aquatic taxa do not show decreases in diversity or abundance prior to 6.3 Ma, however. The largest specimens of all aquatic taxa occur between 6.6 and 6.3 Ma, and there is no demonstrable decrease in reptile abundance per locality after 7 Ma. Overall, reptile fossils

from 7 Ma on indicate that even with the increased aridity, large, permanent aquatic environments persisted, allowing both rich taxonomic diversity and the attaining of long life spans/body sizes in the aquatic herpetofaunas. Further research is required to confirm or deny these preliminary observations, as this study is still in its infancy. Future analysis will include changes (or lack thereof) in reptile diversity over a greater range of time, as well as spatial variations in herpetofaunas, through the Siwaliks. Additionally, further collection of specimens may allow observations of species longevity and evolutionary transitions of reptiles over time.

Key Words: Paleontology, Dhok Pathan formation, Potwar, Siwaliks.

H/105. Heintz, E. & Brunet, M., 1982. Une barriere geographique entre le sous-continent indien et Eurasie occidentale pour les faunes continentals du Miocene superieur. *Comptes-Rendus des Seances de l'Academie des Sciences, Serie2: Mecanique-Physique, Chimie, Sciences de l'Univers, Sciences de la Terre*, 294, 477-480.

Key Words: Geography, fauna, Miocene, India, Eurasia.

H/106. Heissig, K., 1972. Palaeontologische und geologische unter suchungen im Tertiär von Pakistan. –Rhinocerotidae (mamm.) aus den unteren und mittleren Siwalik-Schichten. *Bayer. Akad. Wissensch., Math. Natur. Kl. Abh.* 152, 1.112.

Key Words: Paleontology, geology, Tertiary, Siwaliks.

H/107. Hemphill, W.R. & Danilchik, W., 1966. Geologic interpretation of the Gemini V photograph of the Salt Range-Potwar Plateau region, West Pakistan. *NASA Earth Resources Survey Programm, Technical Letter 40*. Houston, Texas.

Key Words: Geology, satellite imagery, Salt Range.

H/108. Hemphill, W.R., & Kidwai, A.H., 1973. Stratigraphy of the Bannu and Dera Ismail Khan areas, Pakistan. *US Geological Survey, Prof. Paper 716-B*, 36p.

The Bannu and Dera Ismail Khan quadrangles cover an area of more than 8,600 square miles in north-central Pakistan, between lat 31 and 33°N and long 70 and 71°E. This area contains two main physiographic units: the alluvial lowlands, which include the structurally undisturbed Indus and Bannu plains and the folded belt which includes the Khisor, Marwat, Bhattanni and Sulaiman Ranges, as well as the highlands of Waziristan. These ranges and highlands form a nearly continuous mountain system between the Salt Range-Potwar Plateau region to the northeast and Baluchistan to the southwest.

Total stratigraphic thickness exceeds 14,000 feet in the Khisor and Marwat Ranges. Sedimentary rocks of the following age are present: Cambrian (?). Permian, Triassic, Jurassic, Cretaceous, middle and late Tertiary, and Quaternary. Lower Tertiary rocks are not present. Stratigraphic terminology for rocks in the Khisor and Marwat Ranges is the same as that used in the Salt Range and Potwar Plateau region to the northeast.

Total stratigraphic thickness exceeds 38,000 feet in the Sulaiman Range-Waziristan area. Sedimentary rocks of Jurassic, Cretaceous, Tertiary, and Quaternary age are present. Rocks of Paleocene and Eocene age are particularly well developed in this region, in places exceeding 13,000 feet. Stratigraphic terminology for units of Mesozoic age is the same as that used in Baluchistan to the southwest. New names are proposed and type sections are designated for seven units in the eastern foothills of the Sulaiman Range. These units are the Baska Shale of early Eocene age; the Domanda Shale and Drazinda Shale Member of the Kirthar Formation, middle and late(?) Eocene age; the Chitarwata Formation of late Oligocene to late Miocene age; and the Vihowa, Litra, and Chaudhwan Formation of Pliocene and Pleistocene (?) age.

Key Words: Geology, stratigraphy, Bannu, D.I.Khan.

H/109. Hemphill, W.R., Kidwai, A.H. & Jamiludin, 1962-64. Geologic Map of Bannu quadrangle, Pakistan. US Geological Survey, Geological Map Series PP716B Plate 2. Scale 1:250,000.

A geological map of the Bannu quadrangle is produced at 1:250,000 scale. For further information, consult the following.

Key Words: Geological map, Bannu.

H/110. Henderson, G. & Hume, A.O., 1873. Lahore to Yarkand incidents of the route and Natural History of the countries traversed by the expedition of 1870 under Forsyth, T.D., Roy. Geographic Society, London, 370p.

On the return to India of the Yarkand Expedition it was believed that sufficient materials had been collected, during the journey, for a paper in some scientific journal, on the Zoology and Botany of the countries traversed, but in preparing the notes for the press it was soon found that their bulk was so great as to necessitate a separate. After everything was ready for publication, the Secretary of State for India in Council most liberally subscribed for a number of copies of the work, sufficient to relieve the Authors of almost all risk. The sale of such a work as the present must necessarily be very limited. The Authors have to acknowledge with thanks the assistance they have received from many kind friends. Dr. Hooker most liberally allowed the Kew Herbarium to be freely consulted in identifying the Botanical specimens, and he and Mr. Bentham have written the descriptions of the new species of flowering Plants, all of which have been figured by Mr. Fitch, under Professor Oliver's supervision; and Mr. James Britten, late of the Kew Herbarium and now of the British Museum, gave very great assistance in identifying specimens of Plants; he also kindly undertook to revise the proof sheets of the botanical portion of the work. The identifications and descriptions of Algae, Diatomaceae, &c., as also the drawings of these, are by Dr. Dickie of Aberdeen, Mr. Fitch having lithographed the drawings. The Ornithological portion of the work has been edited by Mr. E. B. Sharpe, and Mr. H. W. Bates has exercised a general supervision over the work, whilst it was passing through the press. The analysis of the water of the Pan gong Lake was kindly undertaken by Dr. Frankland, and is published with his permission. Mr. Etheridge, of the Royal School of Mines, kindly identified the only fossil which was found in Yarkand territory, and his prognostication that coal would probably be found in Yarkand has already turned out to be true, for Mr. Shaw has informed Dr. Henderson that specimens of coal have since been obtained in Yarkand territory. Mr. Scott, of the Board of Trade Meteorological Office, kindly allowed the observations of the barometer, boiling-point thermometer, and the wet and dry bulb thermometer to be worked out in his office. The Map was drawn by Mr. Oulet at the Royal Geographical Society's rooms, under the supervision of Mr. Bates. The Plates which illustrate the Narrative, if not all works of art, have at least this recommendation, over woodcuts, that they give a truthful representation of the places, without leaving any margin for the imagination of the artist; all these Plates are done by the new Heliotype process, from negatives which were never very good, and which suffered greatly by the rough treatment they were subjected to during the march. It should be mentioned that these views are all reversed i.e., the right hand side of the picture should have been at the left side, and vice versa; this was caused by the negatives having been varnished at the time they were done, which prevented the film being taken off and reversed. The Plates of Birds are all by Keulemans, and with scarcely an exception they are all very accurately done. Few who have not themselves attempted it can realize the difficulty of getting through the press a volume like the present, containing such a variety of information; notwithstanding all the care that has been taken some mistakes may have been over-looked.

Key Words: Lahore, Yarkand, Expedition, Natural history.

H/111. Henderson, W., 1859. Memorendum on the nature and effects of the flooding of the Indus on 10th August 1858 as ascertained at Attock and its neighbourhood. Journal of the Asiatic Society of Bengal 28, 199-219.

As this account does not have an abstract, the first few pages of this account are given for information.

I begin by observing that this is not the first flood of the sort, but that one on a somewhat larger scale, but in other respects very similar, took place in May, 1811. I have seen two very brief accounts of this flood, one I think collated by Col. Abbott, the other furnished by Col. Cunningham. I have also collected at Attok and the neighbourhood some

information on the effects of this earlier flood; and as the two are very similar and mutually throw light upon one another, I shall have to refer to that of 1841, and so premise this allusion to it.

The first point on which information is called for is the spot where the obstruction took place. This can only be ascertained by sending up an Officer by way of Cashmere. In the meantime I may offer a few observations.

The obstruction of 1811, took place in the upper part of the valley of the Shayok River or northern Indus which joins what is considered as the main Indus at Keris, and I think brings down more water than the other, which from its long and straight course is naturally considered the principal or parent stream. The blocking took place in the part of the Valley where the stream runs at the back of a high range which separates it from the Nubra Valley. I have been over this ground and was struck with the frequency and solidity of the glaciers which occupy almost every valley in the range, with their tributary glens also. The range is granite, and large rough blocks of that rock form an important component of these glaciers.

The first information was received in the neighbourhood of Attok about the middle of July 1858, and of all that I have heard of, that which appeared most worthy of credit was a letter forwarding what purported to be a general warning by the Syuds of Kangra or Kangri. The Attok boatmen declared at once that the warning received in 1841, emanated from the same place; they recognized the style and stated that the same form of adjuration was employed and that the signatures appended were the same, except that two or three individuals, who might fairly be supposed to have died in the interval, were omitted from the later document. Search was then made in the house of Bulloo, the oldest of the Mullicks of the boatmen, but though it was well known that the paper was preserved there till a year or two ago, the search proved unsuccessful.

There is a village named Kangri marked in the Surveyor General's map of the Punjab and adjoining countries, and I believe this is the place alluded to, it is at no great distance from the Nubra and Shayok Valleys, and if the fact be that both papers issued from it, a fair inference is that in both cases the obstruction was at no great distance from its site; for in these valleys such news would not travel far except it were down the course of the river. We know that the damming of 1841, took place within two or three days' march of the village, and, till better evidence be obtained, can but conjecture that this also occurred in the Shayok or in the Nubra valley. Both are well adapted for the purpose, being wide with estrangulations at intervals, having comparatively a small slope of bed and being supplied from large glaciers above with considerable and unfailing streams of water. For though the main fall of the Indus-bed takes place between Kangri and Attok, yet the general character of all the streams I have observed in the Himalayas is to fall in steps, a comparatively sluggish portion intervening below the first rush of the minor tributaries, to be succeeded by the main stream making its way in a series of rapids for two or three hundred miles. Both the Nubra and the upper Shayok are thus comparatively slow flowing, and in the former especially there are numerous quicksands.

I have two or three times crossed the Shayok, and found it in the summer time a stream of considerable size. On the other hand, and contradictory to the above, all Major Becher's information pointed to the river of Gilgit, and that pretty consistently; but as this cannot be reconciled to the facts I have noted, as I understand them, I am inclined, till more evidence is obtained, to discredit it. I do not find in the map alluded to glaciers marked so far west as the River of Gilgit nor are the mountains from which it comes so high or so snow-clad as those to the eastward. Indeed I do not know in any part of the Himalayas a region so likely to give birth to catastrophes of the kind as that around the upper part of the Shayok.

The solution of the point is, however, very easy. The whole Indus above the Gilgit river is open to travellers proceeding under the protection of the Maharaja of Cashmere, and any officer starting from that valley and striking the Indus at the foot of the Nunga, Purbut, (a route which I recollect an officer of the artillery following in the summer of 1855,) and thence marching upwards, would very soon ascertain positively the exact locality of the obstruction. I should be glad if opportunity offered to proceed further for the purpose, and regret that when in that country before, I gave less attention to the matter than I should have done had I thought that a flood like that of 1841, could by any chance occur again in any definite number of years.

The second point mooted is the nature of the obstacle. We may pronounce with almost certainty that this was the sudden irruption into a comparatively narrow valley of an immense fragment of a glacier. I have already alluded to the glaciers of the region where I suppose the obstruction to have taken place. I have never seen those of Switzerland, but from what I have heard of them I think that the ones now referred to differ from the character ordinarily assigned to those in Europe, as they certainly greatly excel the latter in magnitude. Yet even in Europe a catastrophe similar to those which have taken place in the Indus valley occurred in that of the Drance in 1818. When crossing from the Nubra to the Shayok valley in August 1855, my companion, who had been in Switzerland, would at first hardly admit that the enormous mass of earth, rock and ice commingled and agglomerated together, with a broad stream of the dirtiest brown water issuing from its foot, and which I pointed out, filling up a tributary valley on our left, was really a glacier; (There are however glaciers in every direction and some remarkable ones. Eds.)

and several hundred miles farther south crossing the great shed between the Lanskar and the Chenab, he pointed out the features he had been accustomed to see, and which we generally find in description, clear ice of various tints of green, and deep crevasses crossed by snow bridges, and with comparatively clean water running within them. The formation in this case was lime-stone, in the former case granite. With regard to the magnitude of these glaciers

I need only say that I travelled nearly a whole day along one which was upwards of fourteen miles in length, varying in width from half a mile to two miles, and several hundred feet in depth.

The glaciers are, it is well known, in constant motion; their progress being subject to the same laws which regulate the motion of rivers. As they advance, their ends melt away and the Moraine gets washed down by the streams that issue from the body of the glaciers. The flow of one glacier measured by Prof. Forbes showed an onward movement of about 450 feet per annum, and it is evident, that where a glacier is cut off above the melting point by a stream running past its end, this motion must make it tend very considerably to encroach into the valley of the stream.

A landslide in one of those huge banks is quite a conceivable contingency, and in no case more likely than when the glacier protrudes with a narrow base and extended top from a small feeding glen coming in, nearly at right angles, into a narrow valley, whose stream crosses the path of the glacier, washing away the narrow foot which the mass behind protrudes, and on which it rests. This foundation being once undermined, the falling forward of a piece of the glacier is the result to be expected; and it is possible that this result often takes place, but that it is not often that circumstances so combine as that the process is delayed till a mass of formidable dimensions topples over.

Key Words: Natural hazards, Indus flood, Attock.

H/112. Henn, U., 1988. Untersuchungen an smaragden aus dem Swat-Tal, Pakistan. Zeitschrift der Deutschen Gemmologischen Gesellschaft 37, 121-127.

Key Words: Emerald, gemology, Swat.

H/113. Heron, A.M., 1950. Directory of economic minerals of Pakistan. Geological Survey of Pakistan, Records 1(2), 70p.

This is one of the earliest compilation of the economic mineral deposits of the newly independent country of Pakistan.

Key Words: Mineral deposits.

H/114. Heron, A.M., 1953. History of geological surveys in Pakistan. Geological Survey of Pakistan, Records 4(2) 44p.

Key Words: GSP.

H/115. Heron, A.M. & Crookshank, H., 1954. Directory of Economic Minerals of Pakistan. Geological Survey of Pakistan, Records 7(2), 146p.

This is an earlier work of the GSP showing the economic minerals found in Pakistan. This record was compiled in the early days of Pakistan's independence.

Key Words: Economic minerals.

H/116. Herzberg, C., 1981. Pakistan debuts first official gemstones collection. Natural Jewel, United States, April, 1p.

Key Words: Gemology, gemstones, Pakistan.

H/117. Hess, H., 1939. Gletscherkundliches aus dem Karakorum. Petermanns Geographische Mitteilungen 85, 91-92.

Key Words: Karakorum.

H/118. Heuberger, S., Burg, J.P., Dawood, H. & Hussain, S., 2001. Mapping of the North-Kohistan Suture, Upper Shishi Valley, Chitral, NW Pakistan. *Journal of Asian Earth Sciences* 19, p.28.

The northern suture, also known as the Main Mantle Thrust, separates the Kohistan island arc from the Karakoram-Hindukush terrains. Its western end occurs in the Chitral area. The NE trending Shishi valley to the north of Drosh marks the trace of the junction between the volcanic and other rocks of Kohistan and the Karakoram-Hindukush terrain. The suture is marked by a *mélange* and contains slivers of ultramafic rocks.

Key Words: Mapping, North suture, MMT, Shishi valley, Chitral.

H/119. Hewitt, K., 1961. Karakoram glaciers and the Indus. *Indus* 2, 4-14. Lahore.

Key Words: Glaciers, Karakoram, Indus.

H/120. Hewitt, K., 1964. A Karakoram ice dam. *Indus* 5, 18-30. Lahore.

Key Words: Karakoram, Ice dam.

H/121. Hewitt, K., 1967. Ice-front sedimentation and the seasonal effect: A Himalayan example. *Transaction of the Institute of British Geographer* 45, 93-106.

Key Words: Ice-front, sedimentation, Himalaya.

H/122. Hewitt, K., 1968a. The freeze-thaw environment of the Karakoram Himalaya. *The Canadian Geographer* 12, 85-98.

Frequent and large temperature shifts across freezing point are well-known features of tropical and sub-tropical high mountains (Troll). In a mountain environment particularly, these temperature shifts can powerfully influence weathering, mass-movements and run-off. Such was very apparent during field work in the Karakoram. So far as the writer is aware, there has been no attempt to analyse the freeze-thaw conditions in the semi-arid Himalaya. This paper sets out to reduce the gap in our knowledge by presenting in detail results from meteorological observations made in 1961-62 in Central Karakoram; and with the aid of certain other published records, to establish the altitudinal and seasonal migration of freeze-thaw belt.

Key Words: Environments, Karakoram, Himalaya.

H/123. Hewitt, K., 1968b. Records of natural damming and related events in the upper Indus basin. *Indus* 10, 11-19. W.L. University, Waterloo, Ontario.

Key Words: Natural damming, Indus basin.

H/124. Hewitt, K., 1969a. Geomorphology of the mountain regions of the upper Indus basin. Ph.D. Thesis. London University, 2 Volumes., 310p. and 121pl.

Key Words: Geomorphology, Indus basin.

H/125. Hewitt, K., 1969b. Glacier surges in the Karakoram Himalaya (Central Asia). *Canadian Journal of Earth Sciences* 6, 1009-1018.

The Karakoram and Alaska–Yukon region between them account for perhaps 90% of the known surging glacier events. While modern research and information is available for the latter region, the Karakoram, though often referred to, remains virtually unknown except in a very general sense. The prime aim of this paper is to collate all the information that is available for the Karakoram from the usually old and inaccessible documents where it is found. It establishes eleven instances of surges with reasonable certainty and the probability of many more. The (rare) instances of detailed descriptions of the phenomena are quoted. A short discussion is given of the degree to which the information, and knowledge of the Karakoram environment, equate with various mechanisms put forward to explain surging glacier events.

Keywords: Glaciers, Karakoram, Himalaya.

H/126. Hewitt, K., 1975. Prospective on disaster and natural hazards in the Northern Areas. Dawn Magazine, January, 1-12.

Consult the following description for further information.

Key words: Natural hazards, Karakoram.

H/127. Hewitt, K., 1982. Natural dams and outburst floods of the Karakorum Himalaya. IAHS-AISH Publication 138, 259-269.

Glacier dams and outburst floods ("jokulhlaups") have been reported in many glacierized mountain regions, and may create hazards for human populations. Specially large and dangerous examples occur where the rivers of extensive ice-free zones are blocked. This hydrological anomaly has been rare in modern times except for two areas: the southern Alaska-Yukon ranges and Karakoram Himalaya. In the Karakoram some 30 glaciers may form substantial dams on the Upper Indus and Yarkand river systems. Many more interfere with the flow of rivers in a potentially dangerous way. There is evidence of some 35 disastrous jokulhlaups since 1826. Rarer landslide dams have resulted in the largest dam-burst floods. The paper provides a record of known dams and related events, and identifies the glaciers involved. It indicates the role of the regional environment in the widespread potential for these glacier dams and catastrophic outbursts. Some data are given on the dimensions of past dams and the nature and impact of the flood waves. No dams were reported from the mid 1930's until 1978 when satellite imagery showed a 6 km glacier lake on the Upper Yarkand. The absence of dams in recent decades relates to a general glacier recession here. Renewed activity creates serious problems for water resource development and settlement growth that occurred in the recent, unusually favourable period.

Key words: Natural dams, glaciers, floods, Karakoram, Himalaya.

H/128. Hewitt, K., 1985a. Pakistan Case Study: Catastrophic floods. IAHS-AISH Publication 149, 131-135.

Within the highly glacierized Karakoram Himalaya situated largely within Pakistan, there have been many cases of catastrophic floods, some the result of river damming by landslide, others the result of river damming by glacier ice with subsequent dam failure. The purpose of this case study is to show, by reference to one particular example, the magnitude and consequences of a glacier outburst flood and possible ways of alleviating the social and economic impact of such floods. This case study is taken from a much more extensive paper on the subject by Hewitt (1982).

Key words: Glaciation, floods, landslides, Karakoram, Himalaya.

H/129. Hewitt, K., 1985b. Snow and ice hydrology in remote, high mountain regions: The Himalayan sources of the River Indus. Wilfried Laurier University, Waterloo, Snow and Ice Hydrology Project Working Paper 1.

Key words: Snow, Ice, Hydrology, Indus River, Himalaya.

H/130. Hewitt, K., 1985c. The Upper Indus snow belts; snow fall and sources of water yield. 1985 Annual Report: Snow and Ice Hydrology Project (upper Indus basin). Wilfred Laurier University, Waterloo, Ontario.

Key words: Snow, ice, hydrology, Indus River, Himalaya.

H/131. Hewitt, K., 1988a. The snow and ice hydrology project: Research and training for water resource development in the Upper Indus basin. *Journal of Canada-Pakistan Corporation* 2(1), 63-72.

Key words: Snow, ice, hydrology, Indus River, Himalaya.

H/132. Hewitt, K., 1988b. Ablation valley landforms and depositional environments of the Karakoram Himalaya. Altitude, Process and Climate-Geomorphic change. Conference abstracts, Neogene Karakoram and Himalayas. University of Leicester.

Key words: Ablation, landforms, Karakoram, Himalaya.

H/133. Hewitt, K., 1989a. The altitudinal organization of Karakoram geomorphic processes and depositional environments. In: Derbyshire, E. & Owen, L.A. (Eds.), *Quaternary of the Karakoram and Himalaya*. *Zeitschrift für Geomorphologie, Supplementband* 76, 9-32.

Key words: Geomorphology, Karakoram.

H/134. Hewitt, K., 1989b. European Science in High Asia: Geomorphology in the Karakoram Himalaya to 1939. In: Tinkler, K.J. (Ed.), *History of Geomorphology: From Hutton to Hack* Unwin Hyman, London. 165-203.

Key words: Geomorphology, Karakoram, Himalaya.

H/135. Hewitt, K., 1989c. Hazards to water resources development in high mountains: The Himalayan sources of the Indus. In: Starosolsky, O. & Medler, O.M. (Eds.), *Hydrology of Disasters*. WMO/James and James, London. 294-312.

Key words: Water resources, hazard, Indus river, Himalaya.

H/136. Hewitt, K., 1992. Mountain hazards. *Geo Journal* 27, 47-60.

Key words: Hazard.

H/137. Hewitt, K., 1993a. Mountain chronicles. Torrential rains in Central Karakoram, 9-10 September 1992. Geomorphological impacts and implications for climatic changes. *Mountain Research and Development* 13, 371-375.

Key words: Geomorphology, climate change, Karakoram.

H/138. Hewitt, K., 1993b. Altitudinal organization of Karakoram geomorphic processes and depositional environments. In: Shroder, J.F. Jr. (Ed.), *Himalaya to the Sea: Geology, Geomorphology, and the Quaternary*, Routledge, 159-183.

Key words: Geomorphology, Karakorum.

H/139. Hewitt, K., 1998a. Catastrophic landslides and their effects on the Upper Indus stream, Karakoram Himalaya, northern Pakistan. *Geomorphology* 26 (1 – 3), 47-80.

The paper examines the nature and geomorphic influences of deposits from rock avalanches that obstruct rivers. Most of the 115 rockslide–rock avalanche events identified in the Karakoram Himalaya straddled one or more stream valleys. At least 73 of these landslides formerly dammed the Indus or its tributaries. Upstream of the barriers, remnants exist of once very extensive lacustrine deposits. The stability and long-term survival of dams from large rock avalanches is addressed, and the reasons for the gradual or phased, rather than catastrophic and sudden, breaching. Case histories emphasise the erosional and depositional forms associated with the barriers. They are reconstructed in terms of the emplacement and properties of the deposits from rock avalanches, and the response of the river to interruption by them. These barriers have exerted a substantial control over stream response and development for most of the Holocene at least. Today, they are associated with distinctive features of channel form and thalweg, river terrace systems, intermontane sediment sinks and sources, and local erosional forms in bedrock. More broadly, the landslide barriers have created a naturally fragmented river system. Deposition and erosion in the lower few tens or hundreds of meters of the Upper Indus stream valleys have been dominated by epicycles of aggradation, trenching, and downcutting that mainly reflect the scale, timing and history of each barrier. The landforms involved are only indirectly related to the late-glacial and paraglacial conditions that have, hitherto, been regarded as the main explanation.

Key words: Landslides, Karakoram, Himalaya, Indus streams.

H/140. Hewitt, K., 1998b. Himalayan Indus streams in the Holocene: Glacier-, and landslide-‘interrupted’ fluvial systems. In: Stellrecht, I. (Ed.), *Karakorum-Hindukush-Himalaya: Dynamics of change*. Rudiger Koppe, Koln (Culture Area Karakorum, Scientific Studies 4).

Key words: Glaciers, landslides, Indus streams, Himalaya.

H/141. Hewitt, K., Wake, C.P., Young, G.J. & David, C., 1989. Hydrological investigation at Biafo Glacier, Karakorum Range, Himalaya; An important source of water for the Indus River. *Annals of Glaciology* 13, 103-108.

Over 80% of the flow of the Upper Indus River is derived from less than 20% of its area: essentially from zones of heavy snowfall and glacierized basins above 3500 m elevation. The trans-Himalayan contribution comes largely from an area of some 20 000 km² of glacierized basins, mostly along the axis of the Greater Karakoram range and especially from 20-30 of the largest glacier basins. Very few glaciological investigations have so far been undertaken in this the major glacierized region of Central Asia. Biafo Glacier, one of the largest of the Karakoram glaciers, drains south-eastwards from the central Karakoram crest. Its basin covers a total area of 853 km², 628 km² of which are permanent snow and ice, with 68% of the glacier area forming the accumulation zone. This paper describes investigations of snow accumulation, ablation, glacier movement, and glacier depth undertaken in the period 1985-87, set against a background of investigations carried out over the last 130 years. Biafo Glacier differs from most of the other Karakoram glaciers in being nourished mainly by direct snowfall rather than by avalanching; this has the advantage of allowing extensive investigation of accumulation over a broad range of altitude. Snow-accumulation studies in the Biafo Glacier basin have indicated that annual accumulation varies from 0.9 to 1.9 m of water equivalent between 4650 and 5450 m a.s.l. This suggests an annual moisture input above the equilibrium line of approximately 0.6 km³. Monopulse radar measurements indicate the presence of ice thickness as great as 1400 m at the equilibrium line, although these results may not be completely reliable. Mean surface velocity during the summer of 0.8 m d⁻¹ has been measured near to the equilibrium line. Calculations of annual ice flux through the

vertical cross-profile at the equilibrium line indicate a throughput of 0.7 km³ a⁻¹. Estimates from stake ablation measurements also suggest that ice loss on Biafo Glacier is about 0.7 km³ a⁻¹. The close agreement between these three sets of measurements is reassuring, indicating that the ablation zone of Biafo Glacier, whose area covers 0.09% of the whole Upper Indus basin, produces approximately 0.9% of the total run-off. However, it should be mentioned that this estimate does not include water originating from seasonal snow melt, either above or below the equilibrium line, or from rainfall. Net annual ice losses due to wastage of the glacier since 1910 are probably of the order of 0.4-0.5 m a⁻¹; this would represent between 12 and 15% of annual water yield from melting ice.

Key words: Glaciers, Biafo, hydrology, Himalaya.

H/142. Hewitt, K. & Young, G.J., 1993. The Snow and Ice Hydrology Project: A Pakistan-Canada Research and Training Programme. In: Young, G.J. (Ed.), *Snow and Glacier Hydrology - Proceedings of the International Symposium, Kathmandu, 1992*. Wilfrid Laurier University, Waterloo, Ontario, 49-59.

The paper describes the inception, implementation and possible future developments of the Snow and Ice Hydrology Project (SIHP), a joint Pakistan-Canada venture. Conceived in 1981, the project entered its first of five summer field seasons in 1985. The project was requested by Pakistan's Water and Power Development Authority (WAPDA), and was funded jointly by WAPDA and by Canada's International Development Research Centre. It involved several Canadian and other universities. In Canada the project was coordinated by the Cold Regions Research Centre of Wilfrid Laurier University. Recognizing that the Indus river is fed largely by melting ice and snow in the Karakoram Mountains and that there is insufficient understanding of the processes of snow and ice melt in this region, the SIHP's main objectives have been to set up within WAPDA a capability for undertaking relevant research, initiating and developing that research and laying the basis for a more operationally focused programme in the future. Field projects have included the setting up of meteorological monitoring stations at relatively high elevations, monitoring snowmelt in basins with and without glaciers and monitoring glacier ice melt in several basins in the Central Karakoram. Office work has included analysis of the data collected as well as the setting up of data bases and inventories of glacier coverage of the region. Technology transfer has been achieved through Canadian professors and students undertaking field work in Pakistan with their counterparts and through several Pakistani officers undertaking formal studies at Canadian universities. Based on the understanding and the experience gained through SIHP, the project has now entered an operational phase with involvement of the Canadian International Development Agency. Recommendations for future work are given.

Key words: Glaciers, hydrology, Himalaya.

H/143. Hildebrand, P.R., 1996. The Structure, Metamorphism and Magmatism Observed in a Transect through the Hindu Kush, Northwest Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 62.

The Hindu Kush range of Northwest Pakistan is the along the strike equivalent of the well exposed and geologically relatively well studied southern Karakoram Range (Searle, 1991) and also what probably lies beneath South Tibet. The range occurs in the axial zone of two converging crustal subduction systems (the northward subducting Indian plate and the southward subducting Tadjik-Tarim plate) which are marked by the most seismically active zone on earth, where earthquakes have been recorded to depths of 300 km.

The transect studied occurs to the northwest of Chitral and the Shyok Suture which separates the Kohistan island arc from the Asian margin, and runs along the roughly west-east flowing Lutkho River. It is bounded to the east by the Reshun fault, which is a reverse fault, with a top to the east sense of movement, and which places greenschist grade phyllites of the Asian margin onto relatively unmetamorphosed sediments of the Shyok Suture (Pudsey et al., 1985). The section contains metamorphosed and post-deformation garnet-tourmaline to mica leucogranite dykes and plutons.

The earliest recognizable deformation event (D1) occurred after the intrusion of the early porphyritic granites. D1 produced a penetrative WNW dipping schistosity (S1) that developed during and after the first recognizable metamorphic event (M1), which was up to garnet-staurolite grade. Near horizontal stretching lineation (L1) suggest that some strike-slip movement was associated with this early deformation.

Late deformation (D2) is spatially associated with the intrusion of leucogranites, and takes two forms, which may or may not be contemporaneous. The first form is associated with the intrusion of the large Gharam Chasma

leucogranite, pluton, which folds S1, producing horizontal N trending fold axes and crenulation lineations (L2), and has no effect on M1. The second form is associated with the emplacement of leucogranite dykes and sills during top the east movement along S1. Like the first form, this event produced folds with N trending, sub-horizontal fold axes (L2), suggesting that D2 involved dip-slip movement (as opposed to the D1 strike slip movement). However, this second form of D2 differs from the first in that it has a thermal overprint on M1, characterized by sillimanite-in and staurolite-out.

A limited amount of whole rock major and trace element geochemistry has been carried out on the Hindu Kush granites. The pre-deformation porphyritic granites are apparently different from the pre-collisional granites of the Karakoram, in that they are higher in K and Rb, and slightly lower in Sr, Ba and Ti. The post-deformation two mica-garnet-tourmaline leucogranites are typical peraluminous, near minimum crustal melt granites. They differ in their trace element compositions from the Karakoram post-collision Baltoro granites in that they are not similarly enriched in large ion lithophile elements and Th and Zr. The trace element compositions are more like the High Himalayan leucogranites such as those found at Langtang.

Key words: Structure, metamorphism, magmatism, Hindu Kush.

H/144. Hildebrand, P.R., 1997. Leucogranite gneisses in the Hindu Kush. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 47.

The Hindu Kush Range of Northwest Pakistan is the along strike equivalent of the well exposed and geologically relatively well studied southern Karakoram Range (Searle, 1991) and also what probably lies beneath South Tibet. The range occurs in the axial zone of two converging crustal subduction systems (the northward subducting Indian plate and the southward subducting Takjik-Tarim plate) which are marked by the most seismically active zone on earth, where earthquakes have been recorded to depths of 300 km.

Leucogranites in the Hindu Kush occur within highly graphitic, pelitic metasediments with minor amounts of calc-silicate and amphibolite. The pelitic sediments have been subjected to an early metamorphic event of garnet-staurolite grade. The leucogranites are associated with a later thermal metamorphism, characterized by sillimanite, andalusite and sometimes K-feldspar. This later metamorphism and leucogranite emplacement is also associated with late thrusting movement along faults.

The leucogranites occur as a large pluton (the Gharam pluton, Calkins et al., 1981), deformed bodies within migmatites, dykes and pegmatites. The structural relationships between these varieties are complex and difficult to interpret, although it appears that they are all broadly contemporaneous. They are peraluminous and consist of quartz, K-feldspar, plagioclase, biotite, muscovite and sometimes, tourmaline and/or garnet. Although the structural relationships suggest a common origin between the garnet ± staurolite schists, the migmatites and the varieties of leucogranites, geochemistry suggests that this is not the case. In particular the Sr isotope ratios for the Gharam Chasma ($^{87}\text{Sr}/^{86}\text{Sr}=0.720\text{--}0.742$). Interestingly these Sr ratios for the pluton are similar to those from the Baltoro pluton (Searle et al., 1992), suggesting a common origin.

Key words: Leucogranites, Hindukush.

H/145. Hildebrand, P.R., 1998. The Hindu Kush of Pakistan: mountain range evolution from active margin to continent-continent collision. PhD thesis, Oxford University, England.

Key words: Tectonics, orogeny, Hindukush.

H/146. Hildebrand, P.R., Noble, S., Searle, M., Parrish, R. & Shakirullah, 1998. Tectonic significance of 24 Ma crustal melting in the eastern Hindu Kush, Pakistan. *Geology* 26, 871-874.

Northward-directed subduction has continued beneath the Hindu Kush from the Mesozoic, when the region formed part of the southern margin of Asia, until today. The Kohistan arc was accreted at ca. 100 Ma, followed by the Indian plate at 54–50 Ma. After the India-Asia collision, a regional crustal-melting event occurred at ca. 25–21 Ma to the east of the Hindu Kush in the Karakoram Range, producing the Baltoro pluton. In the eastern Hindu Kush Range, most of the granitoids appear to be subduction-related plutons that predate the India-Asia collision. However, the Gharam Chasma pluton is a two-mica (± garnet ± tourmaline) leucogranite that has intruded into staurolite-grade schists and (sillimanite ± K-feldspar)–grade migmatites. U-Pb ages on monazite, xenotime, and

uraninite from undeformed samples of the Gharam Chasma pluton and a leucogranite dike that crosscuts the migmatites indicate that crustal melting occurred at ca. 24 Ma, synchronous with the Baltoro melting event. This age also provides an upper limit on the age of the regional staurolite-grade metamorphism in the eastern Hindu Kush.

Key words: Tectonics, crustal melting, granite magmatism, Hindukush.

H/147. Hildebrand, P.R., Searle, M.P., Noble, S.R. Parrish, R.R., Shakirullah, 1998. The tectonic significance of 24 Ma crustal melting in the eastern Hindu Kush, Pakistan. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 77-79.

Northward directed subduction has taken place beneath the Hindu Kush from when it formed part of the southern margin of Asia in the Mesozoic, and still continues today. Accretion of the Kohistan arc took place at about 100-85 Ma, followed by the Indian plate at 55-50 Ma. After the India-Asia collision, a regional crustal melting event occurred around 25-21 Ma to the east of the Hindu Kush in the Karakoram range, producing the Baltoro pluton. In the eastern Hindu Kush range, most of the granitoids appear to be pre-India-Asia collision, subduction related plutons. However, the Gharam Chasma pluton is a two mica garnet $\pm$ tourmaline leucogranite that has intruded into staurolite grade schists and sillimanite K-feldspar grade migmatites.

U-Pb ages on monazite, xenotime and uraninite from undeformed samples of the Garam Chasma pluton and a leucogranite dyke that cross cuts the migmatites indicate that crustal melting took place in the eastern Hindu Kush at around 24 Ma. This is contemporaneous with the event that produced the Baltoro pluton in the Karakoram, 400 km to the east. This extends the range and confirms the importance of widespread crustal melting in the southern margin of the Asian plate around the earliest Miocene.

The presence of lamprophyres with the same early Miocene age as the Baltoro pluton support the possibility of a mantle heat input to promote the crustal melting in the Karakoram [8]. In the eastern Hindu Kush, there is no indication of any lamprophyres or other potentially mantle derived melt that could potentially have a similar 24 Ma age, so alternative heat sources are required. The leucogranites in the Gharam Chasma area are spatially associated with sillimanite grade metamorphism and migmatites. Consequently, a more likely model for the generation of these leucogranites would appeal to peak metamorphism and decompression provide the heat and conditions necessary for melting. Such a model would be similar to models proposed for the generation of the High Himalayan leucogranites.

Key words: Tectonics, crustal melting, Garam Chasma granite, Lamprophyre, Hindukush.

H/148. Hildebrand, P.R., Searle, M.P., Shakirullah, Khan, A.Z. & Heijst, H.J.V., 2000. Geological evolution of the Hindu Kush, NW Frontier Pakistan: active margin to continent-continent collision zone. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.) *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 277-293.

A geological map of the eastern Hindu Kush, northwest of Chitral, Northern Pakistan, is presented. The lithologies are placed into two main categories, divided by the Tirich Mir Fault Zone. To the northwest, the units of the eastern Hindu Kush are dominated by monotonous sequences of graphite-rich pelitic rocks. Southeast of the fault, the phyllites and diamictites are thought to be lateral equivalents of the Northern Sedimentary Belt of the Karakoram. A structural analysis of the area studied identifies a major, early deformation phase which is usually characterized by tight to isoclinal folding with a well developed axial-planar schistosity. This deformation is thought to have been related to the northward-directed subduction and accretion beneath the southern margin of Asia during the Mesozoic, and may have taken place over a considerable period of time. A major phase of crustal melting at c. 24 Ma generated migmatites and biotite + muscovite $\pm$ garnet $\pm$ tourmaline leucogranites (including dykes and the Gharam Chasma pluton). This age is comparable to that of the Baltoro pluton in the Karakoram to the east, confirming the regional importance of crustal melting along the southern margin of the Asian plate during the earliest Miocene. The crustal melting was associated with thrusting and folding of the earlier schistosity. Subhorizontal stretching lineations indicate a phase of strike-slip deformation that is thought to have been associated with anticlockwise rotation of the regional foliation strike from E to NE and N after the emplacement of the Gharam Chasma pluton at c. 24 Ma. This deformation and rotation was probably a directed result of the northward-moving Indian plate forcing Kohistan to indent into Asia, resulting in a left-lateral transpressional tectonic environment.

which remains today. The anomalous height of the Tirich Mir massif, relative to other peaks in the Hindu Kush and the nearby Hindu Raj, may be accounted for by the onset of this transpression.

Intensely active seismicity to depths of 300 km beneath the Hindu Kush is associated with seismic shear wave velocities that are significantly faster than those beneath Tibet, where earthquake occurrence is restricted to the upper crust, and previous geophysical studies indicate elevated thermal conditions and possible crustal melts. U-Pb ages suggest that post-India-Asia collision crustal melting beneath the Hindu Kush is restricted to c. 24 Ma, whereas in the Karakoram, the record is both more voluminous and more continuous from c. 37 to c. 9 Ma. These observations reflect major differences in the thermal histories of these regions, where the relatively cooler condition beneath the Hindu Kush are associated with continental subduction-related seismicity.

Key words: Tectonics, collision, Himalaya.

H/149. Hiller, K. & Ahmad, J., 1989. A subthrust play in the southeastern Potwar Depression. *Pakistan Journal of Hydrocarbon Research* 1, 14-17.

Key words: Geology, structure, Potwar depression.

H/150. Hirayama, J., Karim, T., Okamura, N., Hada, S. & Sato, M., 1995. A geological study and some feasibility considerations for the production of fused magnesium fertilizer (FMP) in Pakistan. *Proceedings of Geoscience Colloquium; Geoscience Lab, Geological Survey of Pakistan, Islamabad*, 11, 3-147.

Fused magnesium phosphate (FMP) is a phosphatic fertilizer consisting of P_2O_5 , MgO, CaO, and SiO_2 . It is ordinarily produced by fusing and quenching a mixture of quality-ore of phosphate containing more than 30 % of P_2O_5 and serpentinite. Substituting serpentinite as the material by magnesite is considered to not only make the utilization of low-grade ore of phosphate in the Hazara area possible but also promote the exploitation of under-developed magnetite in the same area. To verify the idea, a JICA team consisting of a mining engineer, a manufacturing engineer, and a fertilizer and marketing specialist was invited to conduct an extensive survey on mining costs of raw materials, production costs and the marketability of FMP under a close cooperation with Geoscience Laboratory, Geological Survey of Pakistan between May 23 and June 12, 1994. The conclusion of the study is that the manufacturing of FMP with 20% of P_2O_5 is feasible in Pakistan, if the following requirements are met:

1. The effectiveness of FMP be verified through experiments for various crops to be conducted by competent authorities;
2. Infrastructures required for the project, including access roads to mining sites and power supply, be consolidated by the Pakistani authorities concerned;
3. The Pakistani governments, Federal and Provincial, actively participate in implementing this project to extend necessary supports;
4. Financial and technical assistance for opting this project be offered from external resources including JICA.

Key words: Phosphate, Fused magnesium fertilizer.

H/151. Hirayama, J. & Mononobe, S., 1992. Pakistan is an underdeveloped treasure land-a perspective of new exploitation for unused mineral resources. *Proceedings of Geoscience Colloquium; Geoscience Lab, Geological Survey of Pakistan, Islamabad*, 3, 29-34.

Pakistan has got mineral resources which need to be exploited. This account gives information on reserves and potential for industrial use of Kakul phosphorite deposits and Kumhar magnesite deposits.

Key words: Exploitation, mineral resources, Pakistan.

H/152. Hirayama, J., Mononobe, S. & Karim, T., 1995. A proposal for the use of phosphorite and magnesite in Hazara division, NWFP, Pakistan. *Geologica* 1, 97-103.

Key words: Phosphates, Hazara.

H/153. Hochleitner, R., Weiss, S. & Weerth, A., 1991. Neu mineralfunde aus Pakistan und Afghanistan. *Lapis* 16(3), 15-16.

Stibiotantalite from Stak-Nala, Pakistan and tremolite from Nooristan, Afghanistan, are briefly described in this account.

Key words: Minerals, Afghanistan, Pakistan.

H/154. Hoffstetter, R., 1965. Les serpents du Neogene du Pakistan (Couches des Siwaliks). *Bulletin de la Societe eologique de France*, 7(6), 467-474.

Key words: Palaeontology, Siwaliks.

H/155. Holland, T.H., 1907. A preliminary survey of certain glaciers in the northwest Himalayas: Introduction. *Geological Survey of India, Records*, 35(3), 123–128.

Key words: Glaciers, Himalaya.

H/156. Holmes, D.A., 1968. The recent history of the Indus. *The Geographical Journal* 134, 367-382.

Key words: Geomorphology, Indus Rivers.

H/157. Hood, J.W., Khan, L. & Jawaid, D.K.H., 1970. Water resources and related geology of Dera Ismail Khan District, West Pakistan, with reference to the availability of groundwater for development. *US Geological Survey, Water Supply Paper* 1608-K, 74p.

Key words: Groundwater, water resources, geology, D I Khan.

H/158. Hora, S.L., 1936. The fish of Chitral. *Records Indian Museum*, 36, 307-310.

Key words: Palaeontology, Chitral.

H/159. Hora, S.L., 1937a. Fossil fish remains from the Saline Series of North western India. *Geological Survey of India, Report* 72(2), 188-194.

Key words: Palaeontology, Himalaya.

H/160. Hora, S.L., 1937b. Distribution of Himalayan fishes and its bearing on certain palaeogeographical problems. *Indian Museum, Records*, 39, 251-259.

Key words: Palaeontology, Himalaya.

H/161. Houston, C. & Bates, R., 1955. K-2 the Savage Mountain. Collins, London, 192p.

This account contains general geographic details of the K2 Mountain, the second highest after Everest.

Key words: K-2, Karakoram.

H/162. Howells, M., 1976. The Biafo Peaks. *Mountain* 49, 38-41.

Key words: Glaciers, orogeny, Biafo.

H/163. Hubbard, M.S. & Spencer, D.A., 1990a. Indian plate deformation between Babusar pass and Nanga Parbat, NW Himalaya, Pakistan. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 22.

The Nanga Parbat region of the northwest Himalaya has seen a complex tectonic history from the subduction of the oceanic India plate rocks beneath the Kohistan island arc; to collision of continental Indian plate rocks with Kohistan and southeast directed thrusting of Kohistan along the Main Mantle Thrust (MMT); to rapid exhumation of the Nanga Parbat massif, possibly by a combination of thrust faulting and erosion. We present preliminary results of a structural analysis of Indian plate rocks between Babusar Pass and Nanga Parbat. This study is aimed at a better understanding of the deformational history of this region and will help provide the much-needed geologic constraints for tectonic models of the area. Specifically we hope to distinguish deformation which is associated with the early collisional processes from later deformation which may be related to the exhumation of the Nanga Parbat massif.

A traverse was made from Babusar Pass eastward to the Barai valley, the Toshe Gali area and north to the Indus valley at the village of Bunar. Work was predominantly within the Indian plate where lithologies are similar to those in the adjacent, upper Kaghan Valley. Gneiss, granitic-gneiss, and metapelite are overlain by a sequence of amphibolite, marble, and quartzite. In situ granitization of probable Himalayan age has affected the structurally lower units of the area. A pervasive stretching lineation is oriented EW to S50W with a shallow plunge. The origin and age of this lineation is, as yet, unknown. Folds are found from hand sample-scale to nappe-scale and the orientations of fold axes are parallel to the stretching lineations suggesting rotation of folds during the stretching deformation. Strike of schistosity is $\pm$ N45-55E in the western part of the study area, but becomes more NS toward the west, near the contact with the Nanga Parbat gneiss. The stretching lineation is less pronounced in the Nanga Parbat gneiss. Future fieldwork will target: the possibility of late, brittle faulting in the area; the geometry of the nappe-scale; the relationship of the stretching lineation to MMT deformation or to the exhumation of the Nanga Parbat massif.

Key words: Deformation, Indian plate, MMT, Kohistan, Himalaya, Karakoram.

H/164. Hubbard, M.S. & Spencer, D.A., 1990b. WSW-trending deformation between Babusar pass and Toshe Gali area, northern Pakistan. Geological Bulletin, University of Peshawar 23, 101-110.

The Himalaya and Karakoram Mountain ranges of northern Pakistan are the product of multiple deformational phases from continental collision events that trapped the Kohistan island arc between the Asian and Indo-Pakistan plates to the development and emergence of the Nanga Parbat syntaxis. Fieldwork along the Main Mantle Thrust (MMT) and within the Indo-Pakistan plate rocks in the area between Babusar Pass and Toshe Gali was aimed at an understanding of the kinematic relationship between these deformational phases. The MMT is the suture between rocks of the Indo-Pakistan plate and rocks of the Kohistan sequence. Workers in adjacent areas have found evidence that the MMT has southeast-directed transport of the Kohistan rocks over the Indo-Pakistan plate. In the study area that deformation has been overprinted by a ductile fabric that has top-to-the-WSW sense of shear on a shallowly WSW-plunging stretching lineation. This ductile fabric is pervasive at the MMT contact, within the Indo-Pakistan plate cover sequence below the MMT, but decreases in intensity in the Indo-Pakistan plate basement rocks and the Nanga Parbat gneiss. If this ductile fabric represents normal fault movement then this deformation may have been responsible, in part, for the exhumation of the Nanga Parbat massif.

Key words: Deformation, Indian plate, MMT, Kohistan, Himalaya, Karakoram.

H/165. Hubbard, M.S. & Spencer, D., 1991. Top to the WSW displacement along the MMT, Babusar pass Nanga Parbat region, Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 49.

The Himalaya/Karakoram mountains of northern Pakistan are the product of multiple deformational phases from continental collision events that trapped the Kohistan island arc between the Asian and Indian plates, to the development and emergence of the Nanga Parbat Syntaxis. Fieldwork along the Main Mantle Thrust (MMT) and within Indian plate rocks in the area between Babusar Pass and Toshe Gali was aimed at an understanding of the kinematics and temporal relationship between these deformational phases. The MMT is the suture between the Indian plate rocks and rocks of the Kohistan sequence. Workers in adjacent areas have found evidence that the MMT had southeast directed transport of the Kohistan rocks over the Indian plate. In the study area, that deformation has been overprinted by ductile fabric with a shallowly WSW-plunging stretching lineation. Quartz grain shapes, asymmetric augen, and shear bands suggest a top-to-the-WSW sense of shear. This ductile fabric is pervasive at the MMT contact, within the Indian plate cover sequence below the MMT, but decreases in intensity in the Indian plate basement rocks and the Nanga Parbat gneiss. This top-to-the WSW sense of shear represents normal, or extensional, shear relative to the Nanga Parbat massif. If there has been sufficient displacement across this zone then the WSW- trending deformational phase may have been responsible, in part, for the exhumation of the Nanga Parbat massif. Shallowly WSW-plunging stretching lineations have been reported in the adjacent areas to the northeast by Butler et al., 1989 and to the west by Greco, 1989.

Key words: Deformation, Asian plate, Indian plate, MMT, Kohistan.

H/166. Hubbard, M.S., Spencer, D.A. & West, D.P., 1995. Tectonic exhumation of the Nanga Parbat massif, northern Pakistan. *Earth and Planetary Science Letters* 133, 213-225.

Structural analysis in the Nanga Parbat region of northern Pakistan indicates that extensional deformation has been, in part, responsible for the exhumation of gneissic rocks of the Indian plate basement complex that dominates the Nanga Parbat massif. This massif has been mapped as a syntaxis at the boundary between the Indian and Asian plates in the northwest Himalaya and has received recent attention for evidence of rapid exhumation within the last 10 Ma. Field work along the Main Mantle Thrust (MMT) and within the Indian plate rocks in the area between Babusar Pass and Toshe Gali, southwest of the peak of Nanga Parbat, provided us with evidence from shear fabrics and a shallowly WSW-plunging stretching lineation for a dominant phase of extensional deformation. During this deformation rock of the Kohistan sequence and the Indian plate cover sequence moved to the WSW relative to rocks of the Indian plate basement including the Nanga Parbat gneiss. A post-metamorphic ductile shear fabric pervades the MMT contact, the Indian plate cover sequence below the MMT, but decreases in intensity in the Indian plate basement and the Nanga Parbat gneiss. Using $^{39}\text{Ar}/^{40}\text{Ar}$ geochronology of hornblendes we have constrained the age of pre-deformational, amphibolite facies metamorphism to be $\leq 40\text{--}56$ Ma. Published cooling ages from the Babusar Pass region further document that the extensional deformation was completed by ~ 20 Ma. We interpret this ductile, extensional shear as the mechanism responsible for significant tectonic exhumation of the gneissic and granitic rocks of the Nanga Parbat massif.

Key words: Tectonics, structure, exhumation, Nanga Parbat, Himalaya.

H/167. Hudleson, W.H., 1902. Fossils from the Hindu Kush. *Geological Magazine, New Series*, Decade 4, 9, 49-58.

Key words: Palaeontology, Hindukush.

H/168. Hughes, R.E., 1984. Yasin Valley: The analysis of geomorphology and building types. In: Miller, K. J. (Ed.), *The International Karakoram Project 2*, 253-288. Cambridge University Press.

The author's previous paper in these proceedings attempted to define a methodology for the study of building. This involves the examination of building construction, behavior and decay with all aspect being related to the environment.

A second theme showed that structural deformations and material decay if not remedied by "maintenance", "restoration" or "conservation" inevitably significance to the people than the less frequent, though more catastrophic, events such as earthquake and floods.

The intention of this paper is to show how the methodology was applied to the study of the Yasin Valley. It firstly concentrated on the geomorphology and relates to the inhabitants' awareness of, and response to, natural hazards. The buildings are then examined in detail: materials, construction, structural performance and decay. Methods for improving the houses are then discussed.

Of all the field studies undertaken by the author, this is considered the most important as there is a real and practical application, in conjunction with the UNDP development proposals, for benefiting the inhabitants.

Key words: Geomorphology, environment, disaster, floods, earthquakes, Yasin, Gilgit.

H/169. Humayun, M., 1985a. A rapakivi granite occurrence from Swat. Geological Bulletin, University of Peshawar 18, 198-199.

The Rapakivi granites of Swat are locally developed facies within large lensoidal bodies of biotite granites occurring in a mylonite zone at the base of the Swat granitic gneisses (Humayun, 1985). Large bodies occur just south-east of Manglaur and extending north of Dangram to Shamelai (Humayun, 1985, Fig. 1). They show intrusive relations with associated mafic rocks. The biotite granites have been tourmalinized in places. These appear to be the first known metamorphosed Rapakivi granites and the first reported occurrence from Pakistan.

The typical rapakivi texture consists of euhedral pinkish phenocrysts of orthoclase mantled by plagioclase. Unmantled ovoids and euhedral phenocrysts of orthoclase are also common. The biotite granites are apparently undeformed in the centre of a typical body, such as that at Shamelai, but show incipient metamorphism, mortar texture and recrystallization of biotite. On the contacts, however, the granites are mylonitized. A spectacular spotted gneiss results when a mylonite of rapakivi granite is seen in a section perpendicular to the lineation.

Key words: Rapakivi granite, Swat, Himalaya.

H/170. Humayun, M., 1985b. Tectonic significance of mylonites from Mingora, Swat. Geological Bulletin, University of Peshawar 18, 137-146.

Rocks below the Swat gneisses, formerly thought to be a single unit, are a varied assortment of thrust slices consisting of rapakivi granites, sillimanite gneisses, marbles, and schists, in a mylonite zone. This zone is interpreted as the base of a large thrust. Thus, the overlying Swat gneisses and associated schists constitute a crystalline thrust sheet or nappe (?), that probably formed in response to the obduction of the Kohistan island arc.

Key words: Tectonics, mylonite, Swat, Himalaya.

H/171. Humayun, M., 1986. Petrology of the Swat amphibolites and the development of a "lesser Himalayan" Basin. Geological Bulletin, University of Peshawar 19, 83-100.

A geochemical study of amphibolites from the lower Swat valley, Lesser Himalayas, identifies a suite of continental flood basalt erupted over a gneissic basement of probable Late Cambrian age. Fractionation of clinopyroxene and plagioclase controlled chemical variation in the protolith. Metamorphism, retrogression and granitic intrusion strongly affected the alkali and mobile trace element contents. The magmatism was probably associated with the early rifting stage of the development of Paleotethys. Subsidence of the rifted margin followed the extrusion of the basalt, and arkosic continental sediments gave way to marine carbonates and clastics. The carbonates belong to a reefoid association of Middle Paleozoic age. The basin extended over much of present-day northwestern Pakistan with probable analogues along the length of the Lesser Himalayas.

Key words: Petrology, amphibolite, Lesser Himalayan basin, Swat.

H/172. Humayun, M., Jan, M.Q. & Khan, M.J., 1987. A review of "Evidence of an incipient Paleozoic ocean in Kashmir, Pakistan" by K.A. Butt, M.N. Chaudhry & M. Ashraf. Kashmir Journal of Geology, 5, 121-126.

Geochemical data presented in the paper under review is shown to be erroneous. Severe overestimation of Al₂O₃ and underestimation of TiO₂ and MnO, with evidently altered alkali and silica contents, render the analyses invalid for proposing a new tectonic model. The treatment does not prove the stated conclusion that the Punjal basalts are

MORB, and cannot even prove whether the rocks are tholeiitic, alkaline or otherwise. Finally, the rocks are claimed to be primitive, which we do not agree with.

Key words: Paleozoic, oceanic rocks, Panjal volcanic, tectonics, Kashmir.

H/173. Humayun, M., Mayeda, T.K., Clayton, R.N., Petterson, M.G. & Windley, B.F., 1991. Oxygen isotope study of the Kohistan Batholith. Abstracts, Fall Meeting, American Geophysical Union.

The Mesozoic Kohistan island arc of northern Pakistan represents a major addition of juvenile crust to the Asian landmass. The arc was formed at a convergent plate margin by northward subduction of the Neotethys ocean. The Kohistan sequence is unique in that it is tilted to expose a complete section through the crust of a fossil island arc. The Kohistan sequence comprises a lower crust of mafic amphibolites and mafic-ultramafic granulites. This is overlain by a mid-crustal batholith, an extension of the Trans-Himalayan batholith, which is intrusive in its upper reaches into greenschist grade metavolcanics and metasediments.

We present oxygen isotopic data on the Kohistan batholith with evidence regarding the nature of crustal differentiation in island arcs. Geochronological work shows the rocks of the batholith to have formed in three discrete phases of magmatism. Stage I: trondjemites and K-rich diorites emplaced ca. 100 m.y., and subsequently metamorphosed; Stage II: gabbros, diorites and granodiorites emplaced 85-40 m.y., and constituting about two thirds of the batholith; Stage III: peraluminous leucogranites emplaced ca. 30 m.y., as minor dykes and veins. Diorites and granitoids from Stages I+II have $\delta^{18}\text{O} = 6.7\text{--}7.7\text{‰}$. Sr and Nd isotopic characteristics of mantle derived materials. We believe that these rocks formed by partial melting of the juvenile arc crust in Kohistan, and that the Sr and Nd isotopic and trace element ratios are entirely inherited from the (subarc) mantle source. We consider the higher $\delta^{18}\text{O}$ to be the result of a mixture of submarine weathered volcanic (+ sedimentary ?) material ($\delta^{18}\text{O} = 10\text{‰}$) with a plutonic component ($\delta^{18}\text{O} = 6\text{--}6.5\text{‰}$) in the lower crustal sources of the batholith. Such a source is conceivably found in the amphibolite belt underlying the batholith.

Stage III peraluminous Parri leucogranites pose something of an enigma. These rocks postdate collision of Kohistan with the Indian plate, and are mineralogically similar to and coeval with the Higher Himalayan leucogranites (HHL). Isotopic characteristics distinguish these rocks (initial $^{87}\text{Sr}/^{86}\text{Sr} = 0.7052$ and $\delta^{18}\text{O} = 8.4\text{--}9.2\text{‰}$) from HHL granites (initial $^{87}\text{Sr}/^{86}\text{Sr} = 0.727\text{--}0.785$ and $\delta^{18}\text{O} = 10.9\text{--}14.0\text{‰}$). It is quite obvious that the Kohistan leucogranites formed by partial melting of arc crustal materials, too. The slightly higher initial $^{87}\text{Sr}/^{86}\text{Sr}$ (0.7052 VS. 0.7044) can be entirely accounted for by Rb decay during residence in the arc source (> 10 m.y.), while the higher $\delta^{18}\text{O}$ may result from isotopic exchange between the fluid-rich leucogranite melts and country-rock metasediments.

The Kohistan batholith provides an excellent example of intra-crustal differentiation in island arcs, without the participation of pre-existing continental crust. Juvenile mafic crust is remelted during basaltic underplating of the lower crust to form granitic batholiths. Felsic crust made in island arcs is subsequently laterally accreted to the edges of continental plates, and can be incorporated in the interiors of continents by collisional events, as in the case of the Kohistan arc.

Key words: Kohistan batholith, geochemistry, isotopes.

H/174. Humayoon, S., 1976. Field report on the geology of Ayubia. M.Sc. Thesis, Punjab University, 90p.

Key words: Geology, Ayubia, Hazara.

H/175. Husain, V. & Bilquees, R., 1991. Developing Pakistan's mineral resources and mineral industry. Proceedings, First SEGMENTE Symposium, Peshawar, 17-26.

Key words: Mineral industry, Pakistan.

H/176. Husain, V., Bilquees, R. & Nasreen, S., 1989. Petrology and industrial application of Nizampur limestones, NWFP, Pakistan. Pakistan Journal of Scientific and Industrial Research 32, 11, 775-00.

Nizampur limestone samples have been studied for their petrology and geochemistry. The results of these studies indicate that Nizampur limestones are suitable for cement, chemical, paper and other industries.

Key words: Petrology, limestone, Nizampur, NWFP.

H/177. Husain, V., Ghani, A. & Qureshi, K., 1994. Vast export potential in dimension stone sector of Pakistan. Abstracts, Second SEGMIITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, p.16.

In recent years there has been the development of a "New Stone Age" with the increasing use and production of dimensionstone. Its demand in the international market is increasing with an average of 6% per year. Another important development has been the rise in production and export from developing and newly industrialized countries. In 1990 India and China contributed 7.4% and 5.9% to the total world exports of dimensionstone respectively. This industry plays most important role in the economy of even rich and developed country like Italy, which has 25% share in total global exports of dimension stone.

Despite huge deposits of large varieties of marble, granite and other building stones occurring in Northern areas, North West Frontier, Sindh and Balochistan provinces of Pakistan, dimensionstone industry remains backward, unorganized and unprotected by the government. Thus the exports of mostly raw blocks and small manufactured items from Pakistan is only 30 million US\$ per year, which can touch the mark of 3 billion US\$ per year in next 5-7 years, provided following steps are taken on urgent basis. Due importance is given to the buildingstone mining and manufacturing industry by the government.

Making and implementing clear cut national dimensionstone policy to encourage modern mining and processing methods and to attract non-traditional and big local and foreign investment in this sector. Providing soft term loans and other facilities as India, China and Brazil have done to make export oriented development of dimensionstone industry in recent years.

Providing road, rail network and other infrastructure including supply of electricity and water in the marble granite mining and processing districts. Close coordination among dimensionstone related businessmen and professionals in Pakistan for organizing seminars and exhibitions in the country and abroad and to raise issues confronting the dimensionstone industry before local and federal governments.

Key words: Dimension stones, export potential.

H/178. Husain, V., Haneef, M., Khan, H. & Siddiqi, F., 1990. Barite deposition near Haripur, Hazara. In: Siddiqi, F., Husain, V., Kaifi, Z. & Ghani, A. (Eds.), Proceedings, First SEGMIITE Conference on Industrial Minerals, March 1990, Peshawar, 22-28.

A barite district about 10 km north of Haripur occupies about 30 km² area. About a dozen vein deposits of barite occur in quartzites and dolomites. Regional analysis of this district suggests that barite occurs as veins and lenses in fractures and breccia zones. Field and laboratory evidence indicates that the barite deposits have good potential and are suitable for chemical paint and other industries. The occurrence is described in detail, together with stratigraphy, and chemical analyses of six barite ores and five of their associated rocks.

Key words: Barite, Haripur, Hazara.

H/179. Husain, V., Jan, N., Bilquees, R. & Ahmad, N., 1990. Petrology, mineralogy and origin of Hazara phosphates. In: Siddiqi, F., Husain, V., Kaifi, Z. & Ghani, A. (Eds.), Proceedings, First SEGMIITE Conference on Industrial Minerals, March 1990, Peshawar, 45-52.

Sedimentary phosphate deposits of Hazara have proven reserves of over 8 million tons. The phosphatic beds occur in two horizons-cherty dolomite (Abbottabad Formation) and siltstones (Hazira Formation) of Early Cambrian age. Tectonic activity resulting in highly complex structural features have disrupted and segmented the deposits. Two distinct types of phosphorite are common in the area; very fine-grained phosphorite and ovel-shaped pellets. The deposits may have formed authigenically by direct precipitation of fine-grained mud (carbonate fluorapatite), which subsequently modified into pellets. Deposition seems to have taken place in shallow waters within low paleolatitudes like major phosphorite deposits of the world.

Key words: Mineral deposits, phosphate, Abbottabad

H/180. Husain, V., Jan, N. & Siddiqi, F., 1990. Mineralization of Kumhar magnesite, Hazara, NWFP. (short communication) Pakistan Journal of Scientific and Industrial Research 33(9), 325.

Key words: Mineralization, magnesite, Hazara.

H/181. Husain, V., Khan, H., Husain, M., & Bilqees, R., 1997. Composition, origin and economic potential of Kakul, Lagarban and Tarnawai Phosphorite deposits of Hazara, Pakistan. Pakistan Journal of Scientific and Industrial Research, 40(1–4), 6–40.

The carbonate fluorapatite, dolomite, calcite, quartz, hematite, magnetite, feldspar, kaolinite, montmorillonite and illite were important minerals identified by XRD and microscopy. Apatite mainly occurs as microspherite and oolitic or disc shaped pellets of variable size. The P₂O₅ content of these phosphorites range from 22 to 36% with major impurities of silica, magnesium, iron oxides, alumina and alkalis. All field and laboratory data generated on these phosphorites suggest that Hazara phosphorites were formed authigenically and underwent various phases of deformation, variable degree of weathering and recrystallization to produce pelletal or granular phosphorites.

Key words: Petrography, economic geology, phosphorites, Hazara.

H/182. Husain, V., Khan, H., Qureshi, K., Ahmad, N. & Ali, I., 1991. Mineralogical and analytical studies of the southwestern Tanol Barite District, Hazara, Pakistan. Pakistan Journal of Scientific and Industrial Research 34, 2-3, 65-00.

The Southwestern Tanol mineralized area north of Haripur is one of the most promising areas of barite deposits in NWFP. Several vein type barite deposits occur in Lower Cambrian quartz and dolomite of Abbottabad Formation. Barite veins have a direction that is parallel to the general trend to the host and associated rocks. Barite, quartz, calcite, feldspar, pyrite, illite and chlorite were identified by XRD and microscopy. Barite and quartz are predominant. Some textural features like the absence of primary bedding, coarse grain size of barite and cherty quartz with cross cutting relationships suggest an epigenetic origin. To date, Kag deposits have been mined by open pit method to 300 feet below the surface and the ore veins are expected to continue further deep. The mineralization occurs in lens shaped bodies having strike length of several hundred meters. The barite content of vein deposits range from 53-97% BaSO₄ and impurities include quartz, calcite, dolomite, pyrite and limonite. The physical and chemical characteristics of the barite from this district suggest that these barites are suitable for drilling and chemical industries. They can also be used as filler in paint, plastic, paper and rubber industries.

Key words: Mineral deposits, Barite, Hazara.

H/183. Husain, V., Khan, H. & Siddiqi, F.A., 1990. Barite deposition in Haripur, Hazara. Abstracts, First SEGMIITE Conference on Industrial Minerals, Peshawar, p.6.

Key words: Barite, sedimentary rocks, Haripur, Hazara.

H/184. Husain, V., Khan, M., Husain, M. & Siddiqi, F.A., 1994. Petrochemical and flotation studies of barite deposits near Haripur, NWFP, Pakistan. Sindh University, Research Journal 26, (1&2), 145-156.

The vein type barite deposits occur in Kag, Aluli and Darwaza near Haripur in NWFP. The coarse and interlocking grains of barite are hosted in quartzite and dolomite belonging to Abbottabad Formation. The barite is mostly whit to creamy, dark gray to brown in color. Barite textures vary systematically from coarse bladed to finely crystalline or massive. The specific gravity varies from 4.26 to 4.63. It contains 75-92% BaSO₄. Quartz, calcite, dolomite, pyrite, goethite and hematite are the principal impurities.

The purpose of the present study is to describe Kag, Darwaza and Aluli barite deposits from the economic point of view. The description includes the petrological, mineralogical and chemical characteristics of the ore. The flotation studies have also been carried out on these barite samples and results have been discussed.

Key words: Petrochemistry, barite, Haripur, Hazara.

H/185. Husain, V., Khan, M.M. & Siddiqui, F.A., 1990. Vein type barite deposits in Kag, Alulai and Dawaza near Haripur, NWFP, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 9-10.

Vein type barite deposits occur in Kag, Aluli and Darwaza near Haripur, NWFP. Coarse and interlocking of grains of barite are hosted in dolomite and quartzite of Tanawal Formation. The barite rock is mostly grayish white to snow-white and massive, having a specific gravity that averages about 4.0 and contains 65-98 percent BaSO₄. Quartz, calcite, dolomite and iron oxide are the principal impurities. Preliminary flotation studies have indicated that quartz and other impurities can be removed from low-grade barites.

Key words: Barite, Tanawal formation, Hazara.

H/186. Husain, V., Sultan, S., Bilqees, R., Mateen, A. & Khan, B., 1993. Petrographic and geochemical studies of some phosphorite deposits of Hazara, Pakistan. Pakistan Journal of Scientific and Industrial Research 37, 6-7, 245-00.

Samples from Kakul mine and trenches of several phosphorite deposits were studied. These phosphorites occur in gradational contact with siltstone, dolomite and chert belonging to Abbottabad Cambrian System. Thinly bedded phosphorites occur mostly as pellets and microspherulites, while the intraclasts and pseudo-oolites are rare. Fluorapatite is abundant in all the samples, while quartz, calcite, dolomite, feldspar, illite and hematite occur in minor phases. These phosphorites are primary marine formed mostly by direct precipitation. Recrystallization is due to intense diagenesis, whereas ferruginization suggest weathering of phosphatic horizons in Hazara.

Key words: Petrography, geochemistry, phosphorites, Hazara.

H/187. Husnain, T. & Chaudhry, M.N. 1997. Strata-bound volcanic hosted gold, silver and sulphite mineralization occurrence in Paleocene-Eocene Dir volcanic group, District Dir, NWFP, Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Dir volcanic group which hosts Au, Ag and sulphide mineralization is composed of calc alkaline volcanic flows, tuffs, agglomerates and ignimbrites. The volcanic and volcanoclastic horizons are often intercalated with and are underlain by shallow marine meta-argillites and quartzites. Therefore, at least the lower part of the Dir volcanic group is submarine. Upper part was deposited under marine to sub areal conditions. The age of this group is constrained by Eocene larger benthic Foraminifera which occur in the slightly metamorphosed marl and shales at the base of this group. Dir volcanic group represents the final stages in the magmatic/volcanic evolution of the Kohistan island arc terrain (Searle, 1991).

Although the Kohistan island arc itself was intra oceanic yet this volcanic group was laid down after the suturing of India with Asia sandwiching the Kohistan island arc. Therefore, these eruptions are in the nature of Andean type continental margin formed after the collision of Kohistan with Asia and closing of the Shyoke suture zone.

The rock which hosts gold, silver and copper anomalies occurs within the Dir volcanic group. The Dir volcanic group is composed of a lower Bawal Banda tuff and upper Utror volcanics. It represents the roof zone of the Kohistan batholith. One possible mechanism for mineralization is the late phase of southeast directed thrust sheets which cut the roof zone of the Kohistan batholith thus providing pathways to the hydrothermal copper rich fluids and strata bound mineralization in the Dir area. (Sullivan, 1989).

The geochemical studies of the mineralized zone show that Au varies from 3 to 11 ppm Ag varies from 6 to 200 ppm and Cu from 1% to 6.5%. The results are given in Table-1. Field observation and geochemical studies show that mineralization is strata bound type. Since the anomaly appears promising, therefore detailed studies should be carried out in the region to assess the potential of this mineralization.

Data analyzed on Atomic Absorption Spectrophotometer by Chemistry Division, GSP, Quetta.

Key words: Sulphide mineralization, gold, silver, Paleocene, Eocene, Dir volcanics.

H/188. Husnain, T., Khan, M.S., Hussain, K. & Chaudhry, M.N., 2000. Stratabound volcanic hosted gold, silver and sulphide mineralization in Paleocene-Eocene Dir volcanic group, District Dir, NWFP, Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 83-88.

Consult the preceding account for further information.

Key words: Sulphide mineralization, gold, silver, Paleocene, Eocene, Dir volcanics.

H/189. Husnain, T. & Hussain, S.F., 1980. Geology and petrology of Naran–Saif–ul–Maluk area, Kaghan valley. M.Sc. Thesis, Punjab University.

Key words: Petrology, Naran, Himalaya.

H/190. Hussain, A., 1974a. Copper occurrence of Dir and Chitral district NWFP, Pakistan. Geological Survey of Pakistan, Information Release 73, 25p.

Key words: Mineralization, copper, Dir, Chitral.

H/191. Hussain, A., 1974b. Antimony, lead and zinc occurrences of Chitral District, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 75, 31p.

An evaluation study of antimony, lead and zinc showings of Chitral district North West Frontier Province was made during the field season of 1971-72. Numerous showings of economic significance occur in Kamal gol (Krinj), Awrit gol and Pakhturi areas. In Kamal gol area (Krinj) the antimony ore is emplaced into Chitral slate at and near its faulted contact with the marble of Reshun Formation. The ore is being mined from Kamal gol 2A mine; the other mines viz. Angargun and Kamal gol 1A mines are closed since long. Probable reserves of 10,638 tons of ore has been estimated from Kamal gol 2A mine. In Awrit gol area, the high grade lead-antimony ore with some zinc is intermittently exposed for about 2000 feet along the faulted contact between the marble of Reshun Formation and phyllites of Kafirstan-Partsan area. Probable reserves of 57,142 tons of ore has been estimated.

In Pakhturi area, a hillock of calcarious quartzite and sandstone is traversed by a network of nineteen quartz veins containing lead-zinc ore with some copper. Reserves of exposed ore are small but the wide distribution of mineralization indicates the possibility of larger deposits at depth. Geophysical survey and exploratory development work at Kamal gol, Awrit gol and Pakhturi areas are recommended.

Key words: Metallic minerals, Lead-Zinc, Chitral.

H/192. Hussain, A., 1975. Silica sand deposits of Khisor and Marwat Ranges, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 91, 22p.

This report gives details of Silica sand deposits in Khisor and Marwat ranges, D.I.Khan. The deposits are at the base of the Datta formation, with an average length of 4.2 miles in Marwat Range and 3 miles in Khisor Range. The deposit with a little effort at beneficiation can be made used for making flint glass containers, table ware, sheet, rolled and polished glass.

Key words: Silica sand, Khisor-Marwat Range, D.I.Khan.

H/193. Hussain, A., 1976. Silica Sand Deposits of Munda Kachha Area, District Hazara, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 95, 21p.

An evaluation study of Silica sand deposits of Munda Kachha area, District Hazara, N.W.F.P. was conducted during the field season of 1972-73. The silica sand deposits are found in quartzose sandstone beds which is considered equivalent of Abbottabad Formation. The deposits occur in a broad syncline which extends from Sunda Gali to

Lugga Gali for a strike distance of four miles. The estimated reserves of silica sand upto a workable dip depth of 300 feet are found to be 57 million tons.

The average chemical analyses of 22 channel samples from silica sand outcrops of Munda Kuchha area contain SiO_2 95.93%, Fe_2O_3 0.61%, Al_2O_3 1.26% CaO 0.52%, MgO 0.79%. The sieve analyses results indicate that a major portion of silica sand lies between -20 mesh to -120 mesh which is the required grain size for the manufacture of glass sand. The deposit with a little effort at beneficiation can be made usable in glass manufacture. The sand in the area fall in the 3rd, 5th, 7th and 9th category according to US Bureau of standard specification for glass sand and is suitable for the flint glass, green glass and amber glass.

Key words: Silica sand, Munda Kuchha, Hazara.

H/194. Hussain, A., 1978a. An interim report on high grade limestone deposits around Attock, Nizampur area, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 100, 21p.

A study of high grade Limestone deposits of Attock-Nizampur area, NWFP, was carried out on the request of State Cement Corporation of Pakistan for setting up of a Cement plant. The limestone is exposed in the form of five isolated outcrops which belong to Paleocene and Eocene ages. A reserve of about 930 million tons upto a workable dip depth of 200 feet in the area has been estimated.

The average chemical analyses of ten representative channel samples from the outcrops reveals CaO 51.34%, MgO 1.85%, SiO_2 3.42%, Fe_2O_3 0.5%, Al_2O_3 0.94%, SO_3 0.15% and L/ig. 40.96%. The limestone is suitable for the manufacture of Port land Cement and also suited for other industrial uses. The area is easily accessible and located close to rail and road links. This report is an interim document and will be followed by a more elaborate publication.

Key words: Limestone, Attock, Nizampur, NWFP.

H/195. Hussain, A., 1978b. Method for concentration of magnesite ore. Proceedings, National Seminar on Development of Mineral Resources, Lahore, 237-248.

Key words: Magnesite, minerals, ore.

H/196. Hussain, A., 1978-80. Electrical Resistivity Survey for ground-water exploration in Mardan Township Area, District Mardan, NWFP. M.Sc. Thesis, Punjab University, Lahore, 76p.

This report presents the results of ground-water geoelectric investigations carried out in the Mardan Township area during the month of August, 1982, with the collaboration of Hydrological Directorate, WAPDA, Peshawar. The purpose of investigation was to collect the data to delineate the sub-surface geology of the area, and give some suitable sites for the installation of tubewells.

Mardan Township comprised an area of over 2 miles². Total 23 resistivity probes were run in the area. The electrical resistivity measurements were made with Georesistivity meter using the schlumberger electrical configuration. The common depth of exploration at these resistivity stations was 600 meter. The electrical resistivity curves obtained in the field were evaluated, interpreted and sub-surface geological cross-section based on true resistivity values were prepared to determine the vertical and horizontal extent of the sub-surface materials and aquifers.

Two-test hole upto a depth of two hundred feet were drilled and test wells were installed to determine hydrologic characteristics of the sub-surface sediments. The results of these studies indicate that within explored depth of 600 meters, the project area is under by sediments that consist dominantly of clay and silty clay. Beds of gravel and sand are present in the northwestern part of the project area extending further in the north-west. These beds of sand and gravel, constitute the aquifers in the subsurface, which may yield a fair supply of ground water discharge of these aquifers will be insufficient to meet the requirements of the area, which prohibits the installation of heavy duty tubewell in the project area.

Key words: Groundwater, hydrology, Mardan.

H/197. Hussain, A., 1984. Regional geological map of Nizampur covering parts of Peshawar, Mardan and Attock districts. Geological Survey of Pakistan Geological Map Series 142, 1:50,000.

Key words: Regional Geology, mapping, Nizampur, Peshawar, Mardan, Attock.

H/198. Hussain, A., 1985-87. The geology and petrography of Sharda-Kel area, Neelum valley (Azad Kashmir) with special emphasis on granites. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 96p.

A geological map of 80 Sq. Km, between Sharda-Kel area is presented at the scale of 1: 25,000 on toposheets Nos 43 J/5 and 43 J/1 issued by survey of Pakistan. Metasediments comprised of garnet mica schist, granite gneiss, amphibolites and migmatites which host small and large sheets of granites. Metamorphic rocks from Sharda to Kel area represent inverted sequence which is conformable to rocks south of MCT in occupied Kashmir. Petrographic analysis identifies deformation features which more likely are attributed to thrusting. Field and petrographic study of granites of the project area indicates that granites are S-type and are formed by high degree of partial melting of metasediments in catazone environments. Economic mineral deposits like marble, garnet and kyanite are identified.

Key words: Granite, petrography, maps, Neelum valley, Azad Kashmir.

H/199. Hussain, A., 1989. Geology of Dunga Gali-Barian Area District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 105p.

Geological and structural mapping of Kotli-Nikial-Khuiratta area of about 300 square km was carried on 1:50,000 scale of toposheet No's 43 K/2, 43 K/3, 43 G/11 and 43 G/15 of survey of Pakistan. The lithostratigraphic units described range in age from Pre-Cambrian to Pleistocene and consist mainly of sedimentary rocks. The Pre-Cambrian rock formation is Dogra Slate and Cambrian rock unit is Sirban Formation. In this area apart from Lower Cambrian, all the formations of Paleozoic and Mesozoic are missing. Either they were not deposited or were weathered to form Bauxite/Fireclay representing an unconformity of a big gap. In the Tertiary period, Patala Formation, Margala Hill Limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy.

The rocks are folded and faulted comprising the major and minor structures of the area. The major folds of the area are khuiratta-Kohali anticline (11pp/325pp), Devigarh-Palana anticline (04pp/313p), Tattapani-Karela anticline (6pp/116pp) and Khad-Bahni syncline (6pp/228pp). The major fault is the Himalayan Frontal Thrust with minor thrust like Gala Thrust and Khad Thrust. Deformational events and stereographic projection of the area have been interpreted. The tectonic setup has been also discussed. About eighty five rock samples were taken from the field and carried back to the laboratory for petrographic studies. In the field of economic geology, a number of deposits including Fireclay, Bauxite, Coal, Limestone, Chalk and Dolomite are of economic interest.

Key words: Mapping, geology, Abbottabad.

H/200. Hussain, A., 1989-90. Geology and structure of Kotli-Nikial Khuiratta area with special emphasis on Himalayan Frontal Thrust and related structures. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 111p.

This report incorporates a comprehensive geological study of nearly 25 sq. km. area between Dunga Gali and Barian on the Murree-Abbottabad road. The study includes the preparation of a geological map on the scale 1:7040.

Stratigraphically the rock units range from Upper Jurassic to Eocene and represent the sequence of the Hazara Province of the Kohat-Potwar Basin. It is primarily a limestone-shale sequence reflecting a stable shelf facies. Structurally, the area shows the development of a few synclinoria and anticlinoria, within which a generally tight parallel to similar asymmetric to overturn style of folding predominates. A number of dip-slip-strike faults, both of the normal and reverse type are present. A petrographic study of all rock units, based on fairly representative field sampling, is also present.

Key words: Structure, Himalaya frontal thrust, Azad Kashmir.

H/201. Hussain, A., 1995. Cement raw material in the North West Frontier Province, Pakistan. Abstracts, International Symposium and Field Workshop on Phosphate and Other Industrial Minerals, Abbottabad, p.19.

Consult Hussain and Arbab, 1997.

Key words: Cement raw material, limestone.

H/202. Hussain, A., 1997-98. Geological mapping and hydrological studies of Rawalakot area (District Poonch) A.K., with special emphasis on quality of water. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 96p.

The pearl valley, investigated for water resources is present in the lesser Himalayas and exposed rock units are from Pre-Cambrian to Recent age. MBT and Pir Panjal thrusts are two main structural elements nearer to the area. The area under investigation is mostly in hilly regions. There were three main available sources of water, springs, streams and wells. The springs water and ground waters are polluted by organic, inorganic and biological contamination and by domestic and other wastes. Chemical and physical quality of water is at intermediate to high risk but microbiological and pollutant results showed that drinking water is at high risk. Chemically the quality of water is at low to high risk. The chemical constituents (Ca, Mg, Na, K, HCO₃, CL, SO₄, NO₃, I, Fe, NO₂ and F) indicate the water is at high risk. T.D.S, T.S.S and temperature enhance the growth of bacteria in water. The toxic metals in water cause diseases like kidney stone, liver stone, blood cancers, vomiting, abdominal problems and headache etc. It is concluded that the drinking water available from springs, streams and ground water are at intermediate to high risk.

Key words: Mapping, hydrology, geology, water quality, Rawlakot, Azad Kashmir.

H/203. Hussain, A., 2000. Cement raw materials and their requirements in the North West Frontier Province. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 161-171.

Consult Hussain and Arbab, 1997.

Key words: Cement raw material, limestone.

H/204. Hussain, A., & Arbab, M.S.H., 1997. Cement raw materials and their requirements in the North West Frontier Province. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1 p.

The main raw material components for cement production are limestone providing CaO and clay/shale/slate providing SiO₂, Al₂O₃ and Fe₂O₃. When the set points for certain constituent are not met by using only two raw material components, then the additive admixtures which include Si-Carrier (sand), Al-Carrier (bauxite) and Fe-Carrier (laterite/iron ore) have to be added in the raw mix. The content of oxides in the cement are approximately as follows:-

Calcium oxide	(CaO)	62-68%
Silica	(SiO ₂)	21-24%
Alumina	(Al ₂ O ₃)	4-8%
Ferric oxide	(Fe ₂ O ₃)	2-5%

The North West Frontier Province is gifted with extensive deposits of suitable grade raw materials for the manufacture of Portland cement. The potential calcareous raw material comprises of Shekhai Limestone of Precambrian age, Samana Suk Limestone of Jurassic age and Lockhart Limestone of Eocene age. The argillaceous raw materials include Manki Slate of Precambrian age, Patala Shale of Paleocene age. Kuldana Shale of Eocene age and Lacustrine deposits of Quaternary age. The additive admixtures include iron ore and silica sand deposits of Data

Formation of Triassic age and the laterite deposits at the unconformable contact between the Cretaceous and Paleocene rock sequence.

The chemical analysis of the channel and core samples from these deposits show that all the elements are within permissible limits for the production of the Portland cement. The reserves of the raw materials are vast and several cement plants can be installed within Nowshera. Haripur. Kohat. Dera Ismail Khan and Federally Administrative Tribal Areas. Water, electric power. road links and other infrastructural facilities are also available in the areas. Cement is in considerable demand in Pakistan and there are also bright prospects for exporting cement to the neighbouring countries.

Key words: Cement raw material, limestone.

H/205. Hussain, A., Arbab, M.S.H. & Pogue, K.R. 1998. Stratigraphic and structural evolution of the Peshawar Basin, Pakistan. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 32-33.

The Peshawar intermontane basin is a broad, oval shaped and low-lying depression at the southern margin of the Himalayas (Pakistan). It lies to the north of the Attock-Cherat

Range and contains rocks transitional between the sedimentary fold- thrust belt to the south and a metamorphic terrane to the north.

The basin came into existence as the Kalachitta Range was faulted south on the Main Boundary Thrust (MBT) pushing the Siwalik foreland basin still farther south. The basin fill sediments predominantly comprise of lacustrine, deltaic and fluvial deposits which are overlain by loess, flood-plain and alluvial-fan deposits of younger age. The study of the Landsat data, aerial photographs and subsequent field studies indicate a zone of late Quaternary deformation that extends across the southern margin of the Peshawar basin. Lacustrine, fluvial and alluvial-fan deposits that are dated at 2.8 to 0.6 Ma are tilted, folded and faulted along four left-stepping pressure ridges that extend for nearly 60 km.

Alluvial-fan and fluvial sediments are also folded and faulted at the Tarbela Dam and the base of the Indus River appears to be displaced by a reverse fault with its northwest side up. Additional small lineaments and faults occur parallel and oblique to the major fault structures. As a result of the present study, especially the finds of conodonts, the bed rock sequence of the Peshawar basin established previously, has been modified and revised. An almost complete sequence of rocks ranging from Precambrian to Triassic in age has been established for the first time in the Peshawar basin.

Key words: Stratigraphy, structure, Peshawar basin.

H/206. Hussain, A., Arbab, M.S.H., & Sadin, M., 2000. Geological Road Log along Islamabad-Peshawar-Khyber Pass. Islamabad-Peshawar Section. Geological Survey of Pakistan. Highways Geological Map Series, Map No. 3.

Key words: Maps, Islamabad, Khyber pass.

H/207. Hussain, A., Arbab, M.S.H. & Siddiqi, F.A., 1996. Prospects and potential for lightweight aggregates in Pakistan. Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, 18-22.

Consult Hussain, Siddiqi and Arbab, 1994.

Key words: Light weight aggregates.

H/208. Hussain, A., Chaudhri, M.A., Siddiqi, F.A. & Chughtai, M.Z., 1983. Lightweight aggregates; study of raw material in Pakistan, Islamabad and Peshawar region. Geological Survey of Pakistan, Records 66, 27p.

Key words: Light weight aggregates.

H/209. Hussain, A., DiPietro, J.A., & Haq, I., 1995. Geological Map of Choga quadrangle, (Toposheet No. 43 B/10, Scale 1:50,000), NWFP, Pakistan. New Geoscience No. 1107 (Old Sheet No. 72), Geological Survey of Pakistan. NWFP. Geological Map Series, III.

Key words: Geological map, Choga, Swat.

H/210. Hussain, A., DiPietro, J.A., & Pogue, K.R., 1997. Stratigraphy and structures of Peshawar Basin, Pakistan. Abstract volume, 2nd Nepal Geological Congress p.8.

Key words: Stratigraphy, structure, Peshawar basin.

H/211. Hussain, A., DiPietro, J.A. & Pogue, K.R., 1998. Stratigraphy and structure of the Peshawar Basin, Pakistan. Journal of the Nepal Geological Society 18, 25-35.

Key words: Stratigraphy, structure, Peshawar basin.

H/212. Hussain, A. & Karim, T., 1993. Mineral Map of NWFP. Geological Survey of Pakistan, Geological Map Series, Scale 1:1,000,000.

This report contains a map with showings, prospective deposits and productive deposits of metallic minerals, non-metallic minerals, fuel and energy minerals, and precious and semi precious stones. Also given are the locations, reserves, annual production and brief remarks. An inset map shows the location of the mineral based industries.

Key words: Maps, minerals, NWFP.

H/213. Hussain, A., Khan, R.N., Saeed, G. & Haq, I., 2002. Geologic map of Naushera District, NWFP, Pakistan. Geological survey of Pakistan (scale 1: 100,000).

Key words: Geologic map, Naushera

H/214. Hussain, A., Khan, S.R. & Saeed, G., 1990. A new look at the coal occurrence In Cherat area, N.W.F.P., Pakistan. In: Siddiqi, F., Husain, V., Kaifi, Z. & Ghani, A. (Eds.), Proceedings, First SEGMITE Conference on Industrial Minerals, March 1990, Peshawar, 34-37.

Small occurrences of coal deposits occur in Late Paleocene to Early Eocene Patala Formation in several places in the province. The Cherat coal, instead, occurs in the Early Paleocene Hangu Formation. The general stratigraphic setup of the Cherat Range comprises 1) Precambrian Dkhner Fm That is unconformably overlain by 2) Jurassic Samana Suk Fm, itself overlain by 3) Hangu Fm, 4) Paleocene Lockhart Limestone, Patala Fm, and unconformably overlying Early Miocene Murree Fm. Reserve estimates are not available, but the occurrence of coal in abandoned mine workings and boreholes suggest that its occurrence is widespread. The coal deposits of Aurakzai Agency and Makerwal are also located in the Hangu formation, raising the possibility of widespread occurrence of the coal of this age.

Key words: Coal, Hangu Formation, Cherat Range, Nowshera

H/215. Hussain, A., Pogue, K.R. & Arbab, M.S.H., 1992. Stratigraphy of the Himalayan foothills of northwest Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.16.

Key words: Stratigraphy, Himalaya foothills.

H/216. Hussain, A., Pogue, K.R., & DiPietro, J.A., 1988. Paleozoic stratigraphy of the Peshawar Basin, Pakistan. Geological Society of America, Abstracts 20, 266–267.

Key words: Stratigraphy, Paleozoic, Peshawar basin.

H/217. Hussain, A., Pogue, K.R. & DiPietro, J.A., 1995. Stratigraphy and tectonics south of Main Mantle Thrust, Peshawar Basin, Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 17-18.

Key words: Stratigraphy, Tectonics, MMT.

H/218. Hussain, A., Pogue, K.R. & DiPietro, J.A., 1998. Stratigraphic and structural framework of the Himalayan foothills between Panjal-Khairabad thrust and MMT, Peshawar Basin, Northern, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.82.

The Panjal-Khairabad Thrust form the boundary between the Lesser Himalayan and Tethyan section, a function performed by the Main Central Thrust (MCT) in the Central Himalaya of India and Nepal. All pre-Cenozoic rocks north of the Panjal-Khairabad Thrust have been metamorphosed. The metamorphism increases from south to north from greenschist to kyanite grade. An almost complete sequence of rocks ranging from Precambrian to Jurassic age has been established for the first time in the area. The Proterozoic rocks represented by Gandaf Formation and Manki Formation with associated carbonate form the base of the stratigraphic section. These rocks are overlain by Precambrian and Cambrian Tanawal Formation; Cambrian (?) Ambar; Ordovician Misri Banda; Llandoveryan to Pridolian Panjpir Formation, Lochkovian to Frasnian Nowshera Formation and Kinderhookian to Westphalian Jafar Kandao Formation. The Karapa Greenschist, consisting of metamorphosed lava flows separate the Jafar Kandao from Upper Triassic (Carnian) marble of Kashala Formation. The upper Triassic and Jurassic (?) Nikanani Ghar Formation forms the top of the section.

Correlatives to the stratigraphic setup of the Peshawar Basin are present in the Khyber-Mohmand to the west and Hazara to the east. The sequence contrasts markedly with the Paleozoic and Mesozoic sequence exposed to the south of Panjal-Khairabad Thrust. The newly - dated Carboniferous to Triassic rocks provide age constraints on the high-grade metasediments of Swat exposed to the south of MMT. The dating has also provided age constraints on pre-Himalayan tectonism and intrusions. The stratigraphic information combined with geochemical analyses and radiometric dates on the igneous rocks of the area permits the recognition of a major phase of Paleozoic rifting in the Peshawar Basin.

Key words: Stratigraphy, structure, tectonics, MCT, MMT.

H/219. Hussain, A., Pogue, K.R. & DiPietro, J.A., 1999. Paleozoic stratigraphy of the Himalayan foothills of northern Pakistan: Correlation and implications. Additional abstracts, IGCP 421 (North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics), Peshawar Meeting, 1p.

Key words: Stratigraphy, Paleozoic, Himalayan foothills.

H/220. Hussain, A., Pogue, K.R. & DiPietro, J.A., 2001. Stratigraphy of the Precambrian rocks of the northwest Himalaya, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.28.

The Precambrian rocks of the northwest Himalaya, Pakistan consists of Proterozoic and Archean (?) crystalline basement rocks overlain by a Proterozoic sedimentary and metasedimentary cover sequence. The effect of regional metamorphism increases gradually from south to north. South of the Main Boundary Thrust (MBT) Upper Proterozoic evaporites (the Salt Range Formation) unconformably overlie Proterozoic metamorphic and igneous

complex exposed in the Kirana Hills of Sargodha, Chiniot and Sangla areas (Gee, 1989). Between the MET and the Panjal-Khairabad thrust (PKT), the Proterozoic sedimentary cover is represented by sandstone, argillite, slate, and limestone of the Dakhner Formation in Attock-Cherat Range and its eastern equivalent the Hazara Formation in Hazara. Gypsum intervals in the Hazara Formation imply that the Hazara and Salt Range Formations may be lateral equivalents. Between the PKT and Darband Fault, the oldest exposed Precambrian rocks are slate and phyllite of the Manki Formation, which are interpreted as the metamorphosed equivalent of the Hazara/Dakhner Formation. The Manki Formation is overlain by limestone and argillite of the Shahkot, Utch Khattak, and Shekhai Formations. These limestones thin northward to be replaced by quartzite and argillite of the Tanawal Formation. Near Tarbela Lake, the Tanawal Formation overlies marble and graphitic schist of the Gandaf Formation, which is interpreted as a higher-grade equivalent of the Manki Formation. The Gandaf Formation thickens northward in the Indus syntaxis and unconformably overlies graphite-muscovite plagioclase schist and tremolite marble of Karora Formation of Proterozoic age. The metaconglomerate is found at the base of Karora Formation where it unconformably overlies small outcrop of quartzo-feldspathic rock, gneiss, and quartzite of Kishar Formation of Early Proterozoic age. The entire Precambrian sequence around Tarbela Lake is extensively intruded by Cambrian granodiorite (the Mansehra and Swat Granites), Late Paleozoic alkaline granitoids (the Ambela intrusive complex), and Permian mafic dikes and sills. In the Indus Syntaxis north of Tarbela there is evidence of plutonism of Early and Late Proterozoic age by the granodiorite gneiss, orthogneiss and leucogneiss of Besham Complex, orthogneiss of Kotla Complex and biotite orthogneiss and migmatite of Black Mountain Complex.

Key words: Stratigraphy, Precambrian, metasediments, Himalaya.

H/221. Hussain, A., Pogue, K., Khan, S.R. & Ahmad, I. 1990. Palaeozoic stratigraphy of the Peshawar basin, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.35.

Consult the following account.

Key words: Stratigraphy, Paleozoic, Peshawar basin.

H/222. Hussain, A., Pogue, K.R., Khan, S.R. & Ahmad, I. 1991. Paleozoic stratigraphy of the Peshawar basin, Pakistan. Geological Bulletin, University of Peshawar 24, 85-97.

An almost complete Paleozoic sequence of sedimentary rocks is exposed in the ranges fringing the Peshawar basin. The present study establishes a revised stratigraphy and modifies the stratigraphic nomenclature of the previous workers. The Pre-Cambrian – Cambrian Tanawal Formation forms the base of the sequence and is overlain unconformably by the Ambar Formation (Cambrian?). The Misri Banda Quartzite unconformably overlies the Ambar Formation and contains Cruziana ichnofossils, which indicate an Early to Middle Ordovician age. The limestone at the base of the Panjpir Formation contains siluric zone conodonts (Ludlovian) and unconformably overlies the Misri Banda Formation. The Early to late Devonian Nowshera Formation overlies the Panjpir and contains a reef facies first recognized by Stauffer in 1968. The youngest recognized Paleozoic unit is the Jafar Kandoa Formation from which Carboniferous conodonts have been obtained. The section outlined above has possible correlatives in the Khyber and Hazara regions, but differs dramatically from the Paleozoic sequence of the Salt Range to the south. The tectonic setting of the area is transitional between a sedimentary fold belt to the south and a metamorphic terrane to the north.

Key words: Stratigraphy, Paleozoic, Peshawar basin.

H/223. Hussain, A., Siddiqui, F.A. & Arbab, M.S.H., 1994. Prospect and potential of the light weight aggregates in Pakistan. Abstracts, Second SEGMITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, p.19.

Lightweight concrete aggregates are expanded rock material weighing less than the conventionally used aggregates of sand, gravel and crushed stone. These aggregates are produced from natural deposits of pumice, scoria, volcanic cinder, tuff and diatomite; by industrial cinder; and by the application of heat to expand clay, shale, slate, diatomaceous shale, perlite, obsidian and vermiculite. In Pakistan workable occurrences of these material except for

clay, shale and slate are either non-existent, at present, or are found in such remote regions that the cost of their mining and transportation to the consuming centres, is prohibitive.

Bloatable argillaceous raw material suitable for use in the making of lightweight aggregate has been proved to exist in large quantities in the region between Islamabad and Peshawar. This raw material comprising of Eocene shale and Precambrian slate is exposed in parts of the Margalla and the Attock-Cherat Ranges respectively. Low cost open pit mining can be applied for its extraction. Field and laboratory studies conducted jointly by the GSP and the Pakistan Council of Scientific and Industrial Research have established that the unit weight and compressive strength of the cubes (test) made from this material (expanded compares well with the ASTM specification for the structural concrete).

The clay deposits are widely found in the country but most of these attain the desired level of bloating only after the addition of organic matter. This raises the production cost and often creates processing problems.

Investigations in other parts of the country for lightweight aggregates are planned to be undertaken in the near future.

Key words: Light weight aggregates, sand, gravel.

H/224. Hussain A., Turi, A.A. & Haq, I., 1995. Geological map of Mazri Tang (38 O/7). Geological Survey of Pakistan.

Key words: Geological map, Mazri Tang.

H/225. Hussain, A., & Yeats, R.S., 1991. Geology and tectonics of the Attock-Cherat Range and southern Peshawar Basin, Pakistan. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, p.4.

Key words: Maps, Attock-Cherat, NWFP.

H/226. Hussain, A., & Yeats, R.S., 2000. Geology and tectonics of the Himalayan foothills of Northern Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 3-4.

Key words: Tectonics, Himalayan foothills.

H/227. Hussain, A., Yeats, R.S. & Pogue, K., 1989a. Stratigraphy and structural events around the southern margin of Peshawar basin, Pakistan. Geological Bulletin, University of Peshawar 22, 45-54.

The Peshawar intermontane basin is superimposed on the fold-thrust belt at the southern margin of the Pakistan Himalayas. In the southern part of the basin the first Ordovician rocks were identified near Nowshera on the basis of discovery of trilobite trace fossils and consequently the Paleozoic stratigraphy of the area has been revised and modified. The Attock-Cherat Range forms the southern boundary of the Peshawar basin and includes rocks transitional between metasediments of Lesser Himalayas and foreland basin strata of Kala Chitta Range to the south. The range is dominated by slate, less metamorphosed argillaceous and arenaceous strata and subordinate limestone of Precambrian to Paleozoic age. These rocks are unconformably overlain by a thin cover of Jurassic, Cretaceous (?), Paleocene, Eocene and Miocene rocks. The structural events close to the Peshawar basin are recognized in pre-Paleocene, pre-Pliocene and late Quaternary times. The Peshawar basin formed as the Kala Chitta Range was faulted south on the Main Boundary Thrust (MBT) pushing the Siwalik foreland basin still further south. Evidence for active tectonics is found in four left-stepping en-echelon pressure ridges formed within Peshawar basin parallel to its southern margin.

Key words: Stratigraphy, structure, Peshawar basin.

H/228. Hussain, A., Yeats, R.S., & Pogue, K.R., 1989b. Geological Map of Attock-Cherat Range and adjoining areas, NWFP, and Punjab Pakistan (Scale 1:100,000). Geological Survey of Pakistan. NWFP Map Series, vol. III.

Key words: Maps, Attock-Cherat, NWFP.

H/229. Hussain, A., Yeats, R.S. & Pogue, K., 1990. Geologic map of Attock-Cherat Range and adjoin areas of NWFP and Punjab. Geological Survey of Pakistan (scale 1: 100,000).

Key words: Geological map, Attock-Cherat Range

H/230. Hussain, A., Yeats, R.S. & Shah, R., 1997. Geology of the Himalayan foothills from the perspective of the Attock-Cherat Range; Correlations and implications. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.18.

Key words: Stratigraphy, structure, Attock-Cherat, Himalayan foothills.

H/231. Hussain, B.R., 1966. Oil in Pakistan, an evaluation. The Geologist, Karachi, University, 75-78.

Key words: Hydrocarbons.

H/232. Hussain, B.R., 1967. Saidwali member, a name for the lower part of the Permian Amb Formation, West Pakistan. University Studies (Karachi), Science & Technology 4(3), 88-95.

Key words: Amb Formation, Saidwali member, Permian.

H/233. Hussain, B.R., 1969. Mianwali Group Redefined. Geological Bulletin, University of Peshawar 4, 14-17.

Mianwali, if at all retained in the nomenclature, must be restricted to a group name only.

The 'Mianwali Group' should embrace only the Mittiwali and Narmia Formations and the Kathwai Dolomite Member be assigned to the lower part of the Mittiwali Formation. Landa and Khatkiara may be assigned separate formational status and if necessary, be included under the Tredian Group which may then be defined according to the notes and letter of Dr. Geo on this subject.

Key words: Stratigraphy, Mianwali group.

H/234. Hussain, F., Bhatti, N.A. & Sethi, U.B., 1990. Geologic map of Attock area, Punjab and NWFP, Pakistan. US Geological Survey, Geological Map Series. Scale 1:250,000.

Key words: Mapping, Attock-Cherat, Punjab, NWFP.

H/235. Hussain, I., 1990-92. Sedimentology of Middle Jurassic Samana Suk Formation, District Abbottabad, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 186p.

The Samana Suk Formation is a part of Mesozoic sequence, starting from Early Jurassic Datta Formation to Upper Cretaceous Kawagarh Formation. This sequence is interrupted by one break in deposition.

The sedimentology of Samana Suk Formation exposed at Sikhar ridge (Sangar Gali) and Thai Barrier (near Abbottabad) is based upon thorough section measurements, collection of more than three hundred samples followed by extensive laboratory work. The Samana Suk Formation represents five shallowing upward cycles. Every cycle is topped by hard ground surface on ooidal grainstone. The sediments have been subjected to various diagenetic events, out of which dolomitization is significant phenomenon. At least two phases of dolomitization have been determined. The zonation in the dolomite crystals not only represents the pore water chemistry but also varied

environments of formation. Dedolomitization has led to the development of porous horizons. The third order sea level curves based upon microfacies assemblage and diagenetic events generally match with P.R. Vail's curves.

Key words: Sedimentology, Samana Suk Formation, Datta Formation, Mesozoic, Jurassic, Abbottabad.

H/236. Hussain, I., Mahmood, A. & Ali, Z., 1974. Field report on eastern Chamla and Khadukhel, Lower Swat. M.Sc. Thesis. Punjab University, Lahore.

Key words: Petrology, Buner, Swat.

H/237. Hussain, K., Sultana, I. & Sheikh, N., 1983. Beneficiation of Malakand graphite on pilot plant scale. Second National Seminar on Development of Mineral Resources, Peshawar, 3, 6p.

Key words: Graphite, beneficiation, Malakand.

H/238. Hussain, M., 1972. Thesis on geology of Dir - Bibior area, District Dir, with special emphasis on Amphibolite and Calcareous Quartzite. M.Sc. Thesis, Punjab University, Lahore.

Key words: Amphibolite, calcareous quartz, petrography, Dir.

H/239. Hussain, M., 1981-83. Geology and petrology of Darel valley (District Diamer) with special emphasis on the petrology of diorites and amphibolites of the area. M.Sc. Thesis, Punjab University, Lahore, 65p.

This thesis presents a geological map of the 30 sq .miles of project area (DAREL) on scale 1" = 1 mile. The project area (Darel) lies in Gilgit Agency, district Diamer. The area is located in the centre of Kohistan. Area is disturbed tectonically, being involved in Himalayan orogeny. The area is composed of igneous and metamorphic rocks. The main rock units in the area are Norite, Diorite, Amphibolites and Granodiorites. Mineralogical description and petrographic analysis of these rock units are reported in detail. An attempt is made to interpret the petrogenesis of rock types. The Thesis presents a detailed geological and petrological investigation of the project area. Norite and amphibolites represent oceanic crust while Diorite and Granodiorite etc. represent plutonic equivalents of arc. To achieve this goal a period of 45 days was spent at the site during July, August 1984.

Key words: Petrology, diorite, amphibolite, Diamir.

H/240. Hussain, M., 1988. Report on Geology and Structure of Balakot-Kummi Area. M.Sc. Thesis, Punjab University, Lahore, 100p.

The present work constitutes a comprehensive report on the geology of Balakot-Kummi area and is submitted in partial fulfillment of the requirements for the degree of M.Sc. at the University of Punjab. The report includes a detailed geological map at 1:6,000 of about 65-km²-area alongwith a number of geological sections and sketches. The various chapters include geomorphology, stratigraphy, structure and tectonics. Stratigraphically, the Balakot-Kummi area includes a number of diverse sedimentary and metamorphic elements ranging in age from Precambrian to Miocene with a fairly large gap in the Mesozoic period. Structurally, the area incorporates part of the core and western limb of the Hazara-Kashmir syntaxis and through it pass the major Murree and Panjal Faults. The Balakot-Muzaffarabad anticline is the major fold overturned and overthrust to the southwest. No major economic mineral deposit was found within the project area, although a lot of material is available as rock crush, aggregate components and building stones.

Key words: Mapping, structure, sedimentary rocks, metamorphic, Precambrian, Miocene, Balakot, Hazara.

H/241. Hussain, M., 1990-92. Geology and structure of Changla Gali Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 170p.

Large-scale (1:7000) geologic mapping of a small segment of the Lesser Himalaya in the Chhangla Gali area is presented. A Jurassic to Eocene succession mainly comprising shallow shelf carbonates, with an important unconformity at the Cretaceous-Tertiary boundary, is part of the southern Hazara sedimentary province. A petrographic microfacies study of measured sections of Lockhart limestone reveals that the formation comprises 31 microfacies of mudstone, wackestone and packstone. Structurally the area comprises NE-SW trending double plunging folds constituting anticlinoria and synclinoria. The folds are tight to isoclinal with a general vergence to the southeast. The folded sequence is disrupted by a number of high angle dip-slip strike faults especially within or on the margins of anticlinoria.

Key words: Structure, petrography, Jurassic, Eocene, Abbottabad.

H/242. Hussain, M., Rashid, M.A., Sethi, U.P. & Meisner, C.R., 1967. Geology of the Parachinar quadrangle, West Pakistan. Geological Survey of Pakistan and U.S.G.S., Project Report, PK (IR)-28, 75p.

Key words: Geology, mapping, Parachinar.

H/243. Hussain, M. & Siddiqi, R.A., 1993. Phosphorite prospecting in Nizampur area, District Peshawar, NWFP. Geological Survey of Pakistan, Information Release 539.

Geological and geochemical investigations were conducted in Nizampur area, district Peshawar, NWFP, for the phosphorite prospecting. Rock units exposed in the area belong to the formations ranging in age from early Triassic to recent deposits. Field and camp chemical tests were conducted for P_2O_5 content in the samples collected from the outcrops. Detailed analyses were also done of few selected samples from different formations.

The work concluded that two formations i.e., Chichali formation (early Cretaceous to late Triassic) and Lumshiwal formation (early Cretaceous) have Phosphatic nodules which contain upto 27% and 28% P_2O_5 respectively. The size and percentage of these nodules are varying whereas the matrix is mostly devoid of P_2O_5 content. There is no economic significance of these phosphatic rocks. However the green sand part of the Lumshiwal formation which has 1-2% P_2O_5 and quite friable can directly be applied in the fields to give better crops. Green sand has also been used as potassic fertilizer and water softener in different parts of the world. It was observed that crops growing on green sand bearing area, were looking better and reportedly giving better yield in comparison to the one's on the other rock units.

Key words: Geochemical prospecting, phosphorite, Nizampur, Peshawar.

H/244. Hussain, M.A., 1997. Sustainable groundwater development, Lei-Basin (Islamabad-Rawalpindi), as an example of groundwater recharge, prospects for arid and semi-arid countries. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, 19-20.

Key words: Groundwater, sustainability, Islamabad.

H/245. Hussain, M.I., 1961. Engineering geology and some pertinent problems at the Warsak dam site. Abstract volume 13th All Pakistan Science Conference Dacca, p.7.

Key words: Dams, engineering geology, Warsak.

H/246. Hussain, M.S., 1990-91. The geology and stratigraphy/micropaleontology of Bagla, Khala-Bala Area District Haripur, Hazara (NWFP) Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 103p.

Patala Formation having khaki Shales with fossiliferous limestone bands. The environment is shallow marine, (Circa littoral sub-zone). Margala Hill Limestone is fossiliferous, nodular limestone. It shows deep sea depositional environment. Chorgali Formation consists of limestone with marl, having abundance of fossils. It shows shelf

environment. Kuldana Formation mainly has shale, marl and sandstone with gypsiferous bands. The Formation was deposited in shallow marine oxidizing conditions. The climate was hot and arid and the rate of evaporation was high. The thin section slides from Jurassic to Eocene rock units have been studied. Petrographically Lockhart Limestone (Paleocene) and Margala Hill Limestone (Eocene) have been studied in detail. According to Folk's (1962) classification, Lockhart Limestone is normally Wacke to pack stone while according to Dunham's (1962) it is fossiliferous to packed biomicrite. Margala Hill Limestone is mainly wacke stone, mud stone and packstone (Folk's) and it is biomicrite, biosparite and biosparry micrite (Dunham's). The measured stratigraphic sections of the rock units from Jurassic to Eocene are presented in Lithologs No 1 to 4 (Pocket). Tectonically the area is highly disturbed, being involved in Himalayan Orogeny. Geological sub surface structures are described with the help of cross section. Almost all the major structures follow the general trend NE-SW. From the cross-section line along AA' shows that there is intrusive deformation in the area. Some important folds are Hili-Bagla anticline, Seri and Kuhmal synclines. The project area is highly faulted. The major faults Malat Thrust fault and Kohala-Darkot Thrust fault running parallel to sub parallel following general trend. These faults are reverse and thrust steeply dipping to SE. The Economic potential of limestone of various rock units, Laterite and aggregates have been

Key words: Stratigraphy, micropaleontology, Haripur, Hazara.

H/247. Hussain, M.S. & Ahmad, S., 1969. A study of analcime mineral in some soils of West Pakistan. Pakistan Journal of Scientific and Industrial Research 12, 34-36.

Three out of a total of nine soil samples from West Pakistan showed unusually high (more than 100) exchangeable sodium percentage (ESP) when determined according to the conventional methods. But the pH of these soils ranged from 7.0 to 7.6. This was regarded as an unusual result. It was suspected that the high ESP in the soils may be due to "zeolitic sodium" released from analcime mineral. An intensive mineralogical investigation showed that there is no analcime mineral present in these soils. The high ESP in the soils was therefore not caused by analcime mineral. Low pH values (7.0-7.6) might be regarded as the main obstacle in the way of the synthesis of analcime in the soils under study.

Key words: Soil, West Pakistan.

H/248. Hussain, M.T. & Aslam, M., 1974. Reconnaissance geology of Indus Valley road, Pakistan. Geological Survey of Pakistan, Information Release 78.

This report gives an account of the road side geology from the area between Thakot and Chilas. It gives some minor details of the geology around Thakot, Duber, Patan and Kyal. It contains four maps.

Key words: Mapping, Indus valley road, Thakot, Chilas.

H/249. Hussain, N. & Rehman, S., 1980. The general geology and the structure of the area between Khairabad and southern abutment of Attock bridge. M.Sc. Thesis, Peshawar University.

Key words: Structure, Attock-Cherat, Attock.

H/250. Hussain, R.I., 1985-87. Geology and structure of Doarian Khojaseri area Neelum valley District Muzaffarabad Azad Kashmir with special emphasis on metamorphic tectonics. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 56p.

About 130 sq. km Doarian, Dudhnial, Khoja-Seri area a part of Neelum valley (Azad Kashmir) has been mapped at a scale of 1:50,000. The area is characterized by high relief and v-shaped valleys. The rocks of the area are metamorphic of lower Pre-Cambrian, injected by later intrusions of igneous bodies, granites with some basic. Regional metamorphism and accompanying penetrative deformation post-dates the granite intrusions, because the granite itself is involved in the deformation. Field evidences and laboratory studies favour magnetic origin for the granitic bodies. The area is tectonically highly disturbed being involved in Himalayan orogeny. For petrographic analysis thirty thin sections were studied. Petrogenesis of the rocks of the area is interpreted. Major and minor structures of the area are described. Geological history of the Project area is worked out in comparison with adjoining areas of Punjab Himalayas and northern peninsular India. Economic minerals found in the area are listed.

Key words: Tectonics, structure, metamorphism, Muzaffarabad, Azad Kashmir.

H/251. Hussain, S., 1983-85. Biostratigraphy of the Jhalar Area-the Kala Chitta Range, Attock District. M.Sc. Thesis, Punjab University, Lahore, 90p.

A geological map of the Jhalar area-the Kala Chitta Range, on a scale of 1" to 0.789 mile or 1:50,000 and covering an area of 16.43 miles² has been prepared to discuss the stratigraphy and micropaleontology of the area. An attempt has been made to discuss the importance of foraminifera content of these rock units, for determining the depositional pattern and age. The geological sequence of the Kala Chitta Range with a view to recognize the continuity or unique aspects of the lithostratigraphic units in the adjoining area. The various geological events that occur in the area and their geological implications have also been discussed. In the Kala Chitta Range there are some eighteen lithostratigraphic units but the area under discussion comprises ten lithostratigraphic units mostly of marine environments and with non-marine units.

Key words: Stratigraphy, micropaleontology, Foraminifera, Kala Chitta, Attock.

H/252. Hussain, S., 1999-2000. Geological mapping of Kohala-Muzaffarabad area with special emphasis on slope stability problems identification analysis & remediation along Kohala Muzaffarabad Road Azad Kashmir. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 75p.

Gullian, Dulai and Rara is an area of high landslides hazards. The landslides are at the right bank of the River Jhelum, characterized by high and narrow divides separated by steep tributaries cut into bedrock. The rocks are highly fractured and jointed with steep dipping slopes agitated by (MBT) and pore water pressure. The abundance of clays and silty soils and humid climatic condition of the area contribute to landsliding in Muzaffarabad region. The situation is aggravated by cutting for road widening and destabilization of slopes by earthquakes resulting in major landslides. Rock fall, rock topple shear failure. Earthflow, slumps and combination of these are most common modes of failure. Gullian (1-2)) Dulai and Rara landslides were investigated in detail because of the proximity to roadways. Topographic and geological maps were prepared for each soil and soil samples were collected to establish engineering properties and stratigraphic succession involved in failure. It has been concluded that the slope failure is mainly in the areas where Murree clays are involved. The swelling potential of Murree clays, pore water pressure, Main Boundary Thrust (MBT) and uneven drainage also contribute to landsliding. It is suggested that the improvement of drainage pattern calculation of overburden material, pore water pressure and after the consideration of seismic loads retaining walls should be constructed. At places piling is also necessary.

Key words: Mapping, slope stability, Muzaffarabad, Azad Kashmir.

H/253. Hussain, S.M., 1957. Salt Range, Potwar, Murree, Abbottabad and Swat. M.Sc. Thesis, Punjab University, Lahore.

Key words: Mapping, stratigraphy, Salt range, Potwar.

H/254. Hussain, S.S. & Akbar, H.D. (Eds.), 2000. Economic Geology of Pakistan. Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad. Pakistan Museum of Natural History, Islamabad, 302p.

This is a compilation of paper presented in 1997 Conference. Thirteen of the 18 papers are summarized at appropriate places. The papers have been distributed into five sections: I Metallic Minerals, II Industrial Minerals, III Energy Resources, IV Geological Materials/Geohydrology, and V Gemstones. These are followed by general recommendation.

Key words: Economic geology.

H/255. Hussain, S.S., Chaudhry, M.N. & Dawood, H., 1992. Emerald mineralization of Barang, Bajaur Agency, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.57.

Consult the following account.

Key words: Emerald, gemstone, mineralization, Bajaur.

H/256. Hussain, S.S., Chaudhry, M.N. & Dawood, H., 1993. Emerald mineralization of Barang, Bajawar Agency, Pakistan. *Journal of Gemmology* 7, 402-408.

This is the first account of emerald mineralization from Barang, Bajaur Agency, NW Pakistan. Emerald mineralization is associated with talc carbonate host of the Indus suture ophiolitic mélange. The mineralization is pneumatolytic and hydrothermal late to post tectonic and structurally controlled. For the first time it is being recognized and proposed that the source of beryllium bearing fluids responsible for emerald mineralization are the Tertiary minor granites of S-type occurring in the area. This is contrary to the already held views that beryllium fluids emanated from a trench or arc source. The color of Barang emerald varies from light bluish green to deep green and the crystal range from minute to 2.5cm. This paper for the first time presents cell dimension of emerald from Pakistan by using an advanced computer program and four cycles of refinement.

Key words: Emerald, gemstone, mineralization, Bajaur.

H/257. Hussain, S.S., Chaudhry, M.N., Dawood, H. & Anwar, J., 1989. Geology and emerald mineralization of Barang-Turghao area, Bajaur Agency, Pakistan. *Kashmir Journal of Geology* 6 & 7, 87-102.

Geology and emerald mineralization of Barang-Turghao area have been studied for the first time. Rocks of the area are comprised of (a) granite gneisses, arenaceous, calcareous and argillaceous metasediments (rocks of Indian Plate) and (b) greenschists, greenstones, quartzites, gabbros and talc-carbonates (ophiolitic melanges zone). Emerald mineralization is associated with talc-carbonates. Petrographic and field studies reveal that this mineralization is pneumatolytic, post tectonic and structurally controlled. The source of the beryllium bearing fluids, responsible for emerald mineralization could be the non-foliated younger granites in the surroundings. It is also supported by the presence of the blue beryl in the area. Other minerals which may have some economic significance are hessonite garnet, green garnet, epidote, graphitic and apatite.

Key words: Emerald, gemstone, mineralization, Bajaur.

H/258. Hussain, S.S. & Dawood, H., 1996. Beryl Mineralization of Higher Himalayas and its implications for emerald mineralization in Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 69.

Blue and green beryl in granites of Higher Himalayan Crystalline Block in Malakand Agency and district Dir has been found at a number of places. Emerald is being mined from the adjoining areas of Seat district and Bajaur Agency since the late sixties. The beryl mineralization has been studied in detail with the aim of determining its nature and to see its implications for emerald mineralization in the region.

Stratigraphically, the Higher Himalayan Crystalline block exposed to the south of the Main Mantle Thrust (MMT) is comprised dominantly of (i) granitoid-migmatitic complex with metasedimentary enclave and abundant pegmatites, (ii) pelite-psammite sequence with abundant pegmatites, intrusive granites and contact migmatites and (iii) pelite-psammite of kyanite-sillimanite grade with pegmatites and granites. The beryl mineralization has been noted in simple pegmatites and hydrothermal/pneumatolytic veins including quartz veins, quartz-feldspar pegmatites, quartz-feldspar-mica pegmatites and quartz-feldspar-mica-fluorite pegmatites. The pegmatites and veins are of variable dimensions up to a few meters long and wide. Besides, in Dir District, quartz, quartz-calcite and quartz-ilmenite veins are observed to contain beryl mineralization. From the field observations it is noted that beryl mineralization phase is younger than quartz ilmenite phase.

The beryl mineralization is observed in pockets or cluster. The color of beryl varies from light blue, through deep blue to greenish blue. The crystal is usually small sized and fractured, opaque to translucent and slightly transparent. Five samples of granite gneiss from the mineralized areas have been studied petrographically. These are mostly hypidiomorphic granular. Granite gneisses of Barh and Kot (Malakand Agency) have dominant orthoclase with only up to 2% albite, whereas Turghao and Agra gneisses have 34% and 35% albite/plagioclase respectively. Amphibole

(0.5% in each) is present in two samples. Muscovite and biotite occur as elongated flakes and impart gneissic structure to the rock. Feldspar shows alteration to clay. Calcite, epidote, sphene and ore minerals are the other accessories.

Two beryl samples from Badwan and Ramial, district Dir were analyzed chemically. Among the major elements, SiO₂ is 62.74% and 65.80%, Al₂O₃ is 13.23% and 16.08% and BeO is 12.99% and 7.31% in Badwan and Ramial samples, respectively. Comparison of major and trace elements in beryls from Badwan and Ramial (Dir) and Swat emeralds shows that Na is high in beryls as compared with emeralds, whereas Bi, Co, P, W and Zn is high in beryls found in hydrothermal/pneumatolytic veins than in pegmatitic beryls as well as emeralds. Cr, Ni and V are high in emeralds, which is attributed to the host ultramafics.

Beryls from Ramial and Badwan (Dir) and Barh and Batoo (Malakand Agency) have also been studied by XRD techniques. The cell dimension of beryls were found to cover the ranges: $a=9.9216-9.259\text{\AA}$ and $c=9.189-9.219\text{\AA}$. The densities of beryl range from 2.611 to 2.633. It is the lowest case of the Badwan beryl.

The granites represent different episodes of magmatism. The younger fine-grained Tertiary granites intrude older Proterozoic granitic gneisses. The mineralized veins and pegmatites cut gneissic as well as younger fine-grained granites. Beryl mineralization found in quartz veins and pegmatites associated with Proterozoic granite gneisses as well as younger, undeformed Tertiary granites is widespread.

Based on field and laboratory studies, it is considered that the Be-B-F-Al bearing solutions, which gave rise to beryl as well as emerald mineralization originated from the post-tectonic Tertiary granites. In the case of emeralds, the required Cr was imparted by the host talc carbonates.

Key words: Emerald, beryl, gemstone, mineralization, Malakand, Dir.

H/259. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1990a. Application of geochemistry to emerald exploration in Swat, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 25-26.

Geochemistry has been rarely used for emerald exploration. The present studies for finding geochemical Pathfinders for emerald mineralization in Swat are significant.

Geochemical characteristics of the emerald bearing rocks of Emerald Mines have been determined. For this purpose, rock and stream sediment analyses of mineralized and non-mineralized areas were carried out using Induced Couple Plasma Emission Spectrometry. Multi-variate studies on the analytical results of 105 samples reveal that high Be, along with high Li, Sr and La may be taken as pathfinders for emerald mineralization in the Swat Emerald Mines.

Malam was selected as the target area where talc carbonates have the same physical and mineralogical characters like that of the Swat Emerald Mines. In this area, no significant anomalies could be distinguished using the geochemical model of Swat Emerald Mines; however, high Be and Li anomalies are evident in Malam stream sediments. Such geochemical studies, if carried out in conjunction with mineralogical and structural studies of a particular area, would be more helpful for pinpointing its emerald mineralization.

Key words: Emerald, gems, exploration, geochemistry, Swat.

H/260. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1990b. Ophiolite related manganese mineralization in Kassai, Lower Mohmand Agency and Shangla, Swat, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 47p.

Ophiolite related manganese mineralization in Kassai area, lower Mohmand Agency has been studied and its comparison with that of the Shangla area, Swat has been done. Kassai Mn mineralization is observed as hydrothermal lenses and veins in tectonic block of quartzite in the Kot-Prang Ghar melange complex. Petrographic and chemical analyses of eight samples are presented. Samples of manganese ore of Kassai and Shangla contain upto 60% and 32.46% MnO₂ respectively. Field observations reveal that Kassai area might contain more mineable reserves of similar nature.

Field and laboratory studies indicate that the manganese mineralization of Kassai and Shangla is of hydrothermal origin related to the volcanic activity during the closure of Tethys ocean. It is assumed that manganese has been incorporated hydrothermally in the oceanic sediments in shallow ocean environments during the tectonic activity.

Key words: Ophiolites, ultramafics, manganese, mineralization, Mohmand Agency, Shangla, Swat.

H/261. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1990c. Application of geochemistry to emerald exploration in Swat, Pakistan. Geological Bulletin, University of Peshawar 23, 45-65.

There are very few cases in the world where geochemistry has been used for emerald exploration. The present studies to fine out geochemical pathfinders for emerald mineralization in Swat are hence significant.

Geochemical characteristics of the emerald bearing rocks of Swat Emerald Mines have been determined. For this purpose rock and stream sediment analyses of mineralized and non-mineralized areas are carried out using Induced Couple Plasma Emission Spectrometry.

Univariate and multi-variate studies on the analytical results of 105 rocks and stream sediment samples of Swat Emerald Mines and Malam area were carried out. These studies reveal that high Be along with high Li, Sr and La may be taken as pathfinders for emerald mineralization in the Swat Emerald Mines.

Malam was selected as target area where talc-carbonate have the same physical and mineralogical characters like that of the Swat Emerald Mines. In this area no significant anomalies could be distinguished using the geochemical model of Swat Emerald Mines, however, high Be and Li anomalies are evident in Malam stream sediments. Such geochemical studies, if carried out in conjunction with mineralogical and structural studies of a particular area, would be more helpful for pinpointing its emerald mineralization.

Key words: Ophiolites, ultramafics, manganese, mineralization, Mohmand Agency, Shangla, Swat.

H/262. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1992. Significant characteristics of the World's major emerald deposits and their relevance to emerald mineralization in N.W. Himalayas, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.56.

Key words: Emerald, mineralization.

H/263. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1995a. Mineralization associated with the Himalayan suture zone of Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.10.

The authors briefly described the Indus Suture rocks and associated ophiolitic mélange. A number of metallic/non-metallic mineral and gemstone reported from the suture include emerald/beryl, manganese, chromite, nickel, green garnet, epidot, rodingite and talc.

Key words: Mineral deposit, Suture zone, Himalayan

H/264. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1995b. Green Garnet (Tsavorite) Mineralization in Higher Himalayan Basement Rocks of NorthWest, Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

This is the first detailed account of the vanadium and chromium bearing green garnet (tsavorite) mineralization associated with metasediments and carbonatites of Higher Himalayan crystalline slab of Bajaur and Malakand agencies and Swat district, north- west Pakistan.

Euhedral and anhedral tsavorite in Jambil, Swat is found in quartz veins within graphitic schists which are part of Proterozoic basement pelitic-psammitic metasediments, metamorphosed to upper amphibolite facies and intruded by granitic rocks of Tertiary? as wells as 400 Ma, 51 0-560 Ma, 580-600 Ma, 1517 Ma, 1970-2031 Ma in age. These rocks make the northern margin of the Indian plate, south of the Main Mantle Thrust.

In Mairagai (Swat), Selai Patti (Malakand Agency) and Bagh-Turghao (Bajaur Agency) green garnet bearing carbonatites are exposed in a linear belt of more than 100 kms and occur as sheets, sills, ring type and lensoidal bodies of variable dimensions. These rocks are generally medium to coarse grained, white, earthy white to brownish in colour having sugary texture.

Selai Patti (Malakand Agency) and Bagh-Turghao (Bajaur Agency) carbonatites show alteration to feldspathic material along joints and in certain zones, which are mineralized. However, in Mairagai (Swat) no such alteration has been seen. The altered parts of carbonatite in Selai Patti and Bagh-Turghao areas lack the ferro-magnesian minerals however non-crystalline green garnet is present in these zones as aggregates. The carbonatites are

composed of calcite, siderite with variable quantity of amphibole, pyroxene, biotite, vermiculite, sphene, apatite, pyrite and garnets. At places crystals of amphibole, pyroxene and vermiculite flakes occur as aggregates. Sphene and apatite are transparent to translucent. The carbonatites in Selai Patti area locally contain a few apophysis of undeformed Tertiary? granite. Quartz, feldspar and amphibole bearing pegmatites also cut these carbonatites in Mairagai and Selai Patti area. The carbonatites and pegmatites show tight folding and appear to have suffered multiple deformation. In carbonatites the green garnet occurs either as disseminated crystals or their aggregates and range in size from tiny specks to 1 cm across. These are generally transparent to translucent. The colour varies from light pale green, olive green to mottled green.

The garnet of Jambil area is generally dark green and occurs as disseminations and crystal aggregates in hydrothermal quartz veins and in the graphitic schists adjacent to the quartz veins. Inclusions of graphite and mica are common. These transparent to translucent garnets can be cut in exquisite melle sized gems.

The cell dimensions of two crystals of Jambil (Swat) green garnet and one each of Turghao and Mairagai were determined on X-ray diffractometer. In Jambil green garnet the cell dimensions are 11.8902 Å and 11.8809 Å with SD of 0.0005 and 0.0087 respectively. Turghao and Mairagai garnets have 11.8453 Å with SD of 0.0125 and 11.8650 Å with SD of 0.141. Chemical analyses of green garnets from these areas are also presented in this paper. The green garnet of Jambil is high in Ca, typical of grossular garnet. High V and small quantity of Cr impart deep green colour to the Jambil green garnet. However the garnets in carbonatites have both V and Cr but in very small quantity compared with that of Jambil. The occurrence as well as physical and chemical properties of green garnet indicate their mineralization in two different geological environments.

Key words: Garnet, mineralization, Swat.

H/265. Hussain, S.S., Dawood, H. & Chaudhry, M.N., 1997. Talc/magnesite deposits along Main Karakoram Thrust zone, N. Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

Extensive occurrences of talc/soapstone and magnesite from Shishi Valley. Chitral and from Yasin and Lshkuman valleys. Gilgit are being reported and studied in fair detail for the first time. These talcose rocks occur within the Main Karakoram Thrust Zone (MKTZ), which extends for a distance of more than 300 kms from the Pak-Afghan border near Mirkhini. Chitral and continues in the east through Shishi. Yasin. Lshkuman, Hunza and Shigar valleys, Northern Areas. The ultramafics which variably alter to talc carbonates are serpentinite, serpentinitized harzburgites and serpentinitized dunite. These studies have revealed that the talc rich bodies are intimately associated with border areas of talc carbonates. Talc may constitute upto 70% of these rock and in a few bodies it may go as high as 80%. Petrographic and chemical analyses of these rocks are also presented. These bodies are measurable from a few metres in tens of metres wide and upto hundred of metres long. These talcose rocks, thus, have huge reserves. The laboratory scale beneficiation test show that these rocks can be upgraded for commercial use. Magnesite can also be obtained from these rocks as a bye-product. These talcose deposits merit detailed economic evaluation.

Key words: Talc, magnesite, MKT, Chitral, Yasin.

H/266. Hussain, S.S., Dawood, H., Chaudhry, M.N. & Weiss, M., 2001. Geochemistry and genesis of manganese mineralization in Kasi and Moto Shah area, Mohmand Agency, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.68.

Manganese mineralization occurring in meta-cherts of the Indus suture zone melange in Mohmand Agency has been studied in detail. The mineralized meta-cherts in Kasai and Moto Shah areas. Mohmand Agency are part of the Kot-Prang Ghar melange complex where all the lithologies of ophiolites, intact as well as dismembered, are exposed (Hussain et al., 1984).

Petrographically the Kasai ore comprises upto 30% manganese ore minerals. The manganese ore and gangue of Kasai area are characterized by the presence of 3% and 60% piemontite and 20% & 5% garnet, respectively. The manganese ore of Kasai contains upto 60% MnO₂. The associated spessertine garnets are quite rich in manganese with 32.65 to 37.14% MnO₂ whereas SiO₂ ranges from 36.11 to 42.97%, Al₂O₃ from 19.75 to 21.18% and CaO from 3.57 to 4.20%. Microprobe studies were also carried out on two samples, which show that the Kasai manganese ore comprises brahinite as well as rhodonite.

Fe/Mn ratio of manganese ore in Kasai ranges from 0.035 to 0.037 whereas in Moto Shah this ratio is 2.05. The trace element contents and Fe/Mn ratio suggest that Kasai manganese mineralization is hydrothermal whereas that of

Moto Shah appears to be hydrogenous. The presence of spessartine garnet, piedmontite and other associated minerals in the Kasai manganese deposit suggest that these rocks suffered low temperature, high-pressure metamorphism. Geochemistry, morphology and sedimentological & geotectonic setting of these deposits suggest that manganese mineralization in Kasai, Mohmand Agency originated as a result of submarine hydrothermal activity in the Tethyan Ocean.

Key words: Geochemistry, manganese, mineralization, microprobe, Mohmand Agency

H/267. Hussain, S.S., & Iqbal, M., 1975. Field Report on the geology and petrology of Malakand and Chakdara. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Key words: Petrology, maps, Malakand, Chakdara.

H/268. Hussain, S.S., Khan, T., Dawood, H. & Khan, I., 1984. A note on Kot-Prang Ghar melange and associated mineral occurrences. Geological Bulletin, University of Peshawar 17, 61-68.

Lower Mohmand and western part of Malakand Agency are characterized by ophiolitic Late Jurassic to Cretaceous Melange Complex. Middle to Late Paleozoic metasediments, and Malakand-Kot and Silai Patti-Kolangi granitic gneisses of Cambrian age make up the rest of the rock sequence within the area. Thrust faults, intricate folds, joints and complex foliation planes are the major structural features. These structures are the result of multiple tectonic events in this region. Gemstone and metallic ore mineralization has taken place in the Melange Complex, of which emerald, epidote, beryl, rutile, jadeite/nephrite, manganese and chromite may be of economic significance.

Key words: Ophiolites, ultramafics, Jurassic, Cretaceous, Melange, Prang Ghar, Malakand.

H/269. Hussain, S.S., & Wazir, A.K., 1999. Structure, stratigraphy and tectonic setup of a part of northern Suleman Range, North Waziristan Agency, N.W.F.P. M.Sc. Thesis, University of Peshawar, 71p.

Key words: Structure, stratigraphy, tectonics, Suleman Range, North Waziristan Agency.

H/270. Hussain, S.T., 1970a. Status and scope of mineral statistics in the mineral industry of Pakistan. Proceedings, National Seminar on Mineral Development, Lahore, 20-23rd April, 1970.

Key words: Mineral industry.

H/271. Hussain, S.T., 1970b. Summary review of gypsum, its projected demands in saline-alkali soils of West Pakistan. Proceedings, National Seminar on Mineral Development, Lahore, 20-23rd April, 1970.

Key words: Gypsum, soils.

H/272. Hussain, S.T., 1973. Appearance Hipparion in the Tertiary of the Siwalik Hills of north India, Kashmir and Pakistan. Nature, 246-531.

The earliest occurrence of *Hipparion*, a tridactyl fossil equid, in the Tertiary of the Siwalik Hills (Pakistan and India) has been discussed by Simon et al. Their statements are confusing and they have misinterpreted one of my publications. Simons *et al.*¹ reject a possible Chinji occurrence of the genus, partly because "Hussain has pointed out that regardless of the validity of occurrence of the *Hipparion* reputed to have been found near the base of the Chinji, the teeth of these specimens are very large. It is implausible that such animals should have preceded in time the small and structurally different species *Hipparion nagriensis* Hussain".

Key words: Palaeontology, Siwaliks, Tertiary, India Pakistan.

H/273. Hussain, S.T., 1984. Paleo-environmental studies of continental sediments in Pakistan. Abstracts, First All Pakistan Geological Congress, Lahore, p.43.

The study of paleoenvironments in the geological time is of great importance for the evaluation of life and processes of mineralization. In the continental sediments, paleo-channels and paleoriver systems have been studied which point out sources of certain minerals and animal life. It has been established that Indo-Pak Plate collided with Asia in Paleocene times, the first evidence of land mammals has been seen in early Eocene in Pakistan. The biostratigraphic and chronostratigraphic relationships of certain orders. The biostratigraphic and chronostratigraphic correlations within Pakistan help in the determination of similar paleoenvironments which may lead to the formation of certain mineral deposits and development of life. The process of evolution is a complex one which involves chemistry of the animals and the morphology changes in spurts. The evidence is seen in certain groups such as trilobites, reptiles and mammals. The change in environments can also produce abnormal chemistry which ultimately may result in pathologic morphology.

Key words: Sediments, paleoenvironments.

H/274. Hussain, S.T., 1986. First appearance of land mammals on Indo-Pakistan subcontinent. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, p.18.

The artiodactyl rodents and several specimens of a new dichobunid artiodactyl, *Discodexis Pakistanensis* have been found in the Kuldana Formation of the Kohat area. These are the earliest land mammals ever found on the Indo-Pakistan Subcontinent. The artiodactyls from Kohat, one of the oldest records of the super-family, have lophodont upper cheek teeth. The micro-structure of the enamel of the incisors is diversified. The discovery of *Discodexis Pakistanensis* in Kohat establishes the presence of *Discodexis* on all continents of the northern hemisphere at the beginning of the Eocene and possibly suggests an Asian Origin for the Artiodactyla. It is now established that the land mammals arrived on the Indo-Pakistan Subcontinent from Central Asia approximately 50 million years ago. This confirms that the Indo-Pakistan Subcontinent, which was originally part of Africa, collided with Asia prior to this time. Soon after that there was a major influx of land vertebrates, particularly of mammals into the Indo-Pakistan Subcontinent.

Key words: Palaeontology, mammals, Kuldana.

H/275. Hussain S.T., DeBrujn, H. & Leniders, J.M., 1978. Middle Eocene rodants from the Kala Chitta Range (Punjab, Pakistan). *Kan. Nederland Akad. Wetensche. Series B*, 8, 81-112.

Key words: Rodents, Eocene, Kala Chitta.

H/276. Hussain, S.T. & Khan, A.L., 1969. Fire clay deposits of Kala Chitta Range District Campbellpur, West Pakistan. Geological Survey of Pakistan, 89.

Key words: Fire clay, Kala Chitta, Campbellpur.

H/277. Hussain, S.T., Munthe, J., Shah, S.M.I., West, R.M. & Lukas, J.R., 1979. Neogene stratigraphy and fossil vertebrates of Daud Khel area, Mianwali District. Geological Survey of Pakistan, Memoir 13, 27p.

Key words: Palaeontology, vertebrates, Siwaliks, Mianwali.

H/278. Hussain, S.T., Munthe, J., West, R.M. & Lukas, J.R., 1977. The Daud Khel local fauna: A preliminary report on a Neogene vertebrate assemblage from Trans-Indus Siwalik, Pakistan. Milwaukee Public Museum, Contributions in Biology and Geology 16, 17p.

Key words: Palaeontology, Vertebrates, Siwaliks, Tertiary, Trans Indus.

H/279. Hussain, S. T., Sonders, P.Y. & Shah, S.M.I., 1983. Fossil mammal bones of Pakistan: A field atlas. Geological Survey of Pakistan, Memoir 14.

Key words: Palaeontology, Vertebrates, Mammals.

H/280. Hussain, S.T., Van den Bergh, G.D., Steensma, K.J., De Visser, J.A., De Vos, J., Arif, M., Van Dam, J., Sondaar P.Y. & Malik, S.M., 1992. Biostratigraphy of the Plio-Pleistocene continental sediments (Upper Siwaliks) of the Mangla-Samwal Anticline, Azad Kashmir, Pakistan. Proceedings of the Koninklijke Nederlandse Akademie Van Wetenschappen. 95 (1), 65-80.

Key words: Biostratigraphy, sediments, Plio-Pleistocene, Azad Kashmir.

H/281. Hussain, T., 1972. Geology of the Manarai Banda area, Upper Swat, with special emphasis on mineralogy of the area. M.Sc. Thesis, Punjab University, Lahore, 69p.

Key words: Petrography, Swat.

H/282. Hussain, T., 1984-85. Geology and structure of Reshian-Lamnian-Panhkot-Nauseri Area Neelum-Jhelum valleys District Muzaffarabad, Azad Kashmir, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 78p.

This report comprises a complete geological study based on mapping of nearly 180 sq. km. located between Beehian-Nauseri of Jhelum and Neelum Valleys respectively. Special emphasis has been put on describing the tentative stratigraphic correlation of the rock units. In the project area a large number of rock units including volcanics, microaugengneiss, micaceous quartzites, quartz mica schists, granite gneiss, sandstones, shale, and siltstones are encountered. A stratigraphic sequence has been worked out. The rocks extend in age from Devonian to Miocene and have been correlated with Tanawal Formation, Agglomeratic Slates, Panjal Formation and Murree Formation respectively. Structurally, the rocks are folded into a number of major structures which are now separated from each other by mostly north dipping high angle thrust faults. The area comprises of two major thrusts known as Murree Thrust/Main Boundary Fault and Panjal thrust. Hazara Kashmir syntaxis has a great influence on the stratigraphy, structure and tectonic of the investigated area. That is why we have generally interpreted our results with respect to the syntaxis, as the project area lies on its eastern limb. In the field of economic geology a number of economic deposits including marble, graphite, gypsum and building-stone have been discussed. This report also includes a petrographic description of the rock units as well as numerous sketch section and photographs, illustrating the geology of the area.

Key words: Structure, maps, Neelum-Jhelum valley, Azad Kashmir.

H/283. Hussain, T. & Naqvi, A.A., 1973. High aluminous clay deposits of the Punjab province, Pakistan. Geological Survey of Pakistan, Information Release 59, 16p.

Deposits of fire Clay/bauxite of commercial significance occur in the salt range and the Kala Chitta Range. These deposits have been investigated under a joint project of G.S.P. and P.C.S.I.R. Geological mapping of these deposits has been carried out by the G.S.P.

Mineralogical and chemical tests of the samples discussed in this report indicate that the clays are free from any visible impurities, their plasticity varies from fair to moderate and their slacking behaviour is slow. As a whole the composition and characteristics of the high aluminous clay deposits of Salt Range and Kala Chitta range are fairly conformable with the specifications laid down by the Soviet experts for the clays required for the proposed Karachi

Steel Mill. The total reserves estimate of the deposits discussed in this report are a little over 85 million tons and as such these are enough to meet the annual requirement of 75,000 tons of clay for Karachi Steel Mill for several decades.

Key words: Clay, high alumina, Punjab.

H/284. Hussain, V., Bilqees, R. & Hussain, A., 1995. Industrial mineral resources of Pakistan. SEGMITE Souvenir on International Symposium on Phosphate and Industrial Minerals, at Abbottabad, 21–25 May, 1995.

Key words: Industrial minerals.

H/285. Hussain, V. & Kaifi, Z., 1995. Industrial mineral potential of North Pakistan and scope for trade and technological cooperation between Pakistan and Sri Lanka. In: Abstract volume Dissanayake, C.B., Almond, D.C. & Cooray, P.G., (Eds.), Second South Asia Geological Congress, (GEOSAS-II), Colombo, Sri Lanka, p.237.

Key words: Industrial minerals.

H/286. Hussain, V., Khan, M.M. & Siddiqui, F.A., 1990. Vein type barite deposits in Kag, Aluli and Darwaza near Haripur, NWFP, Pakistan. 2nd Pakistan Geological Congress Abstract, 9p.

Key words: Barite, Haripur.

H/287. Hussain, V., Qaiser, M.A., Ahmad, N. & Bilqees, R., 1987. Petrology of Kakul phosphorites, district Abbottabad, NWFP, Pakistan. Geological Bulletin, University of Peshawar 20, 153-160.

Two basic types of phosphorites have been recognized within the Kakul stratigraphic sequence: 1) authigenic microcrystalline phosphorite mud (microphorite) or orthochemical phosphorite which has precipitated either biochemically or physiochemically, and 2) pelletal phosphorite or allochemical phosphorite which has been modified into discrete clastic particle from microphosite mud. Microscopically, the primary component is the carbonate fluorapatite matrix with cryptocrystalline dolomite, calcite and quartz. Also there are detrital grains of quartz, dolomite, and calcite with disseminated ferruginous matter.

Key words: Stratigraphy, phosphorite, Kakul, Abbottabad.

H/288. Hussain, V., Siddiqui, F.A., Qureshi, K.M. & Ghani, A., 1987. Petrology of barite deposits of southern Hazara, N.W.F.P., Pakistan. Geological Bulletin, Punjab University 22, 136-142.

The barite occurring in Southern Hazara district near Haripur is snow-white in colour. Barite is coarse grained massive and compact in nature. Barite occurs mostly as veins which contains impurities consisting of quartz, calcite, and traces of pyrite, iron oxide and copper. Barite in tanol area are mostly hosted in quartzitic sandstone and are cavity filling and epithermal vein type deposits.

Key words: Petrology, barite, Hazara.

H/289. Hussain, V., Ullah, W., Qaiser, M.A. & Siddiqui, F., 1992. Clay deposits of Pakistan. In: Nagaswa, K. (Ed.), Clay Minerals, their Natural Resources and Uses. Proceedings of Workshop WB-1, 20th International Geological Congress, 97-105.

Key words: Clay.

H/290. Huzita, K., 1965. Geological research in Gilgit. Ishkuman and Yasin areas. In: Matshushita, S., and Huzita, K., (Eds.), *Geology of Karakorum and Hindu Kush*. Kyoto University Science Exped. 1955, vol. VII, 7–36. Nippon printing & Publishing Co., Ltd. Japan.

This is a detailed description of the sections along the Gilgit, Yasin and Ishkuman river valleys. The lithologic and other characteristics of the (meta)sedimentary rocks, volcanics and greenstones, granite gneisses and granites, glacial and stream deposits along the courses of the rivers are describes and compared with others in the Karakoram. Fossil species in the Yasin valley are also described. The text descriptions are supported by 14 excellent hand sketches and 12 photographs. Huzita compared his geological divisions with those of Ivanac et al. (1956) and Schneider (1957, 1960) as follows.

Geological division of Gilgit-Ishkuman-Yasin areas.

Researcher	K. HUZITA	J. F. IVANAC	H. J. SCHNEIDER
Division	7) Quaternary deposits 6) Granite of Ghizar valley 5) Gneiss of Gilgit 4) Yasin group 3) Green series 2) Granite of Karambar 1) Darkot group	7) Quaternary deposits 6) Ladakh Granodiorite 2) Karakoram Granodiorite 2) Darkot Pass Granodiorite 4) Yasin group 3) Green Complex 1) Darkot group	?) Zone H 5) Zone I 3) Zone II 1?) Zone III 2) Zone IV 1) Zone V

Key words: Geology, lithology, stratigraphy, sedimentology, Gilgit, Karakoram.

H/291. Hyland, F.D., 1957. Mineral resources of Pakistan. Mineral Trade Notes, US Bureau of Mines 45(6), Special Supplement 50, 49p.

Key words: Mineral resources.

H/292. Hyland, F.D., 1958. Bauxite in Pakistan. Mineral Trade Notes, US Bureau of Mines 46(6).

Key words: Mineral resources, bauxite.

H/293. Hylland, M.D., Riaz, M. & Ahmad, S., 1988. Stratigraphy and structure of the southern Gandghar Range, Pakistan. Geological Bulletin, University of Peshawar 21, 1-14.

The southern Gandghar Range is composed of a succession of marine strata of probable Proterozoic age, consisting of a thick basal argillaceous sequence (Manki Formation) overlain by algal limestone and shale (Shahkot, Utch Khattak, and Shekhai Formations). These rocks are thrust southeastward over the Kherimar Hills succession along the Panjal fault. The Gandghar Range and Kherimar Hills successions correlate with the northern and central blocks of the Attock-Cherat Range, respectively, indicating that the combined Panjal-Khairabad fault juxtaposes two major, laterally continuous structural blocks.

The rocks of the southern Gandghar Range occur in two structural blocks juxtaposed along the Baghdarra fault. The hanging wall consists entirely of isoclinally-folded Manki Formation, while the footwall consists of the complete Manki-Shekhai succession which has been deformed into tight, northeast-plunging, generally southeast-verging disharmonic folds. The Baghdarra fault is apparently deformed along with the footwall strata, indicating that it is older than, and is being carried piggy-back style on, the Panjal fault. Phyllite near the Baghdarra fault displays asymmetric deformation of foliation around garnet porphyroblasts, kink bands, and a poorly-developed s-c fabric. These features are consistent with conditions of dextral shear, indicating reverse slip displacement along the fault.

Key words: Stratigraphy, structure, mapping, Gandghar, Hazara.

H/294. Hytton, J.W., 1969. Appraisal of phosphate in Pakistan. Geological Survey of Pakistan and U.S.G.S. Project Report, PK (IR)–53, 36p.

Key words: Phosphat.

I/1. Ibrahim, M., Agha, Z.R. & Iqbal, M.P., 1975. A study of Kala-Chitta and Salt Range clays. Pakistan Journal of Scientific Research, Lahore, 27, 49-55.

Key words: Clay, Kala Chitta, Slat Range.

I/2. Ibrahim, M.Y.H., 1992-94. Sedimentology of Murree Formation and lithostructural mapping of Barian Area, Southern Hazara, Northwestern Himalaya-Pakistan. M.Sc. Thesis, Punjab University, Lahore, 124p.

A detailed geological study of a small part of the Attock Hazara Fold and Thrust Belt in Khaira Gali-Kuldana area of Galliat was carried out. Geological mapping at the scale of 1:21120 of an area of 50 square kilometers was carried out in detail. Lithostratigraphic units in the study area range in age from Middle Jurassic to Upper Eocene in age. Samana Suk Limestone of Middle Jurassic age is an oolitic dolomitic limestone and represents shallow carbonate shelf sedimentation. The Chichali Formation is composed of black shale condensed sequence deposited in a basin of restricted circulation and represents deepening of the basin. This continues into glauconitic Lumshiwal Formation deposited in middle subtidal conditions. Further deepening of the basin deposited pelagic Kawagarh Formation of Cretaceous age. It was deposited in lower subtidal conditions near the shelf edge. This was followed by sudden regression due to contact between Kohistan Island Arc and Indian plate, which resulted in general uplift continental conditions. Residual Hangu Formation of Danian age was thus developed on top of Kawagarh Formation. This was followed by a rise in sea level and deposition of shelf foraminiferal Lockhart Limestone of Paleocene age which is overlain by Patala Shale, Margalla Hill Limestone and Chorgali Limestone and Marl. All these are open shelf foraminiferal deposits. At this point in time collision between India and Asia took place mixed marine continental Kuldana Formation developed. This was followed by a rise of Himalaya, which shed debris in the foredeep. This formed fluvial Murree Formation molasses.

The sedimentary package is composed of lower Marine sequence from Jurassic to Middle Eocene dominated by carbonates with a residual lateritic horizon of Danian age. The upper part of the package starts from mixed marine fluvial sequence (Kuldana Formation) and an upper molassic sequence (Murree Formation) of Upper Eocene to Miocene age. Structurally the area is mapped in detail and is composed of Chumbi Anticlinorium, Khaira Gali Synclinorium, Kali Mitti Synclinorium and Darya Gali Anticlinorium. The area is also cut by Thrust faults. General trend of the rocks is northeast to southwest. The rocks are cross folded and double plunging. The folds are tight to isoclinal with a general vergence to southeast. Murree Formation of Upper Eocene to Miocene age is a molassic fluvial sequence deposited by a meandering river system. This sequence was derived from rising Himalaya after the collision of India with Asia in Eocene times. Facies, microfacies, diagenesis and provenance of this formation were studied in detail. For the purpose of foregoing sedimentological studies a section between Darya Gali and Kuldana Chowk was measured and sampled in detail. The Murree Formation is composed of an alternating sequence of gray to grayish gray sandstone and chocolate, maroon and brown shale. Conglomerates, breccias, limestone and marl are minor lithologies. This sequence was derived from rising Himalaya to the north as well as upper part of Kohistan Island Arc. The sandstones are lithic arenites which are texturally sub-mature and compositionally immature.

Key words: Sedimentology, structure, mapping, Murree Formation, Hazara.

I/3. Ichikawa, K. & Maeda, Y., 1965. Some Lower Cretaceous molluscan fossils from Yasin, West Pakistan. In: Matsushita, S. & Huzita, K. (Eds), Geology of the Karakoram and Hindukush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindukush, 1955, Vol. VII, 137-146. Nippon Printing & Publishing Co., Ltd., Japan.

This is a detailed study of Nerineids and Rudists collected from the highly fossiliferous beds near Yasin. The authors give information about the previous paleontological studies in the area (especially those of Hayden, 1915; Douville, 1926; Ivanac et al., 1956; Desio, 1959) and conclude that the Yasin fauna, as a whole, may properly be referred to the Lower Aptian and/or thereabouts. They determined and described the following species and showed them in eight plates:

Plesioptyxis matsushitai n. sp.

Plesioptyxis huzitai n. sp.

Adiozoptyx cf. A. coquandiana D'ORBIGNY

Horiopleura haydeni DOUVILLE

Horiopleura haydeni var.

Key words: Paleontology, Nerineids, Rudists, Yasin, Eastern Hindukush.

I/4. Idrees, M. & Hammad, A., 1977. Petrology of Utla Granite, Gadoon area, M.Sc. Thesis, Peshawar University, 33p.

Key words: Petrology, granite, Swabi.

I/5. Iftikhar & Jehanzeb, 1987. Report on the groundwater resources in Daggar valley, Buner, Swat, N.W.F.P. M.Sc. Thesis, University of Peshawar, 55p.

A programme for groundwater investigation in Daggar valley, Buner in the North West Frontier Province of Pakistan started in January 1984. The objective of the investigation was the determination of the ground water potential of the valley and the most suitable area for withdrawal.

In order to determine the hydraulic characteristics of the sub-soil, hydrogeologic studies were carried out and six testholes were drilled. Four of them were converted into testwells of which one is suitable as potential production well. The results of the studies show that the alluvial fill can be considered as aquifer of mainly fine grained material with some sand and gravel layers varying both in lateral and vertical sense. The alluvial fill is more than 100 m thick and occasionally more than 200 m. the transmissivity of the wells ranges from 300 -0 500 m²/day in the western part of the valley, and only 20-100m²/day in the eastern parts. The depth to the ground-water table is generally less than 15m except in the south-western part from Jowar to Tursak and on the higher elevated old river terranes. Recharge of the ground-water occurs near the mountainous boundary by inflow from the bedrock (mainly limestone) and run-off from the mountains and precipitation on the plain percolating downward through the alluvial fill. Ground-water development with tubewells is only feasible in the valleys south-west of Daggar, due to the availability of sufficient sand and gravel layer in the alluvial fill.

The recharge of the ground-water in this area is 23x10⁶m³/year pf 18870 acres feet/year and it is recommended during ground-water development not to withdraw more than this amount initially. Water levels should be monitored at regular intervals to assure the effects of the ground-water development.

Key words: Groundwater, Buner, Swat.

I/6. Ihsan, M., Badshah, K. & Ali, S., 1983. Petrology of a part of Ambela Granite Complex, Babaji syenite, Buner-Swat, North West Frontier Province. M.Sc. Thesis, University of Peshawar, 88p.

Key words: Petrology, granite, Ambela, Buner, Swat.

I/7. Ikramuddin, M., Fan, F., Tahirkheli, R.A.K., Jan, M.Q., Majid, M., Haneef, M., Shah, M.T., & Afridi, G.A. 1987.Reconnaissance lithogeochemical survey of parts of northwest Pakistan. GSA Abstract with program, 19(7).

Several recent studies have demonstrated that hydrothermally altered rocks associated with various types of mineral deposits generally contain high contents of Ti and low K/Ti ratios. In order to further test the usefulness of Ti and K/Ti ratio as guides to mineralization, a reconnaissance lithogeochemical survey of northwest Pakistan was carried out. About 200 rocks, collected from various parts of the area extending from Peshawar to Gilgit, were analyzed for Tl, Rb, K, and Au. The rocks studied include ultramafics, gabbro, diorite, granodiorite, granite, pegmatite, aplite, quartz veins, andesite, dacite, rhyolite, gneisses, schists, amphibolite, greenstone, and carbonates. Most of the rocks studied are fresh and unmineralized with the exception of a few samples from Besham area, which are associated with Pb-Zn mineralization. The majority of the rocks have very low contents of Au ranging from 0.1 ppb to 5 ppb. The mineralized rocks of Besham area, however, contain high contents of Au, one sample containing 250 ppb. There are at least 5 different rock types, collected from unmineralized areas, which contain Au concentrations 5 to 10 times higher than the background levels. The Tl contents of rocks are generally low varying from 0.01 ppm to 1.5

ppm with ultramafic rocks containing the lowest values and acidic rocks the highest values; each type of rock has a very narrow range of values. The rocks from mineralized area of Besham contain up to 20 ppm T1. There are several localities in the area which contain significantly higher T1 contents and lower K/T1 ratios compared to the background values. The T1 contents and K/T1 ratios of the rocks from Pakistan suggest that the detailed lithogeochemical and pedogeochemical surveys of certain areas may prove to be very useful in locating potential mineral deposits.

Key words: Reconnaissance, geochemistry.

I/8. Ilyas, M., 1973. Geological mapping of Lowari Pass area with special references to prospects of constructing a tunnel. M.Sc. Thesis. Punjab University, Lahore.

Key words: Mapping, Tunnels, Lowari pass.

I/9. Ilyas, M., 1983. Development, mining and beneficiation of China clay. Second National Seminar on Development of Mineral Resources, Peshawar, 3, 10p.

Key words: China clay, beneficiation.

I/10. Ilyas, W., 1983-85. Geotechnical studies of landslides with special emphasis on slope stability along Karakoram Highway between Thakot and Besham, District Swat. M.Sc. Thesis, Punjab University, Lahore, 117p.

Engineering geological investigations were carried out about the landslides and slope stability problem along the Karakoram Highway between Thakot and Besham. The project area mainly comprises of Thakot metasediments, Lahor granite, Shang granite gneiss and mineralised scree (near Besham). These are mainly controlling the rugged topography and other geomorphological features of the Project area. The general trend of stresses is SE.-NW.

So far the stability of the region is concerned; the detailed analysis for critical slopes is performed. Among different modes of failure encountered, the plane failures are proved to be unstable particularly near Maira and at Kandaurgai. Other than this a large variation in discontinuities is observed that controls sliding in hard rocks and highly weathered rocks which are responsible for mass wasting and rock fall. Road alignments were studied keeping in view landslide problems and slope stability, for potentially unstable regions remedial measures are also given. 1 h: 2V cuts slopes and benches are proposed. Benches may be provided at each 8 meters interval.

Key words: Geotechnical, landslides, slope stability, KKH, Thakot, Besham.

I/11. Imam, S.A. & Kidwai, A.H., 1960. Magnetite deposits of Dammer Nissar, Chitral State, West Pakistan. Geological Survey of Pakistan. Information Release 7, 65p.

Key words: Mineral deposits, magnetite, Dammer Nisar, Chitral.

I/12. Imran, H.M., 1973. Geology and petrology of the area on the right bank of Tarbela dam with special emphasis on igneous rocks. M.Sc. Thesis. Punjab University, Lahore, 97p.

Key words: Geology, petrology, Tarbela.

I/13. Iqbal, A., 1964. Soapstone deposits of Sherwan in Hazara District. Science and Industry 2, 19-24.

The geology and mode of occurrence, with chemical analyses are reported for nine deposits of soapstone. These are mostly found near basic intrusions. Prospects for large-scale mining development are discussed.

Key Words: Mineral Deposits, soapstone, Abbottabad, Hazara.

I/14. Iqbal, A., 1997-99. Petrophysical interpretation, reservoir geology modeling and reserves estimation of Silver Gas Field, Middle Indus Basin, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 159p.

This thesis deals with Petrophysical interpretation and development geology of "Silver Gas Field" which is a fictitious name of an existing Gas field in Punjab plat form within middle Indus basin. Drilling record shows that stratigraphic column in the gas field is table (2.1) with their thicknesses. Based upon various kinds of data (mud log and wire line log data), different reservoir parameters were determined individually and reservoir zonation was also described. Variation in reservoir properties were illustrated with the help of various maps including, structural cross-section, stratigraphic cross section iso-porosity maps, iso-saturation maps, net pay maps and net lime maps. Reserves estimation of the "Silver Gas Field which was at its discovery stage has been accomplished on the basis of volumetric equation. Structurally "Silver Gas Field" is a broad gently dipping monocline with conjugate normal faults in the NNW of the area. Only the original gas in place of Samana Suk formation was estimated which is about 124 billion cubic feet (BCF). For the reserves estimation, well data of five wells was used all of which were gas producing.

Key words: Hydrocarbon, reservoir geology, Indus Basin.

I/15. Iqbal, H., Basit, A.A. & Haroon, M., 2000. Subsurface temperature distributions in Upper Indus Basin. Abstracts, Third South Asia Geological Congress, Lahore, p.30.

Key words: Subsurface geology, Indus Basin.

I/16. Iqbal, I., 1989-91. Slope stability analysis and feasibility studies of sub-grade along Murree-Kohala Road. M.Sc. Thesis, Punjab University, Lahore, 140p.

Landslides are wide spread in Pakistan like other Countries and cause enormous economic loss as well as loss of human lives, particularly when engineering structures are designed and constructed without analysing the slope stability conditions. Pakistan has a very intricate Geological history with numerous active tectonic zones. The project area (Murree –Kohala road) has a very diverse sliding phenomenon particularly along the road. The climate conditions of the project area are such humid to semi-arid. The major part of the road is on the escarp face with variety of slope conditions, from strategic and regular communication point of view, Murree –Kohala road has great national importance. It is the shortest land route bridging Pakistan and Azad Kashmir for the supply of basic needs. This road is also important from defence point of view.

The road (Murree -Kohala) originated as a foot -way, then it developed into mule track, further it took the form of jeepable track and finally to overcome the expenditure, the same track was constructed in the form of road.

Key words: Slope stability, feasibility, Murree-Kohala.

I/17. Iqbal, M., 1973. Geology and Petrology of Aligam-Kabal Area, Swat District. M.Sc. Thesis, Punjab University, Lahore, 99p.

A geological map on a scale of 3 inches to a mile, covering more than seventeen miles area around Aligam-Kabal, Swat District, is presented. The rocks of this area, previously mapped as a single unit, are now subdivided into four map able units on lithological basis. Detailed petrography, mineralogy and structural features of these four litho-types are described. Modal analysis and mineralogical data on 40 thin sections is included. Joints orientation diagrams of measurements on perfectly developed joint surfaces are given. Based on field and laboratory evidence, plausible explanations regarding the petrogenesis of the rock exposed in the area are given.

Key words: Petrology, structure, stratigraphy, Swat

I/18. Iqbal, M., 1990-91. Structure, stratigraphy and petrography of the western limb of the Hazara-Kashmir Syntaxis, Garhi Habibullah-Shinkiari area, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 105p.

The Garhi Habibullah-Shinkari area lies along the western limb of the major northwest plunging antiformal structure known as the Hazara-Kashmir syntaxis. The 293 km² area has been mapped in this study. The western limb of the Hazara-Kashmir syntaxis has been divided into four fault-bounded tectonostratigraphic zones. These are named as the Muzaffarabad-Balakot zone, the Garhi Habibullah-Abbottabad zone, the Panjal zone and the Mansehra zone. These zones belong to different tectonic and stratigraphic provinces which have been juxtaposed during the Himalayan thrusting. The Muzaffarabad-Balakot zone lies to the east of Main boundary fault. This zone constitutes late Proterozoic to Cenozoic sequence. This sequence is involved in the Muzaffarabad-Balakot southwestward overturned anticline. The late Proterozoic Dogra formation forms the core of the Muzaffarabad-Balakot anticline. The Dogra formation is unconformably overlain by the early Cambrian Muzaffarabad formation. The Ordovician (?) Yadgar formation disconformably overlies the Muzaffarabad formation. The Yadgar formation is unconformably overlain by the Paleocene-Eocene sequence which includes the Hangu Formation, Lockhart Formation, Patala Formation and Margala Hill Limestone. This was followed by the late Eocene Kuldana and Miocene Murree molasses. The most of the Paleocene to Miocene sequence along the overturned limb of the Muzaffarabad-Balakot anticline is faulted.

The Garhi Habibullah-Abbottabad zone lies between the Main boundary fault and Garhi Habibullah fault. This zone is involved in the Garhi Habibullah syncline. The Cambrian Abbottabad group lies in the core and Hazara formation along the limbs of the anticline. In the Garhi Habibullah syncline, the late Proterozoic Hazara formation is unconformably overlain by the Cambrian Abbottabad group of rocks. The Jurassic sequence has been eroded from the core of the syncline due to later Himalayan uplift.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir syntaxes.

I/19. Iqbal, M., 1994. The Geology of Siwalik rocks in Potwar area. Geological Survey of Pakistan, Information Release 269.

The field work was sponsored by the Geological Survey of Pakistan in collaboration of YALE and HOWARD Universities, U.S.A. to interpret the geology of Siwalik rocks in Potwar Area.

Moreover, in GSP Museum, there were not a sufficient number of vertebrate specimens. It was a great help for the development of palaeontological museum.

Key words: Stratigraphy, paleontology, Siwalik, Potwar.

I/20. Iqbal, M., & Ali, S.M., 2000. Correlation of structural lineaments with oil discoveries in Potwar Area, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.54.

Key words: Structure, oil, Potwar.

I/21. Iqbal, M., & Ali, S.M., 2001. Correlation of structural lineaments with oil discoveries in Potwar Sub-Basin, Pakistan. Pakistan Journal of Hydrocarbon Development 12, 73-80.

Key words: Structure, oil, Potwar.

I/22. Iqbal, M.I.A., 1985-87. Geology of Dunga Gali-Barian Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 105p.

This report incorporates a comprehensive geological study of nearly 25 sq. km. area between Dunga Gali and Barian on the Murree-Abbottabad road. The study includes the preparation of a geological map on the scale 1:7040. Stratigraphically the rock units range from Upper Jurassic to Eocene and represent the sequence of the Hazara Province of the Kohat-Potwar Basin. It is primarily a limestone-shale sequence reflecting a stable shelf facies. Structurally, the area shows the development of a few synclinoria and anticlinoria, within which a generally tight parallel to similar asymmetric to overturn style of folding predominates. A number of dip-slip-strike faults, both of the normal and reverse type are present. A petrographic study of all rock units, based on fairly representative field sampling, is also present.

Key words: Geology, mapping, stratigraphy, Jurassic, Eocene.

I/23. Iqbal, M.W.A., 1969. The Tertiary palecypod and gastropod fauna from Drug, Zinda Pir, Vidor (Distt. D.G. Khan), Jhalar and Chharat (Distt. Campbellpur), West Pakistan. Geological Survey of Pakistan, Memoirs Palaeontologica Pakistanica 6, 77p.

Key words: Tertiary, Paleontology, D.G.Khan, Cambellpur.

I/24. Iqbal, M.W.A., 1969-70. Bibliography of Tertiary pelecepod and gastropods species of West Pakistan. Geological Survey of Pakistan, Records 18, 63p.

Key words: Bibliography, Tertiary, Paleontology.

I/25. Iqbal, M.W.A., 1972. Paleocene bivalve and gastropod fauna from Jherruk-Lakhra-Bara Nai (Sind), Salt Range (Punjab) and Samana Range (NWFP). Geological Survey of Pakistan, Memoirs 9, 104p.

This is an exhaustive study of gastropod and bivalve fauna of Paleocene age. The three areas are well known for their rich faunal assemblage and have been investigated by several workers in the past. The present detailed compilation also contains three maps, three charts, five figures and nine plates.

Key words: Paleocene, Paleontology, Sind, Salt Range, Samana Range, Hangu.

I/26. Iqbal, M.W.A., 1981. The Tertiary bivalves and gastropods of Pakistan. Geological Bulletin, Punjab University 16, 141-145.

The purpose of this paper is to present a resume of the paleontological research on the Tertiary bivalves, and gastropods of Pakistan. The writer (Iqbal, 1972a) presented a detailed account on the subject for the first time during the 13th Session of the Science conference, Scientific Society of Pakistan, March, 1972.

Later on a brief paper on the Tertiary bivalve and gastropods of Sind was also published (Iqbal, 1972).

The writer (Iqbal, 1974) also presented a paper on the Baluchistan fauna during the Seminar on Development in Geological Sciences in Pakistan, University of Baluchistan, September, 1972. The biostratigraphic research conducted by the writer during 1963 to 1980 has given more emphasis to the Tertiary bivalve and gastropod fauna, In most of the cases, the bivalve and gastropod species were found extremely useful in determination of the specific stratigraphic problems and reconstruction of the depositional history of the geological formations in which they occur. Moreover, the world-wide geographical distribution and comparative analysis of the fauna proved helpful in understanding of the basinal distribution, the possible oceanic connections in between the various n certain, geological time, and the genetic relationship between certain species.

Key words: Tertiary, Palaeontology, Bivalves, Gastropods.

I/27. Iqbal, M.W.A., 1983. Tertiary biostratigraphy study based on bivalve and gastropode fauna. Geological Bulletin, Punjab University 18, 9-17.

The biostratigraphic study of the Tertiary formations based on bivalve and gastropod fauna includes large faunal collection from different lithofacies representing various basinal provinces and covering a large geographic areas of Sind, Baluchistan, Punjab and NWFP. Forty six sections representing twenty six major localities were measured. The study consists of systematic treatment and description of 373 species including 36 new species) revision and redesignation of previously described faunal distribution within and outside Pakistan, determination of Index Species, assignment of age and correlation and paleoecology paleontology.

Key words: Tertiary, Palaeontology, Bivalves, Gastropods.

I/28. Iqbal, M.W.A., 1986. Geology of Siwalik rocks in Potwar area, Pakistan. Geological Survey of Pakistan, Information Release 269.

Key words: Geology, Potwar, Siwaliks.

I/29. Iqbal, M.W.A. & Shah, S.M.I., 1980. A guide to the stratigraphy of Pakistan. Geological Survey of Pakistan, Record 53, 37p.

Key words: Stratigraphy.

I/30. Iqbal, S., Khan, H., Nasreen, S., Ghani, A. & Qaiser, M.A. 1999. Geology and chemistry of limestone resources of Khyber Agency. Geological Survey of Pakistan, Information Release 685.

Large deposits of limestone occurs in Khyber Agency. Much geological work has been done on the area but very little mineralogical and chemical studies have been done. Xray diffraction analysis, derivatography and chemical analysis data for the limestone resources of Khyber Agency are presented. Utilization of these limestone deposit in cement, sugar and chemical industries is suggested.

Key words: Geochemistry, limestone, Khyber Agency, NWFP.

I/31. Iqbal, S. & Khan, M.Z., 1983. Geology of Yasin group around Chalt village northern Pakistan. M.Sc. Thesis, University of Peshawar, 133p.

Key words: Geology, petrology, Yasin group, Chalt.

I/32. Iqbal, S.M., Ahmed, S. & Rashid, S., 2000. Environmental geology and land use planning of Islamabad, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 141-142.

Key words: Environment, land use, Islamabad.

I/33. Ishaque, M., 1983. Utilization of Hazara phosphate rock for fertilizer manufacture. Second National Seminar on Development of Mineral Resources, Peshawar, 3, 10p.

Key words: Phosphate, Hazara.

I/34. Ishihara, S., Kausar, A.B. & Karim, T., 1996a. Sulfur isotopic profile and granitoid series in the northern Pakistan. *Geologica* 2, 77-85.

Consult the following account for further information.

Key words: Sulphur, isotopes, granitoids, Northern Pakistan.

I/35. Ishihara, S., Kausar, A.B. & Karim, T., 1996b. Sulfur isotopic profile and granitoid series in the northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc*. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 15, 57-68.

Reconnaissance studies were made on δ^{34} SCDT of trace amounts of sulfides contained in various rocks and on magnetic susceptibility of Paleozoic to Cenozoic granitoids exposed along the Karakoram Highway. Kamila amphibolites of oceanic crust (?) give "mantle-value" of 1.3 permil, while pyroxenite and hornblendite of the infracrustal rocks yields 2.6 permil. Pelitic metamorphic rocks are more deviated to the positive values (2.3 - 10.2 0/00, average 5.2 0/00). Cretaceous-Tertiary granitoids of the Kohistan Arc and Eurasian Plate have average δ^{34}

SCDT values of 2.9 and 3.0 permil, respectively, and related ores are depleted in ^{34}S . These granitoids are generally ilmenite series, except for the northern part of the Kohistan batholith where small mineral showings have been discovered. Scarcity of oxidized granitic rocks in the high level plutonic zones of the Kohistan Block and Eurasian Plate may be one of the significant reasons for paucity of sulfide-forming mineral resources in northern Pakistan.

Key words: Isotopes, granitoids, Sulphur, Northern Pakistan.

I/36. Islam, F. & Farooq, M., 1987. Petrogenetic studies of the western part of the Kalam Dir, Igneous complex. M.Sc. Thesis, University of Peshawar, 52p.

Key words: Petrogenesis, igneous rocks, Kalam, Dir.

I/37. Ismail, M., 1973. Magnetic Survey of Chalt (Gilgit). M.Sc. Thesis, Punjab University, Lahore, 100p.

The magnetic survey in Chalt, district Gilgit, was carried out in the months of November and December 1974; January, February and March 1975. The purpose was to know the extension of the magnetite body, which was exposed at one place in the area. The portable Proton Magnetometer Model G-816 was used which measure the total intensity of earth's magnetic field. About 712 magnetic stations covering an area of about 5 miles² were made. The rough topography or systematic profiles. The profiles were laid along the pony tracks, jeepable road, on the bed of river and on top of the hill. Magnetite stations were plotted on the map with the help of the odolith. Readings were taken at each magnetic station by Proton Magnetometer. The observed readings were then corrected for diurnal variations. A total magnetic intensity map was constructed with the corrected data. The scale of the map was taken 1:2400 and the map was contoured at an interval of 50 Gamma. The total intensity map was interpreted. No appreciable anomaly was cited on the map.

Key Words: Geophysics, magnetic survey, Chalt, Gilgit.

I/38. Ismail, M., 1975. Geology and petrology of Palai area, Malakand Agency. M.Sc. Thesis, Punjab University, Lahore, 63p.

Key words: Petrology, Palai, Malakand.

I/39. Iturrizaga, L., 1999. On the close connection between the development of postglacial debris accumulations and the Late Glacial glaciation history with case examples from subtropical mountain regions in High Asia (Hindukush and Karakorum Mountains). In: Book of Abstracts. XV. INQUA Congress. The Environmental Background to hominid evolution in Africa. Durban, South Africa 87.

A research study on a typology of postglacial debris accumulations in High Asia revealed that a considerable part of the debris accumulations in the Hindukush, Karakorum and Himalayas results from re-sedimentation of moraine deposits by postglacial slope processes. Especially the semi-arid mountain regions, which feature a high quantity of debris accumulations suggesting intensive weathering processes, show that in many valley sections the secondary debris production, i.e. the dislocation of glacial sediments, exceeds the primary debris production. The conventional classification into talus cones, alluvial cones, mudflow cones and related forms proves to be insufficient for an appropriate typology of debris accumulations in High Asia. It should be expanded to include in particular the glacial transitional debris accumulations as key forms of the secondary debris accumulation landscape. They contain the transformation of glacial sediments by slope processes into mixed forms of debris accumulations composed of glacial debris and slope material. The apparently homogeneous, mostly conical-shaped appearance of many debris accumulations may tempt one to classify them precipitously into the above-mentioned traditional division system and consequently leads to misinterpretations regarding their genesis. The residual debris accumulations provide homomorphologeous landscape elements in view of the talus cones, yet they do not represent accumulation forms but erosion forms formed from loose material. In many valley courses the disproportion between the size of the catchment areas and the corresponding debris accumulations is striking. This seemingly paradoxical relation can be

explained by taking into account the dislocation of moraine material deposited in the upper catchment areas. Another glacial-induced factor for debris supply is caused by the postglacial transformation of the glacially oversteepened trough valley flanks into the more stable form of the V-shaped valley, which results in various collapse accumulations. The misinterpretation of glacial sediments as pure slope sediments is one of the reasons in the controversial debate on the extent of the Last Glacial Maximum respectively the Late Glacial glaciation in High Asia. Therefore, it is necessary to establish detailed criteria for the differentiation of glacial and slope deposits in order to use them consistently as palaeoclimatic indicators.

In addition, characteristic features of the central-peripheric change of glacial transitional debris accumulations from the mountain centre to the foot hills and some aspects of the hypsometric change will be presented. In general, the debris landscape is conceived by means of genetic sequences. Important for the genesis and the chronology is the locational relationship between debris accumulations and glacier stages as well as to other geomorphological elements.

Field work was carried out in various valleys of High Asia including research areas in the E-Hindukush, NW-Karakorum, S-Karakorum (Mustagh-Karakorum), Nanga-Parbat Massif, Ladakh und Zaskar Range, Nun-Kun Massif, Kumaon and Garhwal-Himalayas (Kamet-, Trisul- and Nanda-Devi Massif) as well as in the Central Himalayas (Kanjiroba-, Annapurna-, Manaslu- and Makalu-Massif. In the presentation, representative case examples taken from the mostly semi-arid mountain regions for the glacially controlled formation of debris accumulations will be introduced.

Key words: Glaciation, paleoclimate, debris accumulation, Hindukush, Karakoram.

I/40. Ittekkot, V. & Arain, R., 1986. Nature of particulate organic matter in the river Indus, Pakistan. *Geochemica et Cosmochemica Acta* 50(8), 1643-1653.

Suspended sediments from the Indus River collected during 1981 through 1983 were analyzed for POC and its constituent fractions including amino acids, amino sugars and sugars. Percentage of POC decreased with increasing suspended matter concentrations, which suggested dilution of organic matter by mineral matter.

The concentrations of amino acids, amino sugars and sugars varied, respectively, between 180 and 2000 µg/l, 5 and 125 µg/l, and 60 and 1100 µg/l. Their contributions to POC varied between 2 and 60% for amino acids and amino sugars, and between 2 and 15% for sugars. They were high during low sediment discharge (February to June), and low during high sediment discharge (August and September). Suspended sediments associated with high sediment discharge periods were characterized by low ratios of:

(i) aspartic acid:β-alanine

(ii) glutamic acid:γ-aminobutyric acid

(iii) amino acids: amino sugars

(iv) hexoses: pentoses. These and the relative distribution pattern of the monosaccharides such as galactose, arabinose, mannose and xylose indicated that, not only dilution, but also differences in the sources and processes affect the POC transport in the Indus River. These result in transport of biodegraded organic matter during high sediment discharge periods: this appears to be common to other major rivers of the region, with depositional centers in deep sea areas. These rivers, with their high sediment loads, could contribute up to 8 to 11% of the global annual organic carbon burial in marine sediments.

Key words: Sediments, organic matter, Indus river.

I/41. Ivanac, J.F., Traves, D.M., & King, D., 1956. The geology of the N.W. portion of the Gilgit Agency. In: Haque, A.F.M.M. (ed.). *Geological Survey of Pakistan. Records*, 8(2), 27p.

This is one of the earlier and very important report of the geology of the Karakorum and Himalayan region of Pakistan. It contains details on stratigraphy, structural geology and petrography, along with information on the mineral deposits and a geological map. Descriptions are given for the Kohistan and Ladakh batholiths (granodiorites, granites, diorites, gneisses), Yasin group cretaceous clastic sediments, fossiliferous limestones, and volcanics, Chalt volcanics (greenstone complex), and Permo-Carboniferous (?) Darkot Group sediments.

Key words: Geology, stratigraphy, petrography, Gilgit agency.

I/42. Izatt, C., 1990. Thrust geometries and rates of shortening across the Himalayan external zones, Northern Pakistan. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.24.

As the Himalayan front of deformation migrated south across the Indian Shield the Mesozoic-Cenozoic passive margin and Tertiary Indo-Gangetic foredeep was progressively shortened and involved in the foldbelt. Gravity, seismic and field data confirm that basement under the passive margin was shortened only in the internal zones. Further south shortening in the external zones was "thin-skinned". Geometries of shortening depended upon mechanostigraphy and basement architecture, whereas facies/thickness changes led to changes in thrust front geometry.

The most important domains of shortening across the external zones are as follows:

MAIN BOUNDARY THRUST (MBT), emergent thrust system with ca. 130-km shortening, emplaced between 10-7.5 Ma.

SALT RANGE THRUST SHEET (SRT), emergent thrust propagating under the Potwar Plateau along an Eo-Cambrian evaporite horizon, c.a. 30-km shortening, emplaced between 4.5-0 Ma.

These shortening events give rates of shortening as high as 4-5 cm/yr, the total plate vector of India's flight north into Eurasia. Between 10-5 Ma most of the Himalayan shortening was taken up at the southern margin of the Himalayas rather than to the north.

Key words: Tectonics, thrust geometry, crustal shortening, Himalaya.

I/43. Izatt, C. & Chambers, A., 1992. Structure and stratigraphy north of the Main Boundary Thrust, Hazara and Kalachitta Hill Ranges, North Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.42.

The northern margin of the Potwar Plateau is marked by the Himalayan foothills of the Hazara and Kalachitta Hill Ranges. Outcropping in these foothills is an imbricated section of passive margin strata that are more resistant to erosion than the softer weathering foreland basin sediments to the south. These imbricates have been found to contain strata relating to the following mega-sequences Pre-Cambrian Hazara Slates, of a deep intra continental basin. Lower Jurassic to Upper Cretaceous shallow water marine shelf carbonates and clastics. Palaeocene to Middle Eocene shallow water limestones and shales, with an upper series of evaporitic sands and mudstones. Miocene foreland basin sediments of continental origin.

The dominant phases of Late Pliocene shortening are:-

D1- minor imbrication, thrusts dying out into fault termination folds.

D2- uplift of imbricated strata south over the foreland basin along the MBT.

D3- folding of imbricates and MBT, probably during shortening south in the N. Potwar Deformation Zone.

D4- uplift and shortening along the eastern margins of the Hazara Ranges associated with recent uplift in the Hazara syntaxes.

The topographic break between the Hazara/Kalachitta Ranges and the Potwar Plateau is not marked by the MBT, an alternative model is proposed.

Key words: Structure, stratigraphy, MBT, Kalachitta Range, Hazara.

I/44. Izatt, C.N., 1990. Variation in thrust front geometry across the Potwar Plateau and Hazara/Kalachitta Hill Ranges, Northern Pakistan. Ph.D. Thesis, London University, 353p.

Key words: Structure, thrust geometry, Potwar, Hazara, Kalachitta, Fold-and-thrust belt, West Himalaya.

J/1. Jabeen, N., 1992. Mineralogy and geochemistry of Koga syenites, carbonatites and fenites Buner, N.W. Pakistan. M.Phil. Thesis, University of Peshawar, 163p.

The Koga complex is composed of alkali granite, alkali syenite and nepheline syenite. The syenite and nepheline syenite are intruded and fenitized by carbonatite and ijolites at different places. The ijolites and carbonatites are exposed mainly in the western part of Koga complex.

Amongst the mafic minerals in the Koga syenite, the fenitic Na-pyroxene show trends of crystallization from acmitic to diopsidic and/or hedenburgitic components, which is reversed to the magmatic trend. The fenitic amphibole show a trend from magnesio-arvedsonite to richterite which is opposite to the magmatic subsolidus trend. The fenitic alkali feldspar solid solution series in the Koga fenitized syenite are anomalously low albite and maximum microcline. Temperature for this solid solution series is suggested as 350-500 C in contrast to the magmatic feldspar for which temperature is 800 – 1000 C.

From the whole rock geochemistry and petrography of Koga complex it is suggested that the carbonatite has produced two types of fenites: 1. Na- fenites and 2. K-fenites. Both the types of fenites show great differences in their Ba, Sr, Nb, and Th contents. K- fenites are depleted in REE as compared to the unfenitized rocks whereas Na-fenites show enrichment of REE,

The composition of Na –pyroxenes, Na –amphiboles, feldspars and whole rock geochemistry of Koga complex suggests that the rocks have been fenitized by the solution emanating from at least two carbonatites which have different Na/ K ratios.

Key Words: Mineralogy, geochemistry, syenites, carbonatites, fenites, Koga, Buner.

J/2. Jabeen, N. & Mian, I., 1992. Alkali-feldspar from Koga syenites, Ambela granitic complex, NW Pakistan. Geological Bulletin, University of Peshawar 25, 77-84.

The Koga syenites are intruded at least two carbonatite intrusions, having different Na/K ratios. The carbonatite with high Na/K ratio has produced Na-fenites, while the other formed k-fenites. XRD study of low albite indicates that changes occur in the structural state of albite with increasing grade of fenitization. The Na-feldspar in the unfenitized rocks is low albite, while in the fenitized rocks is anomalous low albite. The degree of order increases with the increasing intensity of fenitization. The K-feldspar is maximum microcline in both the fenitized and unfenitized rocks. The tie lines between the co-existing Na- and K-feldspar deviate from the generally agreed magmatic trend.

Key Words: Syenites, carbonatites, Ambela granite, Buner.

J/3. Jackson, B., 1992. Vanadian grossular garnet (tsavorite) from Pakistan. Journal of Gemmology 23, 67-70.

Faceted vanadian grossular from Swat, Pakistan, has a strong emerald green colour. Average EPMA results show V_2O_3 4.52, Cr_2O_3 0.00%, n 1.734, D 3.640: molecular composition grossular 86.08, goldmanite 12.83%. Inclusions noted include graphite, wollastonite, mica and zircon. Comparison is made with tsavorite from East Africa.

Key Words: Garnets, gemology, Swat.

J/4. Jackson, J. & King, G., 1984. Tectonic studies in the Alpine-Himalayan belt. In: Miller, K.J., (ed.), The International Karakoram Project, Volume 1. Cambridge University Press.

Plate tectonics has successfully explained the behavior of the major ocean basins. However, it has proved to be less successful in describing the processes of continental collision and its associated deformation. Seismic studies proved crucial in providing information on which plate tectonics was established. Recent developments in the study of seismic signals recorded on distant instruments and on portable seismographs temporally installed in the Alpine-Himalayan belt are beginning to reveal the relation between extension, sedimentation, compression and major strike slip faulting such as the Karakoram fault.

Key Words: Tectonics, seismicity, Himalaya.

J/5. Jackson, J. & Yielding, G., 1983. The seismicity of Kohistan, Pakistan: Source studies of the Hamran (1972.9.3), Darel (1981.9.12) and Pattan (1974.12.28) earthquakes. *Tectonophysics*, 91, 15-28.

Long period body waves are examined to show that the Hamran (1972.9.3), Darel (1981.9.12) and Patan (1974.12.28) earthquakes in Kohistan had focal depths of about 8–10 km. All involved high angle reverse faulting (thrusting) and had seismic moments of about 2.2 to $2.7 \cdot 10^{25}$ dyne cm. These shallow depths contrast with the deeper hypocentres found in the Hindu Kush and northeast Karakoram to the north and in Hazara to the south. The Hamran and Patan shocks were assigned depths of 45 km by the ISC, indicating that even well-recorded events in this region may have focal depths in error by 30 km.

Key Words: Seismicity, earthquakes, Hamran, Darel, Pattan, Kohistan.

J/6. Jackson, J.A. & McKenzie, D., 1984. Active tectonics of the alpine Himalayan belt between western Turkey and Pakistan. *Geophysical Society London Journal* 77(1), 185-264.

Over 80 new fault plane solutions, combined with satellite imagery as well as both modern and historical observations of earthquake faulting, are used to investigate the active tectonics of the Middle East between western Turkey and Pakistan.

The deformation of the western part of this region is dominated by the movement of continental material laterally away from the Lake Van region in eastern Turkey. This movement helps to avoid crustal thickening in the Van region, and allows some of the shortening between Arabia and Eurasia to be taken up by the thrusting of continental material over oceanic-type basement in the southern Caspian, Mediterranean, Makran and Black Sea. Thus central Turkey, bounded by the North and East Anatolian strike-slip faults, is moving west from the Van region and overrides the eastern Mediterranean at two intermediate depth seismic zones: one extending between Antalya Bay and southern Cyprus, and the other further west in the Hellenic Trench. The motion of northern Iran eastwards from the Van region is achieved mainly by a conjugate system of strike-slip faults and leads to the low angle thrusting of Iran over the southern Caspian Sea. The seismicity of the Caucasus shows predominantly shortening perpendicular to the regional strike, but there is also some minor elongation along the strike of the belt as the Caucasus overrides the Caspian and Black Seas.

The deformation of the eastern part of this region is dominated by the shortening of Iran against the stable borders of Turkmenistan and Afghanistan. The north-east direction of compression seen in Zagros is also seen in north-east Iran and the Kopet Dag, where the shortening is taken up by a combination of strike-slip and thrust faulting. Large structural as well as palaeomagnetic rotations are likely to have occurred in NE Iran as a result of this style of deformation. North-south strike-slip faults in southern Iran allow some movement of material away from the collision zone in NE Iran towards the Makran subduction zone, where genuinely intermediate depth seismicity is seen.

Within this broad deforming belt large areas, such as central Turkey, NW Iran (Azerbaijan), central Iran and the southern Caspian, appear to be almost aseismic and therefore to behave as relatively rigid blocks surrounded by active belts 200-300 km wide. The motion of these blocks can usefully be described by poles of rotation. The poles presented in this paper predict motions consistent with those observed and also predict the opening of the Gulf of Iskenderun NE of Cyprus, the change within the Zagros mountains from strike-slip faulting in the NW to intense thrusting in the SE, and the relatively feeble seismicity in SE Iran (Baluchistan). This description also explains why the north-south structures along the Iran-Afghanistan border do not cut the east-west ranges of the Makran.

Within the active belts surrounding the relatively aseismic blocks a continuum approach is needed for a description of the deformation, even though motions at the surface may be concentrated on faults. The evolution of fault systems within the active zones is controlled by geometric constraints, such as the requirement that simultaneously active faults do not, in general, intersect. Many of the active processes discussed in this paper, particularly large-scale rotations and lateral movement along the regional strike, are likely to have caused substantial complexities in older mountain belts and should be accounted for in any reconstructions of them.

Key words: Structure, tectonics, Alpine-Himalayan belt, Turkey.

J/7. Jackson, J.A. & Yielding, G., 1984. Source studies of the Hamran (1972.9.3), Darel (1981.9.12) and Patan (1974.12.28) earthquakes in Kohistan, Pakistan. In: Miller, K.J. (ed.), *The International Karakoram Project 2*, 170-184. Cambridge University Press.

Long period body waves are examined to show that the Hamran (1972.9.3), Darel (1981.9.12) and Patan (1974.12.28) earthquakes in Kohistan had focal depths of about 8 to 10-km. All involved high angle reverse faulting (thrusting) and had seismic moments of about 2.2 to 2.7×10^{25} dyne-cm. These shallow depths contrast with the deeper hypocenters found in the Hindu Kush and northeast Karakoram to the north and in Hazara to the south. The Hamran and Patan shocks were assigned depths of 45-km by the ISC, indicating that even well recorded events in this region may have focal depths in error by 30-km. The accurate focal depth control in Kohistan provided by the micro seismic network operated during the International Karakoram Project will be important in understanding how the deeper seismicity further north is related to that in the south.

Key Words: Seismicity, earthquakes, Hamran, Darel, Pattan, Kohistan.

J/8. Jacob, K., 1938. Fossil algae from Waziristan. *Journal of the Indian Botanical Society*, 17, 173-176.

The author, a Research Fellow in the Botany Department, Lucknow University, analyzes two collection of fossils sent to him by the Director, Geological Survey of India. Their provenance is given and the author states that though they are of little value stratigraphically, "botanically they are of interest as practically no records of algal impressions from the Indian rocks are in existence."

Key Words: Fossils, stratigraphy, India.

J/9. Jacob, K.H., Pennington, W.D. & Armbruster, J., 1975. The Patan earthquake of December 28, 1974 in the western Himalayas Pakistan: Damage, tectonic and possible premonitory effects. Abstract volume EOS. *Trans America Geophys. Union*, 56, p.396.

Key Words: Earthquakes, tectonics, Pattan, Himalaya.

J/10. Jacob, K.H., Pennington, W.D., Armbruster, J., Seeber, L. & Farhatullah, S., 1979. Tarbela reservoir, Pakistan; a region of compressional tectonics with reduced seismicity upon initial reservoir filling. *Seismological Society of America Bulletin* 69, 1175-1192.

The Tarbela reservoir is located on the Indus River in the lesser Himalayas of northern Pakistan, a region of considerable natural seismicity. A microseismic survey conducted prior to impounding has indicated that crustal shortening under horizontal north-south compression dominates present-day tectonics, resulting in thrusting and strike-slip motion along numerous faults.

The reservoir was first partially filled for a few weeks in 1974 and then completely filled in 1975. In both cases, the microseismic activity decreased slightly during the impounding period and recovered quickly upon commencement of drainage or establishment of a constant reservoir level. In tectonic environments where the maximum principal stress is horizontal and the tectonic system is compressive, a vertical surface load can move the crustal stresses away from a Navier-Coulomb failure criterion, and hence can temporarily decrease seismicity. The observed rapid recovery of seismicity may alternately be explained by: (1) high rates of tectonic strain accumulation which, in turn, increase horizontal stresses at crustal depths; they may quickly overcome the stabilizing effects of the small vertical stress changes and increased friction across faults from reservoir loading and, hence, may return the crustal stress system to one of failure; or (2) high diffusivity of the basement rock results in a pore pressure increase after a few weeks of raised reservoir head; the raised pore pressure equally reduces the effective horizontal and vertical stresses and brings the crustal system back to failure. Since direct monitoring of pore pressure at crustal depths is not available at Tarbela, it is presently not possible to distinguish between the two alternatives. Indirect

observations, such as long-term monitoring of space-time changes in seismicity, may aid in the resolution of this ambiguity.

A few reservoirs, located in regions with preferentially extensional or pure strike-slip tectonics, have triggered or induced seismic activity, whereas Tarbela reservoir, in a region of convergent tectonics, has (to present) only slightly modified the natural seismicity. Here, in a region of active Himalayan tectonics, it is likely that any severe earthquake to occur in the near future would occur sooner or later, regardless of the presence of the reservoir. Within hundreds of years a major earthquake near Tarbela appears tectonically inevitable. Yet the presence of the reservoir may strongly affect, say, the time of occurrence, exact location, and the details of rupture of an earthquake. The time most likely for inducing a tectonic stress release (if any) would be during or shortly after a rapid draw-down of the reservoir, when the decrease in pore pressure from its high level at crustal depths lags behind the instantaneous stress decrease from reservoir unloading.

Key Words: Tectonics, seismicity, Tarbela reservoir.

J/11. Jacobs, L.L., 1977. A new genus of Muride rodent from Miocene of Pakistan and comments on the origin of Muride. *Paleontology and Biostratigraphy* 25, 1-12, University of California, Berkely.

Key Words: Stratigraphy, paleontology, rodent, Miocene, Siwaliks.

J/12. Jacobs, L.L., 1978a. Pakistan and fossils. Plateau 15, 4-17, Museum of North Arizona, Flagstaff.

Key Words: Paleontology, fossils.

J/13. Jacobs, L.L., 1978b. Fossil rodents (Rhizomyidae & Muridae) from Neogene Siwalik deposit, Pakistan. *Museum of Northern Arizona, Bulletin* 52, 103p.

Key Words: Paleontology, Rodents, Siwaliks.

J/14. Jacobs, L.L., 1981a. Miocene loridid primates from the Pakistan Siwaliks. *Nature (London)*, 289, 585-587.

In 1975–79, joint expeditions from Yale University and the Geological Survey of Pakistan (YGSP) recovered fossil loridids in the Siwalik Group of Pakistan from four localities, spanning a period before 10 Myr ago to about 7 Myr ago. In three of the localities, only isolated teeth or fragments were found, whereas the fourth and youngest locality yielded dental, cranial and some postcranial remains of a single individual described here as a new genus and species. These specimens are the first fossil loridids known from outside East Africa, and include the only recovered postcranial remains from slow-moving arboreal loridines. The findings indicate that significant tracts of forests in the Siwalik environmental mosaic may have been utilized by hominoid primates, notably *Ramapithecus*.

Key Words: Paleontology, Miocene primates, Siwaliks.

J/15. Jacobs, L.L., 1981b. The small mammal fauna of the Neogene Siwalik Group, Potwar Plateau, Pakistan. *Geological Bulletin, University of Punjab* 16, 11-22.

Thirty-five genera of small mammals have been recorded from the Siwalik Group (Miocene-Pleistocene) of the Potwar Plateau, northern Pakistan, by Yale, Geological Survey of Pakistan and Dartmouth-Peshawar expeditions. Preliminary range zones constructed for selected rodent taxa indicate non-synchronous appearances and last occurrences of taxa throughout the section. The small mammal fauna suggests that much of the Siwalik molasse was deposited in an area of warm moist climate. In the Pliocene to Early

Pleistocene, the trend toward modern warm dry conditions may have started. There is no evidence from the small mammal fauna to indicate a cold Pleistocene in the Potwar Plateau area.

Key Words: Paleontology, mammals, Potwar, Siwaliks.

J/16. Jacobs, L.L., & Downs, W.R., 1994. The evolution of murid rodents in Asia. In Tomida, Y. & Setoguchi, C.K.L.t. (eds.), *Rodent and lagomorph families of Asian origins and diversification*. National Science Museum, Tokyo, Monographs, 8, 149-156.

Key Words: Paleontology, rodents, Siwaliks.

J/17. Jacobs, L.L., & Flynn, L.J., 1981. Development of the modern rodent fauna of the Potwar Plateau, northern Pakistan. Neogene/Quaternary Boundary Field Conference, India, 1979, Proceedings, 79-82.

Key Words: Paleontology, rodents, Potwar, Siwaliks.

J/18. Jaeger, J.J., Courtillot, V. & Tapponnier, P., 1989. Paleontological view of the ages of the Deccan Traps, the Cretaceous Tertiary boundary and the India-Asia collision. *Geology*, 17, 316-319.

Volcanism in the Deccan Traps of India occurred over at most three magnetic chrons, centered on a main reversed chron. Paleontological data indicate that this reversed chron must coincide with 29R, which contains the Cretaceous/Tertiary (K/T) boundary. Recent ^{40}Ar - ^{39}Ar data may therefore provide one of the best estimates of the absolute age of the K/T boundary, 65.7 ± 2.0 Ma. Moreover, the Eurasian character of K/T boundary terrestrial faunas in India suggests that this was also close to the time of India-Asia collision. This is significantly earlier than generally recognized, and implies about 4000 km of continental shortening in the collision zone, probably absorbed jointly by crustal thickening and strike-slip extrusion.

Key Words: Paleontology, KT boundary, Deccan Traps, collision.

J/19. Jadoon, I.A. & Saeed, T., 1982. Geology of Yasin group south of Chalt in Hunza valley northern Pakistan. M.Sc. Thesis, University of Peshawar, 139p.

Key Words: Geology, Yasin group, Chalt, Hunza.

J/20. Jadoon, I.A.K., 1996. Application of magnetostratigraphy in thrusting, kinematics evolution, migration and accumulation of hydrocarbons in the North Potwar, Himalayan foreland, Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 113-115.

The Salt Range and Potwar Plateau (SRPP) represents active Himalayan foreland deformation in north Pakistan. It is typified by a tapering wedge of Neogene clastic sedimentation. Magnetostratigraphic (Burbank and Reynolds, 1988; Johnson et al., 1982) and structure combined with seismic reflection and well data (Lillie et al., 1987) provide useful information's on the general features and mechanics of the SRPP. Such studies are critical to provide insight into the evolution of foreland basins.

The SRPP has evolved due to southward translation of a coherent slab (over 90 km) over a thick layer of Eocambrian evaporites. The southern part of this system is relatively undeformed. The northern part, North Potwar Deformed Zone (NPDZ), is characterized by complicated deformation with emergent and buried thrust fronts. The buried thrust front has a triangle zone geometry in the eastern NPDZ (Fig. 1). Here, a core wedge of allochthonous strata is bounded by the Dhurnal backthrust (Jaswal, 1990) and the Khairi-Murat thrust. The Khairi-Murat Range represents a thrust sheet with about 12 km of minimum shortening.

This is overlain by a duplex horse, further deformed by out-of- sequence thrusting, over the footwall flate of the Khairi-Murat thrust' (Fig. 1).

Magnetostratigraphy and zircon fission track dating limits the evolution of the triangle zone between 2.1-1.9 Ma (e.g. Raynolds, 1980). Timing of thrusting is important for an insight into the evolution and kinematics of the NPDZ. Previous models with foreland (Fig. 2B) and hinterland (Fig. 2C) translation of a roof sequence and possibility of an upper detachment at the top of the Eocene suggest 40 to 80 km of shortening. Considering subsequent to the deposition of Siwalik strata (Fig. 2D), piggyback thrusting remains an inadmissible model because Siwalik strata are not exposed north of the Khairi-Murat thrust (Fig. 1), shown as problem in figure 2A. Alternately, with established Dhurnal backthrust (Fig. 1), passive-roof duplex geometry is an admissible solution (Fig. 2E). However, timing of Siwalik sedimentation (13 I to 0 7), thrusting (prior to the 5 Ma motion along the Salt Range thrust, and sequential balancing suggest sedimentation simultaneous to thrusting Thus, we consider the possibility of a disconformity that has evolved into back thrusting and a triangle zone geometry in the eastern NPDZ. Besides, position of the roof thrust in Tertiary Rawalpindi Group strata will reduce shortening estimates to the half Examining of thrust geometries and timing of thrusting is critical to evaluate migration, accumulation, and entrapment of the hydrocarbons.

Key Words: Structure, hydrocarbons, stratigraphy, foreland, Potwar, Himalaya.

J/21. Jadoon, I.A.K., 1997. Shortening and uplift rates along a blind thrust, eastern Potwar Plateau, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.24.

Key Words: Structure, uplift, Potwar, Himalaya.

J/22. Jadoon, I.A.K., & Frisch, W., 1997. Hinterland-vergent tectonic wedge below the Riwat Thrust, Himalayan foreland, Pakistan; implications for hydrocarbon exploration. American Association of Petroleum Geologists, 81(3), 438-448

The Riwat thrust, with a surface trace of over 50 km, is one of the major faults in the footwall of the main boundary thrust in the Himalayan foreland of Pakistan. Surface geology shows that the Riwat thrust is a foreland-vergent thrust along which lower to middle Siwalik molasse strata are thrust southward over upper Siwalik strata. Seismic reflection interpretation shows that the Riwat thrust developed as a roof thrust of a hinterland-vergent tectonic wedge (triangle zone) underlain by evaporites. The Riwat thrust propagates upsection from a depth of about 4 km at the base of the Siwalik Group. At this depth, it merges into a hinterland-vergent blind thrust that propagates upsection as a ramp from Eocambrian evaporites covering the basement at a depth of about 6 km. Bounded between this set of conjugate faults, a tectonic wedge of Eocambrian (evaporites) to Neogene strata is thrust toward the hinterland to form a triangle zone. The roof thrusts of triangle zones have been widely mapped as backthrusts in deformed mountain fronts. Hinterland motion of tectonic wedges as in the Riwat thrust triangle zone may be a feature of the fold-and-thrust belts underlain by evaporites acting as an extremely weak decollement layer. Their recognition, with a trap-forming geometry below a thrust, is important for interpreting particular fold belts and for hydrocarbon exploration. These structures could be predicted by the surface geology data where hinterland vergence of a fold below a thrust is apparent; however, seismic reflection data appear to be critical in recognizing these structures.

Key Words: Tectonics, Riwat Thrust, Himalaya foreland.

J/23. Jadoon, I.A.K., Frisch, W. & Jaswal, T.M., 1996. Geometry of a latest Pliocene-Pleistocene triangle zone in the Himalayan foreland, North Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 72.

Hydrocarbon exploration and magnetostratigraphy from the Himalayan foreland in north Pakistan has provided new surface/subsurface data and informations on the evolution of an overthrust wedge. Surface geology combined with seismic reflection profiles and well data are used to reveal the geometry and

evolution of a latest Pliocene-Pleistocene triangle zone in the eastern North Potwar Deformed Zone (NPDZ). Surface expression of the mountain front is of monocline (Soan) and two thrust faults of opposite vergence (Fig. 1). The steep limb of the monocline is located over the bedding parallel south-dipping Soan backthrust in the Neogene molasse strata. The steep Soan backthrust becomes shallower to the south and dies out at a depth of about 2 to 4 km. At this depth, it merges into a north-dipping blindthrust that propagates upsection as a ramp from Eocambrian evaporites at a depth of about 8-km and makes a flat along a pelitic horizon in the Miocene molasse strata. The two faults bound a blind, tapered and below the backthrust show the undeformed planar and deformed (flat-ramp and pop-ups) geometry of the core wedge. We interpret three-dimensional geometry of the triangle with fault tip-line structures as pop-ups and a core wedge of an overall irregular flat-ramp-flat geometry. A major thrust with about of 12 km of shortening lies to the proximal side of the core wedge. Along and across strike variation of shortening has allowed recognizing the evolution of a linked fault system in the triangle zone.

Magnetostratigraphy and zircon fission track dating (e.g. Burbank and Reynolds, 1984; Reynolds and Johnson, 1985; Burbank and Beck, 1991) limits the evolution of the triangle zone between 2.1-1.9 Ma. We present section balancing and calculate horizontal contraction of 4.5 km along the core wedge and variable degree of uplift from about 3.2-6 km along the core wedge and the Soan backthrust respectively. The shortening and uplift (erosion) rates amount to a minimum of 22 mm/year and about 16 mm/yr. Presence of hydrocarbons (Dhurnal Oil Field) in such a young structural trap has important bearings for the exploration of oil and gas in the Himalayan foreland.

Key words: Structure, hydrocarbon, magnetostratigraphy, foreland basin, Pliocene, Pleistocene, Potwar, Himalaya.

J/24. Jadoon, I.A.K., Frisch, W., Jaswal, T.M. & Kemal, A., 1999. Triangle zone in the Himalayan foreland, north Pakistan. In: MacFarlane, A., Sorkhabi, R.B. & Quade, J., (Eds.). *Himalaya and Tibet: Mountain root to mountain tops*. Geological Society of America, Special Papers 328, 275-286.

Surface geology and seismic reflection profiles reveal the geometry of a triangle zone in the Himalayan foreland of Pakistan. Surface expression of the triangle zone is the Soan syncline (monocline), the northern foreland-dipping steep limb of which is located above a bedding-parallel backthrust in the Tertiary molasse strata. The hinterland-dipping Khairi-Murat thrust is located on the proximal end of the triangle zone. The steep Dhurnal backthrust becomes shallower to the south and dies out at a depth of about 2 to 4 km. At this depth, it merges with a north-dipping blind thrust that propagates upsection as ramp from a layer of Eocambrian evaporites at depth of about 8 km and forms a flat along a pelitic horizon in Miocene molasse strata. The two faults bound a blind, tapered wedge of allocthonous strata (core wedge) inserted below the backthrust. Coherent and dis coherent reflections above and below the Dhurnal backthrust show the undeformed planar and deformed (pop-ups) geometry of the footwall and hanging wall outside and inside the wedge.

We interpret the three-dimensional geometry of the triangle zone in terms of a core wedge having flat-ramp-flat geometry and internal as well as external pop-ups. The presence of blind faults of smaller lateral extent (about 10 km) and shortening (about 2 km) indicates the occurrence of more than one hydrocarbon trap in the triangle zone.

Published magnetostratigraphy limits the formation of the triangle zone between 2.1 to 1.9 Ma. On the basis of cross-section balancing, we calculate horizontal contraction of 4.5 km and rock uplift of about 2.8 km along the core wedge. The shortening and rock uplift rates amount to about 22 mm/yr and about 14 ± 2 mm/yr, respectively. The presence of hydrocarbons (the Dhurnal oil field) in such young structural traps in the Salt Range has important bearings for the exploration of oil and gas in the Himalayan foreland.

Key Words: Structure, foreland, Potwar, Himalaya.

J/25. Jadoon, I.A.K., Frisch, W., Kemal, A. & Jaswal, T.M. 1997. Thrust geometries and kinematics in the Himalayan foreland (North Potwar deformed zone), North Pakistan. *Geol Rund.* 86:120-131

Hydrocarbon exploration and magnetostratigraphy from the Himalayan foreland (Salt Range/ Potwar Plateau) in North Pakistan has provided new surface/subsurface data and information on the tectonic evolution of an overthrust belt. A N-S balanced cross section constrained by seismic reflection and well data across the eastern North Potwar deformed zone (NPDZ) shows a buried thrust front with a triangle zone and ramp and flat structures. The triangle zone is characterized by core wedge of an irregular geometry bounded between a floor thrust in the Eocambrian evaporites and a roof thrust in the Rawalpindi group strata. A blind thrust propagates upsection from a depth of approximately 7 km above the basement and merges in the roof thrust at a depth of approximately 3.7 km. The core wedge is bounded by the Soan back- thrust and the exposed S-verging Khairi-Murat thrust. The Kheiri-Murat thrust soles out in the main decollement and is overlain by a plane-roofed duplex horse over the hanging wall flat of the former structure. Both the Khairi-Murat thrust and the duplex are deformed by out-of-sequence thrusting. The duplex geometry and out-of-sequence thrusting is responsible for the absence of the Siwalik strata and complex deformation north of the Khairi-Murat thrust. Nearly all the seismic lines show a step of approximately 800m in the basement with hanging-wall block down-to-the-north displacement. The basement normal fault seems to provide a buttress for thrusting at the deformation front in the eastern NPDZ.

Timing of Siwalik sedimentation (13.1 - 5.1 Ma) and thrusting (8 - 5 Ma) indicate sedimentation partly simultaneous to thrusting. We consider the possibility of piggyback thrusting and a disconformity prior to the development of a passive-roof duplex with backthrusting and a triangle zone in the eastern NPDZ.

A balanced structural cross section 40 km long is restored to an original length of 81 km. Forty one kilometres of shortening along balanced cross section added to the 14 km along the Golra thrust provides total shortening or approximately 55 km between 8 and 1.9 Ma in the NPDZ. Approximately 49.5 km of shortening has occurred between 8 and 5 Ma. The shortening rate of 16.5 mm/a is roughly 33% of approximately 50mm/a convergence rate between the Indian and Eurasian plates.

Key words: Balanced cross section, hydrocarbons, duplex, thrust geometry, Himalayas.

J/26. Jadoon, I.A.K., Khwaja, A.A. & Awan, M.A., 1987. A study of folded structures west of Hazara Kashmir syntaxial bend, in south eastern Hazara, Southern Himalayas. *Kashmir Journal of Geology* 5, 155.

Key Words: Structure, Hazara-Kashmir syntaxes, Himalaya.

J/27. Jadoon, I.A.K., Khawaja, A.A. & Jamshed, S.Q., 1995. Thrust geometries and evolution of the eastern North Potwar deformed zone, Pakistan. *Geological Bulletin, University of Peshawar* 28, 79-96.

The North Potwar Deformed Zone is part of the active Himalayan foreland fold- and thrust- belt in northern Pakistan. Field work have been carried out mostly along a profile in the eastern North Deformed Zone, to gain an insight into this complexly deformed area of hydrocarbon interest. The results show triangle zone geometry and a set of imbricates between the Soan Syncline and the Main Boundary Thrust. The preserved triangle zone below the Soan Syncline is characterized by a floor thrust located at depth of 6 km in the Eocambrian evaporites. The floor thrust propagates upsection and merges in a roof thrust at depth of about 3 km in the Rawalpindi Group strata. The roof thrust has a hinterland vergence similar to backthrusts of the triangle zones in other fold- and thrust belts. Integration of structural and timing data for consideration of kinematics suggests that thrust imbricate north of the preserved triangle zone is exposed due to increasing uplift and erosion of a duplex.

A structural cross-section indicates that approximately 42 km of shortening has occurred across the NPDZ. The rate of shortening is 16 mm/yr considering deformation that has occurred between 4.5 – 1.9 Ma in the North Potwar Deformed Zone.

Key Words: Tectonics, structure, Potwar, Himalaya.

J/28. Jadoon, I.A.K., Lillie, R.J., Humayon, M., Lawrence, R.D., Ali, S.M. & Cheema, A., 1989. Mechanism of deformation and the nature of the crust underneath the

Himalayan foreland and fold-and-thrust belts in Pakistan. EOS, Transaction, Geophysical Union, 70, 1372-1373.

Key Words: Structure, deformation, foreland, Himalayan fold-and-thrust belt.

J/29. Jadoon, Q.K. & Zeb, K., 1999. Geochemical study of illite and montmorillonite-rich clay sequence from an ancient lake in Jehangira area, District Nowshera, N.W.F.P. M.Sc. Thesis, University of Peshawar, 47p.

Key Words: Geochemistry, clay, Nowshera.

J/30. Jadoul, F., Erba, E. & Gaetani, M., 1992. Uppermost Triassic-Middle Jurassic evolution of the upper Hunza sedimentary cover: implications in the Jurassic geodynamic evolution of the North-Karakoram Microplate. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 115-116.

New data collected during the second Italian expedition in the Chapursan area permit a more detailed reconstruction of the Upper Hunza Jurassic stratigraphy. Two different successions have been recognized. They record, in different ways, the first Cimmerian orogenic episode in the Karakoram. The main stratigraphic characters of the successions, studied in different thrust sheets, are as follows:

- a) during the Norian-Rhaetian two different carbonate platforms were present: eastwards a mainly peritidal dolomitized succession (Guhjal type facies); westward and south-westward a calcareous, subtidal platform with Megalodons (Aghil Fm.), passing laterally to bedded, dark gray probably deeper carbonates.
- b) In the topmost Triassic-Earliest Jurassic the Aghil platform underwent a tectonic dissection ("flexural stage") with local drawing of a more subsident area with slope calcarenitic-ruditic facies deriving from a marginal Upper Triassic platform locally emerged (possible "peripheral bulge stage"). In other areas it is probable that an Upper Triassic-Liassic platform was still growing (Aghil with *Lithiotis*). An important tectonic escarpment was certainly present in the Lupghar area as testified by very thick breccias-paraconglomerates (200-300m thick) with prevalent clasts of micritic, recrystallized limestones rich in dark siliceous nodules.

In this time the early differentiation of the Jurassic sequences took place. An A-type succession characterizes the more subsident area with a prevalent fine siliciclastic euxinic basinal facies with also turbiditic sedimentation. The B-type succession represents a more continuous shallow-water sequence.

A-Type succession. In the forming foreland basin the overlying succession is characterized by a sequence with basal black shales passing upwards to a synorogenic turbiditic siltstones and dark quartzose hybrid sandstones. The petrography of the sandstones shows the presence of quartz, pelagic siliceous micrites with radiolarians, vetrophyric basalts, serpentine schists, granitoids and metamorphic rock fragments. The age of this succession has not been assessed; the stratigraphic position suggests an Early Jurassic age.

B-Type succession. Sparse outcrops would suggest that the Aghil carbonate platform or/and open shelf carbonates and may possibly continue in some area. But the datum is not well constrained.

c) Middle Lias. The B-type succession consists of open shelf dark limestones with many limestones and marls. Fossils, at the top of the succession, are Brachiopods (*Zeilleria* sp., "*Spiriferina*" sp.) followed by Foraminifers (*Haurania* sp.) and calcareous Nannofossils (*Lotharingius hauffii*, *Mitrolithus jansae*, *Schizosphaerella punctulata*) that record a Late Domerian-Early Toarcian age. Upwards there is a shallowing upwards regressive succession with bioclastic-oolitic calcarenites.

Middle Liassic facies have not been recognized in type A succession because of tectonic boundaries or the presence of an erosive unconformity between the synorogenic succession and the overlying basal conglomerates, shales and sandstones of the Yashkuk Fm. The undated shaly and turbiditic synorogenic succession (thickness more than 150 m) is possibly of Triassic age.

d) The Upper Lias-Lower Dogger is everywhere characterized by the deposition of the Yashkuk Fm. that represents an important orogenic event in the North Karakoram Plate (considered as Middle Lias by Gaetani et al., 1990). The Yashkuk Fm., in the B-type succession, is Toarcian and/or Earliest Aalenian in

age, not very thick and characterized by continental to marine transitional sandstones-siltstones passing upwards to fine siliciclastic and shallow-water marine carbonates that contain bioclastic calcarenites with Forams (*Mesoendothya* sp.). This unit overlays the Middle Lias without an evident unconformity.

In A-type succession the corresponding Yashkuk Fm. (Gaetani et al., 1990) is not dated and quite different, shows locally an evident unconformity over the shales and turbiditic sandstones. At the base are present carbonate conglomerates with prevalent clasts of Upper Triassic Aghil Fm. passing upwards to a thick (more than 130 m) continental red sandstones-siltstones sequence (Gaetani et al., 1990).

e) The Early Middle Jurassic marine transgressive sequence is well documented only in the B-type succession. Shallow-water carbonates with ooids, stromatolites, bioclastic calcarenites with mainly intercalations pass upward to dark gray-bedded limestones with frequent oncoids, ooids and thin mainly intercalations. The top of these shelf carbonates has been dated as Late Aalenian (Nannofossil: "small" *Hexalithus magharensis*). In Late Aalenian-Early Bajocian the shelf drowned and pelagic limestones prevail. A decametric intercalation of dark grey fossiliferous mass (Nannofossils: *Hexalithus magharensis*, "small" *Watznaueria manivatae*) documents an anoxic Bajocian event.

In the A-type succession, shallow-water, lagoonal dark grey limestones overlay, in transgression, the thick Yashkuk Fm. At the top of these carbonates a highly tectonized fine terrigenous marine-transitional-evaporitic unit crops out. In intercalated mass we have recognized a Nannofossil (*Watznaueria* cf. *W. communis*) that indicates Bajocian to Cretaceous age for this regressive succession.

The A-type succession is interpreted as a part of the sedimentary accretionary complex in which the dark shales and turbiditic sandstones represent the "starved flysch stage" derived from the erosion of the roof and wallrock of an area. This succession is unconformably channelized by the basal conglomerates, shales and red sandstones of the Yashkuk Fm. Eventually it is transgressed and sealed by the marine late Middle Jurassic fine terrigenous to carbonatic shallow-water sediments.

The B-type succession is considered to represent a more distal or external domain, whose mostly shallow-water environment is temporary, invaded by the terrigenous prism of the Toarcian-Earliest Aalenian Yashkuk red sandstones-siltstones. Both these successions are considered to reflect the first episode of the Cimmerian orogeny. To be noted that presently the A-type succession (accretionary prism) lies at south of the B-type, representing the external domain.

Key words: Sedimentary rocks, Mesozoic, geodynamic, evolution, Hunza.

J/31. Jaffery, S.Q.A., 1974. Geology and petrology of Hero Shah area, Malakand Agency. M.Sc. Thesis, Punjab University, Lahore, 65p.

Key Words: Geology, petrology, Hero Shah.

J/32. Jafery, S.S.A., 1991. Geology of Kahuta and Bhimber area, Azad Kashmir. Geological Survey of Pakistan, Information Release 510.

Key words: Geology, Kahuta, Bhimber, Azad Kashmir.

J/33. Jafery, S.S.A., 1996. Geology and mineral resources of the Collision Zone in Pakistan. Geological Survey of Pakistan, Information Release 444, 22p.

A research project on geology and mineral resources of collision zone in Pakistan under the collaboration of Geological Survey of Pakistan and Geological Survey of Japan was planned in March, 1987.

On behalf of the Director General of Agency of Industrial Science and Technology (AIST) under the ITIT programme, the author visited Japan in February, 89 to carry out the collaborator research, mainly the X-Ray Diffraction and field studies of the geology of Japan at several localities.

The report in general deals with the brief introduction of the geology of Pakistan with specific reference of the collision zones, and related mineral resources with Calc alkaline plutonic bodies intruded into volcanic and volcano-sedimentary rocks which have undergone low to high grade of metamorphism; laboratory examinations of the minerals and rocks of the collision zone using X-Ray Diffraction; and geological field examinations in Japan for comparative type of studies.

All the geological field trip related to the geology of collision zones were for comparative studies between Pakistan and Japan, the zoned pluton of the granite rocks of the Ibaraki (SE of Japan) is much interesting. Here the rocks grade from quartz diorite, granodiorite to adamellite.

The co-magmatic pluton sequences are cocentrally zoned pluton in which relatively magmatic rocks in the margins, composed of high temperature mineral assemblages pass inwards without discontinuities to more felsic rock in the core composed of high temperature. Such type of field studies can be carried out for the study of geological environments and possible mineral resources in Pakistan.

Above all, the studies in Japan provided a better understanding and guideline for the study of the genesis of mineral deposits in the collision zone and its application to the exploration techniques in Pakistan.

Key words: Collision zones, mineral resources, Japan, Pakistan.

J/34. Jaferi, S.S.A. & Rahimuddin, 1997. Contact demarcation using the heavy minerals in the rocks of the Siwalik and Rawalpindi Groups at Ex-Toot Well 7. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 48-49.

The rocks of the Siwalik Group and the Rawalpindi Group are mainly sandstones, claystones and shales that are lithologically difficult to demarcate. Toot Well-7 was spudded in the Dhok Pathan formation of the Siwalik Group; and was drilled through a depth of 4612 m down to the Tredian formation of Jurassic age. The three rock formations within the Siwalik Group, i.e., Dhok Pathan, Nagri and Chinji, may be distinguished by the criteria given below.

Dhok pathan Formation: The presence of fresh, whitish, grey to light greenish grey sandstone, with high clay content and appearance of maroon siltstone in the Dhok Pathan formation.

Nagri Formation: Greenish grey, medium hard micaceous sandstone and brown soft silty clays.

Chinji Formation: Brownish clays with thin bands of sandstone. However, the contacts between the formations belonging to the two Groups are not always demarcable at precise levels due to gradations in lithology. In the present case, their heavy mineral contents are, therefore, deployed for more precise determination of the contacts.

The samples from various depths were sieved through 80 mesh size and treated with 15% chloric acid, washed and dried. Bromoform liquid of specific gravity 2.8205 was used to separate the heavy minerals whose percentage in rock samples provided the criteria deployed to mark the contacts as mentioned below. Contact between Chinji and Nagri Formations: Epidote is more dominant in the Chinji formation than in the overlying Nagri formation. At Toot Well-7, persistent dominance of epidote began at 1615 m.

Contact between Chinji and Kamliyal Formations: Epidote is higher in the Chinji formation than in the underlying Kamliyal formation of the Rawalpindi Group. At Toot Well-7, there is a distinct increase of tourmaline and decrease of epidote at 3105 m. The contact is assumed at 3110 m because the sampling interval is 10 m in contact between Kamliyal and Murree Formation: Epidote is more and tourmaline less in the Murree formation than in the Kamliyal formation. At the well site, tourmaline shows sharp decline at 3185 m, so the contact is positioned at 3190 m. The foregoing is an example of the use of heavy mineral content of sandstones and shales from flush cutting samples of the ex-toot well-7 in demarcating the contacts amongst rock formations of the Siwalik and Rawalpindi Groups.

Key words: Stratigraphy, lithology, heavy minerals, Siwaliks, Murree.

J/35. Jaffery, S.S.A. & Saleemi, N., 1973. Geology of Malakand area. M.Sc. Thesis, Punjab University, Lahore.

Key Words: Geology, petrology, Malakand.

J/36. Jah, M.A., Wazir, A.K., Shah, M. & Ahmad, N., 1978. Geology of Lambidogi area in relation with the Kakul Hazara Phosphate Project. M.Sc. Thesis, University of Peshawar, 79p.

The writers were assigned the responsibilities of trenching including systematic logging and sampling, petrological study of the rocks and regional and detailed mapping of the area in May, 1976. The trenching, (see fig.7) systematic logging, and sampling was completed in September, 1976. The trenches were grouped according to the Village locations like "A & C" group extends from Kalure to Tiryan Village, "B" group from Lambidogi to Kalure and "D" group from Dakhan to Manga-di-Bandi village, during and before mapping the area was divided into different distinctive rock units. The plane table survey was undertaken from March, 1977 to mid May, 1977. The scale used for plane table survey was 1:500. A self reducing alidade was used as surveying instrument.

The data collected to the field was compiled into report which presents a comprehensive petrological study of south western facies of phosphatic youngest sediments in upper most part of the Sirban Formation which is conformably overlain by the Haziran siltstones. The upper most part is well exposed in the area. It extends from Lambidogi on the Banda Pir Khan Road to the crest of the ridge of Kakul mines. However, the area investigated extends upto Manga-di-Bandi south of the Lambidogi. The change that only occurs between Lumbidogi and Kakul west succession is the "C" unit which is sandy dolomite in thesis area and slabby/flaggy phosphatic dolomite to Kakul west.

Key Words: Geology, Lambidogi, Kakul phosphate.

J/37. Jah, S.M. & Masud, B., 1979. Geological mapping of the Gandaf Irrigation Tunnel area, Right Bank, Tarbela dam, with special emphasis on the Engineering Geology properties of the materials. M. Sc. Thesis, Punjab University, Lahore, 190p.

Key Words: Mapping, irrigation, engineering geology, Tarbela, Gandaf.

J/38. Jamal, A., 1995-96. Structure, stratigraphy, micropaleontology and petrography of Jabri and Bodla areas District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 78p.

The Jabri-Bodla area lies in the Attock-Hazara fold-and-thrust belt of the northwestern Himalaya of Pakistan. Precambrian to Cenozoic sedimentary rocks are folded and imbricated during the Tertiary-Himalayan collision.

The oldest exposed stratigraphic unit is the Precambrian Hazara Formation. The formation is composed of slates, shales and phyllites. The presence of ripple marks and graded bedding shows that the Formation is deposited in shallow water turbidity environments. The Middle Jurassic Samana Suk Formation, Late Jurassic to Early Cretaceous Chichali Formation and Early Cretaceous Lumshiwai Formation were deposited in shallow marine conditions. The late Cretaceous Kawagarh Formation was deposited in deep to shallow water shelf environment. The late Cretaceous to Early Paleocene uplift in the area caused the regression of the Tethyan Sea. The Tethyan regression initiated the deposition of ferruginous sandstone of the Hangu Formation.

The lower Tertiary sequence of Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margala Hill Limestone and Early to Middle Eocene Chorgali formation mark the complete cycle of transgression and regression of the Tethyan Ocean. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockhartia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show the tropical sub-tropical open sea upper slope to outer shelf environments. The Paleocene-Eocene boundary cannot be marked on the basis of microfossils in the area because the Patala Formation lacks microfossils. However, the tentative Paleocene-Eocene boundary between the Patala Formation and the Margala Hill Limestone can be marked at the base of Margala Hill Limestone on the basis of first appearance of Early Eocene microfossils. The structural analysis of the investigated area shows that the Precambrian to Eocene rocks record at least two major events of deformations i.e. D1 and D1 deformation phases. The D1 deformation is divided into D1a and D1b deformation phases. The D1a is associated with the southeast-directed thrusts and southeast vergent F1 folds. The second phase of D1b deformation is related with the backsteeping of the major thrusts and northwest overturning of the major F1 folds. The northwest plunging F2 cross-folds are recognized as D2 deformation phase in the project area. These F2 cross-folds are related with the development of the Hazara-Kashmir syntaxis.

Key Words: Structure, stratigraphy, paleontology, petrography, Haripur, Hazara.

J/39. Jamil, K., Jabeen, N. & Fazal, A., 1983. Petrogenetic study of Malakand Granitic Gneisses and Meta-sedimentary Complex, Malakand Agency. M.Sc. Thesis Geology Department, Peshawar University, 113p.

Key Words: Petrology, granite gneiss, metasediments, Malakand Agency.

J/40. Jamiluddin, S. & Khan, S.N., 1984. Radioactive survey of Kundas–Chamongarh, Hanuchal Burmai area, Gilgit Agency, Pakistan. Geological Survey of Pakistan. Information Release, 209.

Key Words: Radioactivity, Gilgit.

J/41. Jankovic, S., 1986. Metallogeny and mineral potential of Northern Pakistan (North of Indus Suture Zone): A preliminary assessment. Geological Survey of Pakistan, Records, 65, 25p.

Key Words: Metallogeny, mineral potential, plate tectonics, Northern Pakistan.

J/42. Jan, M., Nisar, Z.A. & Pervez, M., 1988. Petrography and Geochemistry of the Sillai Patti complex carbonatite. M.Sc. Thesis, University of Peshawar, 53p.

Key Words: Petrography, geochemistry, carbonatite, Sillai Patti, Malakand agency.

J/43. Jan, M.Q., 1964. Geological report of the Makarwal area. Geological Bulletin, University of Peshawar 1, 19-25.

This report was prepared in Dec.1963, after a seven-day field study of the area, mainly along Miranwal Nala. Mr. Farooqui, a junior Geologist in W.P.I.D.C. guided us at times. The Makarwal area is on the South-Western extremity of the Surghar-Range. (Sur---Pashto word for “Red” and Ghar for “mountain”; since the general, colour of these mountains is reddish). The Surghar Range is included in the famous Salt Range series of West Pakistan, on the trans-Indus side between longitudes 71'-72° E and latitudes 31° 32' ~ N. The place is in South-West of Kalabagh at a distance of about 32 miles. The area is on the Western extreme of Mianwali District. The top of these mountains is the boundary between the Distts. of Kohat and Mianwali. Makarwal exposures are located on the East-scarp, slope of the mountain chain of Surghar Range. The place is connected with Kalabagh-Bannu Railway and cemented lorry road which are the side branches of road & railway, separating from main line at Kamar Mashani. The formations at Makarwal have been an important source of Coal in the Western part of Indo-Pak subcontinent for the last 60 years.

Key Words: Geology, coal, Makarwal.

J/44. Jan, M.Q., 1968a. Petrography of the emerald-bearing rocks of Mingora (Swat State) and Prang Ghar (Mohmand Agency) West Pakistan. Geological Bulletin, University of Peshawar 3, 10-11.

Emerald-bearing rocks are present near Mingora in Swat State, and Prang Ghar in Mohmand Agency. Rock containing fuchsite in addition to calcite and /or siderite are perhaps the most favorable for emerald, though some pegmatite and greenschists may also have emerald. The emerald and chrome-mica (fuchsite) probably have some genetic bearing on the chrome-bearing ultramafic intrusions of the two areas.

Key Words: Petrography, gemstone, emerald, Swat.

J/45. Jan, M.Q., 1968b. Pleistocene sandstone. Geological Bulletin, University of Peshawar 3, 34.

Pleistocene sediments are exposed on the northern slope of the Cherat Range, about 1 ½ miles south east of Jalozai village. The beds dip gently to the south, making an angular unconformity with the older rocks. The base of these sediments is composed of sandstone, which is overlain by friable shale, which in turn is overlain by grit stone. This note is written with the intention to introduce the sandstone that has interesting mineralogy, which shed some light on the provenance.

Key Words: Pleistocene, sandstone, Cherat Range.

J/46. Jan, M.Q., 1969. Preliminary geology of the Shilman area, Khyber Agency, with notes on a Copper-bearing Gabbro. Geological Bulletin, University of Peshawar 4, 92-93.

Reconnaissance geological work was carried out in Shilman, Khyber Agency, and traverses were made along roads and major streams. Low-grade metamorphic rocks, striking northeast and dipping northwest, occur in the northwest of the area. The rocks are generally of a grayish color, the phyllitic rocks having well-developed cleavages. Some rocks are greenish-gray to dark gray and contain carbonaceous material. The rocks are cut by abundant quartz veins and also by some basic and a few granitic intrusions. The intrusions in the phyllitic rocks are mostly small, concordant bodies, not more than a few tens of feet thick. The basic rocks are dark colored, medium-grained gabbros and dolorites. The gabbro near Bar Kili is composed of Plagioclase, abundant dark minerals and a little quartz. The gabbro contains various copper minerals – Chalcopyrite, bornite, cuprite, malachite, etc. either disseminated, in a pockets, or as incrustations, in a ten foot-thick brecciated zone along the contact.

Key Words: Reconnaissance, geology, metamorphism, Shilman, Khyber Agency.

J/47. Jan, M.Q., 1970. Petrography of the upper part of Kohistan and southwestern Gilgit Agency along the Indus and Kandia Rivers. Geological Bulletin, University of Peshawar 5, 27-48.

This paper presents a petrographic account of the common rocks of the previously unmapped area of Indus Kohistan and southwestern Gilgit Agency. The study is based on field observations and thin section of 55 rocks selected from over 200 samples quickly collected along the Indus Valley Road and Kandia River. The major rocks of the area are amphibolites (gneissose metaigneous; some banded ? metasedimentary) and norites-diorites (the former also having a clinopyroxene), and minor (?) alpine peridotites, granitic rocks, pegmatites, and low grade regionally metamorphosed schists in the Kandia valley. The norites-diorites are abundant in the north, the amphibolites in the south. Tentative ages have been assigned to the rocks; the various igneous rocks are considered to be related to the Himalayan orogeny and emplaced between Middle/Late Cretaceous and Early Tertiary.

Comparison of the rocks from various parts of the northern West Pakistan shows that the Hornblende Group of Martin et al. (1962) extending from Chilas in Gilgit Agency to at least Western Dir – a distance over 160 miles. There is a probability that the group may be extending in the adjacent eastern Afghanistan, which is covered by the Hindukush Range. North to south, the group may occupy a territory as wide as 60 miles.

Key Words: Petrography, amphibolites, norite, diorite, Indus valley, Kandia River, Kohistan.

J/48. Jan, M.Q., 1973. Topaz occurrence in Mardan, N.W.F.P. Abstracts, 24th Pakistan Science Conference, Islamabad, p. H-2.

Consult Jan, 1979.

Key words: Gemstones, topaz, Mardan.

J/49. Jan, M.Q., 1975. Notes on the igneous rocks of Spinkai and adjacent areas of Tirah, Khyber Agency. Geological Bulletin, University of Peshawar 7 & 8, 73-78.

A brief petrographic account of the most common igneous rocks of the Spinkai area (Tirah) is presented in this note. Reconnaissance survey reveals that like the adjacent Kohat district, much of the Tirah Tribal territory is free of igneous and metamorphic rocks. Traverses in Spinkai area indicate that crystalline rocks, mainly igneous, are confined to a narrow strip of country (only a few miles broad) extending along Afghanistan-Pakistan border. The country rocks on the southern contact are Paleozoic in age (Tahirkheli, et al., 1971). Tertiary and Mesozoic sedimentary rocks are exposed further south and east. This leads to think that in this part of the Safed Koh Range, the intrusive activity was either confined to the central part of the range, or that the main activity was older than the Tertiary (and even Mesozoic). Dolerite intrusions of probable Permian age (Tahirkheli, Personal Communication) are common to the northeast between Torkham and Jamrud. Ahmad et al., (1969) have also reported basic and acid igneous rocks of Late Mesozoic to Early Tertiary age from the Warsak area, farther northeast.

Key Words: Reconnaissance, petrography, Spinkai, Tirah, Khyber Agency.

J/50. Jan, M.Q., 1977a. The Mineralogy, Petrology and Geochemistry of Swat Kohistan, NW Pakistan. Ph.D. Thesis, University of London, 349p.

This is the first detailed petrological description of the southern part of the Kohistan island arc, supported by hundreds of whole rock and mineral chemical analyses. It describes the petrological aspects of the ultramafic rocks and garnet granulites of the Jijal complex sitting on the Indus suture, the southern amphibolites, gabbro-norites of the now called Chilas complex, and quartz diorites to the south of Kalam. It is shown that the amphibolites and gabbro-norites extend from Swat towards Chilas. Mineralogical aspects of pyroxenes, amphiboles, garnets and other minerals are elaborated.

Key Words: Mineralogy, petrology, geochemistry, amphibolites, gabbro-norites, diorites, Jijal complex, Swat Kohistan.

J/51. Jan, M.Q., 1977b. The Kohistan basic complex: A summary based on recent petrological research. Geological Bulletin, University of Peshawar 9&10, 36-42.

The central part of the Kohistan basic complex in the Swat district has been studied in detail petrographically and geochemically. The main rocks of the area—amphibolites, noritic rocks, and quartz diorites – do not appear to be directly related mutually or to the rocks of the Jijal complex (garnet granulites and alpine-type ultramafic rocks). Temperature pressure estimates suggest that the various metamorphic rocks of the area were formed under different geothermal gradients. It is recommended that the noritic rocks be henceforth called pyroxene granulites.

Key Words: Petrography, petrology, geochemistry, Swat Kohistan.

J/52. Jan, M.Q., 1979a. Petrography of the Jijal complex, Kohistan. Geological Bulletin, University of Peshawar 11, 31-49.

This paper presents a detailed petrography of the garnet granulites and garnet-free ultramafic rocks which constitute a > 150 sq. km tectonic block at Jijal, Indus Kohistan. The granulites are classified into 1) those with essential plagioclase, and 2) those with little or no plagioclase; the two types are a consequence of bulk chemical rather than environmental differences (Jan and Howie, in prep.). A total of 17 mineral assemblages have been identified, with garnet + clinopyroxene + plagioclase + quartz + rutile ± hornblende ± epidote being the most widespread. The plagioclase-free granulites are generally composed of two or three of the minerals garnet, clinopyroxene, hornblende, and orthopyroxene or epidote. The granulites were produced by high-pressure metamorphism of a series of hypersthene gabbros with some more and some less silicic rocks.

The ultramafic rocks have alpine-type features but, unlike most alpine-type ultramafic rocks, they are dominated by diopsidites (with or without olivine); dunite, harzburgites and websterites together make less

than 50 % of the > 40 km slab. The granulites and ultramafic rocks are considered to have originated in the Tethyan lower crust-upper mantle before they were metamorphosed during the collision of the Indian-Asian masses. The granulites were intruded in the granulites as plastic material after the main metamorphism but before the two were tectonically brought in their present surroundings.

Key Words: Petrography, garnet granulite, ultramafic rocks, Jijal, Kohistan.

J/53. Jan, M.Q., 1979b. Petrography of the amphibolites of Swat and Kohistan. Geological Bulletin, University of Peshawar 11, 51-64.

The amphibolites of Swat and Kohistan are mainly found in two belts. Those forming the southern belt are the prograde metamorphic products of basic to intermediate rocks, which were intruded into tuffs, with some volcanic flows; the tuffs now represented by banded amphibolites. The rocks are locally migmatitic and are essentially composed of hornblende, plagioclase and/or clino-epidote, with garnet and/or quartz in some places. Opaque minerals, rutile and/or sphene are the common accessory minerals, while white and dark micas, clinopyroxene, carbonate, k-feldspar, margarite, corundum, cummingtonite, zoisite, green spinel and staurolite are locally present. The amphibolites of the granulite belt are retrograde products of the pyroxene granulites, mainly due to an influx of water, and are essentially composed of hornblende and plagioclase.

Key Words: Petrography, amphibolite, Swat, Kohistan.

J/54. Jan, M.Q., 1979c. Petrography of pyroxene granulites from northern Swat and Kohistan. Geological Bulletin, University of Peshawar 11, 65-87.

The pyroxene granulites of Swat and Kohistan, formerly called norites, form a part of an extensive belt stretching between Nanga Parbat and central Dir. They are relatively uniform in composition and usually represented by leucocratic rocks essentially composed of plagioclase, orthopyroxene and clino-pyroxene, with subordinate amounts of quartz, opaque mineral(s), apatite, amphibole, biotite and, locally, garnet; but some of the rocks contain a higher proportion of amphibole and biotite. The proportion of quartz increases towards the intermediate members, which may also have essential K-feldspar. The rocks are gneissose (foliated) and layered/banded, with some of the layers being pyroxenitic or anorthositic. Some of the bands are due to metamorphic segregation whilst others are relict igneous layers modified by metamorphism.

This paper presents a detailed account of the petrography of the rocks together with a discussion on the nature of the foliation, layering, and other aspects (xenoliths, hornblende-pegmatite, etc), and details of the plagioclase in the granulite. Many of the features can be better explained by invoking metamorphism. It appears that the rocks crystallized plutonically from an andesitic basalt magma in an island arc or a continental margin, were metamorphosed (800°C, 7-8 kb) and finally intruded, as crystalline material capable of plastic flow, in the country rocks which were passing through amphibolite facies metamorphism.

Key Words: Petrography, gabbro-norites, pyroxene granulite, Swat, Kohistan.

J/55. Jan, M.Q., 1979d. Petrography of quartz diorites to the south of Kalam, Swat. Geological Bulletin, University of Peshawar 11, 89-97.

The quartz diorites of Swat Kohistan appear to be partial melting products of more mafic rocks during the collision of Asian-Indian landmasses and the Himalayan orogenic-metamorphic episodes. On the basis of texture and type of principal mafic mineral(s), at least four types of quartz diorites can be recognized in the area to the south of Kalam. One of these, with strongly pleochroic hypersthene relics, appears to be a retrograde type after pyroxene granulites. It is not clear whether or not the other types are a product of differentiation from a single parent magma; however, it is likely that they represent independent pulses of diorite (andesite) magma produced over a considerable length of time (Late Cretaceous to Middle Tertiary), the earlier ones having been metamorphosed.

Key words: Petrography, quartz diorites, Kalam, Swat

J/56. Jan, M.Q., 1979e. Topaz occurrence in Mardan, North West Pakistan. *Mineralogical Magazine* 43, 175-176.

Colourless, purple, and pink topaz and transparent quartz crystals have been found in calcite veins (with or without milky quartz) in calcareous rocks near Katlang (34 ~ 24' N, 72 ~ 6' E), Mardan. The veins do not contain any fluorite nor the country rocks any topaz. The topaz and transparent quartz crystals are mostly broken and perfectly euhedral outlines are very rare. Refractive indices, 2V, specific gravity, and the fluorine (determined) and H₂O + (calculated) contents of two topaz crystals are suggestive of their high 100 OH/(OH+F) ratios (> 25). Rather than being derived, the topaz may have formed in situ by hydrothermal/pneumatolytic activity, followed by tectonic movements that fractured the crystals and resulted in their incorporation in later-formed vein calcite.

Key words: Gemstone, topaz, Mardan.

J/57. Jan, M.Q., 1980. Petrology of the obducted mafic and ultramafic metamorphites from the southern part of the Kohistan island arc sequence. *Geological Bulletin, University of Peshawar* 13, 95-107.

The ~ 36,000-km² Kohistan region is a well-defined tectonic zone with unusual lithology when compared to the neighboring regions. It is occupied mostly by plutonic and volcanic igneous rocks ranging from ultramafic to silicic. A few authors have suggested that some or the entire Kohistan zone represents a fossil island arc. Based on over 250 rock and minerals analyses, mainly from Swat, a petrological account of the mafic and ultramafic rocks of Kohistan is presented below, together with comments on their tectonic environments, metamorphism, and the duration of the presumed island arc.

The basic rocks occur in two NE-trending belts of amphibolite and pyroxene granulite stretching from Nanga Parbat to eastern Afghanistan, and in the wedge-like tectonically-emplaced Jijal complex (~ 200 sq. km) which comprises garnet granulites and alpine ultramafics. It is suggested here that most of the southern amphibolites (and the overlying metasediments of the Kalam group) represent the Tethyan oceanic crust and the alpine ultramafics the underlying upper mantle. The pyroxene granulites, some amphibolites and, probably, Jijal garnet granulites have been derived from a high alumina tholeiite (calc-alkaline) magma that was intruded into the oceanic crust during the early phases of arc-building.

Key words: Petrology, mafic-ultramafic rocks, amphibolite, Kohistan Island Arc.

J/58. Jan, M.Q., 1982. Chemical changes accompanying the granulite to amphibolite transition in Swat Kohistan, North West Pakistan. In: Sinha, A.K. (ed.), *Contemporary Geoscientific Researches in Himalaya* 2, 49-52. Singh, Dehra Dun, India.

In southern Kohistan, gabbros and norites (granulite facies) show retrogression to amphibolites on local as well as wide scale. This is a chemical study of the phenomenon. The transition is accompanied by fall in Ti and Fe²⁺, and rise in Fe³⁺, alkalies, H₂O, Ba, Cu, Ni, and Y.

Key words: Geochemistry, granulite, amphibolite, Swat Kohistan.

J/59. Jan, M.Q. 1983. Further Data on ortho- and clinopyroxenes from the pyroxene granulites of Swat-Kohistan, northern Pakistan. *Geological Bulletin, University of Peshawar* 16, 55-64.

Microprobe analyses of pyroxenes from the pyroxene granulites of Swat-Kohistan are similar to their wet chemical analysis and the two sets of analysis yield similar temperature estimates. The pyroxenes are exsolved, but the exsolved pyroxene is similar in chemistry to its corresponding principal pyroxene, suggesting the attainment of physico-chemical equilibrium. The Mg/(Mg+Fe²⁺) ratios for the coexisting pyroxenes have been plotted and the implications of granulite facies metamorphosed noritic lenses in the amphibolite belt of Kohistan discussed.

Key words: Pyroxene, pyroxene granulite, Swat-Kohistan.

J/60. Jan, M.Q., 1984a. Chromian andradite and olivine-chromite relations in chromite layer from the Jijal complex. Abstracts, First Pakistan Geological Congress, Lahore, p.56.

Green chromian andradite associated with chrysolite occurs in a chromitite layer within dunite of the Jijal complex. The garnet contains over 10% Cr₂O₃ and has the formula Ca_{6.13} Cr₁₃₇ Fe⁺³_{2.53} Si_{5.94} O₂₄. The garnet formed during retrograde greenschist facies metamorphism of the Jijal complex. Analyses of chromite in the dunite and chromite, layers resemble those of high Cr-chromite but their total Fe is a little higher. In contrast, the olivine is highly magnesian, with a ratio 100 Mg/ (Mg + Fe²⁺) of about 96%. These features appear to have been caused by Fe ↔ Mg exchange between the two minerals down to a blocking temperature of about 800°C.

Key words: Andradite, ultramafics, Jijal complex, Kohistan.

J/61. Jan, M.Q., 1984b. Some K/Ar ages from the Chilas complex in Swat. Geological Bulletin, University of Peshawar 17, 171-173.

K/ Ar dates (64-79 Ma) have been obtained on four samples from the Chilas complex in Swat Kohistan. Field studies and petrography suggest that hornblende in SH 37 grew secondarily at the expense of pyroxene mainly, whereas the pegmatite bodies have formed by metasomatic processes. The age of hornblende in SH 37 is younger than that of the whole rock but the two ages would not be significantly different at the 95 % confidence level if the error in potassium determination were in fact 2 %. Surprising is the younger age of the granulite (US14) sample compared to others. It can be attributed to a number of factors such as argon loss from the non-retentive sites in the whole rock sample, to overprinting caused by a later tectonic, intrusive or magmatic activity.

It has been noted by a number of workers that K/Ar ages of rocks that have gone through polyphase metamorphism and deformation usually record younger periods than the actual age of formation (cf. Le Fort et al., 1983). It seems that the four K /Ar determinations from Swat record cooling and uplift ages after the rocks had passed through pyroxene granulite facies metamorphism. Similar ages (70-80 m.y., according to Shams, 1980, and Maluski and Matte, 1983) were obtained on Shangla blueschists of the Indus suture zone. Hence Bard (1983) suggested that the high-P metamorphism may have taken place during obduction.

Key words: Geochronology, Chilas complex, Kohistan.

J/62. Jan, M.Q., 1985. High-P rocks along the suture zones around Indo-Pakistan plate and phase chemistry of blueschists from eastern Ladakh. Geological Bulletin, University of Peshawar 18, 1-40.

The Indo-Zangbo suture zone (IZS), the Indoburman suture zone and the Chaman Fault are the traces of major collisional boundaries between the Indo-Pakistan plate and Eurasian block, Gondwanic microcontinents or island arcs. These suture zones are characterized in several places by ophiolites and tectonic melanges. High-P metamorphic rocks, generally belonging to blueschist facies, have recently been discovered along the suture zones in Naga hills, southern Tibet, eastern and western Ladakh, Swat and Afghanistan. The high-P metamorphism probably occurred during the Late Cretaceous / Paleocene. In the IZS it is complemented by low- to medium-P metamorphism to the north, suggesting a northward dip for the subduction zone. Along the southern margin of the Kohistan arc near Jijal, immediately N of IZS, gabbroic rocks were metamorphosed to high-P garnet granulite at a depth of > 40 km about 100 m.y. ago.

Detailed investigations, based on whole rock and 188 point analyses in three sections, suggest that metabasites in the eastern Ladakh ophiolites melange are ocean floor basalts metamorphosed under blueschist facies conditions. They are mineralogically similar to high-grade blueschists of other areas and contain sodic, sodic-calcic and calcic amphiboles, epidote, chlorite, albite, phengite, paragonite, garnet, quartz, rutile, calcite, and magnetite. The PT trajectory suggests that the metamorphic conditions culminated around 370-480°C, 7-8 k-bar and subsequent retrogression, possibly during uplift, took place at similar temperature but lower (6-4) pressure.

Key words: Collision boundaries, phase chemistry, blueschists, Swat, Naga hills, Ladakh.

J/63. Jan, M.Q., 1986a. Composition of the pluton core of the Kohistan island arc, NW Himalaya, Pakistan. Geological Society of America, Annual Meeting, Abstracts with Program 18, p.645.

Consult the following.

Key words: Plutons, Chilas, Jijal, Kohistan arc.

J/64. Jan, M.Q., 1986b. Composition of the pluton core of the Kohistan island arc in NW Himalaya, Pakistan. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 19-20.

The Kohistan island arc covers about 36,000 km² of N. Pakistan. It formed as an intra-oceanic arc in response to northward subduction of Neotethyan lithosphere during Late Jurassic-Cretaceous, and consists of arc volcanics, amphibolites, diorite-tonalite-granite plutons and minor sedimentary rocks. The base consists of the stratiform Chilas complex which stretches for >300 km with a width of about 40 km in the middle. It is composed of mildly layered gabbro-norites with subordinate Qz-Hyp diorites, pyroxenites and anorthosites of calcalkaline affinity. These contain variable amounts of Pg (An₆₄₋₄₃), Opx (En₆₆₋₅₁), Cpx (Fs₁₂₋₂₂, Wo₄₃₋₄₈), Mt, Il ± Qz ± K-spar ± Hbl ± Bio ± rare Scapolite. In the central part of the complex there are small (up to 5 sq. Km), seemingly intrusive bodies of dunite-peridotite-pyroxenite-troctolite gabbro-norite-anorthosite. -ol/pxn pegmatite association displaying excellent layering, graded bedding, slump breccia and syn-depositional faults. These rocks may be derived from a picritic melt or may be remobilized deeper-level cumulates. This association contains Ol (Fo₈₅₋₇₃), Opx (En₈₃₋₆₆), Cpx (Fs_{5.4-12.5}, Wo₄₅₋₄₉), Pg (An₉₈₋₈₃), Chr or Cr-Sp, Hbl and vermicular pleonaste. Association of other arc-related rocks, absence of oceanic rocks, and the chemical and mineralogical features suggest that the Chilas complex is not an ophiolite. It is similar to plutonic rocks from deeper parts of island arcs and analogous to the Border Ranges complex, Alaska. It was re-equilibrated under pyroxene granulite facies conditions (750-850°C, 5-6.5 kb) about 110 mybp. A portion of this complex, subducted to >40 km along the Indus suture was metamorphosed to garnet granulite facies 104 mybp.

Key words: Plutons, Chilas, Jijal, Kohistan arc.

J/65. Jan, M.Q., 1988a. Relative abundance of minor and trace elements in mafic phases from the southern part of the Kohistan arc. Geological Bulletin, University of Peshawar 21, 15-25.

Many pyroxenes, garnet, hornblende, epidote, biotite, and one each of olivine and chromite from amphibolites, gabbro-norites and ultramafic rocks were analysed for up to 21 minor and trace elements. Like major elements, many of these also are systematically distributed between the coexisting mineral pairs and trios. Orthopyroxene contains higher amounts of MnO, Co, Ni, Zn, and lower TiO₂, Na₂O, Li, Pb, Cr, V, Zr, Sr, Ba, Y, Nd and La as compared to clinopyroxene. Biotite contains more Cr, Cu, Li, Pb, and Ni than pyroxenes and hornblende. The amounts of TiO₂, Na₂O, K₂O, Fe₂O₃ and Ni are higher in hornblende than in pyroxenes and garnet. Garnet is impoverished in Li, Ni, V and Zn as compared to clinopyroxene and hornblende.

Key words: Geochemistry, ultramafics, mafic phases, Kohistan arc.

J/66. Jan, M.Q., 1988b. Geochemistry of amphibolites from the southern part of the Kohistan arc, N. Pakistan. Mineralogical Magazine 52, 147-159.

The southern part of the Cretaceous Kohistan island arc is occupied by an extensive belt dominantly comprised of amphibolites. These include banded amphibolites of partly meta-volcanic parentage, and non-banded amphibolites derived from intrusive rock. In addition to being relict, banding has also been produced by shear deformation, metamorphic/metasomatic segregation and, possibly, by lit-par-lit injection of plagiogranitic material. Non-banded amphibolites also occur as retrograde products of noritic granulites forming the lopolithic Chilas complex. The chemistry of 37 rocks has been compared with those of known

tectonic environments. The amphibolites have chemical characteristics similar to volcanic rocks found in island arcs and most of the analyses apparently support affinity with the calc-alkaline series. The amphibolites consist essentially of hornblende, plagioclase and/or epidote. Garnet and clinopyroxene have developed locally in rocks of appropriate bulk composition. Metamorphism may have taken place during the mid-Cretaceous under conditions of 550 to 680 °C and 4.5 to 6.5 kbar p_{H2O}. The metamorphic grade appears to increase from the centre of the southern belt toward the Chilas complex to the north and Indus-Zangbo suture (IZS) to the south. In the vicinity of the IZS, garnet-clinopyroxene + amphibole assemblage developed locally in response to high P-T.

Key Words: Metamorphic rocks, amphibolites, Kohistan arc.

J/67. Jan, M.Q., 1990. Petrology and geochemistry of the southern amphibolites of the Kohistan arc, N. Pakistan. *Physics and Chemistry of the Earth* 17, 71-92.

The southern part of the Cretaceous Kohistan island arc is made up of amphibolites and a variety of other rocks. These constitute a more than 350 km long belt extending from eastern Afghanistan to Nanga Parbat. The amphibolites can be divided into banded and non-banded varieties. Despite a minor quantity of associated metasediments, the banded amphibolites are not metasedimentary themselves; they were derived from volcanic and plutonic precursors, whereas the non-banded amphibolites are after plutonic rocks. In addition to being relict, banding was produced by shear deformation, lit-per-lit injection of trondhjemitic material and possibly, other processes discussed in the paper. The amphibolites consist essentially of hornblende, intermediate plagioclase and/or epidote ± quartz. Almandine-rich garnet developed preferentially in rocks with low Mg/Fe ratios and diopside-salite in those with high CaO. Metamorphism took place before late Cretaceous at 550-680 °C 4.5-6.5 kbar p_{H2O}. Locally, however, higher PT conditions operated and the two minerals grew more abundantly over a wider range of rock composition. Metamorphic conditions were locally suitable for extraction of trondhjemitic and granitic melts from the amphibolites. The chemical characteristics of the amphibolites are similar to volcanic rocks found in island arcs and most of the analyses apparently support affinity with the calc-alkaline series.

Key words: Petrology, geochemistry, amphibolites, Kohistan Island Arc.

J/68. Jan, M.Q., 1991. High-P metamorphic rocks from the Himalaya and their tectonic implication - a review. *Physics and Chemistry of the Earth* 18, 329-343.

The suture zones bordering the Indian subcontinent on the E, N and W are characterized in several places by the occurrence of ophiolitic complexes and tectonic melanges. High-P metamorphic rocks have recently been discovered in the melanges in Burma, Naga Hills, southern Tibet, eastern and western Ladakh, Kohistan (Jijal, Allai, Shangla) and Khost (Afghanistan). The development of these rocks has an important bearing on the plate tectonics of the Himalaya.

The High-P metamorphic rocks belong to prehnite-pumpellyite, blueschist and high-P greenschist facies but extensive garnet-granulites have developed at 35 km depth in Jijal. In the Indus-Zangbo suture zone (IZS) the high-P metamorphism is complemented to the N by low- or medium-P metamorphism and calc-alkaline magmatism in Tibet, Ladakh as well as Kohistan. High-P metamorphism in Jijal has been dated at 104 Ma, in Shangla at 70-100 Ma and in western Ladakh during mid-Cretaceous. Elsewhere, the timing of the high-P metamorphism is not known but a Cretaceous age is inferred. Since collision along the IZS occurred during Eocene, the high-P metamorphism is therefore related to the northwards subduction of the neo-Tethyan lithosphere under Tibet or late Mesozoic magmatic arcs. The timing of high-P metamorphism coincides with the breakup of India from Gondwanaland and its rapid northwards movement, whereas the tectonic melanges may principally have formed during Eocene collision and obduction.

Key words: High-P metamorphism, blueschists, greenschists, garnet-granulites, Himalaya.

J/69. Jan. M.Q., 1992. Highly aluminous hornblende-cummingtonite coronas in gabbro-norites of the southern amphibolite belt, Kohistan. *Geological Bulletin, University of Peshawar* 25, 127-131.

The gabbro-norites of the Chilas complex and southern amphibolites belt locally contain thin (<0.2 mm) amphibole coronas around pyroxene. These consist of an inner shell of fibrous, colourless to pale cummingtonite, and an outer shell of bluish green aluminosilicate, with or without a discrete growth of epidote + vermicular quartz on the edges of the plagioclase. The coronas represent the initial stage of amphibolite facies metamorphism, which prevailed in the southern part of the Kohistan arc during mid Cretaceous. The tschermakite, with 19.2 % Al_2O_3 , is one of the most aluminous calcic amphiboles thus far reported. The primary amphibole in the gabbro-norites is brown ferroan pargasite containing much higher Ti and K than the coronitic tschermakite.

Key words: Hornblend, Chilas complex, Kohistan arc.

J/70. Jan, M.Q., 1995. An inventory data base (Presentation by Group 1 in report on the regional workshop "Landslide Hazard Management and Control in the Hindu Kush-Himalayas" Chalise, S.R. & Karki, S., (Eds.), International Centre for the Integrated Mountain Development, Kathmandu, p20.

The Chairperson for this session was Professor A. Herrmann the presentations in this session were made by the chairpersons of the three working groups after extensive discussions in each group. Presentation by Group I on an Inventory Database including Socioeconomic Aspects and institutional Collaboration for National, Regional and International Levels) Professor Qasim Jan, Chairperson of Group I, presented the recommendation on "Inventory Database including Socioeconomic Aspects and institutional Collaboration for National, Regional and International Levels"

Key words: Landslide, hazard.

J/71. Jan, M.Q., 1998. 13th Himalaya-Karakoram-Tibet International Workshop (Conference Report). Episodes 21, p.106.

This workshop was held at the National Centre of Excellence in Geology, University of Peshawar from April 20-22,1998. It was convened by M. A. Khan and M. Q. Jan, and was attended by more than 160 participants, 89 of them from 13 countries outside Pakistan. The workshop consisted of two field excursions and paper presentation.

The workshop was preceded by a field excursion (April 17-19) to the sedimentary sequence of the Himalayan foothills, covering the Islamabad-Salt Range-Kohat-Peshawar section.

The workshop was followed by a week-long excursion along the KKH (April 23-29). The KKH joins China with Pakistan and follows the course of the Hunza and Indus rivers before splitting at Besham into a westerly branch (passing through Swat to Peshawar and an easterly branch (through Hazara to Islamabad). The excursion followed the westerly route on the way up and ended in Islamabad via Hazara. This trip provides a wonderful opportunity of examining a section across the NW Himalaya, Kohistan arc, and central Karakoram and the suture zones between them. Unfortunately, due to unexpected rain storm and landslides, the trip was terminated at the Shyok Suture southwest of Hunza and not much of the Karakoram section could be examined. Each of the 70 participants was supplied a 131 -page field guide edited by R D Lawrence and M A Khan.

There was a brief inaugural session chaired by RAK Tahirkheli, It consisted of introductory remarks, note of thanks, and a summary of the major contributions to the geology of the Himalaya-Karakoram region of Pakistan during the last 50 years by the Chief Guest (S H Gauhar, Geol. Surv. Pakistan).

Technical papers consisted of over 50 poster; and 80 oral presentations, covering eleven sessions:

- 1) NW Himalaya (Chairman: M P Searle, UK).
- 2) Karakoram and Hindukush (M Gaetani, Italy),
- 3) Suture zones and ophiolites (J P Burg, Switzerland),
- 4) Western Himalaya (J DiPietro, LISA),
- 5) Central Himalaya (B Grasemann, Austria).
- 6) Eastern Himalaya and Tibet (K Arita, Japan),
- 7) Tibet (Xian: Xuchang, China).
- 8) Foreland basins (V C Thakur, India),
- 9) Kohistan (P Le Fort, France),

10) Neotectonics and Quaternary (E Appel. Germany),

I 1) Applied geology (M E Brookfield, Canada),

Key words: 13th HKT workshop report.

J/72. Jan, M.Q., Ahmad, I. & DiPietro, J.A., 1999. Mineralogy of a carbonatite-related fenite in Lower Swat, Northern Pakistan. Geological Bulletin, University of Peshawar 32, 71-75.

The Precambrian-Cambrian Manglaur formation contains several small bodies of carbonatite and fenite to the SE of Mingora. Their composition and close association with late Paleozoic granitic rocks is similar to these of the Naranji Kandao area in Buner. The entire suite may be related to Late Paleozoic rifting. The carbonatite is sugary sovite comprising calcite and clinopyroxene, with minor amounts of primary (?) clinozoisite, cancrinite- vishevite, apatite, sphene, opaques and zircon. The fenite consists of pure albite (abundant) calcite, biotite with > 3 % MgO and minor magnetite.

Key words: Mineralogy, carbonatite, fenite, Manglaur Formation, Swat.

J/73. Jan, M.Q. & Arif, M., 1996. Chemistry of chromite in the ophiolite complexes of Pakistan. Abstracts, 30th International Geological Congress, Beijing, p.662.

The northwestern boundary of the Indian plate in Pakistan is demarcated by a series of ophiolitic complexes and, locally, high-pressure rocks. The Indus suture in northern Pakistan contains, from east to west, Sapat, Jijal, Shangla, and Skhakot-Qila complexes, of which the latter two occur in tectonic melange zones. In addition, a lopolithic body of mafic-ultramafic rocks – the Chilas complex - also occurs in a Cretaceous magmatic arc to the north of the Indus suture. The suture on the western margin of the Indian plate contains, from north to south, the Waziristan, Zhob valley and Bela ophiolites, the latter extending for about 400 km from the coast of the Arabian sea northwards. These three are examples of megamelanges; in Bela, blocks measuring more than 100 km have been reported. The tectonic settings of these complexes have been the subject debate, mainly because of a lack of sufficient geological data.

Ultramafic and mafic plutonic rocks, ranging from residual peridotites to cumulate peridotites and gabbros, constitute large parts of these complexes. Disseminated and segregated chromite (in some economically exploitable) occurs in these complexes, and displays field and textural features similar to those reported from other parts of the world. Chemical data on composition of the chromite is available from all the eight occurrences. On the basis of chromium number [$Cr \# = 100Cr/(Cr+A1)$], the complexes can be divided into three groups: (1) the Sapat, Jijal and Waziristan complexes contain high Cr chromites with $Cr \# > 60$; (2) the Shangla, Skhakot-Qila, Zhob and Bela rocks contain chromite which displays a wide range of composition with $Cr \#$ varying from 15 to 90; and (3) rocks of the Chilas complex are characterized by low Cr chromites ($Cr \# < 65$). The petrogenetic importance of chromite chemistry has been discussed by several authors. It is interesting to note that the chromite compositions from Pakistan appear to indicate different tectonic settings for the origin of the complexes under consideration. Those with high Cr chromite have been regarded to represent island arc type origin. Opinion differs on the origin of group (2) chromite-bearing complexes; they may well be of complex origin with components which originated in different tectonic settings. The Chilas complex of group (3) containing low Cr chromite has been considered to have formed in a rift-related set up (intra-arc rifting or back arc basin). The present compilation lays emphasis on the importance of detailed mineral-chemical data to understanding the petrogenesis of ophiolite complexes.

Key words: Chromite, chemistry, ophiolites.

J/74. Jan, M.Q., & Arif, M., 1997. Comparison of chromite chemistry from the Pakistani Ophiolites. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy.

Consult Jan and Arif, 1996.

Key words: Chromite, chemistry, ophiolites.

J/75. Jan, M.Q. & Arif, M., 1997. Comparison of chromite chemistry from the Pakistani ophiolite. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, 26-27.

Consult Jan and Arif, 1996.

Key words: Chromite, chemistry, ophiolites.

J/76. Jan, M.Q. & Asif, M., 1981. A speculative tectonic model for the evolution of NW Himalaya and Karakoram. Geological Bulletin, University of Peshawar 14, 199-201.

The Himalaya are commonly considered to be the product of collision between the Asiatic and Indo-Pakistan plates. A number of plate tectonic models have recently been proposed for the NW Himalayas. Tahirkheli et al. (1979), Klootwijk et al. (1979), and Viridi (1981) suggested the formation of Kohistan Ladakh Island arc between the two plates. Coward et al. (in press, 1982) found that the structure of the Kohistan zone is much complex for such a simple interpretation. Complicated models, involving north- and south- facing subduction zones have been envisaged by Andrews-Speed and Brookfield (1982) and Windley (pers. Comm.).

We present here a model supported by new radiometric ages. The major sequence of events during the evolution of NW Himalaya and Karakoram of Pakistan and Kashmir is tentatively proposed here to be as follow:

Early to Mid Cretaceous: N-facing subduction of the Neo-Tethyan oceanic crust to produce volcanic and plutonic rocks (Dras, Chalt, Shyoke, Kohistan amphibolites) resulting in the formation of the Kohistan – Ladakh Island arc.

Late Cretaceous: Intrusion of the Chilas, Jijal, Kargil basic complex(es); and development of blueschists.

Paleocene to very Early Eocene: Collision of the Island arc with India (Powell, 1979); obduction of ophiolites and blueschist; simultaneous N- and S- facing subduction of the oceanic crust intervening between a Gondwanic microcontinent and the Island arc to produce the earlier phases in the Karakoram- and Kohistan-Ladakh granitic belts, regional metamorphism. Eocene to Early Miocene: Eruption of Eocene Kalam volcanic; younger intrusions (some derived from continental crustal material?) in the two granitic belts (Jan et al., 1981). Post-Early Miocene: Crustal thickening and production of the youngest granitic rocks in the Karakoram belt. The tectonic position of the Khunjerab-Tirich Mir granitic belt (115-84 m. y.) is not clear to us. These rocks might be a product of N-facing subduction N of the microcontinent (? Reshun Fault or Chitral- Upper Hunza Fault of Desio, 1979, however no ophiolitic rocks have so far been found in this area. An alternative of this is to think that the granites are of Late Cimmerian tectonic phase (Desio, 1979), related to Wakhan and Pamir granites and produced by a S- facing subduction zone further north.

Key words: Tectonics, evolution, Himalaya.

J/77. Jan, M.Q. & Asif, M. 1983. Geochemistry of tonalites and quartz diorites of the Kohistan-Ladakh (Trans Himalayan) granitic belt in Swat, N. Pakistan. In: Sham F.A. (ed.), Granites of Himalayan, Karakorum and Hindu Kush. Institute of Geology, Punjab University, Lahore, 355-376.

The Transhimalayan Kohistan-Ladakh granitic belt in the Swat district, NW Pakistan, is mostly represented by plutons of intermediate composition; granites are less abundant while basic bodies are rare. This paper presents a brief account of the petrography and a detailed discussion of the geochemistry of 38 tonalites, (quartz) diorites and related rocks, analysed for up to 25 elements. The chemistry suggests that the rocks are principally calc-alkaline in nature, many of those having island arc affinities. However, chemical variation for some elements is considerable and erratic. It is concluded that the rocks are the product of independent pulses of magma, generated by partial melting of subducted crust or the overlying upper mantle wedge over a long period from Middle Cretaceous to post-Eocene.

Key words: Geochemistry, tonalite, quartz diorite, granites, Kohistan, Ladakh.

J/78. Jan, M.Q., Asif, M. & Tahirkheli, T., 1981. The geology and petrography of the Tarbela “alkaline” complex. Geological Bulletin, University of Peshawar 14, 1-28.

The Tarbela complex comprises gabbroic rocks (oldest), dolerites, melteigites, albitites, normal and sodic granites, albite-carbonate rocks / breccia, and carbonatites (youngest), together covering an area of about 4 sq. km. The rocks have been intruded along a fault zone between the Salkhala and Tanawal formation. Some of the gabbroic intrusions display in situ differentiation with one intrusion grading from pyroxenitic outer margin in leucogabbroic/dioritic interior with a core of intrusive albitites.

Amongst typical alkaline minerals, sodic pyroxenes are restricted to the sodic granite, and nepheline to the melteigite. However, trace elements in albite-carbonate rocks, the high quantity of albite $\pm$ carbonate along with consistent presence of zircon, and rutile / sphene in most albitites are indicative of their alkaline affinity. The gabbroic rocks might also be alkaline, as suggested by the abundance of amphiboles (hornblende, kaersutite, hastingsite), low An-content of plagioclase, clinopyroxene composition, the general absence of primary quartz and the possibly high Ti-content reflected in amphibole, sphene and ilmenite. These observations, coupled with the close field association point towards an overall alkaline nature of the complex. The rocks show a considerable degree of alteration (autometasomatism) with widespread development of scapolite, carbonate, amphibole, mica, sphene, rutile, etc. The country rocks have been metasomatised in the vicinity of the intrusion and scapolite, albite, carbonate, ? quartz, pyrite have been produced. Some of the albitized sedimentary rocks resemble adinoles. This paper presents a detailed account of the petrography of the complex together with optical details of the minerals and a geological map. The petrogenesis of the complex is yet not clearly understood and hypothetical schemes based on differentiation under variable PCO₂ and liquid immiscibility are presented.

Key words: Petrography, alkaline complex, Tarbela.

J/79. Jan, M.Q., Asif, M., Tahirkheli, T. & Kamal, M. 1981. Tectonic subdivision of granitic rocks of north Pakistan. Geological Bulletin, University of Peshawar 14, 159-182.

The granitic rocks of north Pakistan can be divided into five types on the basis of available radiometric, petrographic, geochemical, tectonic and geographic data. (The granitic gneisses in the Nanga Parbat, Mansehra, and Swat areas are Late Precambrian (?) to Cambrian, S-type and possibly related to the Pan-African orogeny. The peralkaline to alkaline granites of Tarbela, Shewa-Shahbazgarhi, Ambela, Malakand proper, and Warsak were originated in extensional environments (rift / graben-related) during Eocene (50 to 40 m. y. ago). Dominantly calc-alkaline, Cretaceous-Tertiary granitic rocks constitute three, several hundred kilometer long belts in the Himalaya-Karakoram-Hindukush region.

The Khunjerab-Tirich Mir belt is the oldest (~ 115 to 86 m. y.) of the three and produced in continental margin environment in response to the subduction of the Paleotethys during the Cretaceous. Radiometric ages in the Karakoram granitic belt (continental margin) ranges from 65 to 5 m. y. whilst those in the Ladakh-Kohistan granitic belt (continental margin or island arc) from 63 to 19 m.y. It is possible that both these belts are a product of simultaneous subduction along the MMT and (?) MKT. It is likely that the more basic plutons in these two belts were produced by the partial melting of a predominantly oceanic crust, whilst in the rest of the rocks of the two belts both oceanic and continental crust contributed to the magma formation.

Key words: Tectonics, granitic rocks, Himalaya, Karakoram, Hindukush.

J/80. Jan, M.Q., Banaras, M., Ghani, A. & Asif, M. 1983. The Tora Tigger ultramafic complex, southern Dir District. Geological Bulletin, University of Peshawar 16, 11-29.

The ultramafic rocks of Tora Tigger near Munda are emplaced in amphibolites of the Kohistan tectonic zone along the Main Mantle Thrust. The amphibolites are represented by metamorphosed gabbros and norites of the Chilas layered complex, and garnet-bearing mafic to intermediate plutons. The ultramafic include dunites and a variety of peridotites, pyroxenites, and hornblendites. The hornblendites are the most abundant of these, are coarse-grained to pegmatite, and contain deformed felsic dykes and veins. The origin

of the olivine- and pyroxene ultramafics is not clear; they might be alpine-type or, more probably, cumulates of the Chilas complex and related to the metamorphosed gabbros and norites. Field relations and textural features suggest that the hornblendites have formed by metasomatism of the various rocks in the area.

Key words: Ultramafic complexes, Tora Tigga, MMT.

J/81. Jan, M.Q., Colback, P.S.B. & Ahmad, M. 1985. Low-temperature secondary minerals from Tarbela. *Geological Bulletin, University of Peshawar* 18, 189-197.

Several types of sulfates and other minerals, believed to have formed at low temperatures, were found in a remedial excavation site overlooking Tunnel 3 and 4 on the right bank of the Tarbela Dam. Identified with the help of optical properties, XRD and chemical analyses, these include gypsum, pickeringite, potassium alum, hydrated iron sulphate, epsomite, locontite, natroalunite, buntite, halloysite, (?) leonite and (?) starkeyite. Optical and chemical data for most of the samples studied are presented in the paper. The sulphates are thought to have formed in connection with the weathering and alteration of pyrite commonly present in the metasediments of the host Salkhala formation. The huntite has formed by the action of ground water on dolomitic rocks, or gabbros and pyroxene / hornblende peridotites, and the halloysite from alkali feldspar-rich intrusive rocks of the Tarbela "alkaline" complex compressive phases. It seems more plausible that the two sets of fractures and faults represent a conjugate set of wrench faults with a maximum stress axis of roughly E-W orientation. This also coincides with the orientation suggested by the folding (Durrani, 1980). I would like to bring the author's attention to the fact that the major faults also show a substantial amount of dip slip (normal) component (Durrani, 1980). This normal component of the faults and the gentle nature of the folds suggest that the compressional phase responsible for the folding and presumably coeval wrench faults was followed by a tensional phase. This tensional phase caused reactivation of earlier faults, now with dip slip movements, and was also responsible for the gentleness (partial unfolding) of early tighter folds. Discordance of the strike of the strata (N-S trend from the rest of the axial belt (roughly NE-SW trend) suggests that these tensional structures are probably related to some sort of rotation of the Indian craton causing subsequently tensional regime. In the light of above it is suggested that the tectonic history of the Dilband area occurred in following steps:

Folding and faulting due to compression (E-W trend).

Reactivation and dip-slip movements of the pre-existing faults and flattening of the original tighter folds due to tensional forces.

The fluorspar deposits are lacking elsewhere, including the type locality of the Chiltan Limestone (near Quetta). It seems that fluorspar deposits formed by late stage hydrothermal activity (Schcheglov, 1969), more likely in a tensional regime. Further study on the morphology and petrology of veins and, especially, new techniques in the field of fluid inclusions have substantial scope to determine the genesis of fluorspar deposits of Dilband area.

Key words: Sulfates, geochemistry, Tarbela.

J/82. Jan, M.Q. & Howie, R.A., 1980. Ortho- and clinopyroxenes from pyroxene granulites of Swat Kohistan, northern Pakistan. *Mineralogical Magazine* 43, 715-726.

This paper presents wet chemical analyses of forty-one pyroxenes (thirty-nine of them new) from pyroxene granulites and a few neighbouring rocks from Swat Kohistan and the adjoining Indus Valley. The granulites, considered to be derived from plutonic norites of an island arc tholeiitic nature, constitute one of the most extensive belts of its kind in the world. The pyroxenes are not unusual in any respect but they bear a closer resemblance to metamorphic than to igneous pyroxenes crystallized from deep-seated tholeiitic magmas. The distribution of Mg, Fe, and Mn (average $K^{MgFe}_D = 0.57$) and the tie-line intersections on the Wo-En join (generally from Wso.5 to Wov6.5) between the coexisting eighteen pyroxene pairs from the granulites are discussed. Based on eight different methods of geothermometry and other considerations, it is concluded that the pyroxene granulites were metamorphosed at around 800 °C and 7 to 8 kbar.

Key words: Pyroxene granulite, Swat Kohistan.

J/83. Jan, M.Q. & Howie, R.A., 1981a. The mineralogy and geochemistry of the metamorphosed basic and ultrabasic rocks of the Jijal complex, Kohistan, NW Pakistan. *Journal of Petrology* 22, 85-126.

The Jijal complex, covering more than 150 sq. km in the extreme north of Pakistan, is a tectonic wedge of garnet granulites intruded in the south by a 10×4 km slab of ultramafic rocks. The granulites are divisible into plagioclase-bearing (basic to intermediate) and plagioclase-free (ultrabasic to basic) types, the two types reflecting differences in bulk chemistry. Garnet + plagioclase + clinopyroxene + quartz + rutile $\pm$ hornblende $\pm$ epidote is the most common assemblage. The plagioclase-free rocks are composed mainly of two or three of the minerals garnet, amphibole, clinopyroxene and epidote. Orthopyroxene occurs in websteritic rocks devoid of epidote. Much of the amphibole and some epidote appear to be prograde products. Although variation diagrams do not reveal a genetic link between the two types of granulite, it is considered that they are comagmatic rather than the products of two or more unrelated magmas. The compositions of garnet ($\text{Py}_{28-46} \text{Alm}_{27-43} \text{Gro}_{16-28}$), clinopyroxene ($\text{Mg}_{44-34} \text{Fe}_{5-17} \text{Ca}_{51-49}$, Al_2O_3 3.0–9.9 per cent), orthopyroxene (with up to 5.5 per cent Al_2O_3), amphibole (with up to 16.3 per cent Al_2O_3 and high $\text{Al}^{\text{vi}}/\text{Al}^{\text{iv}}$), and the abundance of garnet suggest a high-pressure origin for the granulites. The rocks appear to have differentiated from a tholeiitic magma of oceanic affinity or they may be genetically related to the pyroxene granulites of Swat considered to have originally crystallized from a calc-alkaline magma of island arc or continental margin affinity. They probably crystallized in the ancient Tethyan crust/upper mantle (or less likely in a continental margin), later to be metamorphosed to granulites (670–790 °C, 12–14 kb) during the collision of the Indian-Asian landmasses, and carried upwards during later Himalayan orogenic episodes. The ultramafic rocks are alpine-type in nature and devoid of garnet. They are dominated by diopsidites; dunites, peridotites, and harzburgites together form <50 per cent of the area of outcrop. The chemistry of the rocks, and their olivines (Fo_{92-89}) and clinopyroxenes ($\text{Mg}_{49.5-48} \text{Fe}_{2.8-5.2} \text{Ca}_{47.4-46.8}$) are similar to those of alpine complexes of the harzburgite subtype. It is not clear whether they represent a faulted slab of suboceanic crust/upper mantle, mantle diapirs in deep orogenic roots, or dismembered ultramafic rocks differentiated from a basaltic magma. They seem to have a complex history; their present mineralogy is suggestive of high grade metamorphism (800–850 °C, 8–12 kb). They are magmatically unrelated to the garnet granulites and were probably intruded into the latter as plastic crystalline material after both had been independently metamorphosed, but before the entire complex was carried tectonically into its present surroundings. The abundances of the diopsidites is in marked contrast to other alpine-type complexes and the possibility of Ca and Si metasomatism during or before their metamorphism should not be totally ruled out.

Key words: Mineralogy, geochemistry, basic rocks, ultrabasic rocks, Jijal complex, Kohistan.

J/84. Jan, M.Q. & Howie, R.A., 1981b. Petrology of minor olivine gabbros and ultramafic rocks from upper Swat, N.W. Pakistan. *Geological Bulletin, University of Punjab* 16, 1-10.

Small bodies of ultramafic and olivine gabbroic rocks have been reported from a number of places in the amphiboles and pyroxene granulites of Swat. Most of these rocks are inconsistent in texture, mineralogy, chemistry and the extent of metamorphism. They have probably been emplaced at different times and do not seem to be directly related mutually or to their host rocks. As an illustration, the petrography and chemistry of two olivine gabbros, two pyroxenites, one bahiaite, and a two-pyroxene-two amphibole-olivine-plagioclase-spinel rocks is presented, together with comments on the relationship between various rock types of the area.

Key words: Petrology, ultramafic rocks, Swat.

J/85. Jan, M.Q. & Howie, R.A., 1982. Hornblendic amphiboles from basic and intermediate rocks of Swat-Kohistan, northwest Pakistan. *American Mineralogist* 67, 1155-1178.

Chemical analyses for 21 elements together with physical data are presented for 38 amphiboles (34 of them new) from garnet granulites, pyroxene granulites, amphibolites, and quartz diorites constituting the southern half of the Kohistan Cretaceous-early Tertiary arc. The metamorphic hornblendes are rich in alumina and some of them have high Al^{vi}/Al^{iv} ratios. The influence of metamorphic conditions is not important except on A-site occupancy and, possibly, on Ti and Mn contents. Refractive indices, birefringence, and density display a systematic increase (and 2V a decrease) with decrease in the ratio $(Mg + Al^{vi})/(Mg + Al^{iv} + Al^{vi} + Ti + Fe^{3+}) + Fe^{2+} + Mn$. Pleochroic colors and amount of absorption are controlled by Fe^{3+} , Ti, Fe^{2+}/Ti , and Mg/Fe^{2+} , while Z:c appears to increase with $Fe^{3+} + Ca$.--Modified journal abstract.

Key words: Amphiboles, basic rocks, Intermediate rocks, Swat Kohistan.

J/86. Jan, M.Q. & Howie, R.A., 1987. Some garnets, epidotes, biotite, micas and feldspars from the southern part of Kohistan, NW Pakistan. *Acta Mineralogica Pakistanica* 3, 5-25.

Partial or complete analyses of 52 mineral (with trace elements for 22) from amphibolitic rocks, mafic granulites and quartz diorites are presented. Garnet development in the amphibolite belt is sporadic and controlled by bulk chemistry, especially low Mg/Fe, but in Lilauni area of the amphibolite belt and in the garnet granulites of Jijal, abundant garnet has developed in response to high pressures. The amphibolite facies garnets are distinctly richer in almandine+spessartine and poorer in pyrope and grossular components as compared to the high-pressure granulite. The epidote is mostly monoclinic with Ps content ranging from 0 to 32-mole %. Epidote composition is controlled by the Fe^{3+}/Al ratios of the environment and by fO_2 but other factors might also exert some influence. No obvious difference is seen in the epidote compositions from the amphibolites and Jijal granulites.

The biotites in granulites generally have higher Ti, and lower Mn, Al and Na than those in amphibolites and diorites, which are considered to have equilibrated at lower temperatures than the granulites. Four of the biotites are altered to varying extent and show a loss in K (and Si) and gain in H_2O and to a lesser extent, in Ca. The feldspar analyses in some cases have excess Si and Al over Ca and alkalis. The plagioclase in a calc-silicate rock within the amphibolite terrain is albitic, it's abnormally low An content reflecting the peculiar bulk chemical and mineralogical composition of this rock.

Key words: Garnets, epidotes, biotite, micas, feldspars, Kohistan.

J/87. Jan, M.Q. & Jabeen, N., 1990. A review of mafic-ultramafic plutonic complexes in the Indus suture zone of Pakistan. *Physics and Chemistry of the Earth* 17, 93-117.

Several small to large bodies of mafic-ultramafic rocks have recently been studied in the Indus Suture Zone of Northern Pakistan. These occur in tectonic melanges along the suture, as klippe over-riding the Indian plate, and as cumulate/intrusive bodies in the Kohistan arc sequence. In this paper we present the salient petrological features of six well studied and prominent complexes. The Jijal (granulite), Chilas and Tora Tiggia complexes are closely associated with rocks of the Kohistan arc and have petrographic and chemical features similar to plutonic rocks from deeper levels of island arcs. The Jijal, Dargai, Shangla and Allai ultramafic bodies are found along the Indus suture. The Shangla serpentinized peridotites and Dargai klippe represent segments of the Neotethyan oceanic crust/upper mantle. The Jijal and Allai Kohistan dunite-peridotite-diopside association appears to have complex origin.

Key words: Mafic-ultramafic complexes, Indus suture.

J/88. Jan, M.Q., Kamal, M. & Khan, M.I. 1979. Tectonic control over emerald mineralization in Swat. *Geological Bulletin, University of Peshawar* 14, 101-109.

Emerald and chromian tourmaline occur in carbonate-talc / serpentine / chlorite rocks, carbonate-bearing talc schists, and associated quartz veins near Mingora, Charbagh, and Shangla. The rocks are altered ultramafics found in a discontinuous belt of volcanic, volcano-sedimentary, and sedimentary rocks that have undergone high P – low T metamorphism. The belt is a thrust slice overlying Gondwanic sialic metasediments and underlying the Kohistan (? oceanic) amphibolites both of which display Barrovian

metamorphism in the almandine amphibolite facies. It appears that the emerald-bearing belt represents a marginal basin or trench rocks of (?) Mesozoic age with tectonically incorporated lenses of ultramafic rocks from the upper mantle.

Key words: Emerald, tourmaline, talc schists, tectonics, MMT.

J/89. Jan, M.Q., Kamal, M. & Qureshi, A.A., 1981. Petrography of the Loe Shilman carbonatite complex, Khyber Agency. Geological Bulletin, University of Peshawar 14, 29-43.

The Shilman complex comprises sill-form bodies emplaced along a fault zone in Palaeozoic to Precambrian metasedimentary rocks. The largest outcrop is 2.5 Km long with a width of 170m in the central part. The rock-type of the complex include altered (meta) gabbros / dolerite, followed by amphibole-apatite-, biotite / phlogopite-, and dolomitic carbonatites, syenites and lamprophyric rocks, and Fe-rich hydrothermal veins. The syenitic rocks have locally been intruded and brecciated by light-coloured sovitic veins. It is suggested that the basic rocks might be related to the rest of the complex.

The country rocks (slates, phyllites, mica schist, recrystallized limestone and quartzite) have been regionally metamorphosed up to the biotite zone of Barrovian. They display, locally, considerable fenitization with development of alkali pyroboles, phlogopite and alkali feldspars. The complex is westward extension of the over 200km arcuate belt of alkaline complexes found around the northern half of the Peshawar plain and intruded during Early Tertiary along faults resulting due to the collision of the Indo-Pak plate with Eurasia.

Key words: Petrography, carbonatite, Khyber agency.

J/90. Jan, M.Q. & Karim, A., 1990a. Continental magmatism related to Late Paleozoic-Early Mesozoic rifting in northern Pakistan and Kashmir. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 22-23.

For details consult the following account.

Key words: Continental magmatism, Paleozoic, Mesozoic, rifting, northern Pakistan, Kashmir.

J/91. Jan, M.Q. & Karim, A., 1990b. Continental magmatism related to Late Paleozoic-Early Mesozoic rifting in northern Pakistan and Kashmir Geological Bulletin, University of Peshawar 23, 1-25.

During the Late Paleozoic and very Early Mesozoic, three groups of igneous rocks originated in the present day northwestern part of the Indo-Pakistani subcontinental landmass: 1) The Peshawar plain alkaline igneous province (PAIP), 2) The Panjal volcanics and associated intrusive rocks of Kashmir and Kaghan, and 3) The dolerite dykes in Peshawar, Hazara and Kashmir regions. The PAIP comprises the Tarbela complex (gabbros, albitites, granites), the batholithic Ambela granitic complex (AGC: granites, syenites, carbonatite, dolerites), the Shewa-Shahbazgarhi and the Warsak granites (some alkaline), gabbros and dolerite, the Malakand granite, and the carbonatite complexes of Sillai Patti (Malakand) and Loe Shilman (Khyber). The Panjal volcanics consist of flows (basalt, andesite, rhyolite and alkaline types), agglomerates and tuffs, dolerites, gabbros and norites. The Panjal igneous activity spans from Carboniferous to Triassic, but it were most extensive and voluminous during Permian. Dolerite dykes of the Peshawar, Hazara and Kashmir regions are quartz-hypersthene normative in character and have a Permian stratigraphic age.

Reliable age data are lacking for most of the PAIP, but the Koga alkaline rocks within the AGC have Rb-Sr isochron ages of 297-315 Ma, the U-Pb systematics of zircon in the Malakand granite suggest a Carboniferous age, and the Shahbazgarhi porphyries have a Carboniferous stratigraphic age. The Panjal volcanics and the dolerite dykes have similar (essentially Permo-Carboniferous) stratigraphic ages. Based on the available geochemical data in combination with the ages of the three groups of rocks, it is suggested that the present day northwestern margin of the Indo-Pakistani landmass experienced a major episode of swelling and rifting, with associated magmatism which culminated during Late Carboniferous to Early Triassic.

Key words: Continental magmatism, Paleozoic, Mesozoic, rifting, Northern Pakistan, Kashmir.

J/92. Jan, M.Q. & Karim, A., 1992. High-pressure veins in corona gabbros of Khwaza Khela Kohistan. *Geological Bulletin, University of Peshawar* 25, 47-50.

Gabbroic rocks of Khwaza Khela in the southern amphibolite belt of the Kohistan island arc preserve a record of thermal history from magmatic crystallization to high-pressure vein formation. The rocks formed from arc-related magma at about 1000 °C, 3-4kb, probably during the Early Cretaceous, subsequently calcic plagioclase and olivine reacted to form orthopyroxene + clinopyroxene + spinel ± tschermakite coronas at 800 °C, 6-8kb. The corona formation may have occurred in the early stages of the closure of the arc with the Karakoram plate (~ 95-102 Ma ago). Finally the rocks were subjected to high-pressure metamorphism, which is reflected in thin quartzofeldspathic veins containing garnet, zoisite, paragonite and kyanite were formed at 500-600°C, 10-12 kb. This paper presents petrography of these rocks and discusses the tectonic implications of the coronas and high-pressure veins, which developed in response to cooling and crustal thickening.

Key words: Gabbros, amphibolite belt, Khwaza Khela, Kohistan.

J/93. Jan, M.Q. & Karim, A., 1994. Crustal thickening observed through Coronas and high-P veins in metagabbros of Kohistan island arc, N. Pakistan. *Journal of Nepal Geological Society* 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal, 70.

The southern margin of the E-W trending Kohistan magmatic arc in the NW Himalaya-Karakoram ranges is made up of amphibolites and a variety of other lithologies ranging from peridotite to granite. The amphibolites are derived from volcanic and plutonic rocks of Early Cretaceous age. Gabbroic relics in the amphibolites are common both in Swat and Indus valleys. They display calc-alkaline character and their mineralogy is similar to low-pressure island arc plutonic rocks. During cooling and crustal thickening, olivine and anorthite in the gabbroic relics near Khwaza Khela (Swat) reacted to produce coronas consisting of two pyroxenes+pleonaste+tschermakitic hornblende at about 800°C, 5.5-7.5 kbar. Later these rocks were locally traversed by veins containing high-P assemblages: garnet, kyanite, zoisite, paragonite, corundum, chlorite, plagioclase and quartz. These formed in the range of 510-600°C, 10-12 kbar, either due to India-Kohistan collision in Eocene or earlier. This paper presents microprobe data on the minerals and discusses the tectonic implications of the coronitic and vein assemblages in the gabbros, which appear to have formed during cooling and crustal thickening.

Key words: High-P veins, metagabbros, Kohistan island arc.

J/94. Jan, M.Q. & Karim, A., 1995. Coronas and high-P veins in metagabbros of the Kohistan island arc, northern Pakistan: evidence for crustal thickening during cooling. *Journal of Metamorphic Geology* 13, 357-366.

The E-W-trending Kohistan terrane in the NW Himalaya is a sandwich of a magmatic arc between the collided Karakoram (Asian) and Indian plates. The southern part of the Kohistan arc is principally made up of amphibolites derived from volcanic and plutonic rocks of Early Cretaceous age. Gabbroic relics in the amphibolites display calc-alkaline character, and their mineralogy is similar to low-P plutonic rocks reported from modern and ancient island arcs. The largest of these relics, occurring along the southern margin of the amphibolite belt near Khwaza Khela, is subcircular in outline and is about 1 km across. It consists of cumulate gabbros and related rocks displaying a record of cooling and crustal thickening. Primary olivine and anorthite reacted to produce coronas consisting of two pyroxenes +Mg-Fe²⁺-Al spinel ± tschermakitic hornblende at about 800° C, 5.5–7.5 kbar. This thermotectonic event is of regional extent and may be related to the overthrusting of the Karakoram plate onto the Kohistan arc some 85 Ma ago, or even earlier. Later the gabbros were locally traversed by veins containing high-P assemblages: garnet, kyanite, zoisite, paragonite, oligoclase, calcite, scapolite and quartz ° Chlorite ° Corundum ± diopside. Formed in the range 510–600° C, and 10–12 kbar, these suggest further thickening and cooling of the crust

before its uplift during the Tertiary. This paper presents microprobe data on the minerals, and discusses the tectonic implications of the coronitic and vein assemblages in the gabbros.

Key words: High-P metamorphism, Kohistan island arc, P-T path.

J/95. Jan, M.Q. & Kempe, D.R.C., 1970a. Recent researches in the geology of Northwest West Pakistan. Geological Bulletin, University of Peshawar 5, 62-89.

The northwest part of the West Pakistan has seen detailed geological investigation in several areas during the past ten years. In this paper, an attempt has been made to give a brief account of the research work (much of which has already been published) carried out in Peshawar and Malakand Divisions, and Gilgit Agency since 1974. A summary of economic investigations is given and a detailed account of the bibliography has been presented in the end to provide an easy source of references for future workers.

The important conclusion that the authors have reached from this work is that many of the more or less regionally metamorphosed rocks, previously considered Precambrian, are mainly Siluro-Devonian, to a lesser extent, Carboniferous in age, with a relative abundance of reef complexes. Many of these rocks were intruded by various types of igneous (mainly granites), mostly during the Late Cretaceous and Early Tertiary periods.

Key words: Geology, bibliography.

J/96. Jan, M.Q. & Kempe, D.R.C., 1970b. Contributions of the Department of Geology, University of Peshawar, to the geology of the N.W.F.P. Geozine, University of Peshawar, 26-31.

The Department of geology has been active in research, especially field mapping in Kohistan and Dir, and the area between the Khyber Hills and Attock, during recent years. In this paper these activities are summarized.

Key words: Field mapping, Khyber Hills, Attock, Kohistan, Dir.

J/97. Jan, M.Q. & Kempe, D.R.C., 1973. The petrology of the basic and intermediate rocks of Upper Swat, Pakistan. Geological Magazine 110, 285-300.

A series of metamorphosed (amphibolite facies) basic and intermediate igneous rocks from upper Swat, Pakistan, is described, with seven chemical analyses. The rocks intrude Palaeozoic metasediments and are partially bordered by other, later, intrusive and volcanic rocks. The group, now represented by, from S-N, epidote amphibolites, amphibolites, noritic and hypersthene gabbros, and quartz diorites, is considered to be derived from a series of plagioclase hypersthene, norites, hypersthene gabbros, and hypersthene diorites. Variation diagrams are used to show that the series forms a differentiated sequence; FMA and lime-alkali diagrams suggest that it is similar to the rocks of the Garabal Hill-Loch Fyne area of Scotland. Some of the mineralogy of the group is briefly discussed, with five chemical analyses. A K/Ar age determination gives 67 Ma; thus the rocks probably derive from an early Himalayan (Alpine) tholeiitic basalt magma.

Key words: Petrology, basic rocks, intermediate rocks, Swat.

J/98. Jan, M.Q., Kempe, D.R.C & Symes, R.F., 1971. A green chrome-tourmaline from Swat, West Pakistan. Abstracts, 23rd Pakistan Science Conference, Peshawar, p.3.

Traces of a green, chrome-tourmaline occur in calcareous rock in contact with serpentinite, near Alpurai, Swat. The mineral is thought to be produced by silica-rich hydrothermal solutions, which have crystallized as thin quartz veins in the calcareous rocks. The petrography of the rock, and the optical properties of tourmaline along with its chemistry paragenesis and comparison with other such tourmaline occurrences is presented. Beside other constituents the Alpurai tourmaline has about 7.3 per cent Cr₂O₃ and 0.2 per cent V₂O₃ as revealed by electron microprobe analysis.

Key words: Tourmaline, Swat.

J/99. Jan, M.Q., Kempe, D.R.C & Symes, R.F., 1972. A green chromian tourmaline from Swat, West Pakistan. *Mineralogical Magazine* 38, 756-759.

Traces of a green chromian tourmaline occur in calcareous rocks in contact with serpentinite near Alpurai, Swat, West Pakistan. The petrography of the rocks and the optical properties of the tourmaline are presented along with its chemistry (it contains over 8 % Cr_2O_3 and about 0.2 % V_2O_3). The mineral is compared with other chromian tourmalines and its paragenesis discussed: it is thought to have been produced by silica-rich hydrothermal (or gaseous) solutions, which have crystallized as thin quartz veins in the calcareous rocks, introducing boron and other constituents.

Key words: Tourmaline, Swat.

J/100. Jan, M.Q., Kempe, D.R.C. & Tahirkheli, R.A.K., 1969. The geology of the corundum-bearing and related rocks around Timurgara, Dir. *Geological Bulletin, University of Peshawar* 4, 83-89.

The geology of the Timurgara, Dir area has been mapped, largely because of the occurrence of ruby corundum associated with some ultramafic bodies intruding the regional hornblende gneisses, quartzofeldspathic gneisses, and minor phyllites.

The most abundant intrusive rocks are diorites, themselves intruded by granites. The ultramafic bodies include serpentinites, pyroxenites and the corundum-bearing amphibolites. The relationship of the other intrusive rocks is not clear.

Key words: Mapping, geology, ultramafics, ruby, corundum, Dir.

J/101. Jan, M.Q., Kempe, D.R.C. & Tahirkheli, R.A.K., 1971. Corundum, altering to margarite, in amphibolites from Dir, Pakistan. *Mineralogical Magazine* 38, 106-109.

Pink to pale purplish corundum crystals, generally less than 15 mm but occasionally reaching 6 cm in length, sometimes idiomorphic, are found sparsely disseminated in a dark grey tremolite rock (amphibolite) associated with small ultrabasic intrusions (?sills) at Timurgara, Dir, West Pakistan (34° 48' N., 71° 50' E.). The corundum bearing amphibolites form bands in contact with pyroxenites and serpentinites intruded into banded hornblende gneisses (Jan et al., 1969); rarely, the amphibolites themselves have a gneissose texture. The banded gneisses are composed of plagioclase, hornblende, epidote (up to 50 % in some rocks), garnet, and minor quantities of iron ore and rutile. The rocks are veined, wedged, and tongued, and are mainly metasedimentary in origin. Other intrusions of granite and, most commonly, dioritic and noritic rocks are found in the area. The latter are composed of plagioclase, bronzite, clinopyroxene, hornblende, quartz, biotite, iron ore, and apatite; such rocks are abundant to the north-east of the area in upper Swat.

Key words: Corundum, amphibolite, Timurgara, Dir.

J/102. Jan, M.Q., Khan, A. & Windley, B.F., 1983. The Waziristan ophiolite complex: Chemistry of chromites and some other minerals. *Proceedings, 2nd National Seminar on Development of Mineral Resources, Peshawar* 1, 16p.

The Waziristan complex covering over 500 sq. km area, was tectonically emplaced during Paleocene - Early Eocene. It consists of ultramafics, gabbros, sheeted dykes, pillow lavas and pelagic sediments rock constituting type ophiolite complexes. However, a complete sequence with all the members intact does not occur in any single locality due to dismemberment and tectonic slicing. This paper presents an account of the petrography of the complex and the mineral chemistry of the podiform chromitites. The chromites consists of aluminochromite ($\text{Cr}_2\text{O}_3 = 49\text{--}61\%$) with subordinate chromian chlorite and/or chromian serpentine+ magnetite / on Cr-Al-Fe³⁺ + Ti diagram the chromites plot in the area of alpine chromite but on the other conventional diagram they occupy the overlapping fields of those from alpine and stratiform complexes. Many of the chromites are zoned with ferrite-chromite margin richer in the Cr/(Cr+Al) and poorer in Mg/(Mg+Fe) ratio than the unaltered cores. The chlorites are generally rich in SiO_2 and MgO

and poor in Al_2O_3 . It is suggested that during greenschist-facies metamorphism diffusion of Mg, Al and some Cr from the chromite margins towards the silicate matrix resulted in the development of ferri-chromite and chlorite.

Key words: Ophiolites, chromite, chemistry, Waziristan.

J/103. Jan, M.Q., & Khan, M.A., 1991. Petrologic evaluation of the mafic-ultramafic complexes in the lower levels of the Kohistan magmatic arc. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, p.6.

Synthesis of petrographic and geochemical data presented in the past three decades suggests that the Indian and Asiatic (Karakorum) Plates in northern Pakistan are separated from each other by a sandwich of an island arc. This, subduction related Cretaceous arc, consists predominantly of igneous rocks showing various degrees of metamorphism. Our detailed investigations on three mafic-ultramafic complexes from Kohistan not only corroborate the idea of the arc but also throw light on the growth of the lower crust.

The Chilas complex is a huge mass, more than 200 km in length and up to 40 km in width. It consists of a gabbro-norites into which are emplaced small bodies of ultramafic-mafic –anorthositic rocks showing excellent layering. Mineralogical and geochemical data support a subduction-related origin for the complex which has remarkable similarities with plutonic rocks of the island arc. The complex may have developed from a mantle diapir during early arc rifting or it may represent the plutonic base for the arc volcanics.

The Jijal complex is a 100 km block of ultramafic rocks and garnet granulites along the MMT. The ultramafic rocks range from pyroxenite through peridotite to dunite with chromite segregations. The granulites range from plagioclase + Garnet + clinopyroxene + quartz + rutile + hornblende + epidote assemblage to those consisting of granulites, hornblendites, pyroxenites and epidotites (meta-anorthositic). These rocks have preserved magmatic layers despite high-pressure granulite facies metamorphism. Geochemical and mineralogical data suggest that the complex represents arc cumulates metamorphosed at 800°C, 10 kbar about 100 m.y. ago.

The small (5 km²) Tora Tigga Complex is emplaced in amphibolites just north of the suture in southern Dir. It consists of hornblendites, olivine-rich and pyroxene-rich ultramafic rocks, and plagiogranite closely associated with metagabbroic rocks probably belonging to the Chilas Complex. These rocks have calc-alkaline magmatic signatures and may be cumulates to hydrous arc magma.

Key words: Petrology, mafic-ultramafics, Kohistan magmatic rocks.

J/104. Jan, M.Q., & Khan, M.A., 1995. Potential for ruby mineralization in upper Kaghan, NW Himalaya. Geological Bulletin, University of Peshawar 28, 1-7.

The Precambrian to Early Paleozoic basement of the upper Kaghan has a cover of metamorphosed sedimentary and volcanic rocks of Late Paleozoic-? Early Triassic age. About 3 km NE of Naran, the cover rocks contain a few tens of meters thick marbles containing thin (mostly <1 cm) micaceous bands one of which hosts tiny (up to a millimeter) grains of pinkish red corundum. The occurrence of the ruby corundum is similar to the Hunza and Azad Kashmir ruby deposits, thereby necessitating further search in the area.

The marbles consist of calcite + muscovite + biotite & quartz + pyrite. The micaceous bands consist of the two mica + pyrite I- opaque oxide + calcite ± rutile ± quartz plagioclase ± chlorite ± garnet. Microprobe analyses are presented for the common phases. Petrography and preliminary geothermobarometry suggest that the marbles were metamorphosed at 450-500°C, 6 kbar, followed by a lower temperature (~280 °C) overprinting of chlorite-epidote grade during retrogression. Considerable inter- and intra-granular variations in the Cr content of peen mica and ruby suggest a lack of mobility of Cr during metamorphism. The abundance of micaceous minerals and pyrite, and local occurrence of garnet and corundum suggest that the thin bands associated with the marbles were highly aluminous and iron-rich (?lateritic), and that reducing environments prevailed during their diagenesis.

Key words: Ruby, metamorphism, Precambrian, Paleozoic, Kaghan.

J/105. Jan, M.Q. & Khan, M.A., 1996. Petrology of gem peridot from Sapat mafic-ultramafic complex, Kohistan, NW Himalaya. *Geological Bulletin, University of Peshawar* 29, 17-26.

A large quantity of peridot has recently been marketed from the Parla Sapat area to the NE of Nara. The peridot occurs in pockets and veins located in shear zones in partially serpentinized dunitic host rocks. The latter constitute basal cumulates of the Kohistan magmatic arc thrust onto the Indian plate during Early Paleocene. The peridot is associated with serpentine (essentially chrysotile), minor magnetite, and local magnesite and talc. It is mostly yellowish green, takes good polish, and suitable specimens are faceted into brilliant stones of highest quality. It occurs in euhedral to subhedral crystals, but most stones are broken due to crude methods of recovery. The stones are mostly <3 cm in length, but up to 15 cm long crystals weighing 2 kg have been recovered. The largest faceted stone is reported to measure about 310ct.

The peridot is pleochroic from pale green ($\alpha=\gamma$) to yellowish green or olive in greenish yellow variety ($\beta=Z$). Refractive indices ($\alpha = 1.644$ to 1.653 , $\gamma = 1.682$ to 1.684 ± 0.003), density (3.26 to 3.44) and EPMA data suggest that most specimens range in composition from Fo89 to Fo92, but some are more magnesian (up to Fo97). The depth of color increase from light green to yellowish green with increase in the Fe content, but the greenish yellow color may partly be related to a higher Ti content. Some peridot contains tiny inclusions of magnetite and hairy to acicular, brownish black ludwigite [(Ti_{0.011} Cr_{0.041} Fe³⁺_{0.947}) (Mg_{1.085} Fe²⁺_{0.897} Mn_{0.004} Ni_{0.013}) BO₅]. The paragenesis may be related to hydrothermal activity with also introduced CO₂ and B. The undeformed nature of the peridot suggests that the solutions may be related to the late phases of Himalayan metamorphism or leucogranites of the underlying Indian plate, both of which are of Eocene age.

Key words: Petrology, gems, peridot, ultramafics, Sapat, Kohistan, NW Himalaya.

J/106. Jan, M.Q. & Khan, M.A., 1997a. Mineralogy of gem olivine (peridot) from Kohistan-Kaghan watershed. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad 2 p.

A large quantity of peridot has recently been marketed from Parla Sapat area to the NE of Naras. The peridot occurs in pockets and veins located in shear zones in partially serpentinized dunitic host rocks. The latter constitute basal cumulates of the Kohistan magmatic arc thrust onto the Indian plate during the Early Paleocene. The peridot is associated with serpentine (essentially chrysotile), minor magnetite and local magnesite and talc.

Physical constants and chemical composition of the peridot were studied in detail during the present investigation. It is mostly yellowish green takes a good polish and suitable specimens are faceted into brilliant stones of highest quality. The mineral occurs in euhedral to subhedral crystals but most stones are broken due to crude methods of recovery. The stones are mostly < 3 cm in length, but larger stones have been recovered including a 10-15 cm long crystal weighing 2 kg. The largest faceted stone is reported to measure about 310 ct.

The peridot is pleochroic from pale green ($\alpha=\gamma$) to yellowish green or olive in greenish yellow variety ($\beta=Z$). Refractive indices range from $\alpha=1.644$ to 1.653 and $\gamma=1.682$ to 1.684 ± 0.003 , and density from 3.26 to 3.44. The refractive indices and electron microprobe analyses suggest that most peridot ranges in composition from Fo89 to Fo92 but some compositions are more magnesian (up to Fo97). The depth of colour increases from light green to yellowish green with increase in the Fe content, but the greenish yellow colour may partly be related to higher Ti content.

Some peridot contains tiny inclusions of magnetite and hairy to acicular inclusions of a brownish black substance, locally forming mats. XRD and probe data suggest that later to be ludwigite (Ti_{0.011} Cr_{0.041} Fe₃+0.097) (Mg_{1.085} Fe₂+0.897 Mn_{0.004} Ni_{0.013}) BO₆ a mineral not reported previously in peridot. It is thought that the paragenesis developed along shear zones and is related to hydrothermal activity, which also introduced CO₂ and B. The undeformed nature of the peridot suggests that the solutions may be related to the late phases of regional metamorphism or leucogranites of the underlying Indian plate, both of which are of Eocene age.

Key words: Mineralogy, gems, peridot, ultramafics, Kaghan, Kohistan, NW Himalaya.

J/107. Jan, M. Q., Khan, M.A., 1997b. A review of the geology and tectonics of N. Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, 1-2.

North Pakistan is significant for its geographical position at the junction of world's three major mountain ranges; Hindukush, Karakoram and Himalayas. Several lines of evidence based on diverse geological studies including lithological and structural mapping, petrography, geochemistry, fossil findings and radiometric age determinations, have led to realization that N. Pakistan comprises three, previously discrete and distant apart, plates named Karakoram, Kohistan and India. These plates accreted to Eurasia during Jurassic-Early Tertiary to form the present-day landmass of south-central Asia.

The Karakoram plate incorporates much of the Karakoram-Hindukush ranges and adjacent areas of south-central Asia. Northern Baltistan (including K2) and upper reaches of the Hunza, Ishkuman, Yasin, Yarkhun and Chitral valleys are parts of northern Pakistan which occur in the Karakoram plate. The plate is divisible into three tectonic units; (1) a metamorphic complex, comprising metapelites with subordinate marbles of probable Precambrian-Palaeozoic age in the south. (2) an Andean-type batholith (granodiorites, diorites and granites) of Late Cretaceous-Tertiary age in the middle and (3) a succession of intact stratigraphy (predominantly carbonates and pelites with subordinate sandstones and conglomerates) from Ordovician to Triassic in the north with rare remnants of a Precambrian basement (metapelites) near the Baroghil Pass. A series of discontinuous plutons of Late Cretaceous age, stretching from Wakhan-Trich Mir to Khunjerab and beyond, intrude this tectonic unit. The Karakoram plate is a lateral equivalent of the Lahasa block in the east, and the Afghanistan and Iran microcontinents in the west. All these microplates are Gondwanic in their faunal affinity and are considered to have been separated from the Gondwana during Permian. The paleotethys closed to the north of these microplates in Jurassic (150-145 Ma) at the site of the Rushan-Pashart-Bangong-Nujiang Suture Zone, accreting these microplates with Eurasia. The southern contact of the Karakoram plate is with the Kohistan island arc terrane at the site of the Shyok suture.

The Kohistan terrane in north Pakistan is a fossil island arc of Cretaceous-Early Eocene age. This is an east-west trending belt of 30-60 km width, encompassing the Kohistan region of north Pakistan, i.e., middle Indus, Swat and Dir valleys. It was formed in an intraoceanic setting in the Neotethys. Basalts, gabbros and ultramafic rocks predominate the early phases of arc growth giving way to the intermediate to felsic (mainly granitic) igneous rocks in the later states. The earliest rocks in the Kohistan terrane are about 120 Ma old. This coincides with the age of the separation and northward drift of the Indian plate from the eastern Gondwana independently deduced from the ocean-floor magnetic anomaly data. The Kohistan terrane suffered two collisions; firstly it collided with the southern margin of previously accreted Karakoram-Eurasia at about 90-80 Ma (Chalt suture), when it became an Andean-type continental margin. Finally the terrane was sandwiched when the Indian plate collided with its southern margin during Early Tertiary at the site of the Main Mantle Thrust or Indus Suture. These multiple tectonic events have exposed the deepest parts of the arc crust, including Moho, attracting considerable attention from petrologists for the study of deep-arc crustal structures and composition.

The Himalayas, in essence, represent the deformed northern part of the Indian plate involved in continent-continent collision. They are regionally divisible into internal (or hinterland) and external (or foreland) zones. The internal zone occurs immediately to the south of the MMT. It comprises crystalline rocks tectonically stacked in such a way that deep-crustal (hence higher grade) rocks occur on the top of shallower, lower-grade rocks successively in the south. Polyphase deformation and metamorphism, accompanied by partial melting and granite gneisses, are characteristic of the internal zone. The external zone, which in essence, is a type foreland thrust-fold belt, comprises successions of stratified sedimentary rocks of Hill Ranges (e.g., Margala, Kalachita and Kohat), Potwar-Kohat plateau, and Salt Ranges. The classical division of the Himalayas into Tethyan, higher, lesser and sub Himalayas is not strictly applicable to the west of the Nanga Parbat Syntaxis, roughly, the Internal zone includes higher and inner part of the lesser Himalaya, while the outer part of the lesser Himalaya and sub-Himalaya occur in the external zone.

A simplistic scenario of the origin of Himalaya includes (1) subduction of the leading oceanic part of the Indian plate from about 120 Ma to about 65 Ma in the north-west, and up to 50 Ma elsewhere, (2) partial subduction of the basal parts of the Indian-plate continental crust leading to Eocene peak metamorphism including the high-P metamorphism responsible for the 49 ± 5 Ma eclogites in the upper Kaghan valley, (3) rapid uplift and shifting of deformation front from the MMT successively southwards to the thrusts in the interiors of the Indian plate; Shontargali and Batal Shears at about 40 Ma, Main Boundary Thrust (MBT) at about 10 Ma and Main Frontal Thrust at the Salt Range in geologically recent past, (4) north-verging

folding of the Himalayan thrust sheets into dome and basin structures (e.g., Hazara-Kashmir, Besham, Indus and Nanga Parbat syntaxial bends and Hazara and Swat arc). Whereas the youngest of these structures are still active (e.g. Raikot fault at the western limb of the Nanga Parbat syntaxis), the older structure (e.g. MBT) have been frequently reactivated.

Key words: Tectonics, Karakoram, Kohistan arc, Himalaya.

J/108. Jan, M.Q. & Khan, M.A., 2000. A Petrological overview of the Kohistan magmatic arc, NW Himalaya, N Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, 5-6.

The Kohistan Terrane in N. Pakistan occupies the suture zone between the collided Indian and Asian Plate. It formed primarily as an intra-oceanic crust between 125 and 90 Ma prior to its accretion with the Asian plate along the Shyok Suture. The final obduction of the Kohistan onto the Indian plate in Early Eocene ensued the principal phase of the Himalayan orogeny.

A two-fold subdivision of the rocks forming the Kohistan crust is now well established. Much of the ultramafic-mafic component of the arc crust developed in the intraoceanic setting prior to collision with Asia. Mafic-ultramafic plutonic complexes (Jijal and Sapat), together with gabbroic-basaltic amphibolites (Kamila belt), at base of the arc crust, and basaltic-boninitic volcanics (the Chalt Formation) and Jaglot-Yasin metasediments, in the upper arc crust are representative lithologies of this tectonic setting. Post Shyok suture lithologies include ca.80~45 Ma Kohistan Batholith, Early Eocene utror-Shamaran volcanics and sedimentary rocks deposited in Early Eocene Dir and Drosh basins in Andean-type setting. The Chilas gabbro-norite-ultramafic complex was magmatically emplaced in the waning stages of intraoceanic phase but preceded the onset of the Andean-type magmatism.

Earlier models suggested that Kohistan is a simple island arc tilted on an end with its base at the Indus suture and top at the Shyok Suture. Later, more detailed studies reported several complexities including large-scale folding of the arc crust, existence of Kamila shear zone and metamorphic ages spanning 95~85Ma. Most tectonic models from the Kohistan Terrane Indus Suture. But several aspects of the terrane are still under discussion and need further investigations. These include: (1) Nature and extent of the oceanic basin consumed at the Shyok Suture and the palaeolatitude position of Kohistan in Late Early Cretaceous; (2) Existence and polarity of subduction zone at the site of the Shyok Suture and facing direction of Kohistan in terms of location of the fore-, and back-arc basins; (3) Timing of emplacement for the Chilas Complex, i.e., pre- or post Shyok Suture; (4) Nature of the Kamila Amphibolite belt, i.e., a stack of gabbroic-ultramafic magma chambers or a metabasalt basement with intrusive gabbroic plutons, both metamorphosed to amphibolites; (5) Nature of the mafic plutonic rocks in the Jijal Complex; garnet granulites, garnet gabbros, or both; (6) Nature of the ultramafic rocks in Jijal and Chilas Complexes: mantle peridotites, or cumulates at the base of an island arc crust or ophiolite.

Lack of rocks in Kohistan crust with a clear continental basement affinity negates possibility of its origin as a continental margins offshore the Karakoram plate. This implies that models suggesting a Sea of Japan type origin for the Shyok Ocean are invalid. Several pieces of evidence, including isotope systematics, palaeomagnetic studies and laterization favor an equatorial palaeolatitude position for Kohistan in Late Early Cretaceous. This implies that the Shyok ocean was a sizeable entity, which closed at the site of the Shyok suture after producing subduction-related 110~90 Ma Karakoram Batholith. The Suggestion that the Shyok ocean was additionally bounded by a subduction zone to its south with southerly dips that gave birth to intraoceanic Kohistan island arc is currently under debate. But the presence of boninites in Chalt Volcanics at the northern margin of the terrane certainly lends supports to this model. The mid-crust levels Chilas intrudes the interface between the Kamila amphibolites and overlying metasediments of the Jaglot group. A lower state of deformation in the Chilas Complex compared to the host Kamila Amphibolite and the Jaglot metasediments and a U-Pb zircon age of 84Ma indicates a post- or syn-Shyok Suture origin for the Chilas Complex. The 110Ma Rb-Sr whole-rocks age contradicts this interpretation warranting further geological and geochronological investigations.

The Kamila Amphibolite belt is composite in nature. It consists of predominantly pillowed metabasalts (both MORB and arc) together with metagabbros. Burial of the Kamila pillowed metabasalts from a surface level to that of lower crust is attributed to (1) mid-crustal magmatic overloading by the Chilas Complex and (2) tectonic burial beneath the folded Chilas Complex and Jaglot Group along the Kamila shear zone. This highlights role of combined tectonics and magmatism in crustal growth in island arc.

The Jijal Complex, exposed at the base of the Kohistan Crust directly above the Indus Suture, is the most studied yet least understood unit in the Kohistan. Workers in the recent past have preferred to place petrological MOHO directly at the Indus Suture implying that the overlying 4-km thick ultramafic unit, together with garnet gabbros/granulites constituted cumulates at the base of the Kohistan Island Arc Crust. Alternatively, petrological MOHO is placed at the contact between the ultramafic and the gabbroic units implying that the ultramafic unit in the Jijal Complex is part of the infra-arc mantle. Another controversy relates with the garnetiferous mafic rocks in the Jijal Complex. These have been interpreted to have directly crystallized as such are a product of high pressure metamorphism imprinted on what were originally gabbroic rocks or pyroxene granulites. Coherently in continuous magmatic layering with both in the ultramafic and garnet gabbros preclude Jijal Complex is a part of mantle. The structure ascribed to upper mantle can equally commonly in ultramafic cumulates. A mineral chemical data of a large number of samples, both from Chilas and Jijal do not favor a mantle nature for the ultramafic rocks of these two complexes.

Key words: Kohistan arc, orogeny, Himalaya.

J/109. Jan, M.Q., Khan, M. A. & Qazi, M.S. 1992. The Sapatgali mafic-ultramafic complex, Kohistan arc, N Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 44.

The Sapatgali complex is one of the several mafic-ultramafic complexes occupying the bottom of the Cretaceous Kohistan island arc. It occurs in the immediate hangingwall of the Indus suture zone along the drainage divide between the Kohistan and Kaghan terrains. Previously undescribed, much of the complex consists of gabbroic rocks, but in the central part, there are basal ultramafic cumulates emplaced onto the Indian plate. It displays well developed layering which may be disrupted, folded, pinched and swelled. The basal ultramafics, attaining a maximum width of 1.5-km, extend for 15-km. In the central part, these can be divided into the following zones, from base to top:

Homogeneous serpentinitized dunites (350 m thick), dunites with thin chromite layers (350 m), thinly layered dunites-pyroxenites (30 m), Layered dunites-pyroxenites-gabbros (170 m) with chromite layers in the lower part, and gabbros. The gabbroic rocks may be amphibolitised and consist of a variety of lithologies ranging from troctolites to anorthosites, with local pyroxenite ($\pm$ olivine) layers and horizons of olivine-rich ultramafics. These rocks are at places cut by pyroxene-rich pegmatites containing upto 45 cm long pyroxene crystals.

Preliminary microprobe studies on the ultramafic rocks show that the clinopyroxene is Mg-Ca-rich diopside, and olivine has a forsterite content of 92 to 78, but in rare cases >95 . The chromite displays high Cr# (75-67) and low Fe³⁺/R₃⁺ (<10). These data, especially the chromite analyses, are akin to those of ultramafic rocks of island arcs, including the Jijal Complex, 80 km to the west. The huge Chilas complex, which occurs in the central part of the Kohistan arc, contains Cr-oxides with Cr# typically <60 .

Key words: Ultramafics, Sapat Complex, Kohistan arc.

J/110. Jan, M.Q., Khan, M. A. & Qazi, M.S. 1993. The Spat mafic-ultramafic complex, Kohistan arc, north Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society, London, Special Publications 74, 113-121.

The Sapat layered complex occupying the tectonic base of the Cretaceous Kohistan island arc, occurs in the immediate hanging wall of the Indus suture zone north of the Kaghan valley. Previously undescribed, much of the complex consists of gabbroic rocks, but in the basal part there are ultramafic cumulates (15 x 2 km) in direct tectonic contact with the Indian plate. In the central part, the complex can be divided into five zones. From the base these are: (1) homogeneous serpentinitized dunites (350 m thick), (2) dunites with thin chromite layers (100 m), (3) thinly layered dunites-pyroxenites (30m), (4) layered dunites-pyroxenites-gabbros (170 m) with chromite layers in the lower part, and (5) gabbros. The gabbroic rocks are amphibolitized and consist of a variety of lithologies ranging from troctolites to anorthosites, with local pyroxenite (+ olivine) layers and horizons of olivine-rich ultramafics. These rocks are locally cut by pyroxene-rich pegmatites containing up to 45 cm long pyroxene crystals. Preliminary microprobe studies on the ultramafic- rocks show that the clinopyroxene is Mg-Ca-rich diopside, and olivine has a forsterite

content of 92 to 78, but in rare cases > 95. The chromite displays high Cr No. (75 to 67) and low $\text{Fe}^{3+}/\text{R}^{3+}$ (<10). These data, especially the chromite analyses, are akin to those of ultramafic rocks of island arcs, including the Jijal complex, 80 km to the west. We suggest that the Sapat complex formed the basal part of the Kohistan terrain and is related to arc magmatism. It has been metamorphosed under epidote amphibolite facies conditions.

Key words: Ultramafics, Sapat Complex, Kohistan arc.

J/111. Jan, M.Q., Khan, M.A. & Windley, B.F., 1989. Mineral chemistry of the Chilas mafic-ultramafic complex, Kohistan island arc, N. Pakistan: oxide phases. *Geological Bulletin, University of Peshawar* 22, 217-239.

The Chilas Complex contains a great variety of Fe^{3+} , Al, Cr, and Ti oxide phases. The principal gabbro-norite association (PGA), which forms much of the complex, and the amphibolite dykes which represent a younger magmatic event in the Chilas Complex, contain magnetite-ilmenite pair exsolved from an initially single phase; no Cr-Al spinel occurs in these rocks. The ultramafic-mafic-anorthosite association (UMAA) of rocks, which appears to be emplaced in the PGA, contains oxides covering the entire range from pleonaste through Al-Cr- Fe^{3+} spinel (with a maximum of 39 wt. % Cr_2O_3) to magnetite. These display complete ranges for Cr / (Cr + Al) and $\text{Fe}^{3+} / \text{R}^{3+}$ ratio which decrease with increase in Mg / (Mg+ Fe^{2+}) ratio (0.7 to 0.0). The composition of the UMAA spinel varies from one to another samples and in some cases from grain to grain within a single specimen. The variations are attributed to subsolidus re-equilibration with adjacent silicate grains and to exsolution. The exsolved pairs define a complete solvus similar in shape to those reported elsewhere. The UMAA also contains pleonaste formed in reaction coronas between calcic plagioclase and olivine, and in few cases, ilmenite formed during exsolution of Cr-Al- Fe^{3+} spinel. Exsolved oxide phases in both the associations of rocks have re-equilibrated under low oxygen fugacity during cooling of the complex at temperature ranging from >800 to 500°C. The detailed microprobe analytical data for the oxide phases discussed in this paper support our earlier view that the Chilas Complex is related to the Kohistan arc probably formed during intra-arc rifting in initial stages of development of a back-arc basin.

Key words: Ultramafics, Spinel, Chilas Complex, Kohistan arc.

J/112. Jan, M.Q., Khan, M.A. & Windley, B.F. 1992. Exsolution in Al-Cr- Fe^{3+} spinels from the Chilas mafic-ultramafic complex, Pakistan. *American Mineralogist* 77, 1074-1079.

The Chilas complex contains accessory and segregated spinels that display a complete range from Cr-poor pleonaste through Al- Fe^{3+} -rich chromite to Cr-poor magnetite. Microprobe data reveal complete ranges for the Cr/(Cr + Al) and $\text{Fe}^{3+}/\text{R}^{3+}$ ratios, whereas the Mg/(Mg + Fe^{2+}) ratio ranges from 0.7 to 0.0; the former two ratios increase as the latter decreases. Grain to grain compositional variation within a thin section is common.

It is particularly drastic in tiny spinel grains and is mainly because of subsolidus re-equilibration with adjacent grains of olivine, pyroxenes, and amphibole. Many samples also contain aluminum chromium spinel with blebs and lamellae of exsolved Fe^{3+} -rich spinel.

The exsolved grains define a complete solvus, the shape of which is similar to those of other documented examples of exsolved spinels in the system $(\text{Mg-Fe})\text{Fe}^{3+}_2\text{O}_4$ -(Mg- Fe^{2+}) Cr_2O_4 -(Mg- Fe^{2+}) Al_2O_3 . Exsolution probably took place during cooling at <600 °C.

Key words: Ultramafics, spinels, Chilas Complex, Kohistan arc.

J/113. Jan, M.Q. & Khan, M.J., 1992. Precambrian sequence of Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 17-18.

Precambrian rocks in NW Pakistan can be classified into a basement (Salkhala Group) and overlying slates (Hazara, Attock Formations), quartzite (Tanawal Formation) and conglomerate (Tanaki Formation). The Salkhala Group consists of metamorphosed pelites with significant graphitic, quartzitic and carbonate

components, and associated gneisses, pegmatites and dolerite dykes at many places. There is a general increase in the grade of metamorphism towards north, with varying types of schists, migmatites and paragneisses. Radiometric studies in the Nanga Parbat Haramosh area and Besham suggest that the oldest rocks are at least 1850.1950 M.Y. in age.

The slate sequence is overlain by the Tanawal Formation and comprises quartzite, quartzitic schist, phyllite and some conglomerate. It is intruded by granitic rocks. Major pluton intruding these quartzites is the Mansehra Granite, with Rb/Sr isochron age of 516 ± 16 MY. The upper most part of Precambrian sequence in NW Pakistan is formed by a conglomeratic unit, the Tanaki Formation.

Key words: Precambrian, Pakistan.

J/114. Jan, M.Q., Khan, M.J. & Hamidullah, S. (eds.), 1989. Tectonic Evaluation of Collision Zones between Gondwanic and Eurasian Blocks. Special Issue Geological Bulletin, University of Peshawar 22, 239p.

Key words: Tectonics, collision zones, Gondwana, Eurasia.

J/115. Jan, M.Q. & Khattak, M.U.K., 1983. Petrology of a hornblende-rich pegmatite and host amphibolites near Matta, upper Swat. Geological Bulletin, University of Peshawar 16, 31-41.

The 500×30 m pegmatite near Matta consists of hornblende + epidote + garnet lithology and hornblendite, with a small proportion of leucocratic, deformed dykes and veins. It is hosted by epidote amphibolites derived from gabbroic rocks and belonging to the southern amphibolite belt of the Kohistan zone. The hornblende-epidote lithology of the pegmatite is chemically identical to the amphibolites and is, therefore, neither a younger intrusion in nor a metasomatic product of the amphibolites. The coarse-grained fabric of the pegmatite may have developed locally in response to a higher concentration of fluid phase, mainly water but some fluorine. The hornblendite, which is coarser grained (with up to 35 cm long crystals) and may cut the hornblende-epidote lithology, may be a product of metamorphic differentiation or, more likely, metasomatism. The amphibolites are tholeiitic in affinity and probably represent the Tethyan oceanic crust.

Key words: Petrology, pegmatite, amphibolite, Swat.

J/116. Jan, M.Q., Khattak, M.U.K., Parvez, M.K. & Windley, B.F. 1984. The Chilas stratiform complex: field and mineralogical aspects. Geological Bulletin, University of Peshawar 17, 153-169.

The Chilas complex in northern Pakistan stretches for about 300 km from Astor to western Dir and attains a width of 40 km in the middle. It was probably emplaced during the early stages of development of the Cretaceous Kohistan island arc. Field observations, supported by petrography and mineral chemistry, suggest that the complex is composed of two groups of rocks. Group A consists predominantly of noritic rocks with subordinate pyroxenites, anorthosites and hypersthene-quartz diorites. These cover most of the complex, are generally strongly foliated and display some layering. The mineral composition of these rocks varies as follows: orthopyroxene En75 to En51; clinopyroxene Mg=43 to 27, Fe=9 to 22, Ca= 42 to 50; plagioclase An62 to An43.

Group B rocks occur in the form of lenses (upto 5 km²) and smaller bodies showing complex contact relations, ranging from concordant to discordant, with their host (group A) rocks. These comprise dunite, peridotites, pyroxenites, troctolites, norite, anorthosite, and pyroxene pegmatites; of these the former two are the most abundant. The principal outcrops of these rocks are found in Chilas area but isolated, small bodies occur as far to the west as Swat. The range in the mineral composition of these rocks is: olivine Fo88 to An77; orthopyroxene En90 to En62; clinopyroxene Mg=46 to 37; Fe= 5 to 17, Ca= 49 to 45; plagioclase An98 to An77. Characteristic features of this group of rocks are the development of excellent layering and corona structure.

The group A association may have evolved from a high-alumina basaltic (calc-alkaline) magma. It is not clear whether the group B rocks represent magmatic cumulates of this magma or younger intrusions of a

more basic (picritic) magma. Both groups were probably metamorphosed under pyroxene granulitic facies, to be followed by amphibolite dykes and hornblend-plagioclase pegmatites.

Key words: Petrology, chemistry, Chilas, Kohistan.

J/117. Jan, M.Q., Khattak, M.U.K. & Tahirkheli, R.A.K. 1983. A comparison of chemistry of chromites from Zhob valley, Harichand and Waziristan ophiolite complexes of Pakistan. Proceedings, National Seminar on Development of Mineral Resources, Peshawar 3, 13p.

Chromian spinels from Zhob, Harichand and Waziristan are essentially aluminos-chromites generally rich in Cr_2O_3 . Different variation diagrams have been used to compare the chemistry of chromites on the basis of 73 analyses from Zhob (15 of them new), 27 from Harichand and 9 new analyses from Waziristan. On $\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$ vs $\text{Cr}/(\text{Cr}+\text{Al})$ and $\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$ and Cr_2O_3 vs. total FeO and mol % Al_2O_3 / $(\text{Cr}_2\text{O}_3 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3)$ diagrams they generally plot in the overlapping fields of chromites from stratiform and alpine complexes.

Their alpine (or ophiolitic) nature is not obvious on TiO_2 vs. Fe^{2+}/Mg diagram either, although the Waziristan chromites plot only in the alpine field on this diagram. However, on $\text{Cr}-\text{Al}-\text{Fe}^{3+}+\text{Ti}$ diagram chromite analyses from all the three complexes are restricted to the field of those from alpine complexes.

The Zhob chromites display a greater range in composition due probably to a higher number of analyses from this area. In general, the Zhob chromites have a higher range in the ratio $\text{Mg}/(\text{Mg}+\text{Fe}^{2+})$ and $\text{Fe}^{3+}/(\text{Cr}+\text{Al}+\text{Fe}^{3+})$ whilst the Harichand ones have a higher range in the ratio $\text{Cr}/(\text{Cr}+\text{Al})$.

Key words: Ophiolites, chemistry, chromite, Zhob, Harichand, Waziristan.

J/118. Jan, M.Q., Malik, R.H. & Ahmad, K.H., 1995. Gem garnet in pegmatites from Neelum valley, Azad Kashmir. Geological Bulletin, University of Peshawar 28, 9-14.

The upper Neelum valley is occupied by a group of basement rocks of Precambrian to early Paleozoic age and a cover of younger rocks. Both the basement and cover contain Late Paleozoic (?) mafic sheets. There are at least two sets of pegmatites, one we-dating and the other post-dating the mafic sheets. A few of these contain green tourmaline, pink beryl, and colourless topaz, one of the pegmatites near the village of Phullawai contains bluish green tourmaline and gem garnet. The garnet is well-formed and reaches up to 30 g in weight. It is clear, transparent, takes a good polish, and ranges from yellowish red to tangerine and crimson red. Many spots analysed in two tiny ($\sim 0.5 \text{ cm}^2$) grains are uniform in composition. The garnet is rich in spessartine (79.9 mole %), with small amounts of almandine (15.3 mole %) and grossular (4.4 mole %) components.

Key words: Gems, garnet, pegmatites, Azad Kashmir.

J/119. Jan, M.Q., & Mian, I., 1971. Preliminary geology and petrography of Swat, Kohistan. Geological Bulletin, University of Peshawar 6, 1-32.

Regional survey, covering 1400 square miles of area, was carried out in Swat Kohistan to prepare a preliminary geological map and investigate the structure, petrography and economic geology of the region. The area is covered by various types of plutonic and a lesser quantity of sedimentary and volcanic rocks. Quartzite, siliceous schist, phyllite, siltstone/shale, and limestone of the Kalam Group (Carboniferous to? Siluro-Devonian) are exposed in the Matiltan-Kalam area. Norites, diorites, and the associated rocks of the Kohistan Basic Complex (Late Cretaceous) cover a large area to the south of Kalam. They form a northeast trending belt that extends to the east in Indus Kohistan and to the west in Dir. To the northwest, the Kalam Group is overlain by a thick sequence of silicic to intermediate lavas, tuffs and agglomerates (the Utror Volcanic Rocks) of probable Cretaceous-Eocene age. These, and the sedimentary rocks, have been cut by various types of plutonic rocks, mainly quartz diorites and granites, in Gabral and Ushu Valleys. The plutons are thought to be emplaced during Early to Middle Tertiary period. Quaternary alluvium and glacial deposits occur in small quantity in all parts of the region.

Key words: Mapping, geology, Swat Kohistan.

J/120. Jan, M.Q., Parvez, M. K. & Khattak, M.U.K., 1984. Coronites from the Chilas and Jijal-Patan complexes of Kohistan. Geological Bulletin, University of Peshawar 17, 75-85.

This paper describes coronites from the Jijal-Patan and Chilas complexes of northern Pakistan. In Jijal, plagioclase and orthopyroxene reacted under high P - high T metamorphic conditions (~ 8500C, 12-14 Kbar) to produce garnet + clinopyroxene coronas. These rocks occur along the MMT suture zone and were metamorphosed at > 40 km depth due to subduction / sinking. In the Chilas complex, orthopyroxene / clinopyroxene / hornblende + spinel coronas developed due to reactions between highly calcic plagioclase and mafic minerals under medium P- high T conditions (750-8500C, 5-7 kbar). These coronas may have formed due to slow cooling, either during uplift or pyroxene granulite facies metamorphism of feldspathic peridotites, troctolites, olivine gabbros, and related rocks. At higher levels during uplift, when the Chilas complex had access to water, labradorite-andesine reacted with mafic minerals to produce thin amphibole and epidote ± quartz coronas in noritic granulites. These medium to low P - low T epidote amphibolite facies coronas are mostly very thin but quite common. In rare cases the rocks are more severely affected, thus bridging the gap to epidote amphibolites.

Key words: Carbonates, High P-T metamorphism, Jijal-Pattan complex, Chilas complex, Kohistan.

J/121. Jan, M.Q. & Rafiq, M., 1999. Highly unusual chloritoid-ilmenite-rich rocks in the Indus suture melange north of Peshawar, North West Pakistan. Terra Nostra 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 75-76.

The Indus suture to the north of Peshawar, along which are juxtaposed the Indian plate and the Kohistan magmatic arc, is characterized by a tectonic melange. It consists of ophiolitic ultramafic rocks, greenstone, and a variety of sedimentary rocks: metamorphosed under greenschist facies conditions (up to garnet grade) (Hussain et al., 1984). The component lithologies in the mélangé may extend for tens of kilometers. Within the greenstone, there occur sparse, up to 200 m long and 1 to 3.5 m thick, lenticular bodies consisting of abundant chloritoid (31 to 59 modal per cent), ilmenite + subordinate, oxidized pyrite (12 to 25 %), quartz (8 to 31%), variable amounts of white mica (up to 3.9 Wt % FeO), and chlorite (pseudoturningite to ripidolite).

The analyses of these rocks consist essentially of SiO₂, TiO₂, Al₂O₃ and iron oxide. Such compositions have neither been reported for igneous nor sedimentary rocks. Although extremely rare, similar compositions have, however, been proposed for weathered and lateritized basaltic rocks and their metamorphosed equivalents (Liou and Chen, 1978; Singer, 1975; La Tour et al., 1980). Major, trace and rare-earth element analyses of three greenstone samples show some transition towards the chloritoid-ilmenite rocks. This, coupled with the presence of local chloritoid in the greenstone, and the close association of the chloritoid-ilmenite rich rocks with greenstone suggest a common parentage for the two. The greenstone analyses contain high TiO₂, Fe₂O₃, and P₂O₅. They show an enrichment in light REE and depletion in heavy REE, a negative Eu and positive Yb anomaly, and their chondrite normalized patterns resemble those of basaltic rocks from some island arcs and oceanic islands (Kay, 1984). Their Hf-Th-Ta (Wood, 1980), Ti-Zr-Y (Pearce and Cann, 1973), and Nb-Zr-Y (Meschede, 1986) relations suggest that the greenstone may be derived from oceanic islands alkali basalt.

Due to inaccessibility of the area, detailed field studies have not been performed to work out the relations of the chloritoid-ilmenite-rich rocks with their host greenstone. The former may represent shear zones in the basaltic precursors of the greenstone along which extensive alteration took place due to passage of water. More likely, the chloritoid-rich rocks may be weathered/lateritized soils whose relations with their host basalt (greenstone) have been exacerbated during melange formation, metamorphism and emplacement during the Paleocene.

Key words: Chloritoid-ilmenite rock, Indus suture, Tectonics.

J/122. Jan, M.Q. & Shah, M.T., 1987. Ni, Cr, Cu, Zn, Co, Ag and Au content of some Talc-carbonate rocks from NWFP, Pakistan. Geological Bulletin, University of Peshawar 20, 215-216.

The principal ophiolite complexes of northern Pakistan (i.e., Waziristan, Skhakot Qila, Jijal, Shangla-Mingora) are characterized by the occurrences of talc-carbonate rocks ($\pm$ quartz, chlorite, serpentine, fuchsite, epidote, oxide and sparingly, emerald and Cr-tourmaline). These rocks occur along the margins of and in shear zones, within ultramafic rocks and have been considered as the product of alteration. In the southern part of the Malakand pass, there are several small lenses of talc-carbonate-quartz rocks in greenschist facies metapelites. Carbonate-bearing ultramafic rocks bordering alpine-type peridotites may contain various mineralization such as Hg, As, Co-Ni arsenides; several occurrences of gold have also been reported. The carbonate-bearing rocks, termed listwaenite, are light grey-green rocks consisting mainly of carbonates with accessory quartz, talc, serpentine, chlorite, fuchsite, hematite, magnetite, pyrite, and Cr-spinel. These grade into serpentinized peridotite through a talc-carbonate zone.

Key words: Ophiolites, talc-carbonates, Malakand.

J/123. Jan, M.Q. & Symes, R.F., 1977. Piemontite schists form upper Swat, northwest Pakistan. *Mineralogical Magazine* 41, 537-540.

The piemontite schist is a fine grained rock with a distinct purplish colour and a silver-grey lustre associated with the schistosity. In thin section it is composed of quartz, albite, muscovite, margarite, tourmaline, piemontite, spessartine garnet, a Mn-rich chlorite (MnO = 2.24%), rutile, and magnetite. A crude segregation of quartz and albite from the muscovite, piemontite, tourmaline laminae occurs in the plane of the schistosity. The quartz grains are anhedral, interlocking and of even grain-size up to 0.25 mm in diameter and constitute modally 40 % of the rock. They commonly contain inclusions of small euhedral piemontite and magnetite crystals. Albite occurs as broadly twinned poikilitic patches up to 1 mm across and containing abundant inclusions of the associated minerals, which form a distinctly crenulated schistose fabric. The albite poikiloblasts often show rotational features suggestive of syntectonic growth. Muscovite occurs as bundles of colourless or slightly rose-coloured grains. Margarite and the manganese-rich chlorite both occur in blebs of small colourless, radiating brushes.

Both the piemontite and the tourmaline occur as euhedral, elongated crystals subparallel to the dominant schistosity, the former being strongly pleochroic whereas the latter is colourless, or a very dull yellow dravite, showing some pleochroism in shades of pink. In the quartz-poor areas of the schistose fabric piemontite constitutes up to 15 % of the rock, some crystals being elongated up to 0.4 mm in length and 0.1 mm broad. The piemontite grains almost always carry tiny magnetite inclusions concentrated in their cores. Spessartine garnet is not common but forms occasional idioblastic crystals the habit of which seemingly indicates a late metamorphic growth, enclosing piemontite and tourmaline. Microprobe studies show that the disseminated magnetite is often intimately associated poikiloblastically with minute rutile grains. The piemontite crystals in orientation suitable for optical examination consist mainly of 0.05-0.1 mm prisms elongated along [010]. Twinning on {100} was only rarely observed. However, two crystals twinned on {100} and lying parallel to the optic plane (010) were measured for u , y , and for the extinction angles. Dispersion of the indicatrix is strong and values are for NaD only: CY 1.748, canary yellow, /1 1.770, amethystine pink, y 1.795, deep rose pink, γ -a 0.047, $2V_y$ calc = $87^\circ 29'$.

An XRF analysis of the whole rock, using pressed-powder discs, was carried out for major, minor, and a range of trace elements. H₂O⁺ was determined by the Penfield method and FeO by Wilson's method. Accuracy should be within $\pm 2\%$ of the amounts present for the major elements. The values quoted in Table I for Co, Ga, Y, and Zr are expected to be correct to within ± 5 ppm, Cr, Ni, and Sr to within 20 ppm, and those for Ra, Cu, and Zn within 40 ppm. Owing to the over-all small grain-size and presence of magnetite inclusions the piemontite was not separated for chemical analysis, but analysed by electron-microprobe. The reported analysis of the piemontite is the average of three homogeneous grains free of inclusions and large enough to allow ten spot counts per grain. Total Mn has been expressed as Mn₂O₃ and total Fe as Fe₂O₃ following Deer *et al.* The analysis shown in Table I is expected to be accurate to $\pm 2\%$ of the amounts present for the major elements.

Compared to an average Palaeozoic shale, from which the piemontite schist is probably formed (Clarke, 1924), the rock has higher SO₂, MgO, CaO, and K₂O and lower TiO₂, Na₂O, and P₂O₅. The values for Ba, Cr, Ga, and Zr are lower, and those for the other trace elements higher than those given for an average shale by Turekian and Wedepohl (1961). The significant difference of the Swat rock from the average values is in its nickel (2 x the average content), copper (> 11 times that of the average), and especially Mn (20 x).

The high manganese value reflects special circumstances, which precipitated abundant manganese at the time of the deposition of the shale horizon. Local volcanic or hydrothermal activity may have been the contributory factor.

The manganese content of the piemontite ($\text{Mn}_2\text{O}_3 = 12.55\%$) is high for this mineral although Bilgrami (1956) has reported up to 17.78 % Mn_2O_3 from a piemontite in a pegmatite from Chikla, India. The analysis has been recalculated on the basis of twelve oxygens in Table I. From this it appears that all the Mn^{3+} and Fe^{3+} are in octahedral co-ordination. However, a survey of the analysed epidote group minerals in the literature suggests that the Mn occurs in different oxidation states, most of it being octahedral but some also occupying some of the large cation sites (Hutton, 1942; Bilgrami, 1956; Cooper, 1971; Marmo et al., 1959; Short, 1933). This also seems to be the case of the Swat piemontite, if the formula is recalculated on the basis of 13 (O, OH) after adding 1.84% H, O to the analysis to give 1 (OH) in the formula $(\text{Ca}_{1.4}\text{Mg}_{0.01}\text{Mn}_{0.16}\text{K}_{0.01})(\text{Al}_{1.88}\text{Fe}_{0.50}\text{Mn}_{0.62}\text{Si}_{3.00012}(\text{OH})_{1.00})$. In this formula Mn is about four times as abundant in the octahedral site as in the large cation site and is in accordance with most of the earliest piemontite analyses (see Short, 1933). Cooper (1971) argues that bulk chemistry (especially oxidation state) rather than the metamorphic conditions controls the occurrence of piemontite. Further determinations of Mn_2O_3 and MnO contents of the piemontite-bearing rocks are needed to verify this, because, as pointed out by Cooper, most metamorphic occurrences of piemontite are in high-pressure or in high-pressure to intermediate-facies series terrains. The Swat rock seems also to have formed under high-pressure conditions. Apart from its closeness to the thrust fault and the glaucophane schist it occurs in a belt of schists that in places contain chloritoid, garnet, staurolite, and kyanite.

Key words: Piemontite, mineralogy, Upper Swat.

J/124. Jan, M.Q. & Tahirkheli, R.A.K., 1969. The geology of the lower part of Indus Kohistan (Swat), West Pakistan. Geological Bulletin, University of Peshawar 4, 1-13.

An area of over 450 square miles in Indus Kohistan, Swat, has been mapped and the detailed petrography of the rocks is presented. The area investigated is bounded by latitudes $35^{\circ} 15'$ to the north, and $34^{\circ} 45'$ to the south, by the Indus River to the east, and by the drainage divide of the Indus and Swat Rivers to the west. The predominant rocks in the southeast and south belong to the Lower Swat-Buner Schistose Group (Siluro-Devonian or possibly Ordovician). The Schistose Group is commonly represented by low grade quartzite, quartz-mica schists, amphibolites, marbles, calcareous schists, phyllitic schists, graphitic schists, and greenschists. These were intruded by ultramafic rocks (pyroxenites and dunites near Jijal; serpentinites near Alpurai, Jijal etc.) during the earlier phases of the Himalayan orogeny (middle to late Cretaceous). During later orogenic phases (early Tertiary), the area was intruded by the abundant Swat Granites and Granite Gneisses (generally leucocratic, two feldspar-bearing rocks) and pegmatite, and major gneissic granodiorites near Shang and Dubair. These events were followed by overthrusting of the (?Precambrian) Upper Swat Hornblendic Group which covers the northern and northwestern part of the investigated area. The Hornblendic Group is represented mostly by diorites, metadiorites, hypersthene gabbros, and garnet-amphibole gneisses.

Key words: Geology, mapping, Indus Kohistan.

J/125. Jan, M.Q. & Tahirkheli, A.Z., 1990. The Tora Tigga complex, southern Dir, NW Pakistan; an example of mafic-ultramafic rocks in the bottom of an Island arc. Geological Bulletin, University of Peshawar 23, 231-251.

The Tora Tigga complex comprises dunite, peridotites, pyroxenites, hornblendites, metagabbros and plagiogranite covering over 6 km area. It is located in the north of the Indus-Zangbo suture, in an extensive terrain of amphibolites that form the southern part of the Cretaceous Kohistan island arc. The ultramafic rocks are closer to those found in stratiform complexes than to oceanic peridotites and the metagabbros are calc-alkaline island arc-type. Chemical variation suggests that the rocks are magmatically related. They probably represent amphibolites facies metamorphosed cumulates in a magma chamber of the Kohistan arc. The hornblendites are medium-grained to pegmatitic, and range from small dykes, patches and pools to large bodies over 2.5 km in length. There are gradational lithologies to pyroxenites and peridotites in which

hornblende is replacive in texture; however, chemical data do not support a metasomatic origin for such rocks and the hornblendites.

Key words: Ultramafics, Island Arc, Tora Tigga, Dir, Kohistan.

J/126. Jan, M.Q., Weaver, B.L. & Windley, B.F., 1997a. Summarized petrology of the garnet granulites of the Jijal complex, Kohistan Himalaya. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, 28-29.

For more details consult the following account.

Key words: Petrology, garnet granulites, Jijal, Kohistan.

J/127. Jan, M.Q., Weaver, B.L. & Windley, B.F., 1997b. General petrology of the garnet granulites of the Jijal complex, Kohistan Himalaya, Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 75-76.

The Indus Suture in northern Pakistan is the trace of the collisional boundary between Indian Plate and the Cretaceous Kohistan magmatic arc. A series of mafic-ultramafic rocks occurs in the hanging wall of the Suture. Of these, the Jijal complex (73°E, 35°N) is unique in several ways. This 150 km² tectonic block consists of a wide range of ultramafic to mafic rocks. The southern part of the complex is occupied by a 10x4 km slab comprising chromite-bearing dunite, peridotites and pyroxenites that are layered in many places. To the northeast of these, the main mass of the complex consists of garnet granulites derived from gabbros, tracholites, pyroxenites and anorthosites that too are locally well-layered. The mineral assemblages in these record granulite facies conditions at 10-15 Kbar, which may be, related to subduction of the complex some 105 Ma ago.

The garnet granulites display many assemblages, of which the most abundant is Grt-Cpx-Pl-Qtz-Rt±Hbl±Ep. Other include hornblendites (commonly with garnet±Cpx), garnetites (±Cpx±Hbl±Pl), garnet pyroxenites (±Hbl), garnet anorthosites (±Cpx±Scp), and retrograde assemblages some of which contain Zo+Ky+Pg. Thousands of mineral analyses have been performed with EPMA. In the ultramafic rocks, the olivine is Fo98-83, orthopyroxene is En91-78, clinopyroxene is diopside with low Al and Na, and chromite has a Cr/(Cr+Al)>0.6[1]. In the granulites, the phases show a wide variation, reflecting variation bulk chemistry.

Garnet consists of 14 to 68 mole% Prp, 23 to 58% Alm, 15 to 45% Grs, and low Adr (<5%) and Sps (<1.5%). Clinopyroxene ranges from Mg50Fe2Ca48 to Mg32Fe17Ca51, with up to 11.3 wt% Al₂O₃ and <2.5% Na₂O. Plagioclase ranges from An50-22, but a few more calcic compositions (up to An87) may be pre-metamorphic. Olivine (Fo85-75) and orthopyroxene (En86-67) occur in a few ultramafic members. Hornblende amphibole contains 14-20% Al₂O₃, moderate Na₂O (typically 2 to 3%), and low TiO₂ (mostly <1%). Paragonite ranges from P99-87, Epidote from Ps0-33, and scapolite from Me72-62.

Major and trace-element analyses of many dozen garnet granulites have been performed. A mantle-normalized multi-element diagram for some of the mafic members shows positive anomalies for Ba, Sr, P and Ti, and negative for Nb, Ce and Zr. These characteristics, especially the Nb and Sr contents and the overall shape of the spidergram, are typical of the subduction-related magmas. The peak and small Ce trough may be reflection some crustal input to the mantle derived magmas. The granulites display rather complex REE pattern but all show a positive Eu anomaly against chondrite. The mutual relationship of the ultramafic rocks and garnet granulites has not been deciphered as yet, but both display layering and probably represent cumulates related to the Kohistan arc.

In the upper structural levels near Patan, the granulites contain blocks of gabbro-norites apparently equilibrated in hornblende granulite facies (Pl-Opx-C0x-Hb). The blocks are traversed by dyke-like bodies of garnet granulite; however, the two lithologies show a gradual passage within a couple of centimeters. There is a perfect match in the major and trace element contents of the and we regard the gabbro-norite as precursor of the garnet granulite. It appears that the development of the garnet granulites due to increased pressure in lower crust accompanied the loss of H₂O (and addition of CO₂) along fractures.

Key words: Petrology, garnet granulites, Jijal, Kohistan.

J/128. Jan, M.Q., Wilson, R.N. & Windley, B.F., 1982. Paragonite paragenesis from the garnet granulites of the Jijal complex, Kohistan, N. Pakistan. *Mineralogical Magazine* 45, 73-77.

Chemistry of six white micas from the high-pressure garnet granulites of Jijal is presented, together with trace elements, refractive indices, and 2V, for one. The micas are rich in the paragonite component (over 93%), with one analysis having the highest 100 Na/(Na + K) ratio (98.5) so far reported. The paragonite is not a stable mineral of the granulites but was overprinted on the granulites at about 505-540 °C and 8-9 kbar (suggesting a depth of 30 km).

Key words: Garnet granulites, Jijal, Kohistan.

J/129. Jan, M.Q. & Windley, B.F., 1990. Chromian spinel-silicate chemistry in ultramafic rocks of the Jijal complex Northwest Pakistan. *Journal of Petrology* 31, 667-715.

The approximately 150 km² Jijal complex occupies a deep-level section of the Cretaceous Kohistan arc obducted along the Indus suture. The complex consists of mafic garnet granulites, and a > 10 km × 4 km slab of pyroxenites (diopsidite > websterite; ± olivine), dunite, and subordinate peridotite, all of which are devoid of plagioclase. These contain chromite either in lenses, layers, and veins or as disseminated grains. The chromite is mostly medium grained, subhedral to euhedral, shows pull-apart texture, and may contain inclusions of associated silicates. Chromite grains within thin sections of chromitite are generally homogeneous in composition, but dunite and pyroxenite samples commonly contain chromite grains of variable composition. The segregated chromite has higher Cr₂O₃ wt%, *cr*-number, and *mg*-number, and lower *fe*-number than the accessory chromite. These variations are mainly attributed to subsolidus exchange of Mg and Fe between chromite and associated olivine or pyroxene, and to inheritance from a magmatic source, but other factors may also be responsible. In general, the chromite grains are altered along margins and fractures to ferritchromite that is enriched in *cr*-number (and generally Fe³⁺, Mn, and Ti) and impoverished in *mg*-number compared with the parent grains. Chromian chlorite (clinochlore, penninite, with up to 7.3 wt.% Cr₂O₃) is commonly associated with the alteration, as is serpentine in most silicate rocks and some chromitites. The chlorite shows considerable compositional variation from grain to grain and in some cases within a single grain. Clinopyroxene is low-Al, -Na and high-Ca diopside. Orthopyroxene ranges from En₉₁ to En₈₂ and olivine from Fo₉₈ to Fo₈₄ (ignoring one analysis each). The *mg*-number of these minerals is higher in chromitites than in dunites and pyroxenites. Several aspects of the petrogenesis of the ultramafic rocks (e.g., the abundance of diopsidite) are not clear, but they seem to have passed through a complex history. The high *cr*-numbers (>60) in the chromite indicate that the rocks may have originated from some form of oceanic lithosphere-island arc interaction. Petrography and mineral compositional data suggest that the rocks are ultramafic cumulates derived from an arc-related (?primitive) high-Mg tholeiitic magma, possibly at pressures in excess of 8 kb. There also are small ultramafic bodies in the form of conformable layers and emplaced masses within the garnet granulites. These contain magnetite and pleonaste with < 10 wt.% Cr₂O₃, and less magnesian olivine and pyroxene than the principal ultramafic mass. These also have the characteristics of island arc plutonic rocks, but it is not clear whether the garnet granulites constitute a continuous sequence or are cumulates with the principal ultramafic mass or the two are produced from different source magmas.

Key words: Ultramafics, chromite, spinels, Jijal, Kohistan.

J/130. Jan, M.Q., Windley, B.F. & Khan, A. 1985. The Waziristan ophiolite, Pakistan, general geology and chemistry of chromite and associated phases. *Economic Geology* 80, 294-306.

The Waziristan complex, covering over 500 km², was tectonically emplaced during the Paleocene to early Eocene. It consists of ultramafic rocks, gabbros, sheeted dikes, pillow lavas, and pelagic sediments--a typical ophiolite suite. However, a complete sequence does not occur in any single locality due to tectonic dismemberment. The podiform chromitites consist of aluminochromite (Cr₂O₃ :49-61%) with subordinate

chromian chlorite and/or chromian serpentine + magnetite. In Cr-Al-Fe (super +3) + Ti space the chromites plot in the area of alpine chromites, but on other diagrams they overlap the fields of chromites from alpine and stratiform complexes. Many chromites are zoned with "ferrit-chromit" margins richer in Cr/(Cr + Al) and poorer in Mg/(Mg + Fe²⁺) than the unaltered cores. The chlorites are generally rich in SiO₂ and MgO and poor in Al₂O₃. It appears that during greenschist facies metamorphism (or alteration) diffusion of Mg, Al, and some Cr from the chromite margins toward the silicate matrix resulted in the development of ferrit-chromit and chlorite.

Key words: Ophiolites, chemistry, chromite, Waziristan.

J/131. Jan, M.Q., Windley, B.F. & Wilson, R.N. 1984a. Chromian andradite and associated phases in a chromitite layer in dunite from the Jijal Complex. Abstracts, First Geological Congress, Lahore, p.55.

Green chromian andradite associated with chrysotile occurs in a chromitite layer within dunite of the Jijal complex. The garnet contains over 10 % Cr₂O₃ and has the formula Ca_{6.13}Cr_{1.37}Fe_{3+2.53}Si_{5.94}O₂₄. The garnet formed during retrograde greenschist facies metamorphism of the Jijal complex. Analyses of chromite in the dunite and chromitite layers resemble those of high Cr chromite but their total Fe is a little higher. In contrast, the olivine is highly magnesian, with a ratio 100 Mg/(Mg + Fe²⁺) of about 96%. These features appear to have been caused by Fe - Mg exchange between the two minerals down to a blocking temperature of about 800° C.

Key words: Chromite, dunite, Jijal, Kohistan.

J/132. Jan, M.Q., Windley, B.F. & Wilson, R.N. 1984b. Chromian andradite and olivine-chromite relations in a chromitite layer from the Jijal Complex, NW Pakistan. Canadian Mineralogist 22, 341-345.

Green chromian andradite occurs associated with chrysotile in a chromitite layer within the dunite of the Jijal alpine ultramafic complex (northern Pakistan). The garnet contains on average 10.1 wt. % Cr₂O₃ (range 9.2-11.6%) and has a formula Ca_{3.04}(Cr_{0.67}Fe_{3+1.29}Al_{0.02})Si_{2.9}O₁₂. The garnet formed during retrograde greenschist-facies metamorphism of the Jijal complex.

Keywords: Chromian andradite, dunite, retrograde metamorphism, Jijal complex.

J/133. Jankovic, S., 1984. Metallogeny and mineral potential of northern Pakistan (North of Indus Suture Zone), A preliminary assessment. Geological Survey of Pakistan, Record 65, 25p.

The area of northern Pakistan situated north of the Indus Suture zone 9the Main Mantle Thrust – Tahirkheli, 1980) is a part of a global metallogenic belt - the Tethyan Eurasian Metallogenic Belt, formed at the southern margin of the Eurasian plate (Jankovic, 1976).

Owing to its remoteness and inaccessibility, the ore mineralization of Northern Pakistan has not so far been systematically investigated, either from a geological or a specifically metallogenic viewpoint. A previous tentative assessment of the mineral potential of the Northern Pakistan, predominantly south of the main Mantle Thrust, did not consider this part of Pakistan as particularly promising. 9Sillitoe, 1978). But recent discoveries of very significant lithium deposits of pegmatite type in Afghanistan, very close to the Pakistani border and tin and boron deposits (skarn type) in southern Pamir, USSR, as well as a regional metallogenic analysis, clearly indicates that the mineral potential of Northern Pakistan may be very promising.

The aim of this brief report is to draw attention to and emphasize the importance which Northern Pakistan, north of the Main Mantle Thrust, may have as a potential source of Li, Ta, Nb, Sn, W, Mn and Be as well as base metals and gold, and to point out the need and justification for a detailed and systematic investigation of this part of Pakistan.

Key words: Metallogeny, tectonics, economic geology, Indus Suture.

J/134. Jaswal, T., 1990. Structure and evolution of the Dhurnal oil field, Northern Potwar Deformed Zone, Pakistan. M.Sc. Thesis, Oregon State University, Corvallis, 62p.

Key words: Structure, hydrocarbon, Potwar, Dhurnal.

J/135. Jaswal, T.M., Lillie, R.J. & Lawrence, R.D., 1997a. Structure and evolution of the Northern Potwar Deformed Zone, Pakistan. American Association of Petroleum Geologists Bulletin 81, 308-328.

The northern Potwar deformed zone (NPDZ) is part of the active foreland fold and thrust belt of the Salt Range and Potwar Plateau in northern Pakistan. About 500 km of seismic reflection profiles are integrated with surface geologic and drilling data to examine the deformation style and structure of the NPDZ with particular emphasis on history of deformation of the Dhurnal oil field. The seismic lines suggest that the overall structure of the eastern NPDZ is a duplex structure developed beneath a passive roof thrust. The roof thrust is generated from a tipline in the Miocene Murree Formation, and the sole thrust is initiated from the same Eocambrian evaporite zone that extends 80 km southward beneath the Soan syncline and Salt Range. The Dhurnal oil field structure is a pop-up at the southern margin of the NPDZ, and developed beneath the passive roof thrust. The passive roof thrust crops out just north of Dhurnal on the steep, northern limb of the Soan syncline. An overstep passive roof thrust (Sakhwal fault) is interpreted west of Dhurnal; this fault developed due to southward progression of the deformation front beneath the earlier passive roof thrust.

Very gentle basement dip and almost zero topographic slope in the NPDZ suggest that the Eocambrian salt provides effective decoupling at the present position of the NPDZ. The strong deformation in the NPDZ appears to have developed farther north, in an area where the evaporites may be lacking. Since 2 Ma, the NPDZ moved farther south over the evaporites without further deformation, whereas erosion removed any former topographic slope. Restoring a balanced cross section suggests that the minimum shortening across the NPDZ is more than 55 km. Assuming that this shortening occurred between 5.1 and 2 Ma, the shortening rate is about 18 mm/yr.

Key words: Structure, seismic reflection, Potwar, Himalaya.

J/136. Jaswal, T.M., Lillie, R.J. & Lawrence, R.D., 1997b. Triangle zone geometry and blind thrusting along the southern margin of the northern Potwar Deformed Zone, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.30.

Key words: Structure, Potwar, Himalaya.

J/137. Jaume, S.C., 1986. The Salt Range-Potwar Plateau, Pakistan: quantitative and qualitative aspect of a fold-and-thrust belt underlain by evaporates. M.S. Thesis, Oregon State University Corvallis.

Consult the following account

Key words: Structure, topography, MBT, Salt Range, Potwar, Himalaya.

J/138. Jaume, S.C. & Lillie, R.J., 1988. Mechanics of the Salt Range-Potwar Plateau, Pakistan: a fold and thrust belt underlain by evaporates. Tectonics 7, 57-71.

The Salt Range and Potwar Plateau are part of the active foreland fold-and-thrust belt of the Himalaya in northern Pakistan. In this region the distance from the Main Boundary Thrust (MBT) to the front of the fold-and-thrust belt is very wide (100-150 km) because a thick evaporate sequence forms the zone of decollement. Recent studies have combined seismic reflection profiles, petroleum exploration wells, Bouguer gravity anomalies, and surface geology to construct cross sections in the eastern, central, and

western Salt Range-Potwar Plateau areas. In this study the sections are compared with a model that considers the mechanics of a fold-and-thrust belt to be analogous to that of a wedge of snow or soil pushed in front of a bulldozer (Chapple, 1978; Davis et al., 1983; Dahlen et al., 1984; Dahlen, 1984). Models which include the effects of evaporites at the base (Chapple, 1978; Davis and Engelder, 1985) suggest that these thrust belts will have (1) narrow ($< 1^\circ$) cross-sectional tapers, (2) larger widths than areas not underlain by evaporites. (3) Symmetrical structures, and (4) changes in deformational style at the edge of the evaporite basin. The section across the eastern Potwar Plateau most closely resembles this latter model, having (1) a taper of $0.8^\circ \pm 0.1^\circ$, (2) a width of 100-150 km, (3) thrust faults that verge both to the north and south, and (4) structures rotated 30° counterclockwise with respect to the Salt Range. From the observed taper and pore fluid pressures of the eastern Potwar Plateau, estimates of the values for the yield strength of the evaporites (τ_o) and the coefficient of internal friction of the overlying wedge (μ) are calculated as $\tau_o = 1.33\text{-}1.50$ MPa and $\mu = 0.95\text{-}1.04$, which are then applied to the other cross sections. In the central and western sections, a basement uplift, the Sargodha High, interferes with the front of the fold-and-thrust belt. This feature causes the ramping of the Salt Range Thrust end produces a relatively steep basement slope ($2^\circ\text{-}4^\circ$) beneath the Potwar Plateau. This dip, in the presence of the weak evaporite decollement, is sufficient to provide critical taper; no topographic slope is necessary, and the thrust wedge of the southern Potwar Plateau is pushed over the decollement without significant internal deformation.

The northern Potwar Plateau is strongly folded and faulted, yet the topographic slope remains flat. Although the deformation suggests that evaporites are not present there, the observed taper in the northern Potwar Plateau is best fitted by the model with evaporites at the decollement. Combining this with published paleomagnetic and geologic constraints, a model for the evolution of the northern Potwar Plateau suggests that the area deformed as a steeply tapered ($3.5^\circ\text{-}5.5^\circ$) thrust wedge until approximately 2 million years ago, when the southward propagating decollement encountered the evaporites. Between 2 Ma and the present the northern Potwar Plateau has been pushed along the salt decollement without deformation, and erosion has reduced its original steep topographic slope to a nearly level surface.

Key words: Structure, MBT, topography, Salt Range, Potwar, Himalaya.

J/139. Javaid, A.R., 1984-86. The geology and mapping of Muzaffarabad area from Chehla Bandi to Chattar Kalas with special emphasis on building settlement and consolidation in Muzaffarabad City. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 63p.

Nearly 100 sq. km area has been mapped mainly East and East--West of Muzaffarabad (A.K.), at the scale of 1:10,000. This thesis is prepared with the aim to study the area in detail and to explore the reasons of building settlement and consolidation in Muzaffarabad. The stratigraphic succession has been established, lithological and structural discontinuities are marked. Structurally the area is complex. Since the area is on the core of Hazara-Kashmir syntaxis, some units of the rocks have been separated due to major thrust faults, among these Jhelum fault (between Hazara Formation and Murree Formation) and Muzaffarabad fault (between Abbottabad Formation and Murree Formation) are the biggest. An attempt has been made to evaluate and put forth the generalized idea about the bearing capacity on different terraces of Muzaffarabad city. The samples of different localities are taken for laboratory tests. The purpose of laboratory test is to evaluate the strength parameters which are responsible for settlement and consolidation. In this report, an attempt is made to explore the reasons of settlement in the area as well as remedial measures were suggested.

Key words: Mapping, geology, Muzaffarabad, Azad Kashmir.

J/140. Javaid, M., 1992-94. Geology of Dubran Area, District Haripur with microfacies study of Langrial algal limestone. M.Sc. Thesis, Punjab University, Lahore, 131p.

Geological mapping of some 64 sq. Km area around Dubran in District Haripur has been carried out at the scale 1: 12500. The geomorphology, stratigraphy, structure, palynology and micropaleontology have been described. Stratigraphically a Mesozoic Tertiary sedimentary cover is overlying a Precambrian to Eo-cambrian basement of Hazara group now metamorphosed in the lower green schist facies. Numerous faults, high angle, reverse and normal have now disrupted the sequence. High angle north dipping Nathia Gali

Thrust is the main fault that passes through the area and has thrust the Precambrian Hazara Slates over the younger sedimentary sequence. Dubran syncline lying on top of a major anticlinorium makes an interesting structure.

Key words: Microfacies, limestone, structure, Haripur, Hazara.

J/141. Javed, H.J., 1985-87. Litho-structural mapping and Geology of Baragali-Kundla Area, District Abbottabad, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 183p.

This report gives an account of geological studies and lithostructural mapping carried out in Kundla-Bara Gali area. The prescribed area lies on both side of the road leading from Murree to Abbottabad. It is a mountainous region with fairly high relief. Litho-structural mapping of approximately 29 km² was carried out. The stratigraphic succession ranges from Hazara Formation (Precambrian) to Kuldana Formation (Eocene) with absence of Cambrian to Jurassic rocks. The lithology is mainly limestone, sandstone and shale. Extensive sampling was carried out and micro structural studies along with petrography of various rock units under the microscope from thin section of certain rock samples was also carried out in the laboratory.

A geological map is prepared on a scale of 1:7060 and two cross sections (AA' and BB') were drawn in order to interpret the regional structure and tectonic history of the area. The report also included the brief study of the rock units exposed in the project area. Major structures (folds and faults) lies in the project area are also discussed. Finally there is a general discussion about the source rocks, reservoir rocks (Hydrocarbon) and the economic importance of the rock units present in the project area.

Key words: Mapping, geology, Baragali, Abbottabad.

J/142. Javed, K., 1983-85. Litho-Structure studies of Fini-Bhirina-Paniali and Haddo Bandi Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 162p.

There is a specific relationship between the geological structures, landforms and the climate. This relationship can be worked out by qualitative as well as quantitative analysis of the topographic map. The most commonly exposed lithologies in the project area, are schist from chlorite to garnet grade, Susalgali granite gneiss, Mansehra granite, quartzites and hornfelses. The rocks of the project area have been classified into nine lithologic units for the sake of mapping purposes at a scale of 9.2 cm to km on 5.8 inch to a mile.

The area is deformed by different deformation phases, among which three are recognize on mesoscopic as well as microscopic scale and area is characterized by heterogeneous deformation. The rocks have been folded isoclinally and later being refolded into open folds.

The area lies in the zone of brittle deformation and show extensive fracturing instead of folding. Mesoscopic and microscopic deformational features are well developed in the area. The rocks exhibit effects of polymetamorphism. The thermal metamorphism is superimposed on the regional metamorphism.

Key words: Structure, landform, climate, Mansehra.

J/143. Javed, M., Haq, A. & Faruqi, F.A., 1964. Investigation on West Pakistan feldspars. Science and Industry, Lahore, 2, 27-36.

Key words: Minerals, feldspar.

J/144. Javed, M.Y., Akhtar, S. & Humayun, M., 1981-82. Geology and petrography of Samana Suk and Chichali Formations near Gumkol Sharif, northwest of Kohat, North West Frontier Province. M.Sc. Thesis, University of Peshawar, 96p.

Key words: Petrography, Samana Suk Formation, Chichali Formation, Kohat.

J/145. Jawaid, A., Javed, A. & Pervaiz, M., 1983. Mineralogy petrology & economic geology with emphasis on mineral deposits of Besham-Lahor area Swat Kohistan. *Kashmir Journal of Geology* 1, 120.

Igneous and metamorphic rocks of the project area (longitude (E) 72° 50' to 72° 54' latitude (N) 34° 54' to 34° 58') represent the leading edge of the Indian continent underthrusting the Kohistan Island Arc. The mineralization described in this work are related to igneous and metamorphic rocks. Granite/pegmatite complex are of Pre-Cambrian age. Metamorphics of the area are correlated with Salkhala Formation, Tanawal Formation and poorly defined Thakot metasediments. In mapped area metamorphism of pelitic rocks ranges from chlorite to biotite grade, and rocks are named as biotite-chlorite-graphite schist, while quartzite and amphibolites are also present. They are folded metasediments and uplifted due to stresses during Himalayan orogenies. Sequences of folded metasediments was followed by the intrusion of Lahor granite/pegmatite. The Lahor granite/pegmatite has been assigned a mixed origin and is result of the processes of intrusion, anatexis and palingenesis of the country rock. The formation of this granite involves more than one phase of magmatic activity and granatization of the country rocks.

Oxides (magnetite, haematite) and sulphides (galena, sphalerite, molybdenite, pyrites) mineralization are associated with Lahor granite/pegmatite complex and metasediments. Oxides occur in skarns which were originated by the igneous/metamorphic activity (metasomatism). Late stage hydrothermal activity formed disseminated and vein mineralization of sulphides. The study covers the petrographic and ore-microscopic aspects. The evaluation of petrographic and ore-microscopic data of Besham Lahor area, shows its economic importance.

Key words: Mineralogy, petrology, mineral deposits, skarns, magnetite, Lahor, Besham.

J/146. Jehan, K., Khan, A.H., Allahuddin, M. & Akhtar, M., 1975. Some bleaching clays deposits of Campbellpur District, Pakistan. *Acta Geologica Hungaria* 19, 257-264.

Key words: Clays, mineral deposits, Campbellpur, Attock.

J/147. Jehan, N., 1983. Geology of the part of the Shewa-Shahbaz Garhi Complex, Mardan. M.Sc. Thesis. Geology Department, Peshawar University.

Key words: Geology, granites, Mardan.

J/148. Jehan, N., 1997. Geology, economics and environmental impacts of asbestos from Mohmand and Malakand agencies and district Charsadda, NWFP, Pakistan. M.Phil. Thesis, University of Peshawar, 127p.

Asbestos is associated with ultramafic rocks of the Mohmand and Malakand Agencies. There are a number of places where it is extracted commercially, although not on a huge scale. The geology of these deposits and their economic potential are described in this thesis, along with the environmental and health hazard related to its exploitation.

Key words: Environmental impact, asbestos deposits, Mohmand, Malakand, Charsadda.

J/149. Jehan, N. & Hamidullah, S., 1997. Physical and chemical characteristics of asbestos from North Pakistan and its significance in the promotion of asbestosis. In: Hanif, J. & Hanif, M.I. (Eds.), *Environmental Pollution. Proceedings, 3rd National Symposium in Contemporary Chemistry, PAEC, Islamabad, 1997*, 139-146.

Key words: Chemistry, asbestos, asbestosis, Pakistan.

J/150. Jehan, N. & Hamidullah, S., 1999a. Lung fibrosis and asbestosis in Northern Pakistan. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, p.76.

The lives of millions of people in most parts of the developing world remain at risk due to ruthless mining practices. Pakistan is not an exception. Asbestos occurs in association with talc and magnesite in the dunites and serpentinites of the Main Mantle Thrust (MMT) melange north of Peshawar Basin, in Mohmand and Malakand agencies and District Charsadda (longitude 71°35' to 71°55'E and latitude 34°25' to 34°30'N; Noor Jehan, 1996). It has formed as a result of metamorphic transformation of olivine in the presence of CO₂ (Hamidullah, 1984). It is mined, transported and crushed in the local crushing plants and sold as pure asbestos or as powder for the production of talcum powder and other industrial products to industries through out the country. In the primitive crushing plants, asbestos is crushed in the same or the nearby (5 feet away) grinder used for grinding grains for flour (Fig. 1).

A variety of studies were carried out on the geology, mineral chemistry, fibre size economics and environmental impacts of this asbestos and related minerals and rocks in the study area and its surroundings. Electron microprobe data (SiO₂=51.69%, MgO=45%, Al₂O₃=1.33%, FeO=1.33%, CaO=0.06%), XRD data (Table 1) and petrographic observations classify these asbestos minerals as chrysotile, antigorite and tremolite, with the former as the dominant type, and highly carcinogenic. The diameter (<0.3 micrometer) and length (>0.8 micrometer) of individual fibers also indicate these to be carrying sufficient inhalation properties. Enhanced occurrences of allergies of lungs, eyes and skin have been noted in the surroundings of the local mines and relevant industries in the area. Worker in these crushing plants are at the highest risk. Little or no precautionary measure are taken (Fig. 1). More than 200 patients were suspected for asbestos-related lung fibrosis in the Government Lady Reading Hospital, Peshawar. Among these, 50 were followed up and confirmed as suffering from malignant mesothelioma (99% due to asbestos). Several are dead now. Sixty seven percent of these patients belong to northern districts of the province from where asbestos comes (Dr. Arshad Javed, Personal Communication). We still have to sort out relationship between these patient and the local asbestoses.

The asbestos-bearing zone (MMT) extends west across the boarder to Afghanistan. Fine quality asbestos is found at Logar in Afghanistan. The MMT also extends east, through Pakistan and across the border through India (as the Indus Tzangbu Suture Zone), ending at Nepal. Thus the problem is regional and if not well taken care of in time, Afghanistan, Pakistan and India may be engulfed by the epidemic of asbestos related diseases in the near future. Some of the important recommendations suggested for mitigation of asbestosis and other related ailments in the light of the data obtained are: adoption of ventilation and water spraying procedures in all processes of mining, transportation and industrial use of asbestos; personal protection of labor and skilled worker; restriction on use of asbestos in the manufacturing of talcum powder; awareness, training and health and safety monitoring of the employees; implementation of international compensation laws and ultimately abandoning asbestos mining and industrial uses in the region.

Key words: Fibrosis, asbestosis.

J/151. Jehan, N. & Hamidullah, S., 1999b. Chemical and physical properties of asbestos from Northern Pakistan. *Souvenir and Abstracts*, 4th Biennial International Conference on chest disease and tuberculoses, p.34.

Key words: Chemistry, physical characteristics, asbestose, asbestosis, Pakistan.

J/152. Jehan, N. & Hamidullah, S., 1999c. Comparison of the conventional map with RS/GIS-based map of the asbestos-bearing region of North Pakistan. *Abstract, International Conference Sustainable Management of Natural Resources*, Department of Geography University of Peshawar-UNESCO, organizers, 49-50.

Key words: GIS/RS, maps, asbestos.

J/153. Jehan, N., Hamidullah, S. & Ahmad, I., 1997. Economic and environmental study of asbestos from Skhakot-Qila ultramafics complex, N. Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

Economic growth must be accompanied by environmental assessment to ensure sustainable development. This paper describes the economics and environmental impacts of asbestos from Skhakot Qila ultramafic complex in the agencies of Malakand and Mohmand and the district of Charsadda at the northern and north western extremities of Peshawar valley. Asbestos is mined at Narai Ohe, Newe Kili, Behram Dheri, Qila Hero Shah and Bucha, and crushed and milled at Tangi, Newe Kili and Berlin, both in primitive and relatively modern crushing plants. From 35 mines in this area, only 15 were found in operation, each producing a truck of raw asbestos and other minerals weighing 10 metric tonnes and sold for Rs. 3000/- per truck. This process daily generates a total 150 metric tonnes of raw stuff and Rs. 45000/- as income in the area. Similarly the 8 crushing plants in the area crush 4 trucks of asbestos: each one sold for Rs. 6000/- and thus generating a total income of Rs. 24000/- per day. Asbestos from the study area has been, however, analysed and proved to be the carcinogenic variety (Noor Jehan & Hamidullah. 1997). No precautionary measures are, however, taken for protection from asbestos dust. (grains and asbestos are ground in the same or closely situated (5 feet apart) crushing machines. These machines dissipate dust to the village population in the surrounding and whole mining and crushing process has therefore, created a considerable environmental chaos in the area. People around the crushing plants have begun suffering from skin and eye allergies as well as asthma. The crushed asbestos is utilised in the production of talcum powder which is another environmental dilemma recently about 100 cases of mesothelioma have been registered in the Lady Reading Hospital. Peshawar, among these 60 are from the asbestos bearing areas. The paper recommends strict environmental laws to control the mining, crushing and industrial use of asbestos.

Key words: Asbestos, ultramafics, Skhakot qila.

J/154. Jehan, N., Hamidullah, S. & Ahmad, I., 2000. Economic and environmental study of asbestos from Skhakot-Qila ultramafics complex, N. Pakistan. In: Hussain, S.S. & Akbar, H.D. (eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 173-182.

For details consult the preceding account.

Key words: Asbestos, ultramafics, Skhakot qila.

J/155. Jehangiri, A.W., Ahmad, I. & Afridi, I., 1999. Geology of Besai area, Khyber Agency, N.W.F.P. M.Sc. Thesis, University of Peshawar, 33p.

Key words: Geology, mapping, Khyber Agency.

J/156. Jiandong, Z., 1995. Tectonic Evolution of the Altun and Karakorum Mountains. Journal of Nepal Geological Society 11, 59-62.

The Altun and Karakorum Mountains lie on the northwestern edge of Tibet. Because of their remote setting these regions were essentially unknown. Recently the author took part in the field investigations in the Altun Mountains and surrounding areas, such as Tarim and Qaidam Basins, and West Kunlun Mountains. Based on the practical data, this paper briefly deals with geological background of the Altun and Karakorum Mountains and discusses an intracontinental subduction or A-type subduction along southwestern margin of the Tarim Basin.

Key words: Tectonics, Altun, Karakorum.

J/157. Jianming, C., 1984. Variations of the Batura glacier's surface from repeated surveys. In: Miller, K.J. (ed.), *The International Karakoram Project*, 1, 196-204. Cambridge University Press.

Repeated terrestrial stereophotogrammetric surveys have been used to make various maps. The glacier example quoted shows basic data requirements and presents standard techniques to study height variations of the surface, the terminus mass and ice movement. The results show that the system is a good method to determine glacial variations. However, when applying this techniques the orientation of each photo should be identical. In order to obtain reliable data, a combination of methods is necessary.

Key words: Glaciers, Batura, Karakorum.

J/158. Jianming, C., Crompton, T.D., Walton, J.L.W. & Bilham, R., 1984. The survey work of the International Karakoram Project. In: Miller, K.J. (ed.), *The International Karakoram Project*, Volume 2, 124-139. Cambridge University Press. Cambridge University Press.

In 1913 a triangulation network was set up to connect the survey systems of Russia and India. This chain crosses the Karakoram a region of intense tectonic deformation. The southern section of the 1913 link was remeasured by the survey party of the International Karakoram Project with a view to detecting continental movement over the intervening 67 years. The fieldwork was completed successfully despite a number of setbacks including the death of one the team. The network has been analyzed in number of ways in order to find the best method for the analysis of possible deformation. Figural distortions have been detected and geophysical interpretation of these has been essayed.

Key words: Tectonic deformation, Karakoram project survey.

J/159. Jianming, C. & Huaiyi, Z., 1980. The terrestrial stereophotographic mapping of the drainage area of the Batura Glacier. In: Shi Yafeng (ed.), *Professional Papers on the Batura Glacier in the Karakoram Mountains*. Science Press, Beijing.

Key words: Glaciers, Batura, Hunza, Karakoram.

J/160. Jijun, L., Derbyshire, E. & Shuying, X., 1984. Glacial and paraglacial sediments of the Hunza valley North – West Karakoram, Pakistan: A preliminary study. In: Miller, K.J., (ed.), *The International Karakoram Project*, Volume 2. Cambridge University Press.

The tills of the upper Hunza region include both lodgement and meltout types. Particle size analysis shows them to be relatively coarse-grained and somewhat positively skewed. There is evidence of modification of the particle size distribution by meltwater eluviation, especially in the case of the Ghulkin and Pasu glacier deposits but the role of bedrock lithology and glacier size is also discernible. Tills currently being deposited are predominantly of meltout type: these have diffuse fabrics, rather granular matrixes and contain evidence of eluviation and collapse. Re-deposition of the abundant coarse supraglacial debris by sliding under gravity is common. The thickest exposures of compact and sheared lodgement till, on the other hand, are of pleistocene age, especially those of the main valley (t 2), diffuence col (t 3) and expanded foot (t 4) stages. There is no evidence of direct deposition of till by viscous flow either during or since the Pleistocene although the abundant debris flows do contain glacial material. It appears likely that the present combination of high-activity glacial regimes and arid to semi-arid valley floor climatic conditions have prevailed since at least the beginning of the late Pleistocene. The distribution of the dense, jointed lodgement tills of Pleistocene age is consistent with their deposition in a generally free-draining environment beneath thick glaciers. The genetic classification of tills based on field relationships is generally confirmed by laboratory-derived data on particle size, particle shape, stone orientation and fabric.

Key words: Glaciers, sediments, Hunza, Karakoram.

J/161. Johnson, G.D., Johnson, N.M., Opdyke, N.D. & Tahirkheli, R.A.K., 1979. Magnetic reversal stratigraphy and sedimentary tectonic history of the Upper Siwalik Group, eastern Salt Range and southwest Kashmir. In: Farah, A. & DeJong, K.A., (Eds.), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 149-165.

The upper Pliocene or lower Pleistocene interval of the Siwalik (Himalaya) molasses exposed in the Jhelum area, Pakistan, has been examined for lateral variation in depositional environment and rate of fluvial sedimentation. Stratigraphic sections measured through this interval at various localities in the Jhelum area are constrained by a magnetic reversal stratigraphy. Variations in the rate of molasses sedimentation appear to be related to large-scale tectonics in the northwestern Himalaya. Sedimentation rates increase towards the axis and apex of the recent structure indicating that the tectonic feature controlled the focus of molasse sedimentation during the sedimentation time. Sediments exposed in the Pabbi hills, Rohtas anticline, Chambal ridge, and the Mangla-Samwal anticline, each display variation of sedimentary/tectonic style as a function of their placement within the overall basin contour of the Himalayan foredeep.

Key words: Stratigraphy, magnetic polarity, Potwar, Siwaliks, Himalaya.

J/162. Johnson, G.D., Reynolds, R.G. & Burbank, D.W., 1986. Late Cenozoic tectonics and sedimentation in the northwestern Himalayan foredeep: thrust ramping and associated deformation in the Potwar region. In: Allen, P. & Homewood, P., (Eds.), *Foreland Basins*, International Association of Sedimentologists Special Publication, 8, 273-291.

Key words: Tectonics, sedimentation, deformation, Himalayan foredeep, Potwar.

J/163. Johnson, G.D., Rey, P., Ardrey, R.H., Visser, C.F., Opdyke, N.D. & Tahirkheli, R.A.K., 1981. Paleoenvironments of the Siwalik Group, Pakistan and India. In: Rapp, G. & Vondra, C.F. (eds.), *Hominid sites: their geological settings*. American Association for the advancement of Science, Selected Symposia Series 63, 197-254.

This is a detailed account of the magnetostratigraphy, sedimentology and structure of the Siwaliks of central Potwar Plateau and a portion of adjacent Kashmir. Particular emphasis is placed on the alluvial character of the Chinji through upper Siwalik formations of the Siwalik Group. Descriptions are given for paleoenvironmental rationale; fluvial character of the stratigraphic succession; lateral variation in sedimentary style; fluvial cycle recurrence rate; development of the floodbasin stratigraphy; evidence of pedogenesis affecting the floodbasin stratigraphy; interpretation of the Siwalik paleosols; application to the Siwalik Miocene record; and Late Miocene Siwalik geochronology, environmental change, faunal implications and habitat. It is speculated "that sites recording favourable hominoid habitat from latest Miocene, Paleocene and Pleistocene age strat should lie to the east of in a more equitable portion of the environmental cline. As such, sites from the contemporary Nepali Siwaliks and further east may record the equitable hominoid habitat which was lost in the Potwar Plateau about six million years ago".

Key words: Paleoenvironments, Nagri, Siwaliks, Potwar, Kashmir.

J/164. Johnson, G.D., Zeitler, P.K., Naesser, C.W., Johnson, N.M., Summers, D.M., Frost, C.D., Opdyke, N.D. & Tahirkheli, R.A.K., 1982. The occurrence and fission-track ages of Late Neogene and Quaternary volcanic sediments in Siwalik Group, Northern Pakistan. *Paleogeography, Paleoclimatology, Paleoecology* 37, 63-93.

Volcanic sediments, now mostly bentonites and bentonitic mudstones, occur throughout the Late Neogene and Quaternary Siwalik Group of northern Pakistan. A number of these deposits have been dated by the fission-track method, utilizing zircon phenocrysts from these deposits, and provide the chronometric constraints upon which a paleomagnetic stratigraphy is developed for the Siwalik Group. Notable in the

occurrence of these altered tuff horizons is an apparent mode in their stratigraphic development from approximately 3.0 to 1.5 m.y. B.P. which coincides with the period of activity of the Dacht-e-Nawar volcanic complex of east-central Afghanistan. Fission-track ages of certain tuffs for critical areas of northern Pakistan are reported herein.

Key words: Fission-track ages, Neogene, Quaternary volcanics, Siwaliks.

J/165. Johnson, M.R.W., 1994. Volume balance of erosional loss and sediment deposition related to Himalayan uplifts. *Journal of Nepal Geological Society* 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal, 70.

The volume of sediment in the foreland basins, deltas and fans which are a consequence of the collision of India and Asia appears to require the removal of a vertical section ~35 km high if the sediments were entirely derived from the Himalaya. It is argued that this is implausible and that it is likely that the Himalayan hinterland (e.g. Karakoram and Tibet) was an important source of sediment prior to -20 Ma when significant Himalayan uplift commenced.

Key words: Sedimentology, erosion, deposition, Himalayan uplift.

J/166. Johnson, N.M., Opdyke, N.D., Johnson, G.D., Lindsay, E.H. & Tahirkheli, R.A.K., 1982. Magnetic polarity, stratigraphy and ages of Siwalik Group rocks of the Potwar Plateau, Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 37, 17-42.

Six magnetic polarity sections have been established over the Potwar Plateau region of Pakistan, including the major stratotypes of the Siwalik Group. In all six sections the dominant feature of the magnetic polarity stratigraphy is a long normal polarity zone, which is contained within the Nagri Formation. This conspicuous normal polarity zone has been radiometrically dated at 9.5 ± 0.6 m.y., which identifies it as magnetic Chron 9. Radiometric dates for the Upper Siwalik Formation have also been used to identify the Chron 2-3 boundary in two of the sections. The magnetic polarity stratigraphy of three of the sections has been correlated securely with the accepted magnetic polarity time scale, so that the ages of the local stratigraphy are indexed accordingly. Based exclusively on data from stratotype sections, the Chinji Nagri and Dhok Pathan Formations have nominal age ranges of 13.1-10.1, 10.1-7.9 and 7.9-5.1 m.y. Age fluctuations on the order of 105 years may be anticipated for these formational boundaries within a radius of some 20 km of the designated stratotype. Mean sediment accumulation rates during the Chinji, Nagri and Dhok Pathan interval range from 13 to 52 cm/103 yr.

Essentially linear sediment accumulations are locally maintained over time intervals of several million years. The Chinji-Nagri lithofacies boundary marks a transition from slow to faster sediment accumulation over much of the Potwar Plateau, indicating a fundamental sedimentary-tectonic change at this time.

Key words: Paleomagnetism, Potwar, Siwaliks.

J/167. Johnson, N.M., et al., 1977. Magnetopolarity stratigraphy of the Middle Siwalik Group, Potwar Plateau, Pakistan. *Geological Society of America Abstracts with Program*, 9, 1039-1040.

Key words: Magnetostratigraphy, Siwaliks, Potwar

J/168. Johnson, N.M., Stix, J., Cervený, P.F. & Tahirkheli, R.A.K., 1985. Paleomagnetic chronology, fluvial processes, and tectonic implications of the Siwalik deposits near Chingji Village, Pakistan. *Journal of Geology* 93, 27-40.

A 2800-m section of Siwalik strata containing the stratotypes for both the Chinji and Nagri formation has been dated by magnetic polarity stratigraphy, and the observed polarity zonation has securely been correlated with the Chron 17-7 segment of the time scale. The base of the section is the base of the Kamlial formation, which occurs near the top of Chron 17 (18.3 m.y.). The Kamlial-Chinji formation boundary

occurs in the middle of Chron 15 (14.3 m.y.), the Chinji-Nagri boundary near the bottom of Chron 10 (10.8 m.y.) and the Nagri-Dhok Pathan boundary at the Chron 8-9 boundary (8.5 m.y.). The Siwalik deposits near Chinji Village consist of four distinct classes of fluvial cycles, each with a characteristics periodicity: a first order of 107 years, a second order of 106 years, a third order of 104-105 years, and a fourth order of 100 – 104 years. The river system responsible of Siwalik sedimentation flowed from west to east and had properties much like the modern Ganges River system. Sedimentation rates in the Chinji Village area increased gradually through time, going from 0.12 mm/yr in the Lower Siwaliks to 0.30 mm/yr in the Middle Siwaliks. At about 11 m.y. blue-green hornblendes suddenly appear in abundance in channel sands. The appearance of these hornblendes, accompanied with accelerated sedimentation, is the effect of uplift in the source area, specifically the Nanga Parbat region. The modern Chinji Village area is no longer a depositional site, but instead is involved in overthrusting, uplift, and erosion. As the Indian Plate has drifted north during the past 18 m.y., the Chinji Village area has been gradually transformed from a subdued karst topography into a major depositional center for Himalayan sediments and finally back into a sediment source area to complete a sedimentary cycle that has spanned some 20 m.y.

Key words: Chronology, paleomagnetism, tectonics, fluvial process, Siwaliks, Potwar.

J/169. Jones, C.L. & Israrullah, 1968. Potential for potash and other evaporite mineral resources in West Pakistan. US Geological Survey/Geological Survey of Pakistan (IR) PK-46, 17p.

Reconnaissance examination of marine evaporites in West Pakistan has revealed a highly favorable resource situation with respect to anhydrite, and a potentially favorable position for potash and sulfur. Further work is needed to evaluate the preliminary interpretations made during the present study. The establishment of a potash resource organisation within the Mineral Resource Directorate of the geological Survey of Pakistan is proposed. The organisation would be concerned exclusively with the investigation of potash deposits in the Salt Range and adjacent parts of the Potwar and Indus Plains.

Key words: Evaporites, potash, mineral resources.

J/170. Judd, E.K., 1957. Possibility of uranium in Pakistan. US Atomic Energy Commission Report, No. RM-E-4042, Review, 51p.

Key words: Radioactive minerals, uranium.

J/171. Jurgan, H. & Abbas, G., 1991. On the Chorgali Formation at the type locality. Pakistan Journal of Hydrocarbon Research, 3 (1), 35-45.

Key words: Stratigraphy, Chorgali Formation.

K/1. Kadri, I.B., 1995. Petroleum Geology of Pakistan. Pakistan Petroleum Ltd., 275p.

This book provides information relevant to various aspects of petroleum geology in Pakistan, including stratigraphy, structure and geophysical data. Areas of interest in northern Pakistan, the focus of the present work, are also included.

Key words: Petroleum geology, structure, stratigraphy, geophysics.

K/2. Kadri, I.B. & Abid, M.S., 1986. Geology of hydrocarbon accumulations in Pakistan. Preprint, 6th Offshore South East Asia Conference, Singapore, 226-235. 6 figures, 1 table.

Key words: Hydrocarbons.

K/3. Kafarsky, A.K. & Abdullah, J., 1976. Tectonics of North–East Afghanistan (Badakhshan, Wakhan, Nurestan) and relationship with the adjacent territories. In: *Geotettonica della zone orogeniche del Kashmir Himalaya–Karakorum–Hindu Kush–Pamir* (Roma, 1974). *Accad. dei Lincei*. Rome, 87–113.

Key words: Tectonics, Himalaya, Karakoram, Hindukush, Afghanistan.

K/4. Kaila, K.L., 1981. Structure and seismo-tectonics of Himalaya-Pamir-Hindu Kush region and the Indian Plate boundary. In: Gupta, H.K. & Delany, F. (eds.), *Zagros-Hindu Kush-Himalaya Geodynamic Evaluation*. American Geophysical Union, Geodynamic Series 3, 272-293.

Key words: Tectonics, structure, Indian Plate, Pamir, Hindukush, Himalaya.

K/5. Kaila, K.L., Chowdhury, K.R., Krishna, V.G., Dixit, M.M. & Narain, H., 1983. Crustal structure of the Kashmir Himalayan and inferences about the asthenospheric layer from DSS studies along the international profile Qarrakol (Karakull) Zorkol-Nangaparbat-Srinagar. *Bollettino di Geofisica Teorica ed Applicata*. Pamir-Himalaya, 25, 221-234.

Key words: Structure, upper mantle, Kashmir, Himalaya.

K/6. Kaila, K.L. & Rao, N.M., 1979a. Seismotectonics of Himalayan belt and the deep tectonic features of the Pamir-Hindu Kush regions. *Geophysics Research Bulletin* 17, 4.

Key words: Tectonics, seismicity, Himalaya, Hindukush.

K/7. Kaila, K.L. & Rao, N.M., 1979b. Seismic zoning maps of the Indian subcontinent. *Geophysics Research Bulletin*, NGRI Hyderabad, 17, 293-301.

Key words: Tectonics, seismicity, Himalaya, Hindukush.

K/8. Kakar, S.K., Mian, S.B. & Khan, J., 1971. The geology of Jandul valley, Western Dir. *Geological Bulletin*, University of Peshawar 6, 54-73.

The geology of Jandul Valley consists of Palaeozoic metamorphic rocks of amphibolite facies, intruded by igneous rocks in Jurassic-Cretaceous times. The plutonic rocks consist of an earlier phase of diorites, granodiorites, and granites and an apparently later phase of norites, hornblendites, pyroxenites and peridotites.

The Mesozoic magmatism was followed by volcanic activity in the Tertiary times. These, consisting of andesitic and dacitic tuffaceous rocks, are intimately inter-bedded with fossiliferous metasedimentary rocks of phyllite grade. This phase is characterised by the intrusion of porphyry dykes, which were probably the main feeds at the time. This was followed by a phase of granite and diorite dyke intrusions. Next quartz and pegmatite veins formed, followed by a final stage of dolerite dyke intrusions. Extension sporadic copper-mineralization is associated with the volcanism.

Structurally, the region is complexly folded and faulted. The main bodies of the intrusive and extrusive rocks seem to be located along a thrust zone. At least three tectonic stages are discernible in the area.

Key words: Metamorphism, magmatism, petrography, Jandul.

K/9. Kaleem, M., Qureshi, A. & Ahmed, M., 2001. Geologic map of the Kala Chitta Range, northern Punjab, Pakistan. Geological Survey of Pakistan (scale 1: 50,000).

Key words: Geologic map, Kala Chitta Range

K/10. Kalim, H.R. & Ali, M., 1985. Petrography and geochemistry of a part of Ambela Granitic Complex. M.Sc. Thesis, University of Peshawar, 129p.

This account describes the petrographic and geochemical aspects of the Ambela granites in Buner area of the Swat district.

Key words: Petrography, geochemistry, granites, Ambela, Buner, Swat.

K/11. Kalpna & Chander, R., 1994a. A simulation of reservoir induced seismicity at the Tarbela Reservoir. Abstracts, First South Asia Geological Congress, Islamabad, p.19.

Consult the following account for further information.

Key words: Seismicity, dams, reservoirs, Tarbela.

K/12. Kalpna & Chander, R., 1994b. A simulation of reservoir induced seismicity at the Tarbela Reservoir, Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 354-357.

Tarbela Dam on the Indus River is a unique case for the Himalayan regions as a whole in that high quality pre- and post-impoundment seismicity data are available. A recently published analysis of post-impoundment data for nine years suggests that earthquakes in 20 km radial zone centered on the reservoir are suppressed when the reservoir levels are high and they reappear again during periods of low water stand in the reservoir. In this rectangular lake. We find that upper crustal faults deduced from published composite fault plane solutions for pre-impoundment earthquakes in the same radial zone could also be the seats of the earthquakes observed during periods of low water level in the reservoir. The importance of this case history for the possibility of reservoir induced seismicity at future sites of high dams in the Himalaya cannot be over emphasized.

Key words: Seismicity, dams, reservoirs, Indus River, Himalaya.

K/13. Kamal, S., 1986-88. Lithostructural mapping and geology of Bagh-Sehri Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 108p.

Key words: Lithostructure, Abbottabad.

K/14. Kaneda, H., 1993. Mineralogy and mineral alteration of the Kalam volcanics in Kalam, Swat valley-a supplement to the paleomagnetic study. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad. 6, 60-65.

A rock sample collected from the Kalam volcanics for paleomagnetic study, was examined by optical microscopy. This note describes the mineralization process of Fe-Ti-oxide and -hydrate minerals which are closely concerned to magnetic properties of the rock. Detailed magnetic data are given in the paper by Ahmad, M.A. et al. 1993.

Key words: Mineralogy, paleomagnetism, volcanics, Kalam, Swat valley.

K/15. Kaneda, H., Karim, T., Yoshida, M., Ahmad, M.N. & Ali, M., 1996. Ore mineralogy and geomagnetic anomaly of Kaldam Gol skarn-type copper ore, Chitral, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, 128-129.

The Kaldam Go1 copper orebody is located at Chitral district, northern Pakistan. Geology around the ore showing consists of alteration of shale and limestone belonging to Gawuch formation of Cretaceous age. At the southern area bordering on the Gawuch formation, acidic to intermediate igneous rocks are distributed widely. The ore mineralized zones occur along the boundaries between limestone and shale. Judging from the geologic feature and mineralogical observation of ore specimens, the copper ore showing can be considered to belong to a skarn-type deposit. Detailed mineralogical studies have been carried out by means of XRD, optical ore microscopy, and rock-magnetic method (Table 1).

Mineral species are divided into two groups, that is, one is primary minerals and another is secondary minerals: The primary minerals are classified into the following three assemblages: (1) magnetite-andradite-chalcopryrite-quartz, (2) clinopyroxene- quartz-calcite-chalcopryrite-pyrite, and (3) epidote-clinopyroxene-quartz-calcite-pyrite-sphalerite. In addition, the volcanic rocks which weakly skarnized and mineralized and highly silicified, show the mineral assemblage quartz-epidote-calcite-pyrite-chalcopryrite- sphalerite. These mineral assemblages and their zonal distribution reveal the feature of typical skarn-type ore. Secondary minerals occur replacing magnetite, chalcopryrite and occasionally pyrite. Maghemite and goethite are the most common minerals of supergene alteration after magnetite. Goethite also occurs replacing chalcopryrite.

Secondary minerals after chalcopryrite are covellite, chalcocite, cuprite, malachite and brochantite. Primary magnetite and secondary (supergene) maghemite are the main source generating strong geomagnetic anomaly around the ore mineralization zone, which makes possible to model the subsurface structure.

Key words: Mineralogy, magnetism, copper ore, Kaldam Gol, Chitral.

K/16. Kaneda, H., Karim, T., Yoshida, M., Ahmad, M.N. & Ali, M., 1997. Ore mineralogy and geomagnetic anomaly of Kaldam Gol skarn-type copper ore, Chitral, northern Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (eds.), Paleomagnetism of Collision Belts. Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, 177-184.

Consult the preceding account for further information.

Key words: Mineralization, ores, copper, Chitral.

K/17. Kaphle, K.P., 1973. Thesis on geology and petrology of southern Dir with special emphasis on amphibolites. M.Sc. Thesis. Punjab University, Lahore.

Southern Dir is a part of the Kohistan terrain. This work provides petrographic information on the rocks, with special reference to amphibolites which may have been derived from different parentages.

Key words: Petrography, petrology, amphibolites, Dir.

K/18. Kapoor, S.K., Bhattacharya, D.K., Chakravarty, A.R. & De. N., 1976. Bibliography on Himalayan Geology. Part I: Bibliography, Geological Survey of India. 101p.

This is the first part of the bibliography of NW Himalaya, Pakistan.

Key words: Bibliography, Himalaya.

K/19. Karavchenkov, K.N., 1964. Soan Formation-upper unit of Siwalik group in Potwar. Science and Industry 2 & 3, 230-233; Karachi.

Key words: Soan Formation, siwalik group, Potwar.

K/20. Karim, A. & Sufyan, M. 1986. Mineralogy, petrology and geochemistry of dolerite dykes in Attock Cherat Range, NWFP. M.Sc. Thesis. Geology Department, Peshawar University.

Dolerite dikes around the Peshawar plain intrude a sequence of rocks, ranging in age from Precambrian to Permian. It is implied that they were intruded during a regional episode of crustal distention in Permo-Triassic times. A study of dikes in Attock-Cherat range, in an area of about 80 km² shows that the dolerites are oriented E-W. The dikes reach upto 10x1000 meters in size and are locally more abundant. They are variably altered, and are classified into (a) sheared, (b) medium grained and (c) Coarse grained dolerites.

Chemically the rocks are quartz and hypersthene normative theollites of continental flood basalt affinities. The rocks are dominantly composed of plagioclase (An₄₈₋₇₁) enclosed ophitically in clinopyroxene. Quartz, magnetite and ilmenite are accessory phases whereas alteration in many rocks has led to the development of abundant epidote, calcite, clay, chlorite, and biotite. Complex grains of clinopyroxene containing domains of augite, ferroaugite, and pigeonite have been studied in detail. A temperature estimate within the range of 1050-1270° has been made for these rocks.

Key words: Mineralogy, petrology, geochemistry, dolerite, Attock-Cherat.

K/21. Karim, E., 1998-99. Geological mapping of Muzaffarabad-Chattar Kalas area with special emphasis on slope instability analysis and Hazards evaluation of Abhal area, Muzaffarabad (A.K.). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 99p.

About 100 sq. Km area including the landslided parts was mapped to find out the possible solution of this hazard. The study was carried out to understand the landslide problems in the area. The Abhal landslide was studied in detail based on its large size and proximity to foot-tracks, residential buildings and land property. Presence of MBT, heavy rain fall, toe-cutting by river Jhelum, steep slopes and water seepages contribute to landsliding in the area. The principal types of failure in the area have been recognized as slumps, earth flows, rock fall or combination of these three types. Soil samples were collected from the slided areas to evaluate the engineering properties of soil that contribute the failure. It includes Atterberg limits, natural water content, specific gravity, plasticity character, compaction and swelling. To establish the causes of landslides all the information and field data were collected. The results suggested that the failure occur due to high swelling potential of soils, steep slopes and presence of active fault (MBT).

Key words: Mapping, slope stability, Muzaffarabad.

K/22. Karim, T., 1993. An overall review of geology and economic minerals of Abbottabad area, Hazara, northern Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 5, 79-86.

The Hazara area lies on the western flank of the Hazara-Kashmir syntaxial belt, and is bounded by the Main Mantle Thrust in the north and Main Boundary Thrust in the south. The southern part of the area consists mainly of sedimentary rocks ranging in age from Precambrian to Miocene. It is underlain by granite and quartzo-felspathic schists, which increase in metamorphic grade towards the north. The paper gives reference to the previous literature,

and contains a regional map and a colored geological map of Kakul-Abbottabad area. Descriptive notes are given on Precambrian, Cambrian, Jurassic, Cretaceous, and Tertiary rocks. Deposits of phosphate, magnesite, barite and soapstone are briefly described. The area also contains limestone and gypsum.

Key words: Minerals, economic geology, Abbottabad.

K/23. Karim, T., 1995. Preliminary results of study on genesis of Kumhar magnesite, Hazara, Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 11, 181-188.

Out of fourteen lenticular bodies of magnesite ore in Kumhar, lens 1 and 2 are the biggest and have been studied in more detail. Total reserves are 6.2 million tons, (mt) and proved reserves of lense 1 and 2 are 2.98 mt with an average of 45% MgO. The magnesite may have formed due to hydrothermal activity. Solutions rich in Mg replaced Ca in the host dolomitic limestone of the early Cambrian Abbottabad formation and which resulted in formation of magnesite. Homogenization temperature of fluid inclusions, varying from 150° C to 350° C, suggests closed relationships of hydrothermal activity with magnesite mineralization.

Key words: Magnesite, Abbottabad..

K/24. Karim, T. & Kaneda, H., 1994. Kumhar magnesite ore mineralization, Abbottabad, NWFP., Pakistan. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) 8, 5-36.

The stratigraphy of the Abbottabad area is given with brief descriptions of various rock formations. Kumhar magnesite deposit is composed of 14 lens shaped ore bodies. One of these has been studied in the field as well as by petrography, XRD, and DTA/TG analytical techniques. Fluid inclusions and geochemical studies have also been performed.

Based on fluid inclusion studies and the field evidence, it is concluded that the Kumhar ore deposit was formed by hydrothermal activities which caused the replacement of the host dolomitic rocks. In addition, the mineralogical features are as follow: (1) ore is consisted of magnesite, calcite, talc and small amount of quartz, (2) dolomite, the host rock, is weakly disseminated with secondary calcite, quartz and talc, and (3) talc usually occur at the marginal parts of magnesite ore body and in the dolomite near the magnesite body. The geochemistry of ore-forming fluids of the Kumhar deposit is quite similar to the one of hydrothermal vein type deposits based on the fluid inclusion studies. This suggests that the related igneous rocks exist necessarily in the near area. In this area, a lot of mineralized showings such as barite, soapstone, gypsum and Pb-Zn sulphides in addition to magnesite have been observed. In order to examine the mineralization in this area, the study of ore-forming fluids and related-igneous rocks should be carried out in more detail through the fluid inclusion studies.

Key words: Stratigraphy, magnesite, Abbottabad, Hazara.

K/25. Karim, T. & Khan, S.R., 1986. Geological map of Darazinda (38 O/7), D.I. Khan District, Scale 1:50,000. Geological Survey of Pakistan, Quetta. Map Series III.

Key words: Geological map, D.I.Khan.

K/26. Karim, T. & Khan, S.R., 1989. Regional geology of Koga quadrangle, Swat district, NWFP, Pakistan. Geological Survey of Pakistan. Information Release, 437.

Key words: Mapping, geology, Koga, Buner, Swat.

K/27. Karim, T. & Luadthong, S., 1972. Geology of the eastern of Jandul valley. M.Sc. Thesis, University of Peshawar, 55p.

Some information is covered under Kakar et al. (1971).

Key words: Geology, metasediments, granites, Jandul, Dir.

K/28. Karsten, C.G.B., 1864. The salt mines of Kohat. In: Lehrbuchder Salinen Kunde, Vol. 1, 16 and Vol. 1, 12; Berlin.

This is amongst the earliest reports on the Kohat (bahadurkhel) salt mines.

Key words: Salt mines, Kohat, Karak.

K/29. Kato, K., Sasahara, H., Hirayama, J., Khan, S.R. & Sano, S., 1993. Preliminary geochemical exploration of chromite deposit in Malakand. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 6, 35-41.

The Malakand ophiolite contains chromite pods, lenses, and stringers. Sixty out of 62 chromite bodies occur in harzburgite-dunite unit. 37 samples have been analysed for Cr, Si, Al, Fe, Mg, Mn, Co, Cu, P, W and Zn.

Key words: Geochemical exploration, chromite, Malakand.

K/30. Kausar, A.B., 1971. Geology and petrology of Timurgara, Lal Qila area, District Dir. M.Sc. Thesis, Punjab University, Lahore, 133p.

This area is occupied by amphibolites, metagabbros and small intrusions. Petrography of the rocks is given.

Key words: Petrology, Timurgara, Lal Qila, Dir.

K/31. Kausar, A.B., 1987. Geological map of Karor (43 G/6), Rawalpindi District, Sheet No. 10, Scale 1:50,000. Geological Survey of Pakistan. Map Series IV; Quetta.

Key words: Geological map, Karor, Rawalpindi.

K/32. Kausar, A.B., 1994a. Alteration study of Ca-Fe skarn at Markoi, Kohistan island arc, Gilgit, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 8, 37-56.

In the Kohistan arc, Northern Pakistan, small lenses of skarn formed in Jurassic (?) limestone and clastic sediments adjacent to the Cretaceous to Tertiary Kohistan batholith. This composite batholith includes the Barite monzonite pluton that hosts porphyry copper mineralization. The Markoi skarn replaces limestone and volcanic rocks in a zone 180 meters by 40 meters along the contact with the potassically altered pluton. The units enclosing the limestone and calcareous sandstone were extensively metasomatized, as were outlying intrusion of Kohistan batholith.

Skarn alteration is divided into eight mineralogical zones away from the pluton to limestone: (1) epidote-amphibole-chlorite zone (2) magnetite-quartz zone (3) epidote-biotite zone (4) epidote-amphibole (actinolite)-magnetite zone (5) epidote-amphibole zone (6) pyroxene-amphibole zone (7) feldspar zone (8) garnet-calcite zone. Alteration zonation is dominantly controlled by faults (?), fractures and sedimentary bedding and composition. The garnet-calcite and magnetite-quartz zones are exoskarn formed in limestone and calcareous sandstone, and the other six zones are endoskarn formed in intermediate volcanic rocks. The andradite molecule of garnet increases in the limestone side. The zoning in exoskarn is in part the result of decrease in the chemical potential of A_{12O3} towards the limestone, where the zoning endoskarn is attributed to a decrease of the chemical potential of CaO towards the pluton. Comparison of bulk chemical compositions in altered and unaltered limestone and calcareous sandstone indicates that alteration was accompanied by overall addition of SiO_2 , A_{12O3} , FeO and MnO and depletion of CaO and CO_2 ; addition of Cu, Pb, and Zn in the garnet-calcite zone. Skarn and ore minerals were formed in the sequence skarn minerals - magnetite - chalcopyrite - pyrite sulfides, and occur in the garnet - calcite zone.

Key words: Skarns, Markoi, Gilgit, Kohistan.

K/33. Kausar, A.B., 1994b. Kohistan batholith in the Kohistan Island Arc, western Himalaya of northern Pakistan: Temporal variation in mineralogy and petrology. Abstract volume International Joint Symposium IGCP Project 283–321–359, 41–45.

Kohistan batholith is a huge body of various types of granitic rocks. This paper describes temporal variations in the petrographic characteristics of the batholith.

Key words: Batholith, Kohistan, Himalaya.

K/34. Kausar, A.B., 1994c. Alteration study of Ca-Fe skarn at Markoi, Kohistan island arc, Gilgit, northern Pakistan. Geoscience colloquium, Geoscience labs, GSP, Islamabad. 8, 37-56

Key words: Skarns, Markoi, Gilgit, Kohistan.

K/35. Kausar, A.B., 1995a. Petrology of the Kohistan arc and hosted hydrothermal sulfides, Gilgit area, Pakistan. M.S. Thesis. Oregon State University, U.S.A., 119p.

Key words: Petrology, sulfides, Gilgit, Kohistan.

K/36. Kausar, A.B., 1995b. Rare Earth Elements variation across the Kohistan batholith, Gilgit area: Their implications for batholithic petrogenesis. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

During a time span of approximately 70 to 80 Ma beginning in Upper Cretaceous / Lower Jurassic a sequence of plutonic rocks was formed in the middle to northern part of the Kohistan terrane known as the Kohistan batholith. Commonly arranged in elongate, arcuate batholithic belts along the southern margin of the Asian plate, these rocks are generally interpreted as the products of intra-oceanic island arc (?) which formed during episodes of convergence between the Asian and Indian plates. It is analogous to the Ladakh batholith in northwest India and the Gangdese batholith in the south Tibet (Heim and Gansser, 1939; Allegre et al., 1984; Searle et al., 1987). Investigations of how these batholithic rocks formed are fundamental to our understanding of the growth and evolution of the Kohistan terrane and of Kohistan batholith crust in general.

Individual plutons of Kohistan batholith range in lithology from gabbro to granite, which is also a characteristic feature of I-type granitoid batholith. There have been fewer attempts, however, to look at the origins of diversity among different intrusions within the same batholith. An important objective in the study of the Kohistan batholith is to establish how their characteristics are related to the tectonic environments in which they are formed. Extensive early studies (Pettersson and Windley, 1985; Pettersson and Windley, 1991) examined the systematic petrological and geochemical characteristics of these batholiths and established the plutonism and volcanism in a generally arc-related environment, but the exact relationships between components of the sequence are still speculative. Using our data and other published information we evaluate the relationships between the different rock units and this have revealed remarkable regularities of longitudinal trends and persistent regional asymmetries in petrological, geochemical, isotopic and geochronological characteristics from north to south in Gilgit area (Pettersson and Windley, 1985; Treloar et al., 1989; Pettersson, 1984; Pettersson and Windley, 1991). The asymmetries have gradients transverse to the structural axis of the batholith and therefore appear to bear some fundamental relationship to its origin. The purpose of this paper is focussed on the REE geochemistry of the major rocks of Kohistan batholith and Rakaposhi volcanics and is used to provide insights into the sources, generation and evolution of the batholithic magmas.

Regional Geology

The Kohistan block of northern Pakistan has been recognized as a Mesozoic intra-oceanic island arc and is sandwiched between the Asian and Indian plates (Fig. 1; Tahirkheli et al., 1980; Bard et al., 1980; Coward et al., 1982). During the collision, this arc was partially thrust under the Asian plate during 75 to 102 Ma, based on Rb-Sr ages of syn-collisional granitoids and then obducted onto the Indian plate. The resulting terrane exposes a virtually complete section from its ultramafic at the deepest to surface volcanic rocks through the crust of an oceanic island arc. The terrane is rimed on the north by the Main Karakoram Thrust (MKT) and is bounded on the south by the Main Mantle Thrust (MMT). South of the MKT are the metasediments of Yasin Group and then volcanic and

volcaniclastic rocks dominate the prebatholithic section along the northern flanks of the Kohistan block. The plutons of the Kohistan batholith were emplaced into thick metavolcanics to the north and metasediments to the south in the Gilgit area, which comprises the focus of this research. The Kohistan batholith followed by a succession of massive diorites and layered gabbros that comprise the Chilas lower crustal mafic cumulate complex. To the south of Chilas complex is the belt of banded amphibolite, amphibole schists and pelitic schists of the Komila amphibolites and are associated with intrusions of hornblende, diorite and anorthosite (Coward et al., 1987). South of the Kamila amphibolites is the deepest levels, basic intrusives occur with garnet-granulite facies assemblages indicating conditions of 670-790 °C 12-14 kbar (Jan and Howie, 1981) and they are considered to be either, a tectonic block from the deeper part of Chilas complex or a lower crustal fragment from an arc distinct from the Kohistan arc (Coward et al., 1987). The Jijal complex is bounded on the south by the MMT, marked in places by a mélange of blueschists, greenschists, piedmontite schists and serpentinites probably derived from the Kohistan arc.

Brief Review and Setting of Kohistan Batholith.

The Kohistan batholith, an arcuate-shaped intrusion measuring 2700 km along the southern margin of the Asian plate, is part of the Trans-Himalayan batholith. The batholith is a composite body made up of a juxtaposition of large plutonic units displaying major differences in age, mineralogical-chemical composition and tectono-metamorphic history. Plutons are generally a few kilometers to a few tens of meters in dimension, although internal intrusive units have only been well defined in a few detailed studies of specific bodies. The intrusions also vary in composition, e. g., tonalite to granodiorite (Matum Das pluton), quartz diorite (Jutal pluton), and monzonite (Barst, Dainyor, Manu Gah and Sakwar plutons). Lithological zonation was not observed in the portion of the complex observed in Gilgit area. The presence of internal boundaries on most outcrops is interpreted as the successive intrusion of relatively small batches of magma of varying composition. Petterson and Windley (1985) described at least 20 separate, discrete plutons in the Kohistan batholith. Their geochronology indicates a 70 Ma time span for the intrusions in the Kohistan batholith approximately from 100 to 30 Ma. Magmatic activity started during the Early Cretaceous (Rb-Sr whole rock isochron age of 102 ± 12 Ma for the early, deformed Matum Das pluton), and the last magmatic phase occurred in Neogene (muscovite K-Ar age of 20 Ma for the last Parri aplite/pegmatite). Petterson and Windley (1985) proposed that the batholith can be divided into three stages: first stage plutons, referred to as earlier deformed plutons; second stage plutons, referred to as undeformed plutons; and late stage plutons, referred to as layered aplite-pegmatite sheets which have been intruded into the first and second stage plutons. Based on paleogeography, petrology, and chemical composition, I have further refined and sub-divided the plutons in Gilgit area into two distinct magma series: the sodic series (low-K) is present to the north of the Nomal - Barit volcanic septum and both deformed and undeformed potassic series (medium- to high-K) lie to the south of this septum (Fig. 2).

The deformation of Rakaposhi volcanics and northern deformed plutons (Matum Das plutons) was accompanied by metamorphic recrystallization of igneous minerals from upper greenschist to amphibolite facies at 76 ± 6 to 82 Ma (Treloar et al., 1989). The southern deformed plutons (Barit pluton) were cooled through about 500 °C to 530 °C, the Ar-blocking temperature of hornblende at approximately 48 ± 1 Ma. Figure 2 indicates that from north to south there is a gradual cooling decrease in age of biotite Ar-Ar ages from 50 Ma to 20 Ma, which reflects more recent uplift and cooling through about 300 °C (the biotite Ar-blocking temperature). In contrast, the hornblende ages indicate a sudden break at the Nomal-Barit septum of the Rakaposhi volcanics which separates the deformed sodic series plutons from the deformed potassic series plutons. This septum suggests a fault between these two series, which more recently, has uplifted the southern block through the 500-530 °C isotherm at about 50-55 Ma, where hornblende Ar-blocking temperatures were achieved. Thus, the data suggests that uplift and unroofing was earlier north of the Nomal-Barit septum than to the south.

Tonalites and low-K granodiorites, the most common rock types in the sodic series, display a limited range in modal and chemical composition and have several unifying characteristics. They are feldspathic, containing 45-50 per cent unzoned andesine to oligoclase and 0-1 per cent alkali feldspar. Quartz contents are typically 15-25 percent. Biotite is the major mafic constituent with minor hornblende yielding colour indices of 8-12 for most. The southern portion (potassic series) of the Kohistan batholith is characterized by a diversity of lithologic types, with gabbro, monzodiorite, monzonite, quartz monzodiorite, and granodiorite joining minor tonalite as common rock types. Gabbro with only minor quartz is not transitional to the more felsic rocks, but forming apparently independent intrusive bodies. Plagioclase in the potassic series is zoned than that in the sodic, low-K rocks. The more distinctive petrographic feature of the potassic series is the presence of thick subhedral books of biotite with more hornblende, which contrast with the small anhedral books of biotite present in the sodic series. This suggests that the potassic suite magma had a higher water content, which has been shown to produce early hornblende and biotite crystallization in granite melting experiments (Naney and Swanson, 1980). In the southern ranges of Kohistan batholith, tonalite appears to drop somewhat in abundance, being supplanted by monzogranite.

Major and trace geochemical evidence indicates that the sodic and potassic series are compositionally distinct from one another. The most important geochemical variations are higher K₂O content and K₂O/Na₂O ratio at given SiO₂, and the higher concentration of the K-group elements (Ba and Rb) and of highly charged cations (Th and Zr) in the potassic series relative to those of the sodic series rocks. The sodic series contain little MgO relative to FeO (total Fe) ($\text{MgO}/(\text{MgO}+\text{FeO}) < 0.5$). The compositional gap between the two series is also visible with respect to Nb, Ce, Zr, and Nd (e.g., Petterson and Windley, 1991). These compositional variations cannot be explained in terms of simple fractionation/melt processes. The goals are to distinguish among different major petrogenetic processes and to limit the composition of the source region or parental melts as proposed four different sources for these plutons by Petterson and Windley (1991).

Sr concentrations in whole rocks show a well-defined increase southward across the Kohistan batholith, with a second-order dependence on rock type. Similarly Rb concentrations also show a well-defined increase from north to south but are dependent on rock type in the potassic series. Both Sr and Rb show a marked step at Nomal-Barit volcanic septum. A similar step has been noted for Sr isotopic compositions. Rb-Sr isotopic studies in the Gilgit area of the batholith have revealed systematic geographic variations in initial ⁸⁷Sr/⁸⁶Sr ratios of whole rocks which rises from 0.7039 in the north to more than 0.7049 in the south (Petterson and Windley, 1985).

REE Chemistry in Kohistan Batholith

Chondrite-normalized REE patterns of Rakaposhi volcanics, sodic and potassic series are presented graphically in Figure 3a,b. The Rakaposhi volcanics and sodic series have low total REE (8xchondritic abundances) leading to generally increase from La to Lu on a chondrite normalized diagram. In all these rock types REE patterns are flat with La/Yb ratios of 1.15 to 2. Only a few samples of volcanics show slightly higher La/Yb ratios 4 to 5. Rocks corresponding to potassic series have higher total REE contents (10x100xchondritic abundances) with higher La/Yb ratios (11 to 28). The slope of LREE is steep and linear and corresponds to the medium- to high-K orogenic andesites (Jakes and Gill, 1970; Gill, 1981). The REE patterns of the rocks fall naturally into two principal REE fractionation groups and this variation is transverse to the structural trends but generally parallel to petrologic and geochronologic properties of the batholith. The Barit-Nomal volcanic septum probably marks the discontinuous zone between the northern and southern regions and transition between them therefore appears to be abrupt.

One of the most surprising feature of the data within the northern region is that the Matum Das tonalite, which intruded into metabasites have the same overall REE pattern shape as the metabasites, but differ from them in having abundances in REE and no Eu anomalies. The flat REE distribution patterns are considered to be typical for mantle derived rocks from a MORB like source (Johnson et al., 1990) at relatively high degrees of melting without major crustal contamination. Garnet was not a residual phase because the heavy REE are not depleted. Such rocks typically occur in tholeiitic island arc basalts (e.g. Wilson, 1989). Southern regions plutons (potassic series) have nearly identical ranges in REE contents (Fig. 3b) with no Eu anomalies and cross-cutting each other near medium-REE. The single monzogabbro (sample KA-15) is somewhat more steeply fractionated across the heavier REE than the monzodiorites. Similar source rocks and similar conditions of melting in the source of the parent magmas should result in consistent ratios at least of some trace elements, as already shown for the REE. Compared to the nearly flat relatively heavy REE abundances of the northern region (sodic series) rocks, the fractionated REE patterns of the southern regions rocks (potassic series) require the involvement of a phase or phases that would preferentially fractionate as well as retain in abundance the HREE. The REE geochemistry of the southern regions of the Kohistan batholith differs from that of oceanic island arcs in the presence of strongly HREE depleted and fractionated magmas. The sharp break in lithological diversity between the sodic and potassic series is suggestive of a major modification or readjustment to phase equilibria controls on magma compositions.

The regional variation in REE from north to south in Kohistan batholith is marked by depletion in LREE in the sodic series; fractionation in middle to heavy REE in the potassic series; no Eu anomalies and an increase in Sr contents. A single condition which can appear to satisfy the above observations is a phase transition in the residual mineralogy of compositionally similar source materials; from a plagioclase-bearing gabbroic assemblage for the sodic series to garnet-bearing, plagioclase poor (garnet-amphibolite) assemblages for the potassic series (e.g., Gromet and Silver, 1987).

Key words: REE, petrogenesis, Kohistan batholith, Gilgit.

K/37. Kausar, A.B., 1995c. Alteration study of Ca-Fe skarn at Markoi, Kohistan island arc, Gilgit, northern Pakistan. *Geologica* 1, 1-14.

Key words: Skarns, Markoi, Gilgit, Kohistan.

K/38. Kausar, A.B., 1998. L'arc sud Kohistan, N. Pakistan: Evolution petrologique et distributions des elements et mineraux du groupe du platine. Ph.D. Thesis, Goseph Fourier University, Grenoble, France, 280p.

Platinum group elements occur in mafic-ultramafic complexes, in some cases in exploitable quantities. These noble elements have also been the subject of preliminary studies in the Chilas and Jijal mafic-ultramafic complexes of the Kohistan island arc. This is a detailed study of the mineralogy, chemistry, and petrology of the platinum group elements in the Kohistan rocks. They are associated with both silicate rocks and chromitites. For more information, see Kausar et al. (2001).

Key words: Platinum group elements, petrology, Jijal, Chilas, Kohistan.

K/39. Kausar, A.B., 1999. Hydrothermal alteration and sulphur isotopic study of sulphide deposits, Gilgit area, Kohistan arc, Pakistan. *Geologica* 4, 1-32.

Sulphide mineralization in the Gilgit area is hosted in the Kohistan arc terrane, which is a tectonic block lying between the Asian plate to the north and Indo-Pakistan plate to the south. These ore deposit include volcanogenic massive sulphide at Jutial and possibly Garesh and porphyry copper at Nomal and Barit. At Garesh, two pyrite-rich (pyrite 3-5%) lenses occur within the volcanic stratigraphy. The alteration is marked by sericite-chlorite (plagioclase-destructive alteration) in the center and is surrounded by albite-hornblende-epidote-biotite (propylitic) within submarine mafic and silicic lavas and tuffs. Pyrite is both disseminated and in quartz veins, and is associated with slightly anomalous values of Cu, Zn, Pb, and Au (average values 47, 21, 18, and <1 ppm, respectively). The Garesh zone is interpreted as a hydrothermal feeder zone of a submarine volcanogenic massive sulphide. At Jutial one or two well-defined layers of massive pyrite (>80 vol. %) approximately 1-3 meter thick are strataform in the Jutial quartzo-feldspathic paragneiss derived from a greywacke sequence. Hydrothermal alteration intensity ranges from weak along the flank (up to 50 m), to intense in the massive sulphide zone, where the entire host rock has been altered to sericite-chlorite-quartz-pyrite. This inner zone is surrounded by semi-massive sulphide consisting of pyrite (20-40 vol. %). The outermost alteration zone is garnet-biotite-muscovite-pyrite. The Jutial prospect is hypothesized to be a Besshi-type volcanogenic massive sulphide with 11 ppm Cu, 15 ppm Zn, 8 ppm Pb and 31 ppm Co.

At Nomal, sulphide mineralization and hydrothermal alteration in the sodic Matum Das composite pluton is centered in the Nomal quartz porphyry. The hydrothermal alteration consists of a central mixed assemblage of sericite+chlorite+biotite+pyrite (potassic-sericitic) zone (300 m wide and 1800 m long), which passed outward into a garnet subzone and then into the propylitic alteration (albite-epidote-actinolite-chlorite-calcite). Pyrite is both disseminated and associated with quartz veins in the potassic-sericitic zone, which averages 85 ppm Cu, 45 ppm Zn, 15 ppm Mo and Au <0.2 ppm. The Barit copper porphyry occurs within the Barit pluton of the deformed potassic suite, and is associated with skarn in adjacent carbonate wallrocks at Markoi. Hydrothermal alteration is characterized by pervasive and widespread biotite-epidote-calcite-K-feldspar (potassic) and younger-fractured controlled sericite-chlorite-clay (sericitic) assemblages. Up to 0.2 wt. % copper occurs in quartz-chalcopyrite veins and stockwork fracturing and is associated with potassic alteration. Sulphur isotopic compositions of sulphide from all the prospects range from -1.01 to +3.6 per mil and are interpreted to indicate sulphur is primarily of magmatic origin.

Key words: Hydrothermal alteration, sulphur isotopes, sulphide deposits, Gilgit, Kohistan arc.

K/40. Kausar, A.B. & Khan, T., 1996. Peridot mineralization in the Spat ultramafics sequence, Naran-Kohistan, Pakistan. *Geologica* 2, 69-75.

Gem quality peridot (Mg-rich olivine of yellowy green colour) occurs in the Indus suture zone at Sapat along the Kaghan-Kohistan drainage divide. The host rocks are metamorphosed peridotite. The geology and petrology of the rocks and occurrence and mineralogy of the peridot are described.

Key words: Mineralization, ultramafics, peridot, Sapat, Kaghan, Kohistan.

K/41. Kausar, A.B. & Picard, C., 2001. Distribution of platinum-group-elements in silicates lithologies and chromite-rich rocks in within the Sapat and Thak gah mafic-ultramafic complexes, Kohistan arc, Pakistan. *Journal of Asian Earth Sciences* 19, p.33.

The data on Thak Gah rocks, which are a part of the mafic-ultramafic rocks of the Chilas complex, are given in Kausar et al. (2001).

Key words: PGE, ultramafics, chromitites, Sapat, Thak, Kohistan.

K/42. Kausar, A.B., Picard, C. & Guillot, S., 1998. Evidence for high-temperature-pressure crystallization during early magmatism of the Kohistan arc, Northern Pakistan. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 91-93.

In the southern Kohistan arc, the Jijal ultramafic complex is commonly interpreted as an assemblage of alpine-type ultramafic rocks intruding garnet granulites (Jan & Howie, 1981) or as the remains of a magma chamber (Coward et al., 1987; Miller, 1991) that formed at the base of an immature intra-oceanic island arc in response to northward-directed subduction of neo-Tethys ocean lithosphere during Late Jurassic and Cretaceous. Located just north of the MMT, it was tectonically emplaced over the gneissic basement of the Indian plate at 50 to 45 Ma.

Jijal complex contains two distinct sections. The basal section is composed of ultramafic rocks consisting basically of layered dunites and pyroxenites. Pyroxenites display large variations in mineralogy and are subdivided into four mappable macro-rhythmic units: olivine clinopyroxenite, websterite which evolves to garnet websterite and garnet clinopyroxenite to the top. The upper section is mainly composed of banded garnet gabbro with small amounts of garnet hornblendites.

All the ultramafic rocks present cumulative textures. The LREE depleted chondrite normalized patterns of pyroxenites ($0.07 < (La/Yb)_n < 1.09$) are consistent with pyroxene accumulation. In the garnet gabbros chondrite-normalized patterns are more REE enriched and are slightly depleted to flat ($0.64 < (La/Yb)_n < 1.26$). Crystallization of olivine and pyroxene minerals in ultramafic section can account at least partially for the LREE enrichment in garnet gabbro as these rocks are resulting from crystallization of residual liquids ($Mg\# = 0.79$ to 0.71). MORB normalized trace element pattern for garnet gabbro shows negative Ta and Nb anomaly, similar to modern arc related basaltic to andesitic rocks. This consistent REE behaviour supports the operation of magmatic crystallization processes and lends confidence to the application of mineral/melt fractionations to the interpretation of the course of plutonic crystallization differentiation.

The mineral chemistry also indicates that the Jijal complex represents a magmatic sequence formed by successive fractional crystallization. The ferromagnesian minerals show large chemical variations in accordance with the lithological change in the series from dunite - olivine clinopyroxenite-websterite-garnet websterite - garnet clinopyroxenite to garnet gabbro. Mg content of olivine regularly decreases from Fo94 to Fo78. Clinopyroxene is also characterized by continuous compositional variation from $Ca_{48}Mg_{49}Fe_3$ in dunite to $Ca_{49}Mg_{33}Fe_{18}$ in garnet gabbro. Al and Ti contents of clinopyroxene increase with decrease of Mg numbers ($Mg/(Mg+Fe)$). Orthopyroxene probably crystallized late with Mg number 85 in the earlier stage to 76 in the later. The slight variation in garnet composition is characterized by $Al_{37}PY_{30}Gr_{29}SP_2Ad_2$ in garnet websterite to $Al_{43}PY_{33}Gr_{21}Sp_1Ad_2$ in garnet gabbro.

The presence of abundant olivine clinopyroxenite and websterite, mineral chemistry of these ultramafic-mafic cumulates, as well as the petrological and field data are not consistent with crystal-liquid fractionation of a primitive basaltic magma at low pressures. It is proposed on the basis of mineral chemistry, crystallization sequences, garnet-clinopyroxene thermometry that the basal sequence of the Jijal complex was crystallized from a melt at pressures >10 kb and equilibrated at temperatures of 1050 to 1100°C which is consistent with data of Irvine (1974) indicating conditions around 14 kb and 1180°C.

Garnet websterite indicates excellent evidence for the exsolution of garnet and orthopyroxene from original aluminous clinopyroxene. This formation of garnet is consistent with the relatively low HREE contents of the garnet pyroxenites. The appearance of clinopyroxene and orthopyroxene having very high Mg number (92 to 85) and the absence of plagioclase as early fractionating phases coprecipitating with forsteritic olivine (Fo94-85) point to a crystallization history at high-pressure.

Al-poor phases such as olivine and pyroxene at moderately high temperatures and pressures, has increased the Al contents in the residual basaltic magma. The onset of the crystallization of plagioclase as a separate cumulate phase is reflected in increased Al_2O_3 and CaO and concomitant fall in MgO in garnet gabbro. This represents the product of evolved magma at relatively shallow level. Such processes are common mechanism for island arc magma evolution at depth (e.g., Aleutian arc, Alaska).

Key words: Ultramafics, magmatism, Jijal, Kohistan, Himalaya.

K/43. Kausar, A.B., Picard, C., Takahashi, Y. & Mikoshiba, M.U., 2001. Petrology and platinum group elements group distribution in the Chilas igneous complex, Kohistan island arc, northern Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 4-7.

The Chilas igneous complex, a large plutonic body extending more than 300 km between Nanga Parbat and western Dir, is composed of several isolated outcrops of ultramafic-mafic-anorthosite associations (UMA), which are intruded by rocks of "Main Facies Zone" (formerly known as gabbro-norite association). The ultramafic-mafic rocks represent plutonic core of the Chilas igneous complex. The largest mass of UMA is Chilas ultramafic-mafic-anorthosite association, located east of Chilas and described in detail by Khan et al. (1989).

In this study, we will refer the Chilas ultramafic-mafic-anorthosite association of Khan et al (1989) as Thak Gab ultramafic-mafic-association (TGUM). The rock assemblages of the TGUM and as a whole Main Facies Zone (MFZ) do not show the effects of intense regional metamorphism but at few places ductile shear zones are exhibited. These shear zones in the MFZ are typically narrow, ranging from centimetres to tens of metres, and are heterogeneously distributed. These are often anastomosing, separating great masses of relatively undeformed gabbro-norite and pyroxene diorite and are more frequently seen in the southern part of the Chilas complex. Most of these shear zones are trending northeast-southwest, with steep northerly dip. East-west trending antiforms and synforms are observed, indicating a folded structure in the Chilas igneous complex.

The TGUM is composed mainly of cyclic units of ultramafic and mafic rocks and crops out in an area as large as 5 km². The ultramafic cumulate consists of olivine cumulate (dunite), associated with minor amount of olivine-clinopyroxene cumulate (wehrlite) and orthopyroxene-clinopyroxene cumulate (websterite). It occurs as 10 to 100 metres thick layers, alternating with thin layers of plagioclase-dominant cumulate. Plagioclase-dominant cumulate (two pyroxene gabbro) occurs as layered, several metres thick and develops on the olivine cumulate. Phase layering, resulting from the appearance or disappearance of a cumulus phase is a dominant feature of the TGUM. The heterogeneous mafic unit comprises of troctolite, anorthosite, olivine gabbro, gabbro and gabbro-norite. This unit has a number of ultramafic xenoblocks. At many places, gabbroic dykes and pockets are also seen in the ultramafic cumulates, whereas in some outcrops ultramafic dykes are seen in the gabbro. All the units from TGUM are enveloped by massive, uniform gabbro-norite.

The rock assemblages from the MFZ form at least 85% of the Chilas igneous complex and has a wide range of rock types, ranging from gabbro-norite, gabbro, diorite, opx-diorite, qtz-diorite, granodiorite to trondhjemite, with the main lithologies typically being gabbro-norite, gabbro and diorite. All these rock units are so complexly mixed that the contact relationship among them is difficult to decipher. Several lines of evidence from the MFZ support a transitional character from tholeiitic to calc-alkaline arc affinity. Major and trace element geochemistry, and MORB-and chondrite-normalized patterns from the Swat- and Indus-Valleys do not differ significantly. The samples are characterized by enrichment of LILE and negative Ta and Nb anomalies, which are similar to modern arc related basaltic to andesitic rocks. Differences between the samples, from the two valleys, occur mainly in the overall REE abundances and not in the shape of the patterns.

Low values in Mg#, Cr and Ni contents, together with rapid decrease in Ni and Cr with decreasing Mg# and increasing Zr abundance, implies that much of the chemical variation in these rocks may be attributed to the crystallization processes. Positive to negative Eu anomalies in the REE profiles for the basic to more evolved rocks indicate that fractionation has taken place during magma evolution.

Another aim of this study is to investigate the platinum-group elements (PGE) and Au distribution in the rocks of the Chilas igneous complex (TGUM & MFZ). The samples have been analysed at the Institut Dolomieu, Grenoble University, France by ICP-MS, after extraction by hydrolysis/reduction using SnCl₂ and collection onto Se-Te (Amosse et al., 1986). PGE concentrations are generally associated with chromitite and sulphide occurrences in ultramafic and mafic rocks within large layered intrusions (Stillwater, Bushveld), or in greenstone belts of komatiitic affinity (Naldrett & Duke, 1980). A silicate type environment is also defined, in which no sulphide or oxide is visible to the naked eye. This type of deposit raises new questions on the origin of PGE concentrations and broadens the exploration field in areas insufficiently explored to date. No sulphide phase and no chromite assemblages of large concentrations are known in the ultramafic and mafic rocks of TGUM and MFZ. However, chrome-spinel occurs disseminated throughout the pyroxenite, and in the dunite, where it is an intercumulus phase forming <1 vol. % in dunite of Thak Gab complex. Small concentrations of chromite occur in the form of thin layers (<5 mm thick layer) or streaks in the dunite and may disappear laterally within a few metres, but very rare in the pyroxenites.

In the Chilas complex, dunite from the TGUM, has total PGE concentrations between 14 ppb and 334 ppb, except for some Cr-enriched dunite which has 1002 ppb abundances. Pyroxenite has total PGE concentrations from 13 ppb

to 19 ppb and total concentrations of PGE in gabbro range between 6 ppb and 20 ppb. In Main Facies Zone, gabbro-norite shows total PGE concentrations between 8 ppb to 17 ppb. This complex has low PGE concentration that correlate with indicators of magma evolution (Mg/Mg+Fe). So the Chilas igneous complex is not likely prospect for stratiform-sulphide mineralization owing to the failure of these melts to reach saturation and these rocks hold little economic prospects.

To allow comparison between samples, analytical data have been normalized against mantle concentrations. Metal patterns from the TGUM reveal that dunite display slightly positively sloping (Pd/Ir=4 to 7), which exhibits relative enrichment in Ni and IPGE. In contrast, samples from the pyroxenite display more pronounced positively sloping metal patterns from Ir to Pt, which indicates their relative enrichment in PPGE (Pd/Ir=4 to 30). These metal patterns indicate that the PPGE and Cu were preferentially incorporated into more evolved rocks and imply relatively incompatible behaviour for these elements. Such incompatible behaviour of Pt, Pd and Au in these rocks is attested by their increasing abundances in more evolved rocks. An exception to this general trend involves the Pt-enrichment for the dunite sample from the TGUM. The observed enrichment particularly in Pt in dunite rock may be related to the precipitation of isoferroplatinum alloy. The factors responsible for the anomalous high Pt abundances in this sample are however poorly understood. The profiles of mantle-normalized Ni-PGE-Au-Cu values of mafic rocks of MFZ shows that all the curves follow a positive slope from Ni to Cu, disturbed only by a strong negative Pd anomaly in some gabbro and gabbro-norite samples. The overall depletion in IPGE and enrichment in PPGE is a pattern typical of fractionation.

The IPGE and Ni were strongly partitioned into the most primitive rock (dunite), which reflects the compatible behaviour of these elements. The good positive correlation between IPGE, Ni and Cr clearly indicates that olivine fractionation in combination with early chromite removal can explain the decrease in Ir and Ni values between primitive and more evolved rocks from the Thak Gab complex. It also accounts for the substantial negative IPGE anomalies on the mantle-normalized diagrams of the complex.

Clear similarities in PGE signature exist between the different lithological units of the Chilas igneous complex and this offers support to hypotheses that similar geochemical processes may have operated on or around these lithologies.

Key words: Petrology, PGE, ultramafics, Chilas, Kohistan, Himalaya.

K/44. Kausar, A.B., Takahashi, Y. & Zafar, M., 1996. Petrological and geochemical observations of the Kohistan batholith with emphasis on REE and their implications for batholith petrogenesis. In: Kausar, A.B. & Yajima, J. (eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc*. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 37-55.

For further information, consult Kausar (1995).

Key words: Petrology, geochemistry, REE, petrogenesis, Kohistan Batholith.

K/45. Kazmer, C., 1986. The Main Mantle Thrust zone at Jawan Pass area, Swat, Pakistan. M.Sc. Thesis, University, Cincinnati, 79p.

The Main Mantle Thrust (or the Indus suture) zone is a *mélange* bounded to the north by Kohistan arc and to the south by the Indian plate rocks. This work delineates and describes the lithologies in the fault-bounded *mélange*. The *mélange* contains components of the Indian plate, Kohistan, and mafic-ultramafic ophiolitic rocks.

Key words: MMT, Jawan pass, Swat.

K/46. Kazmer, C., Hussain, S.S. & Lawrence, R.D., 1983. The Kohistan-Indian plate suture zone at Jawan Pass, Swat, Pakistan. *Geological Society of America, Abstracts with Program* 15, p.609.

The suture between the Kohistan Arc (KA) and the Indian Plate (IP) passes near Mingora in Lower Swat. This suture was identified previously as a single thrust fault, the Main Mantle Thrust, where arc-related amphibolites were brought over IP garnet-grade metasediments. In fact, the suture is a complex zone of thrust slices and *mélanges* bounded by two low-angle thrusts.

The most complete section is exposed SW of Mingora at the Jawan Pass. There, KA amphibolites are thrust over the suture zone. The suture zone consists of two parts: an upper part of imbricate greenstones and meta-volcanics, and a thin band of pelitic mélange comprising rounded to phacoidal serpentinite, metavolcanic, and exotic carbonate clasts in a sheared pelitic matrix; and a lower part of ultramafic (UM) mélange comprising greenstone, schist, serpentinite, and soapstone clasts in a talc-carbonate matrix. The UM mélange is thrust over the IP metasediments. Retrogressive metamorphism and carbonatization has affected the suture zone rocks and the upper section of the metasediments. The UM mélange is emerald bearing at Swat Emerald Mine in Mingora.

Four phases of folding are recorded in the IP metasediments. The UM mélange is found in F2 troughs. Thrusting of the KA amphibolites and greenstones-metavolcanics, formation of the pelitic mélange, and emplacement of some clasts into the UM mélange post-date F3.

The suture zone at Jawan Pass results from obduction of the KA amphibolites over the IP metasediments. The lower ultramafic part was emplaced as a serpentinite mélange prior to F2. The upper greenstone-metavolcanic part was emplaced concurrently with KA amphibolite emplacement but prior to F4.

Key words: Indus Suture, Kohistan, Indian Plate, Jawan Pass, Swat.

K/47. Kazmi, A.H., 1966. Water supply problems in West Pakistan. *Natural Resources* 1(2).

Key words: Hydrogeology, water supply, West Pakistan.

K/48. Kazmi, A.H., 1968. Earthquake problems and programme in Pakistan. CENTO Conference on Earthquake Hazards, Turkey. *Geonews* 2(1).

Key words: Earthquakes, problems, programs, Pakistan.

K/49. Kazmi, A.H., 1972. Earthquakes in Pakistan. *Geonews* 2(1), 22-30.

Key words: Earthquakes, Pakistan.

K/50. Kazmi, A.H., 1974. Report on the development in studies on Recent Tectonics in Pakistan during 1973-74. Report 3rd Meeting. CENTO Working Group on Recent Tectonics. Unpublished Report, Geological Survey of Pakistan.

Key words: Neotectonics, Pakistan.

K/51. Kazmi, A.H., 1977. Application of ERTS-1 imagery to Recent Tectonic Studies in Pakistan. CENTO Workshop on Application of Remote Sensing Data and Methods, 1975. US Geological Survey Project Report, CENTO Investigation (IR) CENT-10, 140-149.

Key words: Remote sensing, neotectonics, Pakistan.

K/52. Kazmi, A.H., 1978. Mineral resources of Pakistan. Pakistan Mineral Development Corporation, Mineral Review, 11.

Key words: Economic geology, mineral resources, Pakistan.

K/53. Kazmi, A.H., 1979a. Active fault systems in Pakistan. In: Farah, A. & DeJong, K.A. (eds.), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 285-294.

Study of aerial photographs, Landsat imageries and seismological data has revealed a large number of lineaments which appear to be active faults. Recent fault activity is discernible through offsets of the topography, deformation of Late Quaternary deposits, offsets of cultural features, seismicity, and historic records. Fifty three such active

faults and features have been mapped and described briefly. These faults comprise four main types: (a) transform faults that mark the western plate boundary of the Indo-Pakistan subcontinent; (b) strike-slip faults which occur mainly along the inner or eastern margin of the axial fold belt and which are mainly responsible for the formation of syntaxial bends; (c) thrust reverse faults which are commonly arcuate faults and traverse the zone between each set of sterile slip faults, and (d) traces of basement geofractures which appear as lineament of various dimensions.

This study demonstrates the use of Landsat imagery, supplemented by aerial photographs, regional geological maps and seismological data in the delineating active fault systems which would remain otherwise untouched.

Key words: Fault system, Pakistan.

K/54. Kazmi, A.H., 1979b. Preliminary seismotectonic map of Pakistan. Scale 1:200,000 Geological Survey of Pakistan, Quetta.

This is a seismotectonic map of Pakistan at 1: 2,000,000 scale. The map shows the major faults in northern Pakistan, traces of other faults, some of them active, and earthquakes magnitude >3. Depth estimates are also given for the instrumentally recorded earthquakes of northern Pakistan and NE Hindukush in Afghanistan, which have been divided into four groups of magnitude <3, 3-5, 5-7 and >7.

Key words: Mapping, seismology.

K/55. Kazmi, A.H., 1984. Pleistocene ice age cycle in the Himalayas. *Kashmir Journal of Geology* 2, 79-82.

Extensive and repeated glaciation of the northwestern part of the Himalayas occurred during the Pleistocene. Godwin (1859) was probably the first to record evidence of Pleistocene glaciation in the Himalayas. Further studies have revealed well preserved outcrops of terminal moraines, ground moraines and associated fluvio-glacial cut wash and boulder and gravel deposits in the Jhelum Valley in Kashmir, in the Pir Panjal Range and in Poonch area which indicate that these localities have witnessed a series of four glacial and three interglacial epochs during the Pleistocene. Whereas the glacial moraines and related boulder gravels provide evidence for repeated glaciation, the interglacial periods were characterized by deep erosion and valley down-cutting as indicated by benches and rock terraces in the valley profiles.

Key words: Glaciation, Pleistocene, Himalaya.

K/56. Kazmi, A.H., 1989. A brief review of the geology and metallogenic provenance of Pakistan. In: Kazmi, A.H. & Snee, L.W. (eds.), *Emeralds of Pakistan: Geology, Gemology and Genesis*, 1-11. Van Nostrand Reinhold, New York.

Key words: Metallogeny, provenance, Pakistan.

K/57. Kazmi, A.H., 1995. Precious stone of Pakistan. *Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan*, Islamabad, October 16-18, 1994, 57-70.

This paper gives information on the emerald, ruby, sapphire, pink topaz, etc. found in Pakistan northern part. For further information, consult the following account.

Key words: Gems, precious stones, Pakistan.

K/58. Kazmi, A.H., 1997a. Precious and semi-precious stones of Pakistan. *Abstracts, National Symposium on Economic Geology of Pakistan*, Islamabad, 1 p.

Gemstones have been intimately linked with the ancient history of Pakistan and since the early civilizations of Mohenjodaro, Harappa, Gandhara and Taxila, they have been used as objects of adornment symbols of power and glory and as exchange in trade. Cutting and polishing of gemstones by traditional methods is an old craft in this subcontinent as evidenced from archaeological remains of these cultures.

During the early years of Pakistan, the gemstone resources in the country remained unexplored. However since 1958 several gemstone discoveries have been made in Pakistan and presently the known occurrences include actinolite, agate, Aquamarine, azurite, emerald, feldspar (moonstone), garnet, onyx marble, pargasite, pink topaz, quartz, rodingite, Peridot, ruby, rutile, serpentinite, spinel, topaz, tourmaline and vesuvianite. Out of these the more significant deposits comprise the Swat emeralds pink topaz of Katlang rubies in Hunza and Azad Kashmir. Hunza spinel peridot from upper Kaghan and mineral specimens from the gem pegmatites of the Karakoram and the High Himalayas. These deposits are briefly described in the paper.

Key words: Gems, precious stones, Pakistan.

K/59. Kazmi, A.H., 1997b. Precious and semi-precious stones of Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 267-284.

For further information, consult the preceding account.

Key words: Gems, precious Stones, semi-precious stones, Pakistan.

K/60. Kazmi, A.H., 2001. Active faults and related high-seismicity zones in Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 33-34.

Active faults are earthquake generating faults that discernible through offsets of topography, deformation of Late Quaternary deposits, offset of cultural features, seismicity and historic records. Several active faults have been identified in Pakistan. They comprise four main types: (1) transform faults that mark the western boundary of the Indo-Pakistan Shield, (2) strike-slip faults along structural arcs, oroclines and syntaxes, (3) thrust and reverse faults between sets of strike-slip faults, and (4) basement fractures. As may be expected, the active faults overlap high seismicity zones and have caused moderate to severe earthquakes. In this study the major seismotectonic zones have been identified and may be summarised as follows:

Tirich Mir Seismic Zone. It covers a large part of the Hindukush in Pakistan and Afghanistan and is probably linked with the Akbaytal Fault in Afghanistan. Numerous 5-7 magnitude earthquakes with 100-200 km focal depth have occurred in this zone. Yasin Seismic Zone, Located on the M1KT near Yasin town, it has generated several 3-5 magnitude events with focal depths less than 50 kms, Hamran Seismic Zone. In Ghizar Range the Hamran Valley has experienced frequent earthquakes of 3-5 magnitude and <50-100 km deep hypocentres. No active fault has yet been located, though focal mechanism of some events indicates thrusting on NW trending nodal planes.

Indus Kohistan Seismic Zone (IKSZ). It is a NW-SE trending zone between MMT and Hazara- Kashmir Syntaxis. It occurs along a detachment zone and it generated the 1974 Pattan earthquake. Tarbela-Hazara Seismic Zone. Located 60 kms SE of IKSZ, it is characterised by an upper seismic zone (the Tarbela zone) comprising steeply dipping strike faults, and a deeper seismic zone (the Hazara zone), where the hypocentres cluster along a steep basement fault. Cherat-Margalla Seismic Zone. It covers the lesser Himalayan ranges and the southern part of the Peshawar plain. Several 3-5 and a few 6 magnitude events have occurred in this region. The MBT and a number of other active faults are located in this zone.

Sargodha- Shahkot buried ridge. Two portions of this ridge, one SW of Khushab and the other in Lyallpur-Jaranwala area are seismically active and fault-plane solutions indicate extensional faulting. Sulaiman Range Seismic Zone. It is characterised by left lateral active faults along eastern and western margins of the Sulaiman Range. Fault plane solutions suggest strike-slip faulting. Sulaiman Lobe Seismic Zone. Though the entire Sulaiman lobe is seismically active, two regions particularly exhibit high seismicity, contain active faults and have suffered devastating earthquakes. One of these is the Loralai- Mekhtar region where several 3-6 magnitude, shallow (<50 km) events are attributed to the active Mekhtar Fault. The other is the 25 to 50 kms wide and 250 kms long Harnai-Kingri arc, which has experienced 3-7 magnitude events related to Khalifat, Kohlu, Tatra and Kingri faults. Focal mechanism solutions indicate strike slip faulting. North Kirthar Seismic Zone. It covers the northern part of the Kirthar fold belt. It has been devastated by a few shallow (30-40 km) earthquakes centered on the Mach, Johan and Kirthar faults.

Quetta-Kalat Seismic Zone. This is a narrow, 150 kms long, high seismicity zone traversed by the active Bhalla Dor, Ghazaband and Chiltan-Takhata faults. Several shallow (5-15 km) events of 5-6 magnitude have occurred in this zone including the devastating 1935 Quetta earthquake. Chaman Fault Seismic Zone. It follows the N-S, 850 kms long, left-lateral, active Chaman Fault and extends from Kharan to Kabul. It produced the destructive earthquakes of 1892, 1975 & 1978.

Makran Coast Seismic Zone. It is a shallow, active subduction zone with high seismicity. Most of the events are offshore, where an earthquake of magnitude 8 occurred in 1945. It uplifted the ocean floor forming small islands and revealed an E-W trending active fault. Inland many 3-6 magnitude events have occurred in the Hoshab- Mashkai Valley, along the Hoshab Fault. Rann of Cutch Seismic Zone. In this zone the frequency of earthquakes is apparently not so high, despite the fact that it has experienced some of the most destructive earthquakes like the one in 1819, which revealed the Allah bund Fault, or the recent Bhuj earthquake. In the remaining areas of Pakistan, the seismicity is relatively low; diffused, and apparently not aligned with 'any particular tectonic feature. In parts of the Indus Plain, particularly in the fore-deep region several lineaments have been traced and shallow, low-magnitude teleseismic activity has been recorded. These may be related to the bending of the lithosphere or due to active basement faults.

Key words: Active faults, seismicity zones, Pakistan.

K/61. Kazmi, A.H. & Abbas, S.G., 1991. A brief review of the mineral wealth of Pakistan. Geological Survey of Pakistan, 35p.

Consult the following account for further information.

Key words: Mineral resources, Pakistan.

K/62. Kazmi, A.H. & Abbas, S.G., 2001. Metallogeny and mineral deposits of Pakistan. Orient Petroleum Inc., Islamabad, 294p.

This detailed work gives information on the tectonics, metallogenesis, and occurrence of the mineral deposits of Pakistan. Information is provided on the statistics, quality and size of the deposits.

Key words: Metallogeny, mineral deposits.

K/63. Kazmi, A.H., Anwar, J., Hussain, S.S., Khan, T. & Dawood, H., 1987. Emerald deposits of Pakistan. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan, Geology, Gemology and Genesis. Geological Survey Pakistan, & Van Nostrand Company, New York, U.S.A., 39–74.

Key words: Gems, emerald, Pakistan.

K/64. Kazmi, A.H. & Jan, M.Q., (Eds.). 1997. Geology and tectonics of Pakistan. Graphic Publishers, Karachi, 569p.

This is a comprehensive treatise on the geology and tectonics of Pakistan. It is divided into 10 chapters: 1) Introduction, 2) Geomorphology, 3) Regional Geological Setting, 4) Tectonic Framework of Pakistan, 5) Stratigraphy, 6) Magmatism, 7) Metamorphism, 8) Neotectonics, 9) Mineral Deposits, and 10) Mineral Fuels. The work is based on more than 1300 references, followed by an Index of 10 pages. The book is highly illustrated, with hundreds of figures, photographs, and tables.

Key words: Geology, tectonics, Pakistan

K/65. Kazmi, A.H., Lawrence, R.D., Anwar, J., Snee, L.W. & Hussain, S.S., 1986. Mingora emerald deposits (Pakistan): suture associated gem mineralization. *Economic Geology* 81, 2022-2028.

Emeralds occur disseminated and in veins along fractures and faults in an ophiolitic mélange of the Indus suture zone. Quartz, calcite and limonite are post-emerald fillings; the principal host-rock is talc-chlorite-dolomite schist, the matrix of the mélange. The occurrence is unique; the source of Be is sought in beryl-bearing granite gneiss of the adjacent Indian plate.

Key words: Ophiolites, gems, emerald, Indus Suture, Mingora, Swat.

K/66. Kazmi, A. H., Lawrence, R.D., Dawood, H., Snee, L.W. & Hussain, S.S., 1984. Geology of the Indus Suture Zone in the Mingora-Shangla area of Swat, N Pakistan. Geological Bulletin, University of Peshawar 17, 127-144.

In the Mingora area the Indus suture zone is largely composed of metamorphosed ophiolites and mélanges which have been wedged in between the Indo-Pakistan crustal plate and the Kohistan andesitic arc block. The Indo-Pakistan subcontinental sequence is made up of the twice metamorphosed Manglaur crystalline schists, the intrusive Swat granite gneiss, and the unconformably overlying once metamorphosed Alpurai and Saidu schists. The recognition of this unconformity requires major revision of the stratigraphic correlation of these units which were previously all considered to the Precambrian. Those above the unconformity are probably Phanerozoic, and the Saidu schist may be the local metamorphosed equivalent of the Indus flysch of Ladakh. The ophiolitic and related rocks of the Indus suture mélange group are subdivided into three separate units. The Shangla blueschist mélange is locally present in the north and represents a subduction complex developed adjacent to the Kohistan arc. The Charbagh greenschist mélange crops out in the center of the group and could be of either mid-oceanic island or island arc origin. The Mingora ophiolitic mélange is obduction complex. It is characterized by metamorphism to talc-dolomite schist and emerald mineralization.

Key words: Ophiolites, metamorphism, Indus Suture, Mingora, Shangla, Swat

K/67. Kazmi, A.H. & O'Donoghue, M., 1990. Gemstones of Pakistan. Gemstone Corporation of Pakistan, 146p.

Pakistan is emerging as an important country for occurrence of wide range of gemstones. This nicely produced volume provides a wealth of information supported by 72 coloured photographs, 24 figures, 19 tables and many references. Following introduction the book describes the composition properties and distribution of gemstones.

The gemstones deposits of Pakistan have been divided into those associated with the Indus Suture, the Karakoram Suture, pegmatite-related, hydrothermal veins related and others. Occurrence, physical and chemical data (where available) and other information has been provided for many of the gems.

Key words: Gems, precious stones.

K/68. Kazmi, A.H., Peters, J.J. & Obodda, H.P., 1985. Gem pegmatites of the Shingus-Dusso area, Gilgit Pakistan. The Mineralogical Record 16, 393-411.

Dassu area flanking the eastern margin of the Nanga Parbat-Haramosh massif is invaded by numerous pegmatites, aplites and leucogranite dykes. The pagmatites are locally zoned, others are associated with aplites. Some of the pegmatites are mineralized and contain gem quality tourmaline, aquamarine, topaz, garnet and other minerals.

Key words: Gems, precious stones, Gilgit.

K/69. Kazmi, A.H. & Qureshi, I.H., 1997. A brief review of depositional and deformational history of northern Pakistan during the Neogene. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.34.

Consequent to the India-Eurasia collision, the deformation, magmatism and metamorphism along the Indian Plate margin has occurred intermittently over a period of about 50Ma. The deformation and uplift of the Himalayan region has been most vigorous during the Neogene. The Neogene sedimentary sequence of Northern Pakistan contains clues to several episodes of spasmodic uplift and deformation. Recent sedimentological paleomagnetic and paleontological researches by several workers have provided a wealth of information indicating abrupt changes in lithology and paleocurrents, facies and provenance changes reflected in the mineral and rock fragment assemblages of sedimentary sequences, facies migration, changes in fluvial sedimentation rates, syndepositional unconformities, angular unconformities, tectonic rotation, folding and faulting of relatively young strata and major mammalian fauna turn over events. These are not isolated events. They have occurred in response to the uplift and deformation of the Himalayan region. Based on this data a tentative chronology of the uplift and deformation of the NW Himalayan region since the Early Miocene has been prepared and discussed in this paper.

Key words: Deformation, neogene, Northern areas.

K/70. Kazmi, A.H. & Rana, R.A., 1982. Tectonic map of Pakistan. Geological Survey of Pakistan, Geological Map Series, Scale 1:2,000,000.

This is 1:200,000 scale map of Pakistan and adjacent areas of Kashmir showing major structural features and tectonic stages. The map also shows broader aspects of geology of the country. Four in set map show regional tectonic setting, tectonic zonation, thickness and distribution of Cretaceous and Eocene sedimentary rocks in Pakistan and major fault and lineaments. Also given is chart showing the sequence of tectonic stages, orogeny, magmatism, volcanism and metamorphism in various tectonic zones of the country.

Key words: Mapping, tectonics, Pakistan.

K/71. Kazmi, A.H. & Sabri, A.H., 1970. Status and scope of geological mapping in Pakistan. Proceedings of National Seminar on Mineral Development, Lahore.

This is a generalized account on the geological mapping of Pakistan.

Key words: Mapping, Pakistan.

K/72. Kazmi, A.H. & Safdar, M., 1963. Clay resources of West Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 122-128.

Key words: Economic geology, clay, Pakistan.

K/73. Kazmi, A.H. & Siddiqui, R.A. (eds.), 1990. Significance of the Coal Resources of Pakistan. Geological Survey of Pakistan, Quetta, US Geological Survey, 270p.

This is an account of the coal resources of Azad Kashmir, Balochistan, Khyber Pakhtunkhwa, Punjab and Sindh. The huge deposits of Thar in southeastern Sindh are described in detail.

Key words: Economic geology, coal resources, Pakistan

K/74. Kazmi, A.H. & Snee, L.W. (eds.), 1989a. Emeralds of Pakistan: Geology, Gemology and Genesis, Van Nostrand Reinhold, New York, 269p.

This book, a comprehensive study of the geology of major emerald deposits, is the result of a collaborative program among the Geological Survey of Pakistan, the Gemstone Corporation of Pakistan, Oregon State University and the US Geological Survey.

The present volume summarizes the work of the authors. Chapters 1, 2 and 3 describe the geologic settings of the emerald deposits and the geology and tectonics of northern Pakistan. Chapter 4 is a summary of the gemological and physical characteristics of Pakistani emeralds. Chapter 5, 6 and 7 investigate emerald chemistry and fluid inclusion characteristics. The chapter 8 summarizes existing literature on world emerald deposits while chapter 9 gives foundation for the classification of emerald deposits and discussion of the origin of emeralds. A list of selected references is also given at the end of the book.

Key words: Gemology, emeralds.

K/75. Kazmi, A.H. & Snee, L.W., 1989b. Geology of world emerald deposits: A brief review. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 165-228. Van Nostrand Reinhold, New York.

Key words: Gemology, emeralds.

K/76. Kazmi, A.H., Snee, L.W. & Laurs, M.B., 1998. Himalayan Emeralds: Geology and Genesis. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 93-94.

The known Himalayan emerald-deposits and showing are confined to the NW Himalayas and occur within a narrow, 450 km long belt that largely comprises the Indus suture rock-sequence. Emeralds occur at Gandao, Nawe Kili, Bucha, Pranghar and Kot (Mohmand Agency); Maimola and Mor Darra (Bajaur Agency); Shamoza, Mingora, Char bagh, Makhad and Gujar Kili (Swat District); Allai Kohistan (?); and Khaltaro (Gilgit District). Some of these deposits have been studied by a number of authors, mainly by Jan 1968, Jan et al., 1981, Kazmi et al., 1986, Kazmi and Snee 1989, and Laurs et al., 1996.

The emeralds occur in a region characterized by three major tectonostratigraphic subdivisions. North to South these are (1) the Kohistan magmatic arc sequence which has been faulted against (2) the Indus suture melange group and the latter had been abducted previously onto (3) the Indo-Pakistan plate sequence. The Kohistan rocks have no bearing on the genesis of emeralds. The Indus suture melange and the Indo-Pakistan hand, directly involved in the formation of the emerald deposits.

The Indus suture melange group comprises tectonic blocks of ophiolites, blueschists, greenschists, metavolcanics and metasediments in a matrix of sheared and variously metamorphosed fine-grained sediments and/or serpentinite. These rocks occupy the MMT zone between the Kohistan andesitic arc and the northern margin of the Indo-Pakistan plate. The latter contains Paleozoic and Mesozoic shelf sediments, unconformably underlain by Precambrian crystalline schists and Paleozoic granitic intrusions. This sequence is intruded by Tertiary granites. The emeralds occur in two distinct geological environments. Except the Khaltaro deposit, all others are suture associated and occur as disseminations or pockets in talc-carbonate-schists. The mineralisation is confined to faults or shear zones. Emeralds formed late in the history of the suture associated rocks after major deformation had been completed as they are nowhere crushed, stretched or otherwise deformed. Emerald mineralisation apparently relates to the final stages of the metasomatic alteration of the ophiolite melange to talc-dolomite melange. The absence of granitic or pegmatitic veins in the melange, presence of beryl pegmatites and tourmaline in the granitic rock near Kot and Pacha Fort and the occurrence of young (tertiary) leucogranites near Karora, Iram and Saidu (close to the suture zone) suggest that the mineralising fluids came from these youngest granitic rocks. Emeralds developed only in the Mingora melange which provided the chromium.

The Swat emeralds are among the most Cr-rich known (up to 2 wt% Cr₂O₃). They have higher Mg and transition metals and lower Al per ¹⁸O atoms than the pegmatite Khaltaro emeralds. They contain inclusions of actinolite, chromite, dolomite, enstatite, feldspar, gersdorffite, magnesite, mica and pyrrhotite. Fluid inclusions are generally two-phase (brine+CO₂- vapour). Homogenisation temperature ranges from 305 to 349°C and salinity ranges from nil to 20 eq.wt% NaCl. The host rocks (talc-carbonate schists) have ultramafic geochemical signatures (930-2520 ppm Cr; 980-2540 ppm Ni). Altered rocks near emerald deposits are locally enriched in Al, Si, Be, and REE reflecting the hydrothermal addition of a continental crust-derived component. Collision of the Indian and Asian plates along the Indus suture zone was an important factor in the genesis of the deposits because it juxtaposed sources of Cr (ophiolitic melange) with sources of Be (continental crust).

South of the Indus suture zone, the Indo-Pakistan plate sequence in the Haramosh Range, comprising Proterozoic schists and layered gneisses, hosts the Khaltaro emeralds. Emeralds occur in thin (0.1-1.0m) hydrothermal veins and granitic pegmatites occurring as sill-like body within garnet-mica schist. The pegmatites give ⁴⁰Ar/³⁹Ar muscovite date of 9.13±0.04 Ma. Emeralds are found mainly within thin (< 30cm) veins of quartz and tourmaline-albite and more rarely in pegmatites, near the contacts with altered amphibolite. The pegmatites are zoned, having an inner zone of biotite, tourmaline and fluorite with local albite, muscovite, quartz, and rare beryl, an intermediate zone containing biotite and fluorite with local plagioclase and quartz and an outer zone of amphibolite containing sparse biotite and local quartz. According to Laurs et al. (1996), the inner and intermediate zones experienced gains of K, H, F, B, Li, Rb, Cs, Be, Ta, Nb, As, Y and Sr, and losses of Si, Mg, Ca, Fe, Cr, V and Se. The outer alteration zone has gained F, Li, Rb, Cs, and As. Oxygen isotope analyses of igneous and hydrothermal minerals indicate that a single fluid of magmatic origin produced the pegmatite-vein system and hydrothermal alteration at temperatures between 550° and 400°C. The emeralds formed due to introduction of HF-rich magmatic-hydrothermal fluids into the amphibolite, which caused hydrogen ion metasomatism and released Cr and Fe into the pegmatite-vein system.

Key words: Gemology, emeralds, Himalaya.

K/77. Kazmi, S.A.T., 1968. Groundwater investigation in Warsak regulating reservoir scheme area. Bulletin 16, Water and Soil Investigation Department Publication 62, WAPDA, Hydrogeology Directorate, North West Frontier Province, Peshawar.

Key words: Groundwater, Warsak.

K/78. Kella, S.C., Qureshi, M.A., Khan, A.B. & Shah, M.Y., 1996. Integrated regional exploration for gold and associated minerals of northern areas of Pakistan. Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, p.152.

Key words: Gold exploration, minerals, Gilgit-Baltistan.

K/79. Keller, H.M., 1975. The magnetic polarity stratigraphy of an upper Siwalik sequence in the Pabbi Hills of Pakistan. M. A. thesis, Dartmouth College, Hanover, New Hampshire, U. S. A.

Consult the following account for further information.

Key words: Magnetostratigraphy, siwaliks, Potwar.

K/80. Keller, H.M., 1977. Magnetic polarity stratigraphy of the upper Siwalik deposits, Pabbi Hills, Pakistan. Earth and Planetary Science Letters 36, 187-201.

Over 1000 m of fluvial molasse, exhibiting a stable detrital remanent magnetization, is exposed in a mammal-bearing sequence in the Upper Siwalik Group of the Pabbi Hills, Pakistan. The magnetic polarity chronology reveals that the sequence records a time period of 2.6 m.y., extending from the early Gauss Normal Epoch into the Brunhes Normal Epoch. During this period, sedimentation rates increased upward in time from 0.25 m/1000 yr to 0.45 m/1000 yr. The sudden disappearance of red beds and a change in the lithoclastic composition of basal channel sands suggests that about 800,000 years ago the primary source area began shifting from the metamorphic terrane of the Himalayan Orogen to a more local sedimentary terrane on the folded margins of the Himalayan foredeep. About 500,000 years ago the anticlinal Pabbi Hills attained surface expression. Uplift continued at a minimum rate of 1 m/1000 yr.

A local Pliocene/Pleistocene boundary based on the Olduvai Normal Event is clearly recognized. Local fossil finds reveal that *Equus*, diagnostic element of the Pinjor faunal zone, appeared locally about 1.8 m.y. ago and that *Hipparion*, a faunal element of the Tatrot and earlier faunal zones, persisted locally until at least 3.0 m.y. ago.

Key words: Magnetostratigraphy, siwaliks, Pabbi hills, Potwar.

K/81. Kelley, J., 1997. The significance of fossil hominoid discoveries from the upper Nagri Formation, Potwar Plateau, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.68.

Almost all of the fossil hominoid specimens known from the Siwalik Nagri Formation have come from a single locality, Y3 11. Y3 11 lies in the uppermost part of the formation and is dated approximately 10 m.y. based on magnetic polarity stratigraphy. It is the richest hominoid locality in the Siwalik Sequence of the Potwar Plateau; approximately 25% of all fossil hominoid specimens collected from the Potwar Plateau since Dehm's first expedition in 1939 have come from this locality. This total includes fully half of all the hominoid postcranial specimens recovered. All of the hominoid material from Y3 11 has been assigned to a single very large species of *Sivapithecus*, *S. parvada*, which is not definitely known from any other Siwalik locality. The *S. parvada* material has contributed significantly to questions concerning hominoid phylogeny and paleobiology. Postcranial remains reveal that large individuals of *S. parvada* were as large as female gorillas or male orangutans, and that body size sexual dimorphism was probably substantial. They also indicate that *S. parvada* was primarily a quadrupedal rather than a suspensory ape. This has raised questions about the relationship of *Sivapithecus* to the extinct orangutan, *Pongo*, established on the basis of craniofacial morphology. Juvenile specimens of *S. parvada* have permitted an estimation

of the overall rate of maturation in the species, based on the ability to calculate absolute ages at death using growth lines preserved on tooth germs. Maturation rate is one of the most fundamental biological attributes of a species and sharply distinguishes, for example, living monkeys and apes. *S. parvada* appears to have matured at approximately the same rate as living apes. The paleobiology of *S. parvada* is now more completely characterized than that of almost any other fossil hominoid.

Key words: Vertebrate palaeontology, hominoid, Nagri Formation, siwaliks.

K/82. Kemp, A.J. & Leake, B.E., 1975. Two hydrous-rich aluminous hornblendes. *Mineralogical Magazine* 40, 308-311.

Previous studies of aluminous hornblendes rich in aluminosilicates, $\text{Ca}_2\text{Mg}_3\text{Al}^{\text{vi}}_2\text{Si}_6\text{Al}^{\text{iv}}_2\text{O}_{22}(\text{OH})_2$, have shown that no natural amphiboles are known that closely approach this composition (Leake, 1971). From a careful scrutiny of about 1500 analysed amphiboles with at least Ca 1.00 in the half unit cell and from reanalysis of a number of perceptibly selected Al-rich samples, it was shown that the maximum possible Al^{vi} in natural amphiboles increased as Al^{iv} increased and it was suggested that the maximum possible Al^{vi} value in natural hornblendes when the half unit cell contained $\text{Si}_6\text{Al}^{\text{iv}}$ was not above 1.40 although the highest reliably determined Al^{vi} value known was only 1.35 (Leake, 1971). Subsequently Bunch and Okrusch (1973) have described a quite extraordinary iron-poor aluminous amphibole (with 22.6 Al_2O_3), which has $\text{K}_{0.16} \text{Na}_{0.54} \text{Ca}_{1.99} \text{Mg}_{3.35} \text{Fe}_{0.01} \text{Ti}_{0.16} \text{Al}^{\text{vi}}_{1.47} \text{Si}_{5.47} \text{Al}^{\text{iv}}_{2.26} \text{O}_{22.13}(\text{OH}, \text{F}, \text{Cl})_{1.87}$. One of the highly aluminous amphiboles described in this paper is from corundum-bearing amphibolite of timargara, Dir (see Jan et al., 1971).

Key words: Mineralogy, aluminous hornblende, Dir.

K/83. Kempe, D.R.C., 1973a. The petrology of the Warsak alkaline granites, Pakistan, and their relationship to other alkaline rocks of the region. *Geological Magazine* 110, 385-404 (Corrigendum, 1974, 111, p.450).

A suite of Tertiary alkaline porphyritic microgranites and hybrid and peralkaline granite from northwest Pakistan is described, with six rock analyses (five of them new). The microgranites, an earlier group of which some contain garnet, have undergone metamorphism, lacking in the granites. The microgranites are shown to be precisely similar to those from the Shewa-Shahbazgarhi area, for which four analyses (two of them new) are presented, and related to a third group from Tarbela. The mineralogy of the rocks is discussed, with seven new analyses of aegirine, riebeckite, ferrohastingsite and astrophyllite, and X-ray determinations of the feldspar compositions. The granites are considered to be related to the undersaturated syenites and associated rocks of Koga, and a petrogenetic scheme for the alkaline province is presented, with a K/Ar age determination, tentatively deriving the source magma (quartz trachytic) from a Himalayan tholeiite.

Key words: Petrology, petrography, alkaline granites, Warsak, NWFP.

K/84. Kempe, D.R.C., 1973b. Tilloids from N.W. Pakistan. *Geological Magazine* 110, 373-374.

This article does not have an abstract as it is published as a letter. It gives detail of the tilloid from Warsak area. It's a metaconglomerate and pebbly quartzite.

Key words: Tilloid, Mullagori, Warsak, Khyber Agency.

K/85. Kempe, D.R.C., 1974. Tilloids from N.W. Pakistan. *Geological Magazine* 111, 568-569.

Key words: Petrology, Tilloids, alkaline granites, Warsak, NWFP.

K/86. Kempe, D.R.C., 1978. Acicular hornblende schists and associated metabasic rocks from North-West Pakistan. *Mineralogical Magazine* 42, 405-406.

A suite of unusual acicular hornblende schists is found at Warsak (34° 10' N. 71° 23' E.), some 30 km WNW of Peshawar, North-West Pakistan. The schists occur in association with sill-like masses of amphibolite facies meta-

igneous rocks, possibly a metamorphosed gabbroic and doleritic, dioritic, and granitic calc-alkaline series, and intrusions of alkaline granite and microgranite. These rocks lie within Palaeozoic metasediments and all are folded synclinally. The area was first described by Ahmad et al. (1969).

The rocks of the acicular hornblende schist suite (fig. 1) consist essentially of large, idioblastic hornblende crystals—comprising some 30–60 % of the rock—in a fine-grained granoblastic matrix of oligoclase feldspar with minor quartz, iron oxide, biotite, and rutile. The boat-shaped, blue-green hornblendes, twinned on {100}, reach 5 mm in length and are often grouped in sprays or clusters; they are sieved with quartz, ilmenite, and patchy calcite. The groundmass also contains patches and veins of calcite, associated with ragged patchy areas of reddish brown, amorphous iron oxide or hydroxide, perhaps introduced hydrothermally. The schists coarsen in grain size outwards through the sill-form, the hornblendes reaching 4 cm, become rich in chlorite and biotite, and grade into the apparently metagabbroic amphibolitic rocks.

The acicular hornblende schists have a generally basaltic composition, while the hornblendes are tschermakitic. An analysed amphibole has 16.5% Al_2O_3 , is slightly zoned with alumina increasing from core to rim, and has the formula: $\text{K}_{0.06}\text{Na}_{0.50}\text{Ca}_{1.90}\text{Mg}_{2.13}\text{Fe}_{1.49}^{2+}\text{Mn}_{0.02}\text{Fe}_{0.14}^{3+}\text{Ti}_{0.04}\text{Al}_{1.16}^{\text{vi}}\text{Si}_{6.31}\text{Al}_{1.69}^{\text{iv}}\text{O}_{21.97}(\text{OH},\text{F})_{2.03}$

Three hypotheses of the origin of the rocks were considered; metamorphism of a suite of basic tufts is the most favoured. Origins involving metamorphism of a lamprophyre-appinite suite or of a gabbroic marginal facies are therefore rejected. Texturally the rocks strongly resemble metatuffs (fig. 2) that occur associated with metagreywackes in the Otago schists of New Zealand (Turner, 1933); like many similar Alpine schists they also contain tschermakitic hornblendes. The Warsak tufts could have formed originally, together with the meta-igneous rocks, possibly as lavas, in an inter-plate tectonic environment; the high Al content of the hornblende, which is typical of many amphiboles from the surrounding alpine environment in North-West Pakistan, and other mineralogical evidence in the region support a high pressure environment for the metamorphism of the rocks to just within the amphibolite facies, at moderate temperatures of approximately 465 °C.

Key words: Hornblende, schists, metabasic rocks, NW Pakistan.

K/87. Kempe, D.R.C., 1982. Nature and source of the Gandhara sculptural schists. *Journal of Archaeological Sciences* 9, 25-8.

No definite source localities have been identified for the stones used by the Gandharan sculptors, but it is considered that the predominant rock was alumina-rich chloritoid-paragonite-muscovite-quartz schist, probably from Swat. A chemical analysis of this rock is presented.

Key words: Gandhara, Swat,

K/88. Kempe, D.R.C., 1983. Alkaline granites, syenites, and associated rocks of the Peshawar plain alkaline igneous province, NW Pakistan. In: Shams, F.A. (ed.) *Granites of Himalaya, Karakorum, and Hindu Kush*. Institute of Geology, Punjab University, Lahore, Pakistan, 143-169.

Alkaline rock complexes are distributed in a semicircle around northern half of the Peshawar plain, NW Pakistan. Stretching west to east for over 200 km, they occur in eastern Afghanistan, Mohmand Agency, Khyber Agency, Warsak, Malakand, Shewa-Shahbazgarhi, Koga-Ambela unit, Tarbela and possibly Mansehra. The rocks, which are described, include alkaline granites and microgranite, albitites, syenites, carbonatites, and silicocarbonitites, intruded generally along fault zones into mainly Early Paleozoic metasediments. They are thought to be associated with rifting, caused partly by relief tension or compression release perhaps during very Late Cretaceous or Early tertiary times, following contact between the Indo-Pak plate and the island arc(s) or southern continental margin of the Eurasian plate.

Key words: Alkaline granites, syenites, carbonatites, Peshawar plain alkaline province, NWFP.

K/89. Kempe, D.R.C., 1986a. A note on the ages of the alkaline of the Peshawar plain alkaline igneous province, NW Pakistan. *Geological Bulletin, University of Peshawar* 19, 113-119.

The available ages published for the alkaline rocks and carbonatites of the Peshawar Plain alkaline igneous province are reviewed, with no new data, and briefly discussed. Repeated magmatism has apparently occurred, over the period ca 315 to 31 m.y. ago, due to rifting and the development of thrust planes.

Key words: Alkaline rocks, carbonatites, Peshawar plain, NWFP.

K/90. Kempe, D.R.C., 1986b. Gandhara sculptural schist: Proposed source. *Journal of Archaeological Science* 13, 79-87.

Previously suggested source localities for the chloritoid-paragonite-muscovite quartz schist, the most widely used Gandharan rock, have been examined and rejected. However, an ancient disused quarry near Sakhakot, south of Dargai, in northern Pakistan, has been located and sampled. Chemical and mineralogical comparisons between two quarry samples and a specimen of artifact schist are very close, leading to the proposal that the quarry is one definite source of Gandhara sculptural schist.

Key words: Gandhara sculpture, schist, petrology, Swat, Buner.

K/91. Kempe, D.R.C., 1986c. The Asota stone circle, Mardan, northern Pakistan. *Antiquite* 60, 47-48.

This article discusses the petrology of the Asota stone circle in northern Pakistan. Description is given of the stone circle, efforts of several geologists and archeologists to define the Asota stone circle, orphyries recorded by A.L. Coulson, a geologist with the Geological Survey of India, at Shahbazgarhi.

Key words: Gandhara, alkaline granite, Mardan.

K/92. Kempe, D.R.C. & Jan, M.Q., 1970. An alkaline igneous province in the North-West Frontier Province, West Pakistan. *Geological Magazine* 107, 395-398.

Alkaline microgranites and granites containing aegirine, riebeckite and astrophyllite, from north-west Pakistan, are briefly described, and tentatively correlated with other alkaline rocks in the Peshawar region. It is suggested that the Warsak granites, Shewa-Shahbazgarhi porphyries, Tarbela and Koga alkaline rocks constitute an alkaline igneous province. For more information, consult the following account.

Key words: Alkaline igneous province, NWFP.

K/93. Kempe, D.R.C. & Jan, M.Q., 1980. The Peshawar plain alkaline igneous province, NW Pakistan. *Geological Bulletin, University of Peshawar* 13, 71-77.

Complexes of alkaline rocks are distributed in a semicircle around the northern half of Peshawar Plain, NW Pakistan. Stretching west to east for over 200 km, they occur in eastern Afghanistan, Mohmand Agency, Khyber Agency, Warsak, Malakand, Shewa-Shahbazgarhi, Koga-Ambela-Utla, Tarbela and possibly, Mansehra; also in Dir. The rocks include alkaline granites and microgranites, syenites, albitites, and carbonatites, intruded generally along fault zones into mainly Early Paleozoic metasediments. It is proposed that they are associated with rifting, caused partly by 'rebound' relief tension or compression release, perhaps during very Late Cretaceous or Early Tertiary times, following contact between the Indian plate and the island arc(s) or southern margin of the Eurasian plate.

Key words: Alkaline igneous province, Peshawar, NWFP.

K/94. Kempe, D.R.C., Jan, M.Q., Jones, G.C. & Din, V.K., 1985. A skarn rock from Dir, northwest Pakistan. *Geological Bulletin, University of Peshawar* 18, 103-111.

The geology and petrology of a skarn from northwest Pakistan are presented. The chemistry of the rocks and their constituent minerals is discussed briefly and compared with other similar occurrences. The rock chemistry and the abundance of ferrosalite, andradite-rich garnet, and epidote ($\text{Fe}^{3+} / (\text{Fe}^{3+} + \text{al}) = 0.30$) are considered to be due to metasomatism or, less likely, volcanic rocks by a biotite-two pyroxene tonalite intrusion.

Key words: Petrology, geochemistry, skarn, Dir.

K/95. Kerrick, D.M. & Caldeira, K., 1995. Himalaya-Karakoram metamorphic CO₂ degassing and Cenozoic paleoclimate: Revisited. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Kerrick and Caldeira (1993, 1994) proposed that CO₂ generated by metamorphic decarbonation during post-collisional metamorphism in the Himalayan orogenic belt may have contributed to the Eocene greenhouse global warming. The validity of their hypothesis depends upon the timing and duration of prograde metamorphism, the amount of metamorphic CO₂ generated at depth from CO₂ source rocks (i.e., carbonate-bearing protoliths), and the flux of CO₂ to the Earth's surface. Their hypothesis requires that prograde metamorphism was contemporaneous with the late Paleocene-early Eocene warming (ca. 55-45 m.y.).

Recent geochronologic evidence for the timing of prograde metamorphism suggests that early Cenozoic metamorphism was confined to the Himalaya and Karakoram in northern Pakistan (i.e., west of the Nanga Parbat syntaxis). Here, carbonate rocks that enjoyed early Cenozoic metamorphism are abundant in the Swat region, Kaghan Valley and southern Karakoram. Following the methodology outlined by Kerrick and Caldeira (1993, 1994), the amount of metamorphic CO₂ produced from these rocks was estimated from bulk-rock compositions and computed decarbonation reaction progress from modal estimates of calc-silicates. Locally there are tremolite-bearing metacarbonate rocks that produced as much as 20 wt % CO₂. However, in the abundant siliceous carbonate rocks of the Kaghan Valley and southern Karakoram, the limited average modal amounts of calc-silicates (<5 vol. %) implies that less than 5 wt. % CO₂ was produced from the bulk of the metacarbonate rocks. At the present level of exposure, metacarbonate rocks occupy less than 10 vol. % of the Karakoram range and Pakistan Himalaya. Coupling this volumetric estimate with average reaction progress, and estimates of the duration of prograde metamorphism based on the timing of collision and geochronologic data, the amount of metamorphic CO₂ generated during the Paleocene-Eocene metamorphism was <1018 moles/m.y. Even with a large crustal permeability, this amount of CO₂ would be insufficient to substantially contribute to the atmospheric CO₂ content and thus to Eocene global warming.

Geochronology data suggests that prograde metamorphism in the central and eastern Himalaya (i.e., Zaskar and eastward) coincides with mid-Miocene global warming. The small proportion of metacarbonate rocks in this region (< 5 % of the Higher Himalayan Crystalline Sequence) suggests insignificant metamorphic CO₂ production from such lithologies. However, in light of the volumetric proportion of metapelitic rocks in this region, coupled with average carbonate and organic carbon contents of pelitic protoliths, the computed amount of CO₂ generated from metamorphism of pelites (>1018 moles) could have contributed to the Miocene paleoclimate. Widespread Miocene metamorphism in the other parts of the Tethyan orogen could have also generated significant metamorphic CO₂.

In Himalayan-Karakoram-Tibet region there were large "pulses" of extrusive and intrusive magmatic activity correlative with the Eocene and Miocene global warming. However, estimates of the volumetric extent of the intrusive and extrusive rocks, coupled with data on the CO₂ contents of magmas, implies that the amount of magmatic CO₂ produced from this region would not have significantly contributed to the atmospheric CO₂ contents during these time periods.

Of all metamorphic belts worldwide, the Cordilleran belt in western North America is the best (and probably only) candidate for climatically significant metamorphic CO₂ degassing during the early Cenozoic. Based on convective hydrothermal circulation modeling, Nesbitt, Mendoza and Kerrick (1995) concluded that Cordilleran metamorphic CO₂ production in the early Cenozoic may have been 1018 -1019 moles/m.y. and thus sufficient to have significantly contributed to paleoatmospheric CO₂ contents at that time.

Based on our preliminary compilation of the volumes of magmatic rocks through time, coupled with estimates of the CO₂ contents of magmas, we conclude that magmatic CO₂ degassing has been a significant factor in the global carbon cycle and a major contributor to paleoatmospheric CO₂. The global cooling in the last 100 m.y. is compatible with diminished volumes of igneous rocks through this time period.

Key words: Metamorphism, CO₂ degassing, paleoclimate, Cenozoic, Himalaya, Karakoram.

K/96. Kerrick, D.M., Caldeira, K. & Kump, L.R., 1993. Paleoatmospheric consequences of CO₂ released during Tertiary regional metamorphism in the Himalayan orogen. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 37-38.

Fluxes of metamorphic CO₂ to the atmosphere have been suggested to be climatically important (Fyfe, 1986; Varekamp et al., 1992; Touret, 1992). Using an overly simplified model of decarbonation of a 1 km-thick carbonate layer, Fyfe (1986) concluded that atmospheric CO₂ content could have been significantly affected by the Tertiary Himalayan orogenesis. However, the validity of the suggestion that metamorphic CO₂ has significantly affected the atmosphere critically depends upon a number of factors; i.e., duration of prograde metamorphism, abundance and composition of CO₂ source rocks, and escape of CO₂ to the Earth's surface. The Himalayan orogenic belt affords an excellent case study for analysis of these variables in determining the quantities and fluxes of CO₂ released by metamorphic decarbonation and graphitization.

The Eocene was the warmest epoch of the Cenozoic, with published estimates of Eocene atmospheric CO₂ content ranging from two to six times the current value. The Early Eocene (50-55 Ma) global warming may have been produced by the greenhouse effect arising from elevated CO₂ contents. Our calculations of CO₂ consumption by silicate weathering show that metamorphic CO₂ releases of Ca. 1018/Ma could readily account for inferred Eocene atmospheric CO₂ contents and, consequently, Eocene warming.

Because of the lack of evidence for Eocene metamorphism in the central and eastern portions of the orogen, we focused on Eocene metamorphism in the western portion of the orogen (i.e., Zaskar and westward). Duration of prograde metamorphism was constrained by the timing of the India-Tibet collision (50-65 Ma) and the peak of prograde regional metamorphism (ca. 40 Ma). Due to lack of published estimates of the proportions and bulk compositions of metacarbonate and graphitic lithologies in the western Himalayan orogen, we coerced selected colleagues (J.A. DiPietro, M.S. Hubbard, K.P. Hodges, and M.P. Searle) into providing "guesstimates" of the proportions of such lithologies. In our computations we assumed marl as the model metacarbonate source rock and that 5wt % of CO₂ was released during prograde metamorphism (Ferry, 1982). With a conservative assumption that carbonate rocks constitute ca. 10% (by volume) of the western Himalayan orogen (J.A. DiPietro, M.P. Searle), and that CO₂ was generated at a constant rate during the prograde event, we estimate that ca. 1019 moles/Ma of metamorphic CO₂ were produced at depth. Assuming 0.5% (by volume) of carbonaceous lithologies, CO₂ released from the graphitization of carbonaceous material is estimated to be Ca. 1018 moles/Ma. These calculations assumed that CO₂ was linearly released during prograde metamorphism; however, because extensive devolatilization of marls and carbonaceous lithologies occurs during progradation through the lower greenschist facies (Ferry, 1982; Labotka et al., 1988), CO₂ production may have been two to four times more rapid than these estimates.

The possibility of escape of metamorphic CO₂ to the atmosphere is indicated by the global correlation between the distribution of major zones of seismicity and carbon dioxide discharged from hot springs (Barnes et al., 1978). Release of metamorphic CO₂ to the atmosphere would have been impeded by retrograde carbonation and carbonate vein formation in the shallower (lower grade) portions of the orogens. However, in light of large fluid/rock ratios, significant expulsion of CO₂ to the atmosphere may have occurred by focused fluid flow along the Main Central Thrust (MCT) in the Himalayan orogen. Transient expulsion of large amounts of metamorphic volatiles is expected to have accompanied seismic activity along the MCT.

Geochronologic analyses reveal a remarkable similarity in peak metamorphic ages (40-50 Ma) for many areas within the Tethys and Circum-Pacific orogens, thus supporting the concept of a major, world-wide Eocene regional metamorphism. This metamorphic culmination was contemporaneous with increased Eocene atmospheric CO₂ and associated global warming. World-wide Eocene regional metamorphism could well have generated ≥ 1020 moles CO₂ /Ma at depth. Even if only 1% of the total metamorphic CO₂ produced escaped to the Earth's surface, there would have been significant paleoclimatic consequences.

Key words: Metamorphism, CO₂ degassing, paleoclimate, Cenozoic, Himalaya, Karakoram.

K/97. Khadim, I.M., 1995. Magnetic minerals in red beds of Murree Formation, Barsala area, Azad Kashmir: A preliminary study. In: Khadim, I.M. & Yoshida, M. (eds.), *Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan*, Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 13, 43-57.

Ferromagnetic minerals contained in red beds of Murree Formation are examined by optical microscopy, thermomagnetic analysis, dual frequency susceptibility measurement, hysteresis loop analysis, and IRM acquisition experiment. The major carrier mineral for ferromagnetic properties of the rock is hematite but a trace amount of goethite is also identified. The red bed is rather inhomogeneous in population of magnetic minerals; some specimens contain iron sulfides, such as pyrite and troilite. Laboratory heating often formed secondary minerals, magnetite (Ti-poor titanomagnetite) and hematite, which are probably decomposed products of the multistage and/or Fe-bearing

minerals by laboratory heating. Goethite is probably a product of weathering. The presence of hematite may prove Murree red bed to possibly maintain the primary remanence component which can be used for paleomagnetic study.

Key words: Magnetic minerals, Murree Formation, Azad Kashmir.

K/98. Khadim, I.M., Ahmad, M.N., Yoshida, M. & Hussain, I., 1996. Magnetic susceptibility variation of granitoid in the Kohistan-Ladakh island arcs, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, 109-111.

Magnetic susceptibility data of rocks is extremely useable for the interpretation of geomagnetic data, assessing mineral potential and classification of rock type based on magnetic mineralogy. With particular reference to granitic rocks, a classification depending upon constituents magnetic mineral has been suggested by Ishihara (1977) as magnetite-series and ilmenite-series which provide sufficient information on assessment of mineral potential of the host rocks. The present study accomplishes susceptibility data along main traverse of Karakoram Highway in Kohistan island arc and along Gilgit-Skardu road, Satpara-Deosai track, Shigar, Kharmang, and Khaplu valleys in Baltistan area in the Ladakh island arc. The observation points along KKH were located about three kilometers apart but different exposures of geological units were also measured (Ahmad et al., 1995) while in Ladakh arc mainly granitic rocks and other associated rocks were measured.

The northern Pakistan is divided into three major terrains, Indo-Pak subcontinent (Indian Plate), Kohistan (on western side) and Ladakh (on eastern side) island arcs and Karakoram block (a part of Eurasian continent). There are two major collision zones in this area: the northern Main Karakoram Thrust (MKT) zone and southern Main Mantle Thrust (MMT) zone.

Kohistan island arc between MKT and MMT is a fragment of Mesozoic intra-oceanic island arc sandwiched between the Eurasian and Indian Plates (Tahirikheli et al., 1980) while the Ladakh terrain is bounded by the Shyok suture zone (MKT) to the north and the Indus suture zone (MMT) to the south. The Ladakh terrain is dominantly composed of granitic rocks of the Ladakh batholith and is variously known as Kohistan batholith in Pakistan (Searle, 1991).

Kohistan arc is divided into four major units from north to south, which has been considered to represent a complete sequence of island arc crust. The northern upper most part of the sequence is comprising metasediments and metavolcanics. Phylitic slates and metavolcanics of this upper most part has very low susceptibilities, $0.1 - 1 \times 10^{-3}$ SI. The first horizon in the north is Kohistan batholith, which comprises granites, granodiorite and diorite and susceptibilities of the granitic bodies in the lower part of the batholith show values $< 1 \times 10^{-3}$ SI except the upper part of the batholith. The next Chilas Complex is consisting of ultramafic to mafic igneous rocks: dunite and gabbro and show high values ($2-5 \times 10^2$ SI), while gabbro and diorite show low values ($< 1 \times 10^{-5}$ SI). The third is Kamila Amphibolite which mainly comprises of metamorphosed amphibolites situated between Chilas and Jijal Complexes. This expresses quite low susceptibility (8×10^{-4} SI).

The lower most unit, the Jijal complex consisting of garnet granulite, pyroxene granulite and serpentine facies. The granulites reveal low susceptibilities but serpentine yields highest value ($> 8 \times 10^{-2}$ SI). The above results clearly show two values of susceptibilities over the granitoids along Kohistan arc (KKH). This study led to measure the susceptibilities over granitic rocks in Ladakh island arc. Here main six sections were measured. On Satpara-Deosai traverse, metasediments and Kohistan-Ladakh batholith exhibit variable character towards susceptibility. Ladakh batholith, comprising of undifferentiated granites, granodiorite and quartz diorite relatively shows higher susceptibilities ($3.5 \sim 10 \sim$ SI) while metasediments show 1.2×10^2 SI. Metasedimentary rocks include greenschist, slates and phylites. In Shigar valley, rocks of Ladakh batholith and Shyok suture zone show high values to moderate (1.8×10^{-1} SI and $4.0 \sim 10^{-1}$ SI). Shyok suture zone rocks include highly deformed, folded and thrust sequence of greenschist facies volcanic rocks, limestones, shales, conglomerates and quartzite. Recent alluvium exhibits very low susceptibilities.

The Ladakh batholith on Kharmang valley traverse repeats high values (2.3×10^{-2} SI) while Chalt Volcanic group rocks indicate low values ($< 3.0 \times 10^{-4}$ SI). The Chalt Volcanic group comprises subaerial and submarine volcanic arc lavas, tuffs and volcaniclastic sediments, metamorphosed to greenschist facies.

The Gol-Saling and Khaplu road profiles were along the Shyok River: the first on the right bank while latter on the left bank. The rocks are almost identical across the river. Ladakh batholith, on the Gol-Saling profile, reflects

generally high values reaching to 2.7×10^{-2} SI while on Khaplu road profile, it reaches to a maximum 4.7×10^{-2} SI whereas the most of the values range in $4-10 \times 10^{-3}$ SI.

Most of the part of the Skardu-Gilgit Road is covered with low susceptibility rocks such as Iskere gneiss, composed of layered quartz-feldspar-biotite-muscovite gneiss, probably orthogneiss with rare meta-sedimentary layers, showing very low values ($<1.0 \times 10^{-3}$ SI). Similar attitude is observed by Nanga Parbat-Haramosh gneisses. They are Precambrian basement gneisses and Paleozoic sedimentaries intruded by Cambrian granites. There are two high values observed across Ladakh batholith ($0.9-3.0 \times 10^{-2}$ SI) and gabbro (-2.4×10^{-3} SI) Metasediments again show very low values ($<1.0 \times 10^{-3}$ SI).

These results clearly show two major types of granitic rocks in the Ladakh arc. one that carrying high susceptibilities (magnetite-series, values $>3.0 \times 10^{-3}$ SI) and the other possessing low susceptibilities (ilmenite-series, values $<3.0 \times 10^{-3}$ SI). There are two regimes of granitoids in northern Pakistan. Kohistan island arc is abundant in ilmenite-series granites while magnetite-series granites are more common in Ladakh arc. The magnetite-series granites might be produced because of relatively reducing environments related to the subduction along the collision belt. The present study recommends further mineral potential oriented research studies should be taken in these island arc areas.

Key words: Granitoid, magnetic susceptibility, Kohistan, Ladakh, Island arc.

K/99. Khadim, I.M., Yoshida, M. & Ahmad, M.N., 1996. First attempt of VLF-EM survey in Pakistan-temporal change in VLF field and sounding of siderite mineralization zone, Chitral, N.W.F.P. *Geologica* 2, 171-194.

Key words: Geophysics, mineralization, siderite, Chitral.

K/100. Khadim, I.M., Yoshida, M., Ahmad, M.N. & Shirahase, T., 1997. Magnetic susceptibility variation of granitoids in the Ladakh arc, Baltistan, northern Pakistan, and surrounding terrains: Its implications for mineralization assessment. In: Khadim, I.M., Zaman, H. & Yoshida, M. (eds.), *Paleomagnetism of Collision Belts*. Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, 73-83.

Low-field magnetic susceptibility was observed for the granitoids and associated rocks in the eastern Ladakh arc, Baltistan area, northern Pakistan. These results were compared with previously reported magnetic susceptibility data of granitoids obtained from the Karakoram block of Asian plate, Kohistan arc, and Indo-Pakistan subcontinent. The granitoids in Karakoram block and Indo-Pakistan subcontinent generally show low susceptibility values, thus relating to the ilmenite-series. Similarly the granitoids in Kohistan arc mostly give low susceptibility values of ilmenite-series except the northern part of Kohistan batholith which shows high susceptibility values indicating, the effect of magnetite-series. On contrary, the majority of granitoids in Ladakh arc marks considerably high susceptibility values which are related to the magnetite-series. This discrepancy between two terranes is probably related to different type of magmatism for each island arc in the Cretaceous-Tertiary time.

Key words: Granitoid, magnetic susceptibility, Kohistan, Ladakh, island arc.

K/101. Khalid, A., 1981-83. *Geology of Northern Hunza*. M.Sc. Thesis, Punjab University, Lahore, 94p.

This report describes the results of the geological studies in Passu area Upper Hunza Valley, Gilgit Agency.

A geological map on scale of 1:250,000 is prepared with main outcrops of granodiorite, limestone, dolomite and slates. The micro-paleontological description of the area is brief, as there is no findings of any fossil by us in given area. The petrographic analysis of these rock units is reported in detail. The petrogenesis (Texture, Mineralogy General description) of these rock units have also been discussed.

Along with the petrographic description the tectonic evolution of Karakoram, stratigraphy and structure of the Karakoram, paleogeography is also discussed. Regional (Lower grade) metamorphic has produced slates from shales and fine-grained dolomite as well as limestone. It is assumed that fossils have been crystallized due to metamorphism. Intense tectonic disturbance is evident from the frequent occurrence of strained and crushing effects on the minerals. The area shows the evidence of extensive mountain glaciation in the Quaternary and glacial deposits are common features due to the presence of huge glaciers.

Key words: Micropaleontology, texture, petrography, glaciation, Hunza.

K/102. Khalid, M., Fayaz, A. & Tahir, A., 1975. Geology of Timurgara area, Dir district. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Timargara, Dir.

K/103. Khalid, S. & Bukhari, S.W., 1999. Case history of Meyal Oil Field in Potwar Plateau of upper Indus Basin. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Hydrocarbons, Meyal oilfield, Potwar.

K/104. Khalil, I.U., Khalil, M.J., Zai, J.K.M. & Khalil, I.H., 1988. General geology of Nizampur area, District Peshawar. M.Sc. Thesis, University of Peshawar.

Key words: Geology, Nizampur, Nowshera.

K/105. Khalil, M.A. & Afridi, A.G.K., 1973. Geology of Deshai-Diwangar area, Ushu Gol Valley, Swat Kohistan, NWFP, Pakistan. M.Sc. Thesis Peshawar University, 42p.

For details consult the following account.

Key words: Petrography, metasediments, Usho Gol, Kohistan, Swat.

K/106. Khalil, M.A. & Afridi, A.G.K., 1979. The geology and petrography of Deshai-Diwangar area, Ushu Gol Valley, Swat Kohistan. Geological Bulletin, University of Peshawar 11, 99-111.

This paper presents a geological map, petrography and structure of about 160 sq. km of Deshai-Diwangar area, Swat Kohistan. The area consists of metasedimentary rocks (? Paleozoic to Mesozoic), intruded by Tertiary Plutonic igneous rocks. The plutonic rocks consist of gneissose-quartz diorites, orbicular diorites, and quartz diorites of Early to Middle Tertiary period. The Early Tertiary gneissose quartz diorites are intruded by Diwangar Granite (? Middle Tertiary). Locally, small granitic intrusions and veins of a later age than Diwangar Granite are irregularly distributed in the area. Pegmatites and aplites are associated with all types of rocks.

Structurally the area is not very complex. A main fault runs along the Ushu Valley and is older than the Diwangar granite.

Key words: Petrography, metasediments, Usho Gol, Kohistan, Swat.

K/107. Khaliq, A., 1991. Primary geochemistry and secondary dispersion from gold prospects in the Karakoram and Hindu Kush, northern Pakistan. Ph.D. Thesis, Leicester University.

Key words: Geochemistry, gold prospects, Karakoram, Hindukush.

K/108. Khaliq, A., 1997. Orientation studies for gold and precious metals in Chitral area, Hindu Kush Ranges, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

To find out the best methods for geochemical exploration of gold and precious metals in Karakoram. Himalaya and Hindu Kush. an orientation study based on different sampling techniques. was conducted around the known gold prospect at Shagor in Chitral, N. Pakistan. This study demonstrates that panned-concentrates give superior anomaly/background contrast compared to wet-sieved and dry-sieved stream sediments. In the case of gold, panned-concentrates are not very successful in the present situation because of the presence of fine-grained gold. which

cannot be recovered in panning. However, for other metallic minerals it is very effective. Wet-sieved stream sediments samples give more useful results.

The effectiveness of panned-concentrates in detecting the mineralization is due to the dominance of clastic dispersion and insolubility of many metallic minerals in the cold alkaline river waters. Wet and dry sieved sediments suffer from excessive dilution by silicates. Therefore, panned-concentrates should be used for regional surveys in the mentioned and similar terranes. Nevertheless, panned sampling should be accompanied by wet-sieving if fine-grained gold search is involved.

Key words: Geochemistry, exploration, precious metals, Chitral, Hindukush.

K/109. Khaliq, A. & Ahmad, J., 1997. Hydrogeochemical prospecting for uranium in Peshawar Basin. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A reconnaissance hydrogeochemical survey for uranium search was carried out in the intramountain Peshawar basin. Stratigraphy of sediments filling this basin is not known due to the Pleistocene alluvial cover. Nevertheless, marginal stratigraphy indicates that the alluvial cover is underlain by sediments equivalent to the sediments of Siwalik group since Siwalik group contains sandstone type uranium deposit, a hydrogeochemical survey was undertaken in the basin for comparable mineralization.

A total of 683 groundwater samples were collected from tube-wells from the entire basin at an average of one sample per 4 sq.km. Analytical results of these samples reveal that besides containing high uranium anomalies at Charsadda, Mardan and Swabi the groundwater of Peshawar basin has generally a high uranium (9pph) background value. Moreover, from the close association of uranium with Cu and V, the signature of sandstone type uranium deposits was recognized which probably registers the presence of Siwalik group and/or equivalent sediments beneath the alluvial cover of Peshawar basin.

Key words: Radioactive minerals, hydrogeochemistry, uranium, Peshawar basin.

K/110. Khaliq, A., Butt, K.A. & Ahmad, J., 2000. Hydrogeochemical prospecting for uranium in Peshawar Basin. In: Hussain, S.S. & Akbar, H.D. (eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 193-209.

For details consult the previous account by the same author.

Key words: Hydrogeochemistry, uranium prospecting, Peshawar basin.

K/111. Khaliq, A. & Moon, C.J., 2000a. Orientation studies for gold and precious metals in Chitral area, Hindu Kush Ranges, Northern Pakistan. In: Hussain, S.S. & Akbar, H.D. (eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 89-109.

For further information, consult Khaliq (1997).

Key words: Gold, precious metals, Chitral, Hindukush.

K/112. Khaliq, A. & Moon, C.J., 2000b. Survival factor of uraninite in the major rivers of Gilgit Kohistan, Indus Basin, northern Pakistan. Abstracts, 3rd South Asia Geological Congress, Lahore, 138-139.

Key words: Uraninite, Gilgit River, Indus River.

K/113. Khaliq, A., Moon, C.J. & Ahmad, J., 2001. Pyrite-gold-uraninite association in Indus Basin, Gilgit Kohistan, northern Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 17-18.

The association of pyrite, gold and uraninite is found in Indus basin and most of the major rivers and their tributaries in Gilgit area of Kohistan, including the Hunza valley north of the Indus suture zone. This association is similar to

the mineralization in the Witwatersrand Basin of South Africa, which has been extensively studied and is the best example of paleo-placer gold uraninite deposits (Khaliq, 1991). However, in the Kohistan area of northern Pakistan and in the Indus basin this system has not yet been studied systematically. In this work an attempt has been made to study and examine the factors controlling the dissolution of uraninite and assess its stability as a detrital mineral in recent alluvial sands of the Indus basin. Moreover, the probable sources of pyrite-gold-uraninite assemblage have been discussed.

The distribution of radioactivity, percentage of pyrite and number of gold flakes in different rivers and streams in the region were studied chemically using SEM on panned concentrate samples.

The concentration of pyrite varies in different valleys and some valleys such as Bagrot, Pisan, Shamshal and Hasis valleys (Ishkuman) contain > 45 % pyrite in panned concentrate samples. Pyrite is mostly fresh and occur as euhedral cubes but there are also some grains showing rounded margins, corrosion and alteration. The microprobe study, of pyrite grains from Bagrot valley, shows some high values (several hundred ppm) for gold (Khaliq, 1991).

Gold flakes have different shapes (rounded, tabular, ellipsoidal and irregular) and sizes (<1 mm to >6mm) which probably show different distances they traveled from their sources. Investigations indicate that the radioactive material consists mainly of thorium-uraninite with lesser uraninite, and monazite grains (Khaliq, 1991 and Khaliq & Moon, 2000). Grains of the radioactive minerals are very fresh and show well-defined crystal faces, some have cubic forms with little evidence of corrosion. However, there are few grains which show rounded margins and corrosion. As far as the size is concerned, they are in the very fine-to fine range of the sand size.

Key words: Pyrite, gold, uraninite, Indus basin, Gilgit, Kohistan, Hunza, Indus suture zone.

K/114. Khaliq, A., Moon, C.J. & Khattak, M.U.K., 1997a. Regional geochemical prospecting for minerals in Chitral, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 31.

For details consult the following account.

Key words: Geochemical prospecting, stream sediments, Chitral.

K/115. Khaliq, A., Moon, C.J. & Khattak, M.U.K., 1997b. Regional geochemical prospecting for minerals in Chitral, northern Pakistan. Geological Bulletin, University of Peshawar 30, 191-207.

A comprehensive regional geochemical survey was carried out in Upper Chitral area. This survey was based on panned concentrates sampling techniques, during which a total of 68 samples were collected from most of major rivers and their tributaries covering an area of more than 1000 km².

The aim of this geochemical investigation was to determine metals dispersion, their relation to mineralization, and regional distribution in the drainage system of the area. Our research reveals that Chitral area has a high potential for mineralization. Some valleys contain polymetallic anomalies while others have either precious or base metals.

Strong anomalies of precious and base metals, together with As and Sb were detected in the northernmost part (Tirich Gol valley) of the surveyed area in which the respective ranges of Au, Ag, As, Sb, Cu, Pb, and Zn are 20-2500 ppb, 2-22 ppm, 2-1500 ppm, 1-18 ppm, 50-400 ppm, 100-1200 ppm, and 50-550 ppm. The significant mineral occurrences are found north of Reshun Formation. The central part (Barum, Pasti and Shoghor) of the survey area shows polymetallic signature with significant enrichment of precious metals Au=10-200 ppb, Ag=1-12 ppm, As=10-200 ppm and Sb=1-10 ppm). The southern part, mainly Kafiristan valley, is high in Pb (100-1800 ppm) with some anomalies of Au (1-100 ppb) and Ag (2-17 ppm).

New targets for mineral prospecting were located at several localities of Chitral valley. Important regional structures, such as faults and their significance regarding mineralization were also defined during this investigation.

Key words: Geochemical prospecting, metal dispersion, stream sediments, Chitral.

K/116. Khaliq, A., Moon, C. J. & Khattak, M.U.K., 1998. Gold potential of Northern Pakistan, An Assessment Based on the Results of Geochemical Exploration Survey for Gold in Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 95.

Northern Pakistan, comprised of three geological units; the Asian Plate, the Kohistan arc and the Indian Plate which are separated by major suture zones, offers a high potential for a variety of mineral deposits occurring in similar geological environments elsewhere in the world. Due to its geotectonic history and associated igneous and metamorphic processes the area seems to be very promising for mineral prospecting. The region is a challenging ground for the mineral prospector because of its complex geological environments and geomorphic features.

Orientation studies based on regional panned-concentrates and geochemical exploration surveys were conducted for gold and precious metals in two geologically different terranes of Northern Pakistan. The Chitral area forms part of the Asian Plate and the Gilgit region is part of Kohistan arc sequence. These two are separated from each other by Northern Suture and from Indian Plate by Main Mantle Thrust (MMT).

Our regional survey in Chitral reveals that the area has a high potential for gold mineralization associated with Ag, As and Sb. Gold anomalies of moderate to high nature were detected in various valleys of the area. The mentioned anomalies contain gold ranging from (10-5000) ppb with an average of 380 ppb. Ag, As, and Sb range between 1-21 ppm, 2-1500 ppm and 1-16 ppm respectively. As far as zonation of anomalies is concerned the area north of Shoghor limestone and the Reshun Formation is better prospects than that to the south of it. Strong anomalies were located in Tirich, Barum and Past valleys while moderate anomalies were found in Kafiristan valley.

The regional panned-concentrates survey of Gilgit area (Kohistan arc) demonstrates that many of the valleys contain anomalies of precious metals along with Ag and As. In these anomalies gold ranges from 10-7800 ppb with an average of 700 ppb and the concentrations of Ag and As are in the range of 10-25000 ppb and 2-1400 ppm respectively. In Bagrot valley, however, the concentration of gold ranges from 2-14 ppm which is associated with very high concentration (up to 6000 ppm) of As. Highly anomalous valleys, for precious metals along with silver, arsenic and antimony, are Bagrot, Dainyor, Pisan and Minapin in the area of Gilgit town.

Key words: Geochemical exploration, gold potential, Gilgit, Chitral.

K/117. Khan, A., 1966. Geohydrology of Sangau area. Bulletin 12, Water and Soil Investigation Department Report 47, WAPDA Hydrogeology Directorate, North West Frontier Province, Peshawar.

Key words: Hydrology, Sangau area, NWFP.

K/118. Khan, A., 1987-89. The geology and petrography of Jijal and Patan complexes southeast of Indus River in southern Kohistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 80p.

The project area lies in some parts of Kohistan and Mansehra districts, covering about 150 sq. kms area, including south easterly sides of Jijal and Patan complexes, starting from Karakoram highway spreading up to Pashto village. The work has evolved geological mapping of the area on a scale of 1:50,000. This thesis deals with the geological, petrographical and petrogenetical studies of the Jijal and Patan complexes and their relation with Kayal complex. The project area lies in the frontal part of the Kohistan island arc which covers about 36,000 sq Km area, structurally bounded by sutures named as Main Mantle thrust (MMT) and Main Karakorum thrust (MKT) on its southern and northern sides respectively. The Kohistan arc is intruded by a large number of basic complexes starting from a very primitive Dasu complex up to Jijal complex along with a Kohistan batholith which was intruded at last. Previously, the metamorphosed mafic complexes have been lumped together as an undifferentiated mass called Kamila amphibolite. Now we under the guidance of our supervisors have divided the Kamila amphibolite into three complexes starting from very older Dasu complex down to Kayal complex and last emplaced Patan complex. Dasu complex is the oldest pluton which is highly metamorphosed, intruded in the island arc. Dasu complex is underplated by another pluton the Kayal complex which is metamorphosed.

Key words: Petrography, Jijal, Patan, Kohistan.

K/119. Khan, A., 1992. Origin of abnormal pressure in the Potwar area of northern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 21-22.

The occurrence of highly pressured formations in the earth's crust has been well documented in recent years. This geological phenomenon has caused severe problems in most Petroleum areas of the world with Adhi Field in

Northern Pakistan supposedly the most difficult area to accomplish successful drilling. Statistically nearly one half of all land wells have experienced trouble of one type or another by drilling through abnormally pressured formations. In Northern Pakistan the structures where high pressure sands had resulted in premature abandonments of wells are Adhi, Chak Beli Khan and Bains (Bhangali). Abnormal pressure can be formed by any one of a number of developments. These include among others rapid sedimentation rates, tectonic activities, and salt diapirism. The origin of abnormal pressures in the Potwar area of Northern Pakistan on evidence of data collected from Adhi wells shows no indication typical of undercompacted sediments (rapid sedimentation); thus the abnormal pressure appears of tectonic origin which includes faults communication. The origin of abnormal pressures has been summarised, following a brief account of the area's stratigraphy and general geology anomalies of copper, gold, silver and platinum be studied on regional scale.

Key words: Hydrocarbons, high-pressure formations, Potwar.

K/120. Khan, A., 1998. Mineralogy, petrology and geochemistry of manganese mineralization and associated rocks in Saidgi area, north Waziristan. M.Phil. Thesis, University of Peshawar, 119p.

North Waziristan is dominantly composed of rocks of the Waziristan ophiolitic complex, Indian plate and the quaternary deposits. The ophiolite complex is composed of ultramafics, gabbros, sheeted dikes, pillow lavas, pelagic sediments and plagiographites which are overlain by massive sedimentary sequences. The rocks of the Indian plate are mainly limestone, shale and sandstone of Jurassic to Cretaceous age. The quaternary deposits occur as heterogeneous material of variable size. The Saidgi and Shuidar Mn-deposits are a part of the Waziristan Ophiolitic complex. These deposits are banded and massive in nature and hosted by metachert. In Shuidar area the Mn-ore bodies are generally banded by having Mn-rich layers alternating with the metachert. The Saidgi ore bodies are generally massive in character and are in the form of lenses. The metacherts are finely crystalline, thin to medium bedded hard rocks. These are generally overlying the metavolcanics (pillow basalts) in the study area. Both Saidgi and Shuidar are bodies are having braunite as the Mn-bearing mineral. Braunite and 'cryptocrystalline quartz are the main constituents, however, the Shuidar are bodies have hematite as an additional phase. The chemistry of braunite has similarity with the natural braunite and a/so with that of the Mn-deposits found in ophiolites- else where in the world. The metacherts of both Saidgi and Shuidar areas have similar field and mineralogical characteristics. These are exceedingly microcrystalline aggregates of microcrystalline quartz, chalcedony, and lesser hematite. Chemically the Saidgi Mn-deposits have higher MnO, but lesser SiO₂ and Fe₂O₃ as compared to that of Shuidar Mn-deposits. The Shuidar Mn-deposits, however, have higher amount of trace elements (Cu, Pb, Zn, Ni, Cr, Co) relative to that of Saidgi Mn-deposits. Both these deposits are, characterized by low Fe/Mn ratio. Majority of the major and trace element data fall within the fields defined for hydrothermal Mn-deposits in various discrimination diagrams and, therefore, have no relation with hydrogenous deposits. Metacherts of Saidgi and Shuidar areas are similar in chemical composition. These have Fe/Mn ratio typical of hydrothermal origin. Both Saidgi and Shuidar Mn-deposits are spatially separated from each other but are cogenetic. These were formed by the submarine hydrothermal solution in an ocean floor spreading environment within the Neo-Tethys Ocean. These deposits are, therefore, originated along sea floor spreading centers (Mid-ocean ridges) and are later on abducted on land alongwith the other ophiolitic rocks of the area. This study also suggest that the Saidgi Mn-deposits (~34000 metric tons) are of greater economic importance as compare to the Shuidar Mn deposits.

Key words: Mineralogy, petrology, geochemistry, manganese, Saidgi, north Waziristan.

K/121. Khan, A., Akhtar, K. & Hussain, I., 1987. Geological map of Chhoi (43 C/14), Attock District, Scale 1:50,000. Geological Survey of Pakistan. Map Series IV; Quetta.

Key words: Geological map, Attock.

K/122. Khan, A., Aslam, M. & Khan, R.N., 1995. Regional Geological Map of Jamrud quadrangle, Khyber Agency (Toposheet No. 38 N/8; Scale 1:50,000), NWFP., Pakistan. New Geoscience No. 933 (Old Sheet No. 90), Geological Survey of Pakistan. NWFP. Geological Map Series, vol. III.

Key words: Geological map, Jamrud, Khyber Agency.

K/123. Khan, A., & Aslam, N., 1974. Emerald deposits of Tora Tigga, Mohmand Agency, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 71, 13p.

Key words: Emerald, Tora Tigga, Mohmand Agency.

K/124. Khan, A., & Aslam, N., 1981. Interim program on magnetite occurrence in Buni Zom area, Chitral District, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 111, 15p.

Key words: Magnetite, Economic geology, Buni, Chitral.

K/125. Khan, A., Basir, H.A. & Rehman, S., 1995. Petroleum prospects and hydrocarbon source characterization of Shekhan Formation in Panoba Section, District Kohat. M.Sc. Thesis, University of Peshawar, 50p.

Key words: Hydrocarbons, petroleum prospects, Shekhan Formation, Kohat.

K/126. Khan, A., Din, W. & Shah, M.R., 1982. Preliminary report of the ophiolite occurrences in parts of Waziristan, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 129, 23p.

This report describes the occurrence of ophiolitic rocks in Waziristan and geological map. The lithologies include peridotites, chromitites, gabbros, sheeted dykes, volcanic rocks and pelagic sediments.

Key words: Ophiolite, ultramafics, Waziristan.

K/127. Khan, A., Kumar S. & Siddique, M., 1971. Magnetic and gravity survey of Swat. M. Sc. Thesis, Punjab University, Lahore.

Key words: Gravity survey, magnetic survey, Swat.

K/128. Khan, A., Rehman, F. & Shah, M.R., 1995. Geological map of Khushalgarh (38 O/15). Geological Survey of Pakistan.

Key words: Geological map, Khushalgarh, Kohat.

K/129. Khan, A., Rehman, F., Shah, M.R., Waliullah & Shah, H., 1995. Coal exploration in Hangu area, Kohat, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 601.

Key words: Coal, economic geology, Hangu.

K/130. Khan, A. & Salam, M., 1990. Discovery of a normal Paleozoic rock sequence in the Khyber Agency, NWFP, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p. 36.

The Khyber Agency, erstwhile considered a very complicated area tectonically, presents a rather simple and undisturbed geological picture in the light of the present study.

A normally folded, Paleozoic rock sequence has been identified for the first time in the area. The sequence is more than 28,000 metres thick. The succession has been established on the basis of the study of contact relationship and the structure of the area.

The prevalent concept of pre-folded thrusts and allochthonous blocks has rather poor and insufficient field evidences. Most of the thrust contacts of the previous workers are clearly normal transitional contacts. The argillites of the area are not a single unit but rather represent different geological horizons. The sequence can be presented as a type Section for the Paleozoic Rocks of the NWFP as observed of late.

Key words: Tectonics, Paleozoic, Khyber Agency.

K/131. Khan, A., Shah, A. & Haq, I., 1988. General geology of part of Karak Quadrangle, N.W.F.P. M.Sc. Thesis, University of Peshawar, 28p.

Key words: Structure, lithology, Karak.

K/132. Khan, A. & Shakirullah, 1980. Geology of Ilum Granites and a part of Lower Swat-Buner Schistose Group, District Swat, North West Frontier Province, Pakistan. M.Sc. Thesis, Peshawar University. 83p

Key words: Geology, granites, Ilum, Buner, Swat.

K/133. Khan, A.B., Shah, Z.H. & Naeem, S.M., 1970a. Geology of the Ghundai Sar and vicinity, Jamrud. M.Sc. Thesis, Peshawar University. 73p.

For details consult the following account.

Key words: Paleontology, Jamrud, Khyber Agency.

K/134. Khan, A.B., Shah, Z.H. & Naeem, S.M., 1970b. Geology of the Ghundai Sar and vicinity, Jamrud, Khyber Agency. Geological Bulletin, University of Peshawar 5, 115-130.

The area of investigation lying in the eastern part of the Khyber Pass, between Jamrud and Waran Ghundai, is covered by the formations of the Lower and Upper Palaeozoic ages. They are represented by the Landikotal Slate (? Ordovician-Lower Silurian), the Shagai Limestone (? Middle to Upper Silurian) and Ali Masjid Formation (Upper Silurian to? Lower Carboniferous).

All of these are marine, and clastic sedimentary rocks account for more than two-third of the total thickness of the strata exposed in the area. The Landikotal Slate constitutes as much as ± 6000 feet of clastic sedimentary rocks.

Of all the formations the Ali Masjid Formation is the only fossiliferous formation. It is reefoid, and extensive reef deposits occur in it. *Thamnopora*, *Cladopora*, and *Favosites* are the important tabulate corals. Other fossils present are stromatoporoids, orthoconic cephalopods, byrozoans, brachiopods, and abundant crinoidal stems and columnals. The fossil assemblage indicates an age between Upper Silurian and Lower Devonian. Large-scale metamorphism and dolomitization has occurred, which has resulted in the obliteration of the details of fossils. This has rendered difficult to identify many fossils even at generic level. The effect of metamorphism increases towards north and the reef limestones are converted to marble.

Late Cretaceous and Early Tertiary igneous activity is indicated by the dolerite, gabbro, and (?) microgranite intrusive bodies. Most of these are sills. Dolerite and gabbro sills have mineralized the calcareous phyllites and reef limestones. Extensive and large deposits of soapstone occur within calcareous phyllites and reef limestones (converted to marble). The area is traversed by NS and NW-SE striking thrust faults. In the northeastern part of the area the rocks are folded into a NE plunging syncline. Recent movements have occurred in the area as indicated by elevated terraces and alluvial valleys.

Key words: Stratigraphy, paleontology, Jamrud, Khyber Agency.

K/135. Khan, A.G., Tahirkhelli, T.K. & Altaf, G., 1982. Geology of a section along Main Mantle Thrust, Jijal-Kohistan, Northern Pakistan. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Geology, MMT, Jijal, Kohistan.

K/136. Khan, A.H., 1961. Beneficiation of chromite in West Pakistan. Proceedings, CENTO Symposium on chrome ore, Ankara, 61-72.

Key words: Beneficiation, chromite.

K/137. Khan, A.H., 1992. Phosphate rock exploration in Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.22.

Alive to the significance of phosphates in Pakistan's agronomy, Geological Survey of Pakistan in collaboration with United States Geological Survey, launched a program of exploration in 1956. But in 1966 eminent Phosphate geologists concluded that suitable environment for the deposition of marine phosphate rock had not become available in Pakistan. GSP have not taken serious interest in phosphate exploration since then. Team members of Geological and Mining Consultants were not discouraged and Mr. Ikramuddin Ali discovered high grade commercially workable Cambrian phosphate deposits (1970-71) in Hazara which are being currently exploited. This discovery has by no means exhausted the possibility of finding more deposits in Hazara and elsewhere.

In 1989-90 GMC carried out preliminary phosphate rock exploration for Directorate of Mineral Development, Balochistan and identified extensive phosphatization in basal and top horizons of Cretaceous. Scope of work permitted reconnaissance of only 30% of prospective area. Although huge tonnages of phosphate rock exist the grade averages 4 to 5% with some 28% P₂O₅ showings. While searching for condensed successions, GMC discovered large deposits of bauxite suitable as feedstock in conventional plants. Although Rs 4 billion worth of phosphates are being imported, little interest is being taken in exploration of indigenous resources.

Key words: Phosphate rocks, exploration, Hazara.

K/138. Khan, A.H., 1994. Phosphate rock exploration in Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 297-299.

Consult the preceding account for more information.

Key words: Phosphates rocks, exploration.

K/139. Khan, A.L., 1965. Geology of lower Batrassi and Mansehra, Hazara. M.Sc. Thesis, Punjab University, Lahore, 90p.

Key words: Mapping, Mansehra.

K/140. Khan, A.L., 1977. Ground water conditions in Paharpur area DI Khan. M.Sc. Thesis, University of Peshawar, 44p.

Key words: Groundwater, Paharpur, D.I. Khan.

K/141. Khan, A.M., 1952. A study of the geological structure of the Lower Himalayas of the Hazara and Mardan districts of the North West Frontier Province. 4th Pakistan Science Conference Proceedings part 3, 125-126.

Key words: Structure, geology, Lower Himalaya, Mardan, Hazara.

K/142. Khan, A.M., 1961. Geological history of the Earth, with particular reference to Pakistan. Natural Resources (Karachi University) 1, 27-31.

Key words: Geological history.

K/143. Khan, A.M., 1962. Construction materials of West Pakistan. Proceedings CENTO Symposium on Industrial Rocks and Minerals, Lahore, 334-342.

Key words: Construction material.

K/144. Khan, A.M., 1965. Sedimentary petrography of Siwalik system exposed in Soan syncline, Sihala, Rawalpindi. M.Sc. Thesis, Sind University, Jamshoro.

Key words: Sedimentology, petrography, Soan syncline, siwaliks.

K/145. Khan, A.M. & Ahmad, A.J., 1988. Groundwater condition in Nizampur area, District Peshawar. M.Sc. Thesis, University of Peshawar, 40p.

Key words: Groundwater, Nizampur, Peshawar.

K/146. Khan, A.M. & Ali, M., 1994. A geo-engineering aspect of Swargali-Bakote Muzaffarabad Road Project. Abstracts, Second SEGMIITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, p.17.

The Swargali - Bakote - Muzaffarabad road project covers part of Punjab, NWFP and Azad Kashmir areas and lies in the outer Himalayas occupying the western limb of Hazara - Kashmir Syntaxis. The 98 KM long new alignment traverses on highly rugged mountains terrain, linking about 25 villages and crossing two major rivers; Jhelum and Kunhar. It also shows a relief of about 6000 feet between starting and end point. The geological formation of the project area, ranges in age from Cambrian to Recent and includes sedimentary rocks. The major rock units include Hazara Slates (Cambrian) and Murree Formation (Miocene) that composed of shales, clay and sandstone. The two have been juxtaposed against each other by a major thrust known as Murree Fault. While fixing the alignment the highly unstable Murree Formation and Murree fault have been avoided. Geological comparison between the existing road on left bank of river Jhelum and the proposed alignment on the right bank of river Jhelum shows that the latter is more stable and economically viable.

Keeping in view the nature of terrain and geology, the road has been carefully designed in order to meet the required specifications of geometrics, traffic load and construction economics. One of the most modern software system of highway design, known as MOSS has been utilized to attain optimum accuracy and economy. The rock cut slopes and drainage have also been designed in such a way to provide sustainable stability to the road and to control geological hazards including landslide, mudflow and rockfall.

Key words: Geo-engineering, Jhelum, Kunhar, Muzaffarabad, Azad Kashmir.

K/147. Khan, A.M. & Ali, M., 1996. A geo-engineering aspect of Swargali-Bakote Muzaffarabad Road Project, Pakistan. Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, 163-168.

For details consult the preceding account.

Key words: Geo-engineering, Jhelum, Kunhar, Muzaffarabad.

K/148. Khan, A.M. & Aurangzed, 1991. Gemstone resources of Pakistan. Proceedings, First SEGMIITE Symposium, Peshawar, 39-45.

The gem resources of Pakistan are mostly found in the Himalaya-Karakorum-Hindukush region. The paper describes emerald, ruby, topaz, aquamarine, tourmaline, zircon, garnet, moonstone, chalcedony, and apatite. These occur in a variety of tectonic setup and have been attributed to complex processes.

Key words: Mineral resources, gemstones, Pakistan.

K/149. Khan, A.M. & Khan, M.A., 2001. Landslide and foundation: An assessment of the problem in sub-Himalayan regions of Muzaffarabad, Azad Kashmir. Abstracts, 4th Pakistan Geological Congress, Islamabad, p. 46.

Slope stability problems in Sub-Himalayan regions have been investigated for foundation engineering, road construction, abutments, for housing and retaining walls. A survey has been undertaken to investigate slope stability problems during 1985-1995. The stable and unstable slopes were separated on right and left bank of river Neelum and river Jhelum. Mahor landslides in unstable slopes have been marked in Murree Formation of Miocene age from crown to toe due to nearness of active fault (MBT), pore water pressure, sink holes at crown, undercutting for road widening, shale undercutting by differential weathering and undercutting by river currents. A method for remediation has been suggested for foundations in slopes, load-bearing capacity of rocks and soils based on in situ and laboratory investigations. The bearing capacity of foundations on level ground is higher as compared to the slopping surface depending upon the slope angle, composition of the soil, flooding in the river, moisture content of the soil and earthquake intensity which agitate the rocks and soils underlying the foundations. The foundations in such regions depend simply on local conditions, footing size, proximity to the slope, depth of footing and design geometry.

Key words: Slope stability, landslides, Muzaffarabad, Himalaya, Azad Kashmir.

K/150. Khan, A.M. & Mariano, A.N., 1992. Mineralogical characteristics of Katlang pink topaz: Cathodoluminescence analysis. Abstracts, First South Asia Geological Congress, Islamabad, p.24.

The autoclastic limestone of probably Silurian- Devonian age in Katlang district Mardan, NWFP, hosts highly prized, exclusive variety of natural pink topaz. Under Cathodoluminescence (CU) it shows blue and violet red color and sectoral zoning. The colors are attributed to the presence of crystal defect in tetrahedral position and Cr^{3+} as ion impurity activator that has probably substituted Al^{3+} in the octahedral site. Mass spectrographic analyses, electron microprobe analyses and CL omission spectrum show that Cr^{3+} is directly related to the violet red CL and pink coloration. Proton induced X-ray excitation (PIXI) analyses indicate that combination of Cr^{3+} , V and Ge are diagnostic for Katlang pink topaz. The sectoral zoning is due to F and OH ordering. Variation in color of crystal and co-occurrence of brecciated and idiomorphic crystals in the same rock indicate several episodes of topaz crystallization.

Key words: Mineralogy, gems, topaz, Katlang, Mardan.

K/151. Khan, A.N., 1993. An evaluation of natural hazard reduction policies in developing countries with special reference to Pakistan. Pakistan Journal of Geography 3, 81-100.

Key words: Natural hazards.

K/152. Khan, A.Q., Jamal, Z., Shah, S.W.A. & Ali, A., 1998. Geology of Kohat, Kotal Pass, N.W.F.P., M.Sc. Thesis, University of Peshawar, 54p.

Key words: Geology, Kohat.

K/153. Khan, A.R., 1992-94. Geotechnical studies and geological mapping of Khan Pur Dam Project area. M.Sc. Thesis, Punjab University, Lahore, 83p.

Key words: Geotechnical, Khanpur dam.

K/154. Khan, A.U., Khan, M.M. & Jadoon, K.G., 1990. Selective floatation of lead from the lead zinc ore of Kohistan, Hazara, Pakistan. Proceedings, First SEGMITE Conference on Industrial Minerals, Peshawar, 79-87.

Flotation studies were carried out to update galena in the lead ore of Besham to make it saleable. The important flotation parameters examined were type and dosage of collector, dosage of the depressant, dispersant and frother, conditioning time for collector and depressant and impeller speed. During step-wise optimization of flotation parameters, lead was upgraded from 3.1% to 16% in the first cycle, and from 16% to 26% in the second cycle of flotation.

Key words: Beneficiation, lead-zinc, Kohistan, Hazara.

K/155. Khan, B., 1983. Lead, Zinc and molybdenite mineralization around Besham, Kohistan, North West Frontier Province. 2nd National Seminar on Development of Mineral Resources, Peshawar 1, 4p.

Key words: Base metals, lead-zinc, Besham, Kohistan.

K/156. Khan, B. & Ahmad, N., 1991. General geology of the Kakul phosphate Deposits, Hazara, Pakistan. Proceedings, First SEGMITE Symposium, Peshawar, 51-60.

Phosphorite in the Kakul area occurs in a folded, thrust and faulted succession of Cambrian to Jurassic sediments. The succession forms part of the Garhi Habibullah syncline on the western flank of the Hazara-Kashmir syntaxis, a major structural element of the southern part of Himalaya orogenic belt. The geology of the Kakul area has been complicated by thrusts which are approximately parallel to the strike and has divided the succession into a number of discrete thrust sheets, one phosphorite of Kakul mines and the other Kakul west phosphorite. Mineralization extends along a discontinuous belt for some 2.5 miles to the North West as far as Iambidogi. The depositional environment of the phosphorite at Kakul mine is notably different from that at Kakul west, indicating that large horizontal movements took place along the thrust planes which brought into juxtaposition rocks of widely different facies of phosphorite deposition.

Key words: Geology, phosphate, Kakul, Hazara.

K/157. Khan, B. & Ahmad, W., 1979. Geology of Shewa Shahbaz Garhi area. M.Sc. Thesis, Peshawar University.

Key words: Granite, Shewa Shahbaz Garhi, Mardan.

K/158. Khan, B., Husain, V., Bilqees, R. & Sultan, S., 1992. Correlation of palaeogeography with phosphorites of Pakistan and India. Abstracts, First South Asia Geological Congress, Islamabad, p.21.

The marine phosphorites of Early Cambrian age presently being exploited in Pakistan occur in an area of about 155 km² at the foot of Himalaya in Abbottabad, Hazara. The proved reserves for these deposits (Kakul, Lagarban and Tarnawai) are 8 million tonnes with up to 20 million tonnes of resources known in the area. These phosphorites are associated with dolomite, chert, siltstone and black shales occurring in upper part of the Abbottabad Formation.

The presence of Early Cambrian age is characteristic of these phosphate beds. Hazara phosphorites resemble Birmanian phosphorites, western Rajasthan and Tal phosphorites, Mussoorie, India, in their composition and origin.

due to their close palaeogeographic relationship. All these phosphorites contain carbonate fluorapatite, quartz, dolomite, calcite, clays, pyrite, orthoclase and muscovite. In thin sections, phosphates occur as a variety of nodular clasts, mostly oval, coarse to fine grained, made up of microcrystalline apatite embedded in chertquartz- calcite matrix. All these deposits are of marine origin, occurring in a few inches to several feet thick beds, containing 10-35% P₂O₅.

The palaeontological, geological and geochemical data support the view that Birmania phosphorites and-Hazara phosphate bearing areas were part of an extensive Palaeozoic (Cambrian-Ordovician) sea with undefined boundaries which came into existence through the subsidence of the old prePalaeozoic land surface. Phosphorites in the areas appear from the stratigraphic and petrologic evidence to have formed authigenically at the sediment - water interface, a common mode of formation in ancient deposits.

Key words: Paleogeography, phosphorite, Abbottabad, India, Pakistan.

K/159. Khan, F., Latif, M., Fayaz, A. & Khan, M.S.Z., 1987. Geology and mineral investigations of Hunza-Nagar area, Northern Areas. Geological Survey of Pakistan, Information Release 291, 32p.

Geological mapping and minerals investigation of Hunza and Nagir areas was carried out in May to June 1985. The mapped area is underlain by metasedimentary rocks of Baltit Group, Chalt ophiolitic mélange zone, and igneous rocks of Karakoram Granodiorite along with veins and dykes of both basic and acidic nature, pegmatites and quaternary deposits.

The area is well known for its ruby deposits in the limesilicate marble of Baltit Group. The Baltit Group mostly consists of gneisses, schists quartzite and marble, The Chalt ophiolitic mélange zone consists of schists, phyllites, marble, dolomitic limestone, slates and Cherty conglomerate. The grade of metamorphism increases from west to east with low grade schists, to limesilicate marble of cata zone. The regional metamorphism is caused by intrusion of Karakoram batholith. The two thrust the main Karakoram thrust and Hispar Hunza thrust are the prominent structural features in the mapped area which both runs in the east-west direction.

The Hispar Hunza thrust is intraformational and separates the high grade rocks from the low grade within the Baltit Group. The area does not possess any other, deposits of economic interest except small pegmatites and an alteration zone near Yal area. A total of 7 samples were analyzed from alteration zone which contains 21-1490 PPM Cu, 32 to 310 PPM Mn, 91-301 PPM Zn and only three samples having Ni values from 177-271 PPM. The higher Cu values are due to malachite veins which are present in the zone. The overall values are not so encouraging to suggest further detail work of the area for Cu mineralization.

Key words: Mineral resources, geology, Hunza, Nagar, Karakoram.

K/160. Khan, F., Latif, M. & Khan, R., 1991. Geology and mineral investigation of the Yasin quadrangle, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 494, 19p.

Geological mapping and mineral investigations of Yasin valley were carried out from September to October 1987. The investigated area falls in the Survey of Pakistan topo sheet No. 42 H/7.

The project area is covered by metasedimentary rocks of Darkot group; meta-volcano sedimentary rocks of Yasin group and meta-volcanic rocks of Greenstone complex which were later intruded in multi phases by the Ladakh - Kohistan granitoids. Owing to the presence of the collision boundary zone between the Asiatic Mass and island arc, the rocks of the investigated area are severely disturbed thus resulting in a number of folds and faults.

Key words: Geology, mineral resources, Yasin valley, Gilgit.

K/161. Khan, G., 1983-85. Geotechnical studies for slope stability analysis along Muzaffarabad-Kohala Road. M.Sc. Thesis, Punjab University, Lahore, 90p.

The Muzaffarabad-Kohala road is the main way of transportation between Pakistan and Azad Kashmir. A number of landslides occur along this road which damaged and blocked it for hours and sometimes for days. Due to the vital importance of the road this frequent sliding is unbearable. So this field report is prepared with the aim to study the area in detail and to explore the reasons of sliding.

For the present study the area was mapped, and lithological and structural discontinuities are marked. The major structure is the Jhelum Fault, which extends full length of the project area. Attempts have been made to give an idea about the stability conditions prevailing in different zones. On the basis of existing condition in the field, the area along the road is divided into three types of zones i.e., Stable zone, Potentially unstable zones, Unstable zones.

Samples from potentially unstable and unstable zone were collected for laboratory tests. The purpose of this test was to evaluate the strength parameters which are responsible for driving and resisting moments. This report also includes the study of the factors responsible to activate the sliding process and their economical and practical remedies. Conclusion and recommendations are given in the end.

Key words: Geotechnical, slope stability, Muzaffarabad, Azad Kashmir.

K/162. Khan, G., Khan, H. & Shah, S.A.H., 1998. General geology of a part of Kalachitta Hill Range, South of Nizampur, District Nowshera, N.W.F.P. M.Sc. Thesis, University of Peshawar, 52p.

Key words: Geology, Kalachitta Range, Nizampur, Nowshera.

K/163. Khan, H., Husain, V., Qureshi, K., Pasha, K. & Ahmad, N., 1994. Petromineralogical and geochemical studies of Havelian barite, Hazara, NWFP, Pakistan. Pakistan Journal of Scientific and Industrial Research 37, 10, 414-00.

The epigenetic vein type barite deposits occur at several localities near Havelian in limestone and shale sequence belonging to Eocene age. Barite veins varying in thickness from a few inches to several feet occur in gray colored argillaceous limestone and shale. Thin bands of barite and galena are also seen in some samples. Important minerals occurring along with barite are calcite, quartz and magnesite. In polished sections, galena, pyrite and goethite were also identified. Petrographically, barite occurs in several textural types: massive, crystalline, lath or platy shaped ranging from fine to coarse in size. The BaSO_4 content in Havelian barite samples ranges from 20 to 92%. Major impurities are SiO_2 , CaO , MgO , Fe_2O_3 and Al_2O_3 . Barite deposits in Havelian are structurally controlled vein and cavity filling type deposits. These barite deposits have not been developed and mined systematically. Barite deposits of this district are good in quality and need detailed investigations for determining mineable reserves. The physical and chemical characteristics of Havelian barite show their suitability for paint, paper, rubber, petroleum drilling and chemical industries with or without processing.

Key words: Mineralogy, petrology, geochemistry, barite, Hazara.

K/164. Khan, I., 1990-91. The structure, stratigraphy & petrography of the western limb of Hazara-Kashmir Syntaxis, Mansehra-Dalola area, Hazara, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 74p.

The Mansehra-Dalola area lies on the western limb of Hazara-Kashmir syntaxis (HKS) in Attock Hazara foreland fold-and-thrust belt. The Hazara-Kashmir syntaxis is a regional antiformal structure of vital significance in the geological and tectonic framework of the Western Himalayas. A sequence from Late Proterozoic to Mesozoic has been deformed during the pre-Himalayan and Himalayan orogenies. The western limb of the HKS shows a complex juxtaposition of three tectonostratigraphic zones. These are the Garhi Habibullah-Abbottabad zone, the Panjal zone and the Mansehra zone.

Several diverse lines of evidence including the presence of metamorphic clasts in unmetamorphosed Cambrian conglomerates, angular relation of Cambrian rocks to the older cleavages and hornfelsic overprint in contact aureoles of Cambrian granites on older cleavages establish a distinctively pre-Himalayan orogenic event of late Proterozoic age. The D2 deformation event is related to the first phase of the Himalayan orogeny. It produced large scale south verging recumbent folds. A strong S2 foliation is axial planar to these F2 folds.

The D3 deformation event forms F3 folds. The F3 folds in the area are Garhi Habibullah syncline, Tarkot anticline, Doga syncline and Gali Mohri anticline. These are southeast verging open to tight folds. D3 thrusts are the Panjal fault, Garhi Habibullah fault, Naroka thrust, Lagarban fault and Sattu fault. Near surface backsteepening due to oblique thrusting and more resistant strata is also documented as a later phase of the D3 deformation. During D4 deformation earlier thrusts and axial planes of F3 folds are refolded into broad map-scale northwest plunging F4

folds. The F4 folds are synchronous to the development of NNW plunging antiformal structure of the Hazara-Kashmir syntaxis. The major counter-clockwise movement along the western limb of the syntaxis also produced Rheidberg faults in addition to sinistral-slip along major thrusts.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis, Mansehra, Hazara.

K/165. Khan, I.A., 1968. Northern Chamla and Eastern Buner. M.Sc. Thesis, Punjab University, Lahore, 89p.

Key words: Geology, Chamla, Buner.

K/166. Khan, I.A., 1981. Lithostructural mapping and geology of Murree-Ayubia area, NW Pakistan with special emphasis on sedimentary petrology and petrogenesis. M.Sc. Thesis, Punjab University, Lahore, 217p.

Key words: Lithostructure, sedimentary petrography, petrogenesis, Murree-Ayubia.

K/167. Khan, I.A., 1982-84. Structural studies of Chinar Kot-Galigada Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 87p.

Key words: Structure, Mansehra.

K/168. Khan, I.A., 1991a. Sandstone petrology in relation to provenance, the stratotype Chinji Formation, Siwalik Group, Pakistan. Abstracts, Annual Meeting, Geological Society of America, San Diego, USA, p. A68.

Key words: Petrology, sandstone, Chinji Formation, siwaliks.

K/169. Khan, I.A., 1991b. Patterns of sedimentological variation within the Miocene Siwalik Group, eastern Potwar Plateau, northern Pakistan. Birbal Sahni Birth Centenary Symposium on the Siwalik Basin, Dehradun, India, 23-24.

Key words: Sedimentology, Miocene, Siwaliks, Potwar.

K/170. Khan, I.A., 1992. River systems recorded within the Miocene Siwalik Group, eastern Potwar Plateau, Northern Pakistan. Abstracts, Annual Meeting, Geological Society of America, Cincinnati, USA, p.A352.

Sedimentologic characteristics of paleochannel and overbank deposits are documented in a kilometer-scale coarsening upward succession of the entire Siwalik Group. (Chinji- Nagri- Dhok Pathan and Soan Formations) exposed in Mahesian and Rohtas areas, eastern Potwar plateau, northern Pakistan.

The major channel sandstone bodies are composed of several storeys, stacked both vertically and laterally and represent either single or superimposed channel-belt deposits. The arrangement and internal characteristics of the storeys indicate deposition as bars and channels hills within low sinosity braided channels. Paleochannel reconstruction from channel-belt deposits, within the Chinji Formation indicate widths of 167-500m, depths of 3.5 to 16 m. bend wavelengths of 1.4-4 km and discharge of 600 – 1300 m³/s. larger channels form the Nagri Formation show widths of 200-1300 m, depths of 3-21 m, bend wavelength of 0.7 – 6.2 km and discharge of 300 – 6000 m³/s. relatively smaller channel segments from the Dhok Pathan Formation indicate widths of 114 – 156 m, depths of 3.5 – 6/7 m, bend wavelengths of 0.9 to 1.6 km and discharge of 300 – 1000 m³/s.

Key words: River systems, Miocene, siwaliks, Potwar.

K/171. Khan, I.A., 1993. Evolution of Miocene-Pliocene fluvial paleo-environments in eastern Potwar Plateau, northern Pakistan. Doctoral Dissertation, State University of New York Binghamton, USA. 188p.

The fluvial Miocene-Pliocene Siwalik Group (Nagri, Dhok Pathan and Soan Formations) in the Mahesian and Rohtas areas, eastern Potwar plateau, northern Pakistan, was studied in order to reconstruct the evolution of depositional environments and the controls on this evolution.

The major sandstone bodies are composed of storeys, stacked both vertically and laterally and represent either single or superimposed channel-belt deposits. Internal characteristics of the storeys indicate deposition as bars and channel fills within low sinuosity (1.1-1.2) braided channels which had a braiding index of at least 2 or 3. Individual channel segments in the Lower Nagri Formation had widths of 167-500m, maximum bankfull depths of 7-17m, bend wavelengths of 1.4-4 km and bankfull discharges of 300-1300 m³/s. The discharges of the channel belts in the Nagri Formation were on the order of 1000 m³/s.

Relatively smaller channel segments from the Dhok Pathan Formation had widths of 114-156m, maximum bankfull depths of 6.7m, bend wavelengths of 0.9 to 1.6km and bankfull discharges of 300-1000m³/s. Overbank sandstone bodies have lenticular, wedge, sheet and channel filling geometries and are interpreted as the deposits of crevasse-splays, levees or floodplain drainage channels. Mudstone sequences consist predominantly of finely laminated to disrupted/bioturbated siltstones which show well developed pedogenic features. Mudstones were deposited from episodic, suspended load deposition from slow moving flood flows on broad, low relief floodplains. Comparison of the Siwalik river systems with modern Himalayan river systems suggests their deposition on large sediment fans and interfan areas.

The following vertical variations are observed within the Siwalik Group: 1) major sandstone bodies coarsen from fine to medium sandstone through the Nagri Formation, there is abrupt fining at the base and top of the Dhok Pathan Formation, followed in the Soan Formation by increasing grainsizes of all facies; 2) the proportion of major sandstone bodies generally increases upwards in the Nagri Formation; however, variation in grainsizes and proportion of major sandstone bodies are not correlated in the Dhok Pathan and Soan Formation; 3) thicknesses of major sandstone bodies increase upwards in the Upper Nagri Formation, due to both thicker storeys and more vertically stacked storeys, and decrease at the base and top of the Dhok Pathan Formation; 4) mean paleocurrent orientations are generally towards the southeast; however, they change to southwest in the Upper Nagri Formation and shift towards the south in the Lower Dhok Pathan and Soan Formations; 5) a decrease in sedimentation rate from 0.34 to 0.25 to 0.21 mm/yr in the Nagri, Dhok Pathan and Soan Formations, respectively, corresponds to a decrease in proportion of major sandstone bodies and increase in proportion of mature paleosols. The association of decrease in sedimentation rates with easterly paleocurrents and increase in sedimentation rates with southerly paleocurrents might be related to periodic regional progradation of wedges or lobes of sediment from the Himalayas. Basin-wide increase in sediment accumulation rate, grainsize and proportion of major sandstone bodies, and changes in their composition in the Nagri Formation are associated with tectonic uplift of the Himalayas, progradation of wedges or lobes of sediment to the south and southeast and increasing depositional slope. Variation in eustatic sea-level had no effect on sedimentation of the Siwaliks. The lack of clear variation in paleochannel geometry through the marked climatic-vegetation change around 7.5-6.5 m.yr suggests river discharges were not affected by climatic change.

Key words: Paleo-environments, Miocene, siwaliks, Potwar.

K/172. Khan, I.A., 1994. Alluvial architecture and sandstone petrology of the stratotype Chinji Formation, Siwalik group, northern Pakistan. *Himalayan Geology* 15, 123-141.

The stratotype Chinji Formation (14.0-10.8 ma) is composed of alternating sheet sandstones (active channel deposits) and mudstones (lower energy overbank flow deposits). The stratigraphic details of the Chinji Formation are based upon measurement of three complete vertical logs in the stratotype area and lateral tracing of lithofacies for kilometers. On the basis of sandbody geometry, the sandstones are classified as "sheet", "ribbon", and "shoestring" types. The mudstones are micaceous and sandy and in the lower part of the formation fine upward into claystones. Thirty-eight sandstone samples in the medium sand range, from the base and top of each sandstone, are analysed by point counting for their modal composition. Quartz (14-36%) is subdivided as monocrystalline non-undulatory (47.12%), monocrystalline undulatory (8.19%), polycrystalline with 2-3 crystals per grain (25.57%) and polycrystalline with > 3 crystals per grain (18.35%). The feldspar (4-16%) consists of plagioclase, orthoclase, microcline and perthite. The lithics are composed of sedimentary (3-29%), metamorphic (7-29%) and volcanic (1-

4%) rock fragments. Calcite (7-36%) occurs as allochems (1-9%), intraclasts (1-7%) and cement (2-26%). The relative percentages of quartz types, plotted on a diamond diagram (Basu et al., 1975), indicate that the sandstones are derived from middle and upper rank metamorphic rocks. The QFL (quartz-feldspars-lithics) triangle after Folk (1968) shows that the sandstones are litharenites to feldspathic litharenites. The LsLmLv triangle after Folk (1968) shows that the sandstone are phyllarenites. The volcanic lithics are mostly pyroclastics. The relative abundance of allochem and intraclast calcite suggests that the rivers drained older limestones during this time. A major uplift of the Kohistan arc began about 15 ma ago and its focus has been Nanga Parbat and Hunza region (Zeitler et al., 1982). Kohistan island arc could be a possible source for metamorphic minerals since the time of deposition of the Chinji Formation.

Key words: Sedimentology, Miocene, Chinji Formation, siwaliks, Potwar.

K/173. Khan, I.A., 1995a. Complexity in stratigraphic division of fluvial successions. In: Abstract volume (Dissanayake, C. B., Almond, D. C., and Cooray, P. G., eds.), Second South Asia Geological Congress (GEOSAS-II), Colombo, Sri Lanka, p.240.

Key words: Stratigraphy, fluvial deposits, siwaliks.

K/174. Khan, I.A., 1995b. Controls on evolution of Neogene fluvial environments in the northwestern Himalayan Foreland Basin. In: Abstract volume (Dissanayake, C. B., Almond, D. C., and Cooray, P. G., eds.), Second South Asia Geol. Cong., Colombo, Sri Lanka, p.240.

The Neogene Siwalik Group (Chinji, Nagri, Dhok Pathan and Soan Formations) in the northwestern Himalayan foreland consists of two major 100m-scale coarsening upward sequences. The lower sequence (Chinji and Nagri Formations) records coarsening upward from fine to medium sandstone, followed by basin-wide abrupt fining at the Nagri/Dhok Pathan Formations boundary. Upward coarsening is associated with increases in grain size, clast, thickness, lateral extent and proportion of channel-sandstone bodies. The highest proportion of major channel-sandstone bodies (e.g., upper Nagri Formation) is associated with relatively thick, laterally extensive and interconnected channel-sandstone bodies, which have relatively thicker and vertically superimposed sandstone storeys. These are generally interpreted as superimposed channel-belt deposits. The upward increase in mean grain size (e.g., upper Nagri Formation) is probably associated with a regional increase in alluvial slope, possibly due to progradation of a large alluvial cone. A high proportion of sandstone bodies in the Nagri Formation might be related to increasing numbers of channels in the area, either simultaneously or due to frequent channel avulsions (diversions). Increasing avulsion frequency into an area might be related to preferred tectonic subsidence, intrabasinal faulting (subsurface controls) and/or increased channel-belt deposition rates, possibly related to basin-scale progradation of large active wedges or lobes of sediment to the south and southeast due to orogenic pulses in the orogenic belts. Although the trends in sandstone body proportion over hundreds of meters of strata can be correlated regionally, the local correlation of the 100m cycles suggests a more local cause such as intrabasinal tectonism or fan progradation.

The abrupt fining at the base of the upper 100 m-scale sequence (Dhok Pathan and Soan Formations) is followed by increasing grain sizes of all facies. Basin-wide decrease in sediment accumulation rates from 0.34 to 0.25 to 0.21m/yr through the Nagri, Dhok Pathan, and Soan Formations, respectively, corresponds to a decrease in proportion of major sandstone bodies and an increase in proportion of mature paleosols. Abundance of overbank channels is generally associated with increase in proportion of major channel sandstone bodies and deposition rate, which might be due to a greater tendency towards river diversions.

The basin-wide trends in increase in sediment accumulation rate, grain size and proportion of major sandstone bodies, and changes in their composition, are approximately coeval with a major eustatic lowering of the sea-level (Chinji-Nagri Formations boundary) and subsequent rise (Nagri-Dhok Pathan Formations boundary). There is no sedimentological evidence for climatic change through the Chinji to Dhok Pathan Formations.

Key words: Neogene, foreland basin, Himalaya.

K/175. Khan, I.A., 1996a. Facies architecture of the Siwaliks-field guide (Mahesian guide): Field excursion guide book, Introductory Course on Paleomagnetic and Rock Magnetic Applications in Geological Sciences, Geoscience Laboratory, Geological Survey of Pakistan, 16-35.

Key words: Paleomagnetism, field guide, siwaliks.

K/176. Khan, I.A., 1996b. Diachroneity of Miocene strata in Himalayan foreland basin. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, 67-70.

Key words: Miocene, Foreland basin, Himalaya.

K/177. Khan, I.A., 1996c. Evolution of Neogene fluvial environments in Himalayan foreland basin. Abstracts, 30th International Geological Congress, Beijing, p.162.

Key words: Neogene, Foreland basin, Himalaya.

K/178. Khan, I.A., 1997. Causes of evaluation of Neogene fluvial environments in Himalayan foreland basin. International Colloquium on Geology and Human Life. Pakistan Academy of Geological Sciences, Lahore, 66-67.

Key words: Neogene, Foreland basin, Himalaya.

K/179. Khan, I.A., 1998. Intra- and extra-basinal controls on sedimentation of neogene fluvial sequence in Himalayan foreland basin. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 95-97.

Molassic, fluvial rocks of the Siwalik Group record changing depositional environments in the Himalayan foreland basin. In the Potwar plateau, Chinji, Nagri, Dhok Pathan and Soan formations of this Group comprise relatively thick (tens of meters) sandstone bodies and mudstones that contain thinner sandstone bodies (meters thick) and palaeosols. Thick sandstone bodies extend for kilometers normal to paleoflow, and are composed of sandstone storeys stacked laterally and vertically adjacent to each other. Sandstone bodies represent single or superimposed braided-channel belts, and storeys represent channel bars and fills. Channel belts had widths of km, bankfull discharges on the order of 103 cumecs and braiding parameter up to about 3. Individual channel segments had bankfull widths, maximum depths, and slopes on the order of 102 m, 101 m and 10-4 respectively, and sinuosities around 1.1. These rivers are comparable to many of those flowing over the magafans of the modern Indo-Gangetic basin, and a similar depositional setting is likely. Thin sandstone bodies within mudstones extend laterally for on the order of 102 m and have lobe, wedge, sheet and channel-form geometries. They represent crevasse splays, levees and floodplain channels. Mudstones are relatively bioturbated/disrupted and represent mainly floodbasin and lacustrine deposition. Mudstones and sandstones are extremely disrupted at places, showing evidence of prolonged pedogenesis. These 'mature' palaeosols are meter-scale thick and extend laterally for kilometers. Lateral and vertical variations in the nature of their horizons apparently depend mainly on deposition rate.

The kilometer scale thick Siwalik Group is comprised of two major 100 m scale coarsening upward megasequences. The lower sequence (Chinji and Nagri Formations, Ca 14-9 Ma) records coarsening upwards from fine to medium sandstones, followed by basin-wide abrupt fining at the base of the upper sequence (Dhok Pathan and Soan Formations, Ca 9-2 Ma). The highest proportion of major channel sandstone bodies (upper Nagri Formation) is associated with laterally extensive and interconnected channel-sandstone bodies, which have relatively thicker and vertically superimposed sandstone storeys. Compacted deposition rates decrease with sandstone proportion (0.53 mm/year for Nagri, 0.24 mm/year for Dhok Pathan and 0.21 mm/year for Soan), and palaeosols are not as well developed where deposition rates are high. Within the Siwalik formations there are 100 m-scale variations (representing on the order of 105 years) in the proportion and thickness of thick sandstone bodies, and tens-of-m-scale alternations of thick sandstone bodies and mudstone-sandstone strata that represent on the order of 104 years. Formation-scale stratal variations extend across the Potwar plateau for at least 100 km, although they may be diachronous: however, 100m and smaller scale variations can only be traced laterally for up to tens of milometers.

Alluvial architecture models indicate that increases in the proportion and thickness of thick sandstone bodies can be explained by increasing channel-belt sizes (mainly), average deposition rate and avulsion frequency on a megafan comparable in size to modern examples. 100-m-scale variations in thick sandstone-body proportion and thickness could result from regional shifts in the position of major channels, possibly associated with fan-lobes on a single megafan or with separate megafans. However, such variations could also be related to local changes in subsidence rate or changes in sediment supply to the megafan system.

Formation-scale and 100-m-scale stratal variations are probably associated with interrelated changes in tectonic uplift, sediment supply and basin subsidence. Increased rates of hinterland uplift, sediment supply and basin subsidence, recorded by the Nagri Formation, may have resulted in diversion of a relatively large river to the area. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (possibly related to tectonic uplift). Climate during deposition of the Siwalik Group was monsoonal. Although the Siwalik sequence contains no direct evidence for climate change, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods (e.g. 10.8 Ma, corresponding to the base of the Nagri Formation). If the Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of 10⁴–10⁵ years. Although eustatic sea-level variations are related to global climatic changes, they are not directly related to Siwalik stratigraphic changes, because the shoreline was around 1000 kilometers away during Miocene.

Key words: Fluvial system, sedimentation, molasse, Siwaliks.

K/180. Khan, I.A., 2000a. Controls on variation in sedimentation rates of fluvial facies. Abstracts, 31st International Geological Congress, Rio de Janeiro.

For further information, consult the preceding account.

Key words: Sedimentation, fluvial facies.

K/181. Khan, I.A., 2000b. Fluvial facies complexities in Himalayan foreland basin. Abstracts, Third South Asia Geological Congress, Lahore, 33–35.

Detailed sedimentological variations documented through the Siwalik Group (Chinji, Nagri, Dhok Pathan and Soan formations) in northwestern Himalayan Foreland Basin reveal that kilometer-scale thick depositional succession is comprised of two 100 m-scale coarsening upwards megasequences. The lower megasequence (Chinji and Nagri formations, Ca 14–9 Ma) records coarsening upwards from fine to medium grained sandstones, followed by basin-wide abrupt fining at the base of the upper megasequence Dhok Pathan and Soan formations Ca 9–2 Ma). Upward coarsening is associated with increases in clast, thickness, lateral extent and proportion of channel sandstone bodies. The highest proportion of major channel-sandstone bodies (upper Nagri Formation) is associated with relatively thick, laterally extensive and intercohesed channel-sandstone bodies, which have relatively thicker and vertically superimposed sandstone storeys. Sandstone bodies represent single or superimposed braided-channel belts, and storeys represent channel bars and fills. Channel belts had widths of km, bankful discharges on the order of 10³ cusecs and braiding parameters up to about 3. Individual channel segments had bankful widths, maximum depths and slopes on the order of 10² m, 10 m and 10⁴ respectively, and sinuities around 1.1. Overbank sandstone bodies have lenticular, sheet and channel filling geometries and are interpreted as deposits of floodplain drainage channels. Mudstone sequences consist predominantly of finely laminated to disrupted/bioturbated siltstones which show evidence of prolonged pedogenesis. These "mature" paleosols are meter-scale thick and extend laterally for kilometres. Lateral and vertical variations in the nature of their horizons depend upon sedimentation rate.

Compacted deposition rates decrease with sandstone proportion (0.53 m/year for Nagri, 0.24 m/year for Dhok Pathan and 0.21 m/year for Soan), and paleosols are not as well developed where deposition rates are high. Within the Siwalik formations, there are 100 m-scale variations (representing on the order of 10⁵ years) in the proportion and thickness of thick sandstone bodies and mudstone-sandstone strata that represent on the order of 10⁴ years. Formation-scale stratal variations extend across the Potwar plateau for at least 100 km, although they may be diachronous; however, 100 m and smaller scale variations can only be traced laterally for up to tens of kilometres.

Quantitative and qualitative interpretations of the Siwalik depositional environments modeled through: 1) comparison of the sedimentological characteristics of the strata with computer simulated paleochannels and floodplains; 2) sedimentological correlations between time-equivalent rocks; 3) 3-D alluvial stratigraphy models; reveal that upward coarsening (upper Nagri Formation) is associated with a regional increase in alluvial slope, possibly due to progradation of large alluvial fan. A high proportion of sandstone bodies in the Nagri Formation

might be related to increasing number of channels in the area, either simultaneously or due to frequent channel avulsions (diversions). Increasing avulsion frequency into an area might be related to preferred tectonic subsidence, intrabasinal faulting (subsurface controls) and/or increased channel-belt deposition rates, possibly, related to preferred basin-scale progradation of alluvial fans to the South and southeast due to orogenic episodes in the orogenic belts. Formation-scale and 100 m-scale stratal variations are probably associated with interrelated changes in tectonic uplift, sediment supply and basin subsidence. Climate during deposition of the Siwalik Group was monsoonal. Although the Siwalik sequence contains no direct evidence for climate change, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods. If the Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of 10^4 to 10^5 years. Although eustatic sea-level variations are related to global climatic changes, they are not directly related to Siwalik stratigraphic changes, because the shoreline was around 1000 kilometres away during Miocene; however, basin-wide trends in increase in sedimentation rate, grain size, proportion of sandstone bodies and changes in composition of sandstones are coeval with a major eustatic fall of the sea-level (Chinji-Nagri formations boundary) and subsequent rise (Nagri-Dhok Pathan formations boundary).

Key words: Sedimentation, fluvial facies, Siwaliks.

K/182. Khan, I.A., Bridge, J.S., Kappelman, J. & Wilson, R., 1997. Evolution of Miocene fluvial environments, eastern Potwar Plateau, northern Pakistan. *Sedimentology* 44, 221-251.

The Miocene-Pliocene Siwalik Group records changing fluvial environments in the Himalayan foreland basin. The Nagri and Dhok Pathan Formations of this Group in the eastern Potwar Plateau, northern Pakistan, comprise relatively thick (tens of metres) sandstone bodies and mudstones that contain thinner sandstone bodies (metres thick) and palaeosols. Thick sandstone bodies extend for kilometres normal to palaeoflow, and are composed of large-scale stratsets (storeys) stacked laterally and vertically adjacent to each other. Sandstone bodies represent single or superimposed braided-channel belts, and large-scale stratsets represent channel bars and fills. Channel belts had widths of km, bankfull discharges on the order of 10^3 cumecs and braiding parameter up to about 3. Individual channel segments had bankfull widths, maximum depths, and slopes on the order of 102 m, 101 m and 10–4 respectively, and sinuities around 1-1. These rivers are comparable to many of those flowing over the megafans of the modern Indo-Gangetic basin, and a similar depositional setting is likely. Thin sandstone bodies within mudstone sequences extend laterally for on the order of 102 m and have lobe, wedge, sheet and channel-form geometries: they represent crevasse splays, levees and floodplain channels. Mudstones are relatively bioturbated/disrupted and represent mainly floodbasin and lacustrine deposition. Mudstones and sandstones are extremely disrupted in places, showing evidence of prolonged pedogenesis. These ‘mature’ palaeosols are m thick and extend laterally for km. Lateral and vertical variations in the nature of their horizons apparently depend mainly on deposition rate.

The 500 m-thick Nagri Formation has a greater proportion and thicker sandstone bodies than the overlying 700 m-thick Dhok Pathan Formation. The thick sandstone bodies and their large-scale stratsets thicken and coarsen through the Nagri Formation, then thin and fine at the base of the Dhok Pathan Formation. Compacted deposition rates increase with sandstone proportion (0-53 mm/year for Nagri, 0-24 mm/year for Dhok Pathan), and palaeosols are not as well developed where deposition rates are high. Within both formations there are 100 m-scale variations (representing on the order of 105 years) in the proportion and thickness of thick sandstone bodies, and tens-of-m-scale alternations of thick sandstone bodies and mudstone-sandstone strata that represent on the order of 104 years. Formation-scale stratal variations extend across the Potwar Plateau for at least 100 km, although they may be diachronous: however, 100-m and smaller scale variations can only be traced laterally for up to tens of km.

Alluvial architecture models indicate that increases in the proportion and thickness of thick sandstone bodies can be explained by increasing channel-belt sizes (mainly), average deposition rate and avulsion frequency on a megafan comparable in size to modern examples. 100-m-scale variations in thick sandstone-body proportion and thickness could result from ‘regional’ shifts in the position of major channels, possibly associated with ‘fan lobes’ on a single megafan or with separate megafans. However, such variations could also be related to local changes in subsidence rate or changes in sediment supply to the megafan system.

Formation-scale and 100-m-scale stratal variations are probably associated with interrelated changes in tectonic uplift, sediment supply and basin subsidence. Increased rates of hinterland uplift, sediment supply and basin subsidence, recorded by the Nagri Formation, may have resulted in diversion of a relatively large river to the area. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (possibly linked to tectonic uplift). Climate during deposition of the Siwalik Group was monsoonal. Although the deposits contain no *direct* evidence for climate change, independent evidence indicates global cooling

throughout the Miocene, and the possibility of glacial periods (e.g. around 10-8 Ma, corresponding to base of Nagri Formation). If the higher Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of 10⁴-10⁵ years. Although eustatic sea-level changes are related to global climatic change, they are not directly related to Siwalik stratigraphic changes, because the shoreline was many 100 km away during the Miocene.

Key words: Fluvial environments, Miocene, siwaliks, Potwar Plateau.

K/183. Khan, I.A. & Dennell, R.W., 1999. Sedimentological context of Plio-Pleistocene vertebrate assemblages in Pabbi Hills, Pakistan. Abstracts, IGCP 421, North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics, Peshawar Meeting, 14-16.

Key words: Sedimentology, Plio-Pleistocene, vertebrates, siwaliks, Pabbi Hills.

K/184. Khan, I.A., Raza, S.M. & Shah, S.M.I., 1995. Tectonic control on Neogene alluvial architecture in Himalayan foreland basin. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 19-21.

A detailed sedimentological variation through the Neogene Siwalik group is given in this account. This includes Chinji, Nagri, Dhok Pathan and Soan formations. Two major coarsening upward sequences at 100 m scale are described.

Key words: Neogene, Foreland basin, siwaliks, Himalaya.

K/185. Khan, I.A. & Shah, S.M.I., 1997. Evolution of Miocene fluvial environments, eastern Potwar Plateau, northern Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 27-28.

The Miocene-Pliocene Siwalik Group records changing fluvial environments in the Himalayan foreland basin. The Nagri and Dhok Pathan Formations of this Group in the eastern Potwar Plateau, northern Pakistan, comprise relatively thick (tens of m) sandstone bodies and mudstones that contain thinner sandstone bodies (m thick) and paleosols. Thick sandstone bodies extend for km normal to paleoflow, and are composed of large-scale stratsets (storeys) stacked laterally and vertically adjacent to each other. Sandstone bodies represent single or superimposed braided-channel belts, and large-scale stratsets represent channel bars and fills. Channel belts had width of km, bankfull discharges on the order of 10³ cumecs and braiding parameter up to about 3. Individual channel segments had bankfull widths, maximum depths and slopes on the order of 10² m, 10¹ m and 10⁴ respectively, and sinuosity around 1.1. These rivers are comparable to many of those flowing over the megafans of the modern Indo-Gangetic basin, and a similar depositional setting is likely. Thin sandstone bodies within mudstone sequences extend laterally for on the order of 10² m and have lobe, wedge, sheet and channel-form geometries: they represent crevasse splays, levees and floodplain channels. Mudstones are more-or-less bioturbated/disrupted and represent mainly floodbasin and lacustrine deposition. Mudstones and sandstones are extremely disrupted in places, showing evidence of prolonged pedogenesis. These 'mature' paleosols are meters thick and extend laterally for km. Lateral and vertical variations in the nature of their horizons apparently depend mainly on deposition rate.

The 500 m-thick Nagri Formation has a greater proportion and thicker sandstone bodies than the overlying 700 m-thick Dhok Pathan Formation. The thick sandstone bodies and their large-scale stratsets thicken and coarsen through the Nagri Formation, then thin and fine at the base of the Dhok Pathan Formation. Compacted deposition rates increase with sandstone proportion (0.53 mm/yr for Nagri, 0.24 mm/yr for Dhok Pathan), and paleosols are not as well developed where deposition rates are high. Within both formations there are 100 m-scale variations (representing on the order of 10⁵ years) in the proportion and thickness of thick sandstone bodies, and tens-of-m-scale alternations of thick sandstone bodies and mudstone-sandstone strata that represent on the order of 10⁴ years. Formation-scale stratal variations extend across the Potwar Plateau for at least 100 km, although they may be diachronous: however, 100-m and smaller scale variations can only be traced laterally for up to tens of km.

Alluvial architecture models indicate that increases in the proportion and thickness of thick sandstone bodies can be explained by increasing channel-belt sizes (mainly), average deposition rate and avulsion frequency on a megafan

comparable in size to modern examples. 100-m-scale variations in thick sandstone-body proportion and thickness could result from 'regional' shifts in the position of major channels, possibly associated with 'fan lobes' on a single mega fan or with separate mega fans. However, such variations could also be related to local changes in subsidence rate or changes in sediment supply to the megafan system.

Formation-scale and 100-m-scale stratal variations are probably associated with interrelated changes in tectonic uplift, sediment supply and basin subsidence. Increased rates of hinterland uplift, sediment supply and basin subsidence, recorded by the Nagri Formation, may have resulted in diversion of a relatively large river to the area. Alternatively, changing river sizes and sediment supply rates may be related to climate changes affecting the hinterland (possibly linked to tectonic uplift). Climate during deposition of the Siwalik Group was monsoonal. Although the deposits contain no direct evidence for climate change, independent evidence indicates global cooling throughout the Miocene, and the possibility of glacial periods (e.g. around 10.8 Ma, corresponding to base of Nagri Formation). If the higher Himalayas were periodically glaciated, a mechanism would exist for varying sediment supply to megafans on time scales of 10⁴ - 10⁵ years. Although eustatic sea-level changes are related to global climatic change, they are not directly related to Siwalik stratigraphic changes, because the shoreline was many 100 km away during the Miocene.

Key words: Miocene, Foreland basin, Himalaya.

K/186. Khan, I.A., Zaleha, M.J. & Bridge, J.S., 1993. Evaluation of Miocene fluvial environments in northern Pakistan. Abstracts, 5th International Conference on Fluvial Sedimentology, Queensland, p.271.

Key words: Miocene, fluvial environments, siwaliks, Potwar Plateau.

K/187. Khan, I.H., Khan, S.R., Kawai, M. & Suzuki, M., 1991. Discovery of scheelite mineralization in Mansehra area, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release, 481, 15p.

Key words: Gold mineralization, scheelite, Mansehra.

K/188. Khan, I.H., Khan, S.R. & Nakagawa, M., 1995. Occurrence of platinum-group mineral in sulfide ore from Jijal complex, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 12, 5-21.

The study for platinum-group minerals (PGM) was carried out as a part of training for the exploration of these in Jijal and Dargai areas which included the geochemical sampling by stream sediment panning and rock chip media in the areas already proved anomalous in the previous surveys. The ore microscopy and microprobe analyses were conducted for the identification of PGM. The EPMA work included extensive high-speed qualitative analysis of the panned concentrates and the polished rock samples. The sample JO-2 revealed a strange PGM composition in qualitative analysis with Pt, Pd, Te, Fe, S. & Ni elements in it. The PGM was mapped by H-111 system for four elements (Pd, Te, Fe and S) for homogeneity check and the center of the mineral was analyzed by quantitative method.

The PG mineral discovered after this analytical work is the merenskyite-(Pt, Pd)Te, which is first time discovered with the host rock other than Sudbury deposit i.e. primary-type, massive sulfide vein in ultramafics of the Jijal complex. The significance of this discovery is towards the further work for the exploration of PGE deposits in Jijal area. The discovery and association of merenskyite (PGM) is described through this report.

Key words: PGE, sulfide ore, Jijal, Himalaya.

K/189. Khan, I.H., Leghari, A., Khan, L., Khan, F. & Mujtaba, G., 1989. Geology and mineral investigation of Naltar Punial area, Gilgit district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 405, 13p.

Key words: Geology, structure, mineral resources, Gilgit.

K/190. Khan, I.H., Mahmood, F., Naeem, M. & Mohammad, W., 1994. Processing of emerald bearing rocks of Gujar Kili emerald mine by washing and screening. *Pakistan Journal of Scientific and Industrial Research* 37(4), 167-00.

The recovery process of talc and emeralds, contained in the emerald bearing altered talcose schists of Gujar Killi were found to be feasible at the bench and pilot plant scale. The various units required for the washing and screening plant were tested. A detailed investigation of size analysis of the head and ground samples, liberation and association of emerald/gangue particles, pulp density, product size analysis and optimization of grinding were undertaken. A tentative block diagram was developed as a result of laboratory tests. The study conducted for the Gem Stone Corporation of Pakistan is encouraging and can be applied to the mechanical recovery of talc and emerald in the Gujar Killi emerald mine.

Key words: Emerald, talc beneficiation, Swat.

K/191. Khan, I.H. & Qazi, M.A., 1983. Mineralogy, chemistry and beneficiation of adit samples of nepheline syenite. 2nd Seminar on Development on Mineral Resources, Peshawar 3, 9p.

Key words: Mineralogy, chemistry, beneficiation, nepheline syenite, Buner.

K/192. Khan, I.H., Qazi, M.A. & Rauf, A., 1984. Mineralogical studies of Kumhar magnesite and dolomite using XRD and DTA data. Abstracts, First Geological Congress, Lahore, 39-40.

Key words: Mineralogy, magnesite, dolomite, XRD, DTA, Hazara.

K/193. Khan, I.H. & Yoshida, M., 1995. EPMA and mineral magnetic analyses of Paleocene oolitic iron stone, Hazara area, northern Pakistan. In: Khadim, I.M. & Yoshida, M. (eds.), *Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium*, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 13, 81-98.

For more information, consult the following account.

Key words: EPMA, mineralogy, Paleocene, iron ore, Hazara.

K/194. Khan, I.H. & Yoshida, M., 2000. Mineral magnetic and EPMA analyses of oolitic ironstone, Hazara area, North Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 35-36.

The oolitic ironstone, known as the Langrial ore (Khan and Ahmed, 1966) Laterite bed (Latif, 1969) underlying the Paleocene Lockhart Limestone as an unconformity, is distributed widely in Hazara, Kalachita and other areas. This ironstone is investigated by mineral magnetic analyses, mineralogy by XRD and mineral chemistry by EPMA (Electron Probe Micro-Analyzer). Yoshida carried out field sampling in Southern Hazara and mineral magnetic studies. The selected sample collected near Bagnotar village was investigated in detail for mineralogy and chemistry. Two mineral magnetic analysis techniques: TM (thermomagnetic) and IRM (isothermal remnant magnetization) were used to identify the magnetic minerals. The Curie temperatures by TM indicated the presence of goethite, Ti-poor titanomagnetite or magnetite and hematite. Two IRM has shown the presence of high coercive ferromagnetic minerals, hematite/goethite with trace amounts of maghemite or magnetite.

The XRD analyses showed the presence of chamosite, hematite, quartz, goethite and siderite for untreated specimen whereas in heated specimen hematite quartz and little smectite were identified. The exact distribution of these minerals was checked by 6-elements (Ca, Al, Fe, Si, Ti and Mg) for corresponding Ka X-rays mapping using EPMA. On the basis of relative intensity of these, the oolites are classified into three types i) A-type mainly goethite - hematite - titanomagnetite and siderite ooides with very low chamosite, ii) B-type-considered chamosite- hematite-goethite ooides and iii) C-type with high Si-content and negligible other elements; the matrix of this oolite is

composed of chamosite, siderite, calcite and quartz. The first two are considered primary and later as secondary type- These studies revealed that formation of these oolite has passed from wide range of conditions (oxic to anoxic, non-sulphidic methane type) as drowning to starvation conditions existed during deposition in the southern hemisphere close to 10' South. The matrix minerals are mainly of secondary origin.

Key words: EPMA, mineralogy, Paleocene, iron ore, Hazara.

K/195. Khan, I.U., 1990-91. The geology, stratigraphy, sedimentation and micropaleontology of Jabri area District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 106p.

The project area is located in district Haripur (N.W.F.P). It covers about 60 sq. km. It is the part of topographic sheet No.43 G/1 published by Survey of Pakistan at the scale of 1: 50000.

Geological map at the scale 1:12500 of Jabri, Akhora, Faqir Muhammad, Lassan and Dunna Nauri area is presented along with complete record of Pre-Cambrian to Eocene rock units especially, Hazara Formation, Samana Suk Formation, Chichali formation, Lumshiwal Sandstone, Kawagarh Limestone, Margala Hill Limestone, Chorgali Formation, exposed in the area.

On the basis of field observations and petrographic studies the depositional environments of rock units have been interpreted. The formations exhibit varying fauna and lithology and microfacies from bottom to top.

Basal unit i.e. Hazara Formation which is predominantly slates and Samana Suk Formation which is mainly oolitic Limestone and shows shallow marine environment. The Chichali Formation which is dominantly Black slates with Iron Pyrite nodules, is the result of anaerobic conditions (lagoon environments) Glauconitic and ferrogenous Sandstone of Lumshiwal Formation shows open marine shelf environment. Kawagarh Formation possesses mainly, fine grained micritic Limestone, which show deep sea environment. Hangu Formation having laterite Bauxite, limonite, quartzite, red clays, Oolitic Haematitic sandstone and Carbonaceous shales which represent facies change and shows that the area was eroded during that time of deposition and marks unconformity between Cretaceous to lower Paleocene which is the result of regression of the sea for long period.

Lockhart Limestone is mainly nodular, Limestone, medium to fine grained with bituminous smell having shales and marl at various places which shows shallow marine environment. Patala Formation having Khaki shales with fossiliferous Limestone and marl which shows that the environment is shallow marine (Circa littoral sub zone).

Key words: Stratigraphy, sedimentation, palaeontology, Haripur.

K/196. Khan, I.U. & Said, M., 1997. Study of landforms: Techniques and Methodology. A study in stratigraphy south of River Kabul, Peshawar vale. Abstracts, 9th All Pakistan Geographic Conference, Islamabad, p.15.

Key words: Stratigraphy, sedimentation, landforms, Kabul River, Peshawar.

K/197. Khan, J., 1972. Geology of Baraul valley, Dir District. M.Sc. Thesis, University of Peshawar, 42p.

Consult the following account for details.

Key words: Paleocene-Eocene, volcanics, metasedimentary rocks, Dir.

K/198. Khan, J., 1979. Geology of the Baraul valley, Dir. Geological Bulletin, University of Peshawar 11, 153-162.

Over 520 sq. km of the Baraul Valley has been investigated geologically and mapped on 1:63, 360 scale. Quartzites are the oldest rocks, exposed in the eastern part of the valley, and overlain by the mixed series of Paleocene-Eocene age which covers the central part of the area. The series includes interbedded volcanics (andesite, dacite, rhyolite, tuff and agglomerates) and metasedimentary/sedimentary rocks (pelitic, calcareous and arenaceous) intruded by small post-Eocene dioritic rocks. A large part of the valley, in the north as well as the south, occupied by (?) Cretaceous

Eocene diorites, quartz diorites, granodiorites and leucodiorites. The northern contact between the diorites and the mixed series is probably faulted.

Key words: Paleocene-Eocene, volcanics, metasedimentary rocks, Baraul, Dir.

K/199. Khan, J.A., 1981. Geology and petrology of southern Dir with special emphasis on Diorites of the area. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, diorite, Dir.

K/200. Khan, J.A., 1997. Impact of Lahore-Islamabad Motorway on natural and human environment. Abstracts, 9th All Pakistan Geographic Conference, Islamabad, 25-26.

Key words: Environment, motorway.

K/201. Khan, K., 1987. Physiography of Pakistan. In: Shams, F.A., Khan, K. & Mrs. Khalida (eds.), Resources Potential of Mountain Regions of Pakistan, Punjab University, Lahore, 1-7.

Key words: Physiography, Pakistan.

K/202. Khan, K., 1995. Mass erosion in the Central Karakorum Range, northern Pakistan. In: Stellrecht, I. (ed.), Pak-German Workshop on Problems of Comparative High Mountain Research with Regard to the Karakorum, Tubingen, October 12-14, 1992. Tubingen (Culture Area Karakorum, Occasional Papers 2), 44-49.

Key words: Erosion, Karakoram.

K/203. Khan, K. & Ali, T., 1990. Hydrometallurgical method for the recovery of molybdenum from molybdenite ore of Kohistan. Abstracts, First SEGMITE Conference on Industrial Minerals, Peshawar, p.9.

Key words: Molybdenite, ore, beneficiation, Kohistan.

K/204. Khan, K., Mumtaz & Amin, M., 1990. Recovery and separation of lead zinc by acid leaching from Kohistan-Hazara ore. In: Siddiqi, F., Husain, V., Kaifi, Z. & Ghani, A. (eds.), Proceedings, First SEGMITE Conference on Industrial Minerals, March 1990, Peshawar, 92-95.

Different mineral acids were used for the leaching of the Pb-Zn ores. Bench-scale parameters, i.e., effect of acid concentration, temperature and leaching time are set up. The results obtained were encouraging and about 90% separation as well as recovery of lead-zinc was obtained.

Key words: Acid leaching, Pb-Zn deposits, Kohistan.

K/205. Khan, K.S.A., 1980. Pattan Earthquake of December 28, 1974 and reconstruction programme in the effected areas of Swat, Hazara and Kohistan Districts. Geological Survey of Pakistan, Record 47, 35p.

Geological studies were carried out during the field seasons of 1974-76 in Pattan and other areas of Swat and Hazara Kohistan region, Northwest Frontier Province which have been seriously affected by an earthquake of moderate intensity on 28th December 1974. The earthquake completely destroyed the towns of Pattan, Jijal and Dubair and caused large scale destruction in the area. The investigations were aimed at selection of safe and suitable sites for the

construction of model colonies in the region, study of various road alignments to connect the interior regions with the main Karakoram Highway and to examine the suitability of various bridge sites along these roads.

The rock types exposed in the area are Palaeozoic schists, marbles and quartzites, late Cretaceous amphibolites, gabbros, diorites, and early to middle Tertiary granitic rocks and serpentinites. The age of garnet gneiss exposed at Pattan is unknown. From engineering geology point of view, the rocks are heterogeneous in texture and composition, and behave differently under different atmospheric and ground conditions. The sites for the construction of townships at Pattan and Besham were selected after a study of the topography, accessibility, availability of space, earthquake intensity and rock and soil conditions of the area.

Road alignment was studied keeping in view landslide problems and slope stability. Rock and soil conditions guided designing of slope. However, as a general rule the ratio of cuts for slopes at 1 horizontal : 3 vertical to 1 horizontal : 4 vertical were recommended in medium hard to hard rocks and 1 horizontal : 5 vertical in very hard rocks. Gentler slopes were recommended in unconsolidated deposits and weak strata. Benches may be provided at each 8 metre interval. The study of bridge sites over the river Indus at Pattan and Besham require detailed surface and sub-surface investigations.

Key words: Earthquake, Pattan, Swat, Kohistan.

K/206. Khan, K.S.A., 1992. Landslide problems and their control along the Karakoram Highway, Northern Areas, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.19.

Key words: Landslides, KKH, Northern Areas..

K/207. Khan, K.S.A., Babar, M.Z., Khan, I.H. & Shakoor, T., 1986. Landslide investigation at the site of Cereal Diseases Research Institute, Pakistan Agriculture Research Centre, Murree. Geological Survey of Pakistan, Information Release 271.

The C.D.R.I. building is faced with the problem of subsidence and development of cracks in the building compound. The cracks have enlarged in magnitude with the passage of time giving rise to small slip circles on the north and northeast slopes. The Murree Formation, consisting of shale and sandstone, is exposed in the area. It is underlain by thick overburden material forming steep slopes.

The initiation and enlargement of the slide is attributed to the excessive infiltration of rain and snow-melt-water, the lithological characteristics of the sediments and the environmental changes in the natural slopes of the area. Based on the site conditions restraining structures such as retaining and crib walls, spur and catch-water drains are recommended to effectively control the problem of slumping and subsidence.

Key words: Landslides, Murree.

K/208. Khan, K.S.A. & Fayaz, A., 1987. Geological appraisal of Malam Jabba Ski-Lift and tourists resort site Swat, Pakistan. Geological Survey of Pakistan, Information Release 281, 14p.

A geological reconnaissance of the Malam Jabba Tourists Resort site in Swat was carried out in August, 1985 to evaluate the stability of slopes and foundation conditions at various tower positions of the skilift.

The area is underlain by mica and graphitic schists with thick accumulation of overburden material consisting of soil and humus. The bedrock at most of the tower positions is deep and beyond the foundation depth of the towers. The rocks are fractured and highly weathered. The foundations of the towers are designed at a bearing capacity of 1.0 Kg/C m². However, the foundation conditions may be improved by filling of fractures by grouting. The stability of slopes may also be improved by construction of retaining walls and catch-water drains.

Key words: Reconnaissance, mica, graphite schists, Malam Jabba, Swat.

K/209. Khan, K.S.A., Fayaz, A., Hussain, S.H. & Latif, M., 2001. Landslides and their control along the Karakoram Highway (Gilgit to Khunjerab Pass) Vol. I, Geological Survey Pakistan. Special Publication.

Key words: Landslides, KKH, Khunjerab.

K/210. Khan, K.S.A., Fayaz, A. & Khan, I.H., 1988. Construction of gravity irrigation system for Northang Maidan on Indus River, Skardu, Baltistan. Geological Survey of Pakistan, Information Release 365.

Key words: Gravity irrigation, Indus River, Skardu.

K/211. Khan, K.S.A., Fayaz, A. & Latif, M., 1988a. Road alignment studies along Rakhiot-Astor road, District Diamir, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 378, 37p.

On the request of Frontier Works Organization (FWO), road alignment studies were carried out by the Geological Survey of Pakistan along the Rakhiot-Astor Road in 1974 which was followed by detailed geological investigations in 1989. The investigations comprised identification of landslide prone areas and measures for their control and correction, application of slope stabilization techniques and foundation studies for bridge sites. The road passes over a variety of rock and soil material, comprising igneous and metamorphic rocks, loose glacio-fluvial deposits and scree all along its length.

These rock and scree deposits are lying at their critical angle of repose and prone to sliding. Depending upon their angle of repose, stable cutslopes have been proposed. The road crosses three major landslide areas namely Lichar, Shah Pul and Mushkin which need special treatment. Methods for their control and stabilization have been proposed. The road also passes over a number of nullahs which have steep banks and deep channels and need construction of permanent bridges. The foundation conditions for the proposed bridge sites have been studied in detail and recommendations made according to the geological conditions prevailing at each site.

Key words: Road engineering, Raikot, Astor, Nanga Parbat, Diamir.

K/212. Khan, K.S.A., Fayaz, A., Latif, M. & Khan, M.S.Z., 1987. Study of landslide problem along the Rawalpindi–Murree–Kohala Road, (Kashmir Highway). Geological Survey of Pakistan, Information Release 279, 36p.

Landslide Investigations were carried out along the Rawalpindi-Murree-Kohala Road (Kashmir Highway) during the field season of 1984-85 on the request of Highways and Forest Departments, Government of the Punjab. Kashmir Highway is an all-weather road and links the Punjab with Azad Kashmir. Landslide activity often blocks the road and hinders the flow of traffic, particularly in the rainy season. The geotechnical problems of the area were thoroughly investigated and classified according to their mode of origin such as landslides, mudflows and bridge abutment problem.

In all, 14 slides have been studied and discussed in this report, Study of slides includes type of rock/material involved in the affected area, reasons of its occurrence and remedial measures to check them. The Kohala landslide has been studied in detail owing to its critical nature as well as its repeated occurrences involving large amount of falling material and road block. Proper execution and proposed implementation of the recommendations may help a great deal in prompting the stability of the Kashmir Highway.

Key words: Road engineering, landslides, Kashmir highway.

K/213. Khan, K.S.A., Fayaz, A., Latif, M. & Khan, M.S.Z., 1988. Development of cracks in village Danser, Kharmang sub-division, Baltistan. Geological Survey Pakistan. Information Release 276, 14p.

The village of Danser, Kharmang Sub-Division, district Baltistan was badly affected by sliding and slumping during the winter of 1985. The sliding caused heavy damage to the land and property of the people and is still in the process of further enlargement in its area of effectiveness.

Diorite rocks constitute the northern side of the Danser village whereas thick alluvial silt, gravel, and talus compose the southern terrane.

The large scale sliding could be due to the underground caving of terraces as a result of sub-surface flow and channelization of the stream from the Shaheen nullah on the eastern side of the village terraces. The effect of caving accentuates because of the infiltration of surface water from the irrigation “Kouhle” constructed at the contact of loose and porous overburden material and the diorite rock basement.

In view of the active nature of the slide and possibility of its further enlargement, the local people should be evacuated and rehabilitated in safe areas. However, the sliding may partially be controlled by constructing a dyke at the nullah bed level and diverting the flow of Shaheen nullah at its point of entrance under the village terrace. The infiltration from the irrigation “Kouhl” can easily be checked by cementing and lining of the drain.

Key words: Landslides, hazards, cracks, Baltistan.

K/214. Khan, K.S.A., Fayaz, A., Latif, M. & Khan, N.A., 1998. Engineering geological suggestions for improvements of road links in and around Chilas district Diamir, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 673, 36p.

Geological investigations were carried out along various side-valley roads in the Diamir district in 1996. These investigations were aimed at improving the present road conditions in relation to their gradient, slope stabilization, bridge locations and excavation problems to be encountered during widening of these roads.

The following road sections were studied in detail:

1. Chilas-Babusar Pass Road.
2. Nihat Gah Valley Road.
3. Chilas-Buto Gah Road
4. Kiner Gah Valley Road
5. KKH-Gini Gah Road.

The rocks and soils exposed along these roads comprise igneous and metamorphic rocks of various types, glacio-fluvial deposits, and unconsolidated materials consisting of boulders, gravels and scree. These deposits lie at their critical angle of repose and are prone to sliding frequently. The slopes are unstable, road gradients are usually steep and curvatures are difficult to negotiate. All these problems were studied in detail and remedial measures have been suggested for their improvement and stabilization as the case may be.

Key words: Engineering geology, Chilas.

K/215. Khan, K.S.A., Fayaz, A., Latif, M. & Wazir, A.K., 1986. Rock and debris slides between Khunjerab pass and Gilgit along the Karakoram Highway. Geological Survey of Pakistan, Information Release 272, 56p.

Rock, debris and scree slides from Gilgit to Khunjerab pass along the Karakoram Highway (KKH) are discussed in this report. Study of slides include type of rock/material involved in the affected area, reason of their occurrences and remedial measures to check the mass movement phenomenon. Kafir Pahar slide zone, Notorious killing zone and Shita Pari slide are studied in detail due to their critical position on the KKH; and the magnitude and repeated occurrences involving large amount of material fall. Specific recommendations for the stabilization of slopes have been proposed for each of the affected areas.

Continuous maintenance of the KKH requires considerable efforts in terms of time and money. Proper execution and implementation of the recommendations proposed in this report may help a great deal in reducing the manpower and maintenance cost of the KKH.

Key words: Debris slide, Karakoram Highway, Khunjerab Pass, Gilgit, Hunza.

K/216. Khan, K.S.A., Khan, I.H., Leghari, A.L. & Khan, M.S.Z., 1987. Geology along the Karakoram Highway from Hasanabdal to Khunjerab Pass. Geological Survey of Pakistan, Information Release 314, 46p.

Additional information may be seen under the entry KSA Khan et al. (2000b).

Key words: Geology, KKH, Hasanabdal, Khunjerab.

K/217. Khan, K.S.A., Latif, M., Akhtar, J. & Fayaz, A., 1990. River bed erosion problem in Hunza, Ishkuman and Yasin River valleys, Gilgit and Ghizar districts, Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 475, 96p.

Geological investigations for river bed erosion control were carried out during 1989 in Hunza, Ishkuman and Yasin River valleys in the Gilgit and Ghizar districts, Northern Areas Pakistan. The rocks exposed in these valleys comprise mostly metamorphic with small intrusions of igneous rocks and some outcrops of sedimentary rocks especially in the Yasin and Ishkuman valleys. The Hunza valley is characterized by two major Cretaceous-Tertiary granitic belts alternated by metasedimentary rocks and a metavolcanic complex which are known as the Ladakh-Kohistan granitic belt and Karakoram granitic belt. Geomorphologically, these valleys are drained by the Hunza, Ishkuman and Yasin Rivers which are perennial streams and fed by glacial melt waters. These rivers have a general north-south flow direction and are in their youthful stage of development. A much greater length of these rivers are confined by high alluvial/colluvial terraces and valley fill, presumably created by tectonically induced incision during the late Quaternary age. Geomorphologically the main river channels of the area are divided into Straight/Gorge River Channel, Meander River Channel and Braided River channel.

Based on the river capture system and mechanism of meandering 28 plantation sites in the flood plain areas have been identified in Hunza, Ishkuman and Yasin River valleys for channelising stream flow and reducing the large scale river bed erosion. These plantations may help in stabilising the river beds against erosion and add to the fuel, fodder and timber resources of the area in the future.

Key words: Riverbed erosion, Hunza, Ishkuman, Yasin, Gilgit.

K/218. Khan, K.S.A., Latif, M. & Fayaz, A., 1988. Reconnaissance geology along Kharmong valley road, District Baltistan, Geological Survey of Pakistan, Information Release 377.

Key words: Reconnaissance geology, Baltistan.

K/219. Khan, K.S.A., Latif, M. & Fayaz, A., 2000a. Site appraisal of the proposed Rawalpindi Medical College Campus and Hospital, Takht Pari Forest Land, Rawalpindi. Geological Survey of Pakistan, Information Release 713.

Key words: Engineering geology, Rawalpindi

K/220. Khan, K.S.A., Latif, M., Fayaz, A., Khan, N.A. & Khan, M.S.Z., 2000b. Geological road log along the Karakoram Highway from Islamabad to Khunjerab Pass. Geological Survey of Pakistan, Highways Geological Map Series 1.

This is a 1:250,000 scale geological map of the highway stretching for 875-km from Islamabad to Pak-China Boarder at Khunjerab. There are 25 plates (photographs), including three on the covers, showing various aspects of geology and geomorphology. Further data on geography, regional geology, mineral showings, and seismic risk is contained in seven inset maps and two tables.

Key words: Geomorphology, geology, KKH, Islamabad, Khunjerab.

K/221. Khan, K.S.A., Latif, M., Hussain, H. & Fayaz, A., 1999. Geomorphological mapping and engineering geological appraisal of the road links of Skardu-Shigar area, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 693.

Engineering geology investigations for road alignment and geomorphological classification of land forms in the Skardu-Shigar quadrangle was carried out on 1:50,000 scale in 1993.

The Shigar Valley is one of the most picturesque areas in Baltistan and serves as a land route to the K-2, Concordia, Broad Peaks and other famous peaks in the region. The valley is traversed by two roads which run on each side of the Shigar River. These roads are jeepable tracks and pass through a variety of land forms which need slope

correction, improvement of gradients and tackling of engineering geological problems during construction and have been described in detail in the section-wise description of each road.

The rock types ranging in age from Cretaceous to Eocene are exposed in the investigated area and comprise Katzarah formation, Greenstone complex, Deosai Volcanics, and the Yasin Group rocks. The metasediment found in the area are slate, phyllite, schists, gneisses, marble and quartzite. The volcanic rocks are composed of basalt and andesite intersected by felsic and mafic dykes. The main Karakoram Thrust (MKT) is encountered in the vicinity of Tassar village in the upper reaches of Shigar Lungma. Geomorphologically, various types of erosional and depositional land forms are identified and these have been classified into fluvial, aeolian denudational and structural units. This classification may help a great deal in tackling the envisaged problems during construction of the road.

Key words: Geomorphology, geography, engineering geology, Skardu.

K/222. Khan, L.A. & Arif, A.H., 1968. Report on geohydrology investigation in Bannu Basin, West Pakistan. Bulletin 15, Water and Soil Investigation Department, Publication 56, WAPDA, Hydrogeology Directorate, North West Frontier Province, Peshawar.

Key words: Hydrology, geology, Bannu.

K/223. Khan, M., 1995. Engineering properties of some building stones from Peshawar plain, NWFP., Pakistan. M.Phil. Thesis, University of Peshawar, 64p.

Rock types including limestone, marbles, quartzite, granites and basic rocks already in use as building and decorative stones are exposed in the surrounding of Peshawar basin. To ensure their safest use in building and other structure, some important geotechnical properties such as compressive strength, tensile strength, compressive strength/tensile strength, durability, water absorption and specific gravity of the se rocks were carried out. Highest compressive strength values are shown by Misri Banda quartzite and are in the range of 12188 to 18179 PSI, whereas Malakand granite show lowest compressive strength values 4559 to 6422 PSI values. Tensile values are highest in Misri Banda quartzite and Tor Warsak marble. Whereas Tor Warsak marble, Bagh and Malakand granite have lowest tensile strength. Tarako marble and Shewa Shahbaz Garhi granite show highest compressive strength/tensile strength ratio. All the geotechnical properties of these rocks are found to be within or very close to the recommended values of American Standards of Testing Materials (ASTM).

Key words: Geotechnical, limestone, marble, granite, Malakand, Misri banda, Peshawar basin.

K/224. Khan, M., Haider, S. & Ahmad, A., 1990. Investigation of comprehensive strength of some commonly found rocks of N.W.F.P. M.Sc. Thesis, University of Peshawar, 93.

Key words: Geotechnical investigation.

K/225. Khan, M., Riaz, M. & Khan, K., 1996. Extraction of alumina from Nepheline Syenite by sintering with limestone. Pakistan Journal Scientific and Industrial Research, 39, (1–4), 25–31.

Nepheline Syenite of Koga (Lower Swat Area) Pakistan was sintered at 125⁰C with suitable quantity of limestone followed by water leaching for the formation of alkali aluminates which are further processed for the extraction of alumina. Parameters such as particle size variation, ratio of nepheline syenite and limestone, time temperature of sintering and sodium hydroxide concentration were optimized to obtained maximum recovery of alumina. The extraction of alumina on the basis of alumina in Nepheline syenite has been found to be about 70%. Such a process may be of vital importance to countries without ready access to supplies of alumina in the form of bauxite.

Key words: Alumina extraction, nepheline syenite, Lower Swat.

K/226. Khan, M.A., 1968. The stratigraphic section on the southern slop of Handyside Fort, Kohat, West Pakistan. Geological Bulletin, University of Peshawar 3, 15-18.

The area of investigation, which lies on the southern slope of the Handyside Fort, is formed of formations of Upper Mesozoic and Cenozoic ages.

The formation of Upper Mesozoic ages are represented by Oolitic Limestone-Late Jurassic, Green Shale-lower Cretaceous, Sandy-shale and silt-stone Middle Cretaceous, and Limestone- Middle Cretaceous. The formations of Cenozoic age are represented by Nodular limestone-Palaeocene and Gritstone-Conglomerate-shale-Paleocene. Of all the formations, the Gritstone, Conglomerate, and Shale represent deposition under fluvial, fluvio-lacustrine, and lacustrine conditions. The carbonate rocks (mainly limestone) account for more than three-fourth of the total thickness of the strata exposed in the area of investigation. The area is very much disturbed. Intense folding and faulting – which occurred during the Tertiary Era has complicated the stratigraphy and structure of the area.

Key words: Stratigraphy, lithology, Kohat Pass.

K/227. Khan, M.A., 1969. Siluro-Devonian reef complex of Ghundai Sar and vicinity, Jamrud, Khyber Agency. Geological Bulletin, University of Peshawar 4, 79-82.

A Siluro-Devonian 'reef complex', striking east-west, and dipping in a northward direction, is exposed to the north of Jamrud Fort along the Warsak Canal. The 'reef complex' forms the entire Ghundai Sar hills comprises four distinct units.

Gray and yellowish-gray dolomitized quartzite; Reef Breccia and talus; Reef Core; Phyllites and crinoidal limestone. Unit 2 and 3 represent the characteristics structural layers of reef.

Key words: Sedimentology, reef complex, Jamrud, Khyber Agency.

K/228. Khan, M.A., 1970. The Ali Masjid Group, Jamrud, Khyber Agency. Geological Bulletin, University of Peshawar 5, 90-95.

Of all the formations exposed in the north of Jamrud, the Ali Masjid Formation is the most diverse lithologically. A detailed work revealed that the so-called Ali-Masjid Formation contains many well-defined and stratigraphically valid formations. As such the Ali Masjid Formation is considered here as a group. Evidence for this conclusion consists of: The snowy white and grayish-white quartzites, which form the base of the group, are traceable over most of the Khyber Agency, Mulla Gori, and in Hazara. The Kandar Phyllite, a formation of considerable distribution, ranges in thickness from 600 to 900 feet. Both lithologically and paleontologically, it is distinguishable from the underlying and the overlying rocks. The Ghundai Sar Reef, already recognized as the Nowshera Formation (Siluro-Devonian), forms a part of the Ali Masjid Group.

The Quartzite conformably overlying the Nowshera and other reef carbonates and measuring about 600 feet in thickness is recognized as the Misri Banda Quartzite. The Warran Ghundai Formation, about 1200 feet thick, is both lithologically and palaeontologically different from other formations exposed in the area. It represents varieties of environment of deposition.

Key words: Stratigraphy, lithology, Khyber Agency.

K/229. Khan, M.A., 1979a. Petrography and sedimentology of the Ghundai Sar reef complex, Jamrud Khyber Agency: Pakistan. Geological Bulletin, University of Peshawar 12, 32-40.

A belt of Siluro-Devonian Coralline limestone of pink, yellowish-pink, and grayish-white color is exposed in the hills of Gundai Sar, near Jamrud; Khyber Agency. The entire formation represents deposition on a stable shelf. The environments were conducive for the development of coral reef. The ortho-quartzites associated with dolomite and limestone supports this observation.

In this paper, petrography and sedimentology of the reef limestone is discussed in detail. 101 specimens were collected and 30 sections were cut to describe the petrography. The limestone and dolomite show variations in their mineralogical composition. All variations from arenaceous limestone to calcareous ortho-quartzite occur.

Key words: Petrography, sedimentology, reef complex, Jamrud, Khyber Agency.

K/230. Khan, M.A., 1979b. Report on Lithostructural Mapping of the Paras area, Kaghan valley with special emphasis on structure. M.Sc. Thesis, Punjab University, Lahore, 153p.

Key words: Mapping, lithostructure, Kaghan valley.

K/231. Khan, M.A., 1985a. Geology of the Babusar-Thak valley, and its implications on the configuration of the Kohistan island arc sequence. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

Most of the stratigraphic and tectono-metamorphic zonation suggests for the Kohistan arc sequence is based on the geological information collected from the Indus- and Swat valleys, the two most accessible traverses across the Kohistan. The Babusar-Thak valley in the SE Kohistan presents an additional section through the southern half of the arc sequence. Unlike the central and western Kohistan, where the southern arc sequence is principally made of amphibolites (together with enclosed isolated zones of blueschist and bodies of ultramafics) and Chilas ultramafic-mafic complex, in the Babusar-Thak valley the sequence is much more varied. Here the sequence principally comprises a thick pile of low-grade metavolcanics and plutons of diorite, granodiorite composition, bounded on the either side (both in the north and south) by amphibolites. The southern of the amphibolite sequence encloses at least one ultramafic body, and amphibolite sequences encloses at least one ultramafic body, and rests tectonically on the Indian plate metasediments. In the northern amphibolites have a banded appearance similar to the ones in the central Kohistan. These amphibolites have a tectonic contact with the Chilas complex in the north, which is marked by 30m thick shear zone.

The stratigraphic succession of gabbroic to metabasaltic amphibolites, island arc type tholeiite-andesite volcanics and calc-alkaline diorite-granodiorite plutons together with the tectonic contacts with the Indian plate metasediments in the south, and with the Chilas Complex in the north, suggest that the southern Kohistan sequence holds a separate entity within the Kohistan sequence, and may represent yet another island arc.

Key words: Tectonics, metamorphism, Babusar, Kohistan arc.

K/232. Khan, M.A., 1985b. Bibliography of the Geological Survey of Pakistan reports on the North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 133, 16p.

This Bibliography lists contributions of the Geological Survey of Pakistan on the geology of the North West Frontier Province. These are included in the more comprehensive Bibliography on the geology of the province prepared by Khan, Karim and Iqbal (1987; given in the following).

Key words: Bibliography, GSP, NWFP.

K/233. Khan, M.A., 1987. One or two island arcs? Petrochemical and structural data from the Chilas-Babusar area, Kohistan. 3rd Himalayan-Karakoram-Tibet Workshop, Imperial College, London.

Key words: Structure, petrology, geochemistry, Babusar, Thak, Chilas, Kohistan island arc.

K/234. Khan, M.A., 1988. Petrology and structure of the Chilas ultramafic-mafic complex, N. Pakistan. Ph.D. Thesis, University of London.

Key words: Structure, petrology, ultramafics, Chilas, Kohistan island arc.

K/235. Khan, M.A., 1988-90. Geology and structure of Kotli-Nikial Khuiratta Area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 115p.

Geological and structural mapping of Kotli-Nikial-Khuiratta area of about 300 square km was carried on 1:50,000 scale of toposheet No's 43 K/2, 43 K/3, 43 G/11 and 43 G/15 of survey of Pakistan. The lithostratigraphic units described range in age from Pre-Cambrian to Pleistocene and consist mainly of sedimentary rocks. The Pre-Cambrian rock formation is Dogra Slate and Cambrian rock unit is Sirban Formation. In this area apart from Lower Cambrian, all the formations of Paleozoic and Mesozoic are missing. Either they were not deposited or were

weathered to form Bauxite/Fireclay representing an unconformity of a big gap. In the Tertiary period, Patala Formation, Margala Hill Limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy. The rocks are folded and faulted comprising the major and minor structures of the area. The major folds of the area are khairatta-Kohali anticline (11pp/325pp), Devigarh-Palana anticline (04pp/313p), Tattapani-Karela anticline (6pp/116pp) and Khad-Bahni syncline (6pp/228pp). The major fault is the Himalayan Frontal Thrust with minor thrust like Gala Thrust and Khad Thrust. Deformational events and stereographic projection of the area have been interpreted. The tectonic setup has been also discussed. About eighty five rock samples were taken from the field and carried back to the laboratory for petrographic studies. In the field of economic geology, a number of deposits including Fireclay, Bauxite, Coal, Limestone, Chalk and Dolomite are of economic interest.

Key words: Mapping, structure, Azad Kashmir.

K/236. Khan, M.A., 1991. Economic evaluation of decorative stones of Neelum Valley, Azad Kashmir. Proceedings, First SEGMITE Symposium, Peshawar, 8-16.

Key words: Economic, decorative stones, Neelum valley, Azad Kashmir.

K/237. Khan, M.A., 1990-92. Sedimentary Petrology/sedimentology of Paleocene Hangu Formation and lithostructural mapping of Changla Gali Area in Galiat region, Hazara, Northern Pakistan. M.Sc. Thesis, Punjab University, Lahore, 97p.

A Comprehensive study of Geology and structure of Chhangla Gali area is, presented along with special constraints on the sedimentology of Hangu Formation. Large scale (1: 7000) Geological mapping of a small segment of the Lesser Himalaya in the Chhangla Gali area is presented. The lithostratigraphic unit range from Upper Jurassic to Upper Eocene, Samanasuk Formation being the oldest. Structurally the area comprises NE-SW trending double plunging folds constituting anticlinoria and synclinoria. The folds are tight to isoclinal with a general vergence to the southeast. The folded sequence is disrupted by a number of high angle dip slip strike faults especially within or on the margins of anticlinoria. A detailed petrographic study of a section of Hangu Formation that comprises 18 microfacies. The deposition of Hangu Formation took place in humid, arid, subtropical conditions.

Key words: Sedimentology, Paleocene, lithostructure, Hangu Formation, Changla gali, Abbottabad, Hazara.

K/238. Khan, M.A., 1992. Petrology of metamorphic rocks in the Chakdara and Landakai areas, Dir and Swat districts, NWF-Province, Pakistan. M.S. Thesis. University of Iowa, U.S.A., 191p.

Part of the information in this thesis is provided in Khan and Foster (1998, 2000).

Key words: Petrology, metamorphic rocks, Dir, Swat.

K/239. Khan, M.A., 1994. Himalayan orogeny: impact on global climate. Symposium on Environmental Geology. Department of Geology University of Peshawar, p.19.

Key words: Structure, climate, orogeny, Himalaya.

K/240. Khan, M.A., 1995a. Utilization of Kakul and Hazara phosphate resources, North West Frontier Province. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 137-152.

Key words: Phosphates, Kakul, Hazara.

K/241. Khan, M.A., 1995b. Geology and tectonic significance of the Himalayas of N. Pakistan. Published in "Souvenir, International symposium and field workshop on phosphorites and other industrial minerals; SEGMITE-UNESCO joint organization, Abbottabad, Pakistan.

Key words: Tectonics, Himalaya.

K/242. Khan, M.A., 1996a. Kohistan terrain of NW Himalayas of Pakistan: A model for crustal growth through accretion of island arc and back-arc assemblages. Abstract volume 30th International Geological Congress, Beijing, China, Aug. 4-14, 1996. G-2-16 01738 1451, p. 296.

Key words: Crustal growth, Kohistan Island arc, Himalaya.

K/243. Khan, M.A., 1996b. Structural geology of the southern parts of the Nanga Parbat Massif, Higher Himalayas, N. Pakistan. Abstract volume 30th International Geological Congress, Beijing, China.

Key words: Structure, petrology, Nanga Parbat, Himalaya.

K/244. Khan, M.A., 1997a. Bearing capacity of foundations in slopes of sub-Himalaya regions. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 34.

The foundations of important national buildings, bridges, common houses and roads are mainly on slopes. Most of the slopes are destabilized by road widening, active landslides and the presence of faults. All the civil engineering structures are designed without prior investigation of grave landslides, active faults and level of seismicity in the area. This paper describes a method of designing foundations on slopes of cohesionless material such as clays and normally consolidated sandy clays. The method is based on the results of physical centrifuge tests. In order to extend the centrifuge findings under the slope, the results of other model tests were incorporated into the design procedure which is outlined. The method presented, is based on mechanical tests. The bearing capacity of a footing on or near the slope is rated as percentage of the capacity that the same footing would have on the surface of level ground. The use of local experience can determine the safe bearing capacity of reference level ground footing. The designer needs correct data of the tests run on footing of reasonable scale. The method is simple to use and covers the design geometries that are most likely to be met in practice.

Key words: Geotechnical, landslides, slope stability, Sub-Himalaya.

K/245. Khan, MA., 1997b. Slop stability analysis in Higher and Sub-Himalayan regions of Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A biplaner shear lies at a depth of 10-25m below the surface affecting the bridge and highway abutment in northern Pakistan. The overlying rocks are highly cracked, sheared, fractured and jointed. Many landslides occur in thick mass on down dip exposures on shear planes in Himalayan regions. An extensive investigation was undertaken to delineate shear zones and other significant stress creating features such as folds and faults, for further probable slides which would endanger the highway and bridge structures in northern Pakistan. An analysis was made to determine the extent and nature of treatment that would be required to stabilize the rock mass.

Shear nets were used to determine failure modes faced with combinations of joint sets and shear zones. Two dimensional studies were conducted leading to 3d i.e. the wedge angle method. Alternative treatments were conducted on the same slope. A monitoring system was installed to document the initial slope movement and the results obtained from this investigation.

Key words: Slope stability, landslides, Himalaya.

K/246. Khan, M.A., 1997c. Tectonic evolution of southeast Kohistan, Northwest Himalayan Pakistan. Ph.D. Thesis, University of Peshawar, 320p.

The Kohistan island arc terrane in the northwestern Himalayas of N. Pakistan is sandwiched between the Indian and Karakoram plates. Structures related to collision tectonics have exposed more or less a complete crust of the arc terrane from its very base at Moho to its subaerial volcano-sedimentary cover. Within southeastern Kohistan, recent geological mapping along a N-S transect across the lower to middle crustal part of arc terrane, provides new and

important information relating to the magmatic emplacement of the principal units. The base of the arc here, is occupied by a major stratiform ultramafic-gabbroic complex (the Sapat-Babusar complex), which overrides the crust of the Indian plate along the Indus suture (i.e., the Main Mantle Thrust; MMT). The complex was intruded into the base of a thick pile of metavolcanics (the Kamila belt) which comprise a tectonic collage of MORB-type tholeiitic basalts (Jal-Niat amphibolites), island-arc tholeiites (Babusar amphibolites) and calc-alkaline andesites (Sumal amphibolites). The Chilas complex comprising ultramafic and gabbro-norite rocks is also intrusive into the Kamila belt but unlike the Sapat-Babusar complex, it was emplaced onto the top, rather than the base, of the belt. The Kamila belt is intruded by a suite of [1]raniloid rocks (gabbro, gabbro-diorite/tonalite-granodiorite granite and trondhjemite). The first group is closely comparable with the host Jal Niat amphibolites, second group rocks are similar to the subduction-related plutonic rocks from Kohistan (e.g., Kohistan batholith), and the trondhjemites were formed from the partial melting of Jal-Niat amphibolites. The field relations suggest a two-stage history of crustal thickening in lower and middle part of the arc crust. From its initiation at ca. 125-120 Ma until ca. 90 Ma, the arc grew by magmatic emplacement, into its base, of stratiform ultramafic-gabbroic plutonic complexes one below the other. In stage two, the focus of crustal growth shifted upwards from the base of the arc with the emplacement of the Chilas complex on top of the Kamila belt. This stage of crustal thickening was accompanied by crustal shortening associated with 90-80 Ma aged Kohistan-Karakoram collision.

Key words: Tectonics, metamorphism, ultramafics, amphibolites, Kohistan.

K/247. Khan, M.A., 2001. Tectonics of north Pakistan: Consensuses and controversies. Abstracts, 4th Pakistan Geological Congress, Islamabad, 35-37.

North Pakistan is a prime example of continent-island arc-continent collision zone resulting in world's most fascinating mountain ranges of Karakoram, Hindukush and Himalaya. Tectonic evolution of this orogenic belt has remained focus of several national and international research programmes in the past three decades. These studies have greatly enhanced our understanding of orogenic processes and mountain building activity, which in turn, have led to the refinement of metallogenic models. At times, however, detailed studies have revealed several complexities leading to controversies.

Karakoram-Hindukush Block

A consensus has developed regarding plate tectonic position of Karakoram-Hindukush block (KHB) as a microcontinental plate accreted to Eurasia in Late Jurassic. Between Late Jurassic and Middle Cretaceous (~90 Ma), KHB served as an active margin for the subduction of the northern Neotethys, before it was accreted by the Kohistan island arc at its southern margin. The presence of subduction related granitoids (145-90 Ma) of the Karakoram batholith and an absence of marine sedimentation younger than Middle Cretaceous testifies to this plate tectonic scenario. The pre-Middle Cretaceous history of the KHB is recorded in well-preserved and superbly exposed stratigraphy dating back to Ordovician. A pre-Ordovician basement has first time been recorded in KHB directly below the Ordovician and younger cover sequence. Faunal comparisons testify to Gondwanic affinity of the 11KB, its separation from Gondwana in the Permian together with other micro continents like Afghan block and Lahasa, and finally collision with Eurasia in Late Jurassic at the expense of Palaeotethys. Despite a Middle Cretaceous minimum age of collision at the margin of the 11KB, recent radiometric dating shows that much of metamorphism and deformation in KHB is Late Tertiary in age and thus related with Himalayan orogeny. Some of the world's largest batholiths of crustal-melt derived leucogranites of Late Tertiary age form an interesting element in the geology of Karakoram and Hindukush.

Kohistan Island-arc Block

The discovery of blueschists from Shangla, Swat (1970) and recognition of two sutures, Main Mantle Thrust in the south and the Main Karakoram Thrust (now commonly referred to as the Shyok Suture) in the north (1976) led to discovery of Kohistan island arc block between the Indian plate and the KHB. This interpretation has withstood the test of time spanning about three decades. There are, however, still some differences of opinion on details:

The high pressure-temperature Jijal complex crystallized in a deep-seated magma chamber as such, or in a shallow-seated magma chamber that was subsequently subducted to depths of ~50 km? or alternatively, Jijal complex represents a mantle-crust transition? The same applies to the Chilas complex, which is interpreted as cumulates crystallized in a magma chamber or alternatively, a solid state intrusion of the mantle slab?

Kohistan formed as an island arc just offshore of Karakoram just like current example of Japan offshore of China, or it formed within the Neotethys far away from both India and Karakoram? This, in turn, questions the size of ocean separating Kohistan from Karakoram; was it of the size of Sea of Japan or of that of Pacific? Subduction polarity is

another issue; most workers prefer a northward subduction polarity for the origin of Kohistan while Khan et al. propose a southward subduction to explain boninites in Chalt volcanics.

Indian plate

Detailed work in N. Pakistan in past two decades has greatly resolved mysteries of Himalayas. For instance we now know ages of peak metamorphism, phases of magmatism and events of deformation. There is a consensus however, that there is a considerable difference in the Himalayas of N. Pakistan compared to those of India and Nepal. Despite this, attempts to stretch some boundary faults into Pakistani Himalayas generate interest. Main Central Thrust (MCT) is one such debatable issue. Other interesting points still under debate include:

The discovery of eclogites from Kaghan and recent recognition of coesite from these rocks suggest a pressure of ~30 Kbars (~90 km depth). More importantly what tectonic processes brought these rocks back to the earth's surface (exhumation) from such depths in such a short span of 5-8 Ma? The age of rift-related magmatism? Dating by radiometric methods with high closure temperatures (Rb-Sr, U-Pb on Zircon) clearly manifested a Permo-Carboniferous age for rift-related magmatism in Peshawar Plain. Is there still a phase of alkaline magmatism as young as Late Tertiary as suggested by some recent data? Compressional tectonics vs transpressional tectonics? In the context of foreland of Pakistan 'Himalaya, some recent work has stressed role of transpressional tectonics in Kohat Plateau. If so how this tectonic style changes to mainly compressional tectonics in the Potwar Plateau, just across the river? This talk is aimed at highlighting some recent advances made in our understanding of the tectonics of N. Pakistan. In this context some unsolved issues are pinpointed to identify the future course of research in this unique orogenic belt.

Key words: Structure, tectonics, Karakoram, Hindukush, Himalaya.

K/248. Khan, M.A., Abbasi, I.A., Khan, S.R., Hadi, S. & Tariq, M., 2001a. Tectonic subdivision of India-Afghan collision zone, Waziristan-Kurram region, NW Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 37-38.

The India-Afghanistan collision zone exposed in Kurram-Waziristan area of NW Pakistan comprises a stack of thrust sheets derived from various parts of a continental shelf-ocean floor transition formerly located at the NW margin of the Indian plate (Beck et al., 1996). From SW to NE, these thrust sheets include; Waziristan ophiolite, Khaisora nappe of outer shelf sediments, Shahur Tangi-Kahi nappe of deep-marine olistostromal sequence and Isha nappe of inner continental shelf Late Palaeocene and younger shallow-marine and fluvial sediments unconformably overlying the thrust stack and are involved in deformation. Four stages of tectonic evolution are recognized in the Waziristan-Kurram collision zone:

Middle Cretaceous (~90 Ma): An early phase of intraoceanic ophiolite obduction at ~90 Ma gave rise to Shahur Tangi-Kahi group of sediments in a fore-deep setting. This event conforms to a regional Middle Cretaceous orogeny (Semail ophiolites; Kohistan-Karakoram collision; Kamila shear zone, Kohistan).

Early Palaeocene (~65 Ma): A major thrust displaced the extensive nappe of Shahur Tangi-Kahi group eastward onto the entire NW continental shelf of the Indian plate during the Early Palaeocene, contemporaneous with and directly above the syndepositional breccia of Lockhart Formation. A closely following break-back thrusting event involved internal imbrication of the Waziristan ophiolite, thrust emplacement of the Waziristan ophiolite stack eastward onto the outer shelf (Khaisora group) and that of the Khaisora nappe onto the Shahur Tangi-Kahi nappe. This Palaeocene thrust stacking was complete prior to the deposition of Late Palaeocene Patala Formation onto the Shahur Tangi-Kahi group (Thai area), that of the Datakhel Formation on the stacked Waziristan ophiolite, and that of the Ghazij Formation and the younger sediments on the contact between the Isha and Shahur Tangi-Kahi groups (Khajuri Post area).

Post Middle Eocene (~45 Ma): Late Palaeocene-Middle Eocene shallow-marine transgression onto the thrust stack was followed by a major hiatus that marked onset of fluvial sedimentation at the expense of marine sedimentation. Late Miocene Kamliyal Formation in the north (near Thai) and the Pliocene Litra Formation (near Bannu) mark the earliest molasse sediments in this region.

Quaternary (<2 Ma): Molasse sediments in Waziristan-Kurram foreland are uplifted, tilted and folded. An extensive sequence of conglomerates overlying the Litra Formations is tilted to high angles in the foreland region near Bannu, suggesting Holocene (<1 Ma) age for this deformation event. A Quaternary transpressional upright fault brings base of the Shahur Tangi-Kahi group in tectonic contact with Ghazij Formation near Shinki Post (Bannu-Miran Shah road section). In the hinterlands, the Quaternary deformation event may be responsible for large structures of Drasmand and Khadimak antiforms together with associated thrust faults.

Whereas the Middle Cretaceous intraoceanic ophiolite obduction event correlates well with documented tectonic events in Kohistan and Oman, the Early Palaeocene thrust stacking is probably related with a second phase of ophiolite obduction similar to that of Spongtag, Ladakh (Searle et al., 1986), rather than with the India-Eurasia collision (Beck et al., 1996). The tectonic event related with Late Eocene termination of marine sedimentation could be the manifestation of India-Afghan collision in this region that continues into Quaternary due to an oblique collision and associated transpressional deformation.

Key words: Structure, tectonics, Kurram, Waziristan, collision zone.

K/249. Khan, M.A., Abbasi, I.A., Khan, S.R., Hadi, S. & Tariq, M., 2001b. Tectonic collage of transitional crust, India-Afghan collision zone, Waziristan-Kurram region, NW Pakistan. *Journal of Asian Earth Sciences* 19, p.35.

Consult the preceding account for more information.

Key words: Structure, tectonics, Kurram, Waziristan, collision, Cretaceous.

K/250. Khan, M.A., Abdelsalam, M.G. & Stern, R.J., 1997. Polarity of the subduction system for the Cretaceous Kohistan island arc terrain, N. Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 35.

Key words: Polarity, subduction, Cretaceous, Kohistan island arc.

K/251. Khan, M.A., Ahmed, R., Raza, H.A. & Kemal, A., 1986. Geology of petroleum in Kohat-Potwar depression, Pakistan. *American Association of Petroleum Geologists Bulletin*. 70, 396-414

The 36,000-km² Kohat-Potwar depression in northern Pakistan has more than 5,000 m of marine deposition (Precambrian to Eocene, with a major break during Ordovician to Carboniferous). More than 10,000 m of Miocene to Pleistocene alluvial sediments overlies the marine sequence. The tectonic depression formed as a result of continent-to-continent collision at the northwestern margin of the Indian plate. Although the region has been under active petroleum exploration since the mid-nineteenth century, it has been tested by only 60 exploratory wells. Ten oil fields have been discovered; original recoverable reserves total 200 million bbl, of which 112 million bbl has been produced. The region has several attractive features for petroleum generation and accumulation including source-reservoir-trap assemblages and thermal maturity regimes. Total ultimately recoverable hydrocarbon resource of the area is estimated at 2.4 billion bbl of oil equivalent.

Many unexplored surface and subsurface prospects and stratigraphic leads are known. Parts of the region, particularly the Bannu depression and Kohat salt zone, can be regarded as frontier areas; based on the exposed geology and available seismic information, we believe these areas are promising. Recent discoveries of Dakhni field (1983) and Dhurnal field (1984), which were the first discoveries in the northern part of the platform zone of the Potwar plateau, and production from Paleozoic horizons have added new dimension to petroleum prospects of the area. The region needs careful reevaluation of available information, exploratory drilling on selected targets, and detailed exploration in its western part.

Key words: Hydrocarbons, petroleum, geology, Kohat-Potwar.

K/252. Khan, M.A. & Ahmad, W., 1991. Report on SDA mineral activities in NWFP. Directorate of Minerals, Sarhad Development Authority. 64p.

This report gives details of the mineral exploration and mining activities in the subject areas of Sarhad Development Authority.

Key words: Minerals, Sarhad Development Authority.

K/253. Khan, M.A., Ali, K. & Khan, M.A., 1992. Structure in the hanging wall of the Main Boundary Thrust: Examples from the Kohat hill range, N. Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.58.

Key words: Structure, tectonics, MBT, Kohat hills.

K/254. Khan, M.A. & Coward, M. P., 1991. Entrapment of an island arc in collision tectonics: A review of the structural history of the Kohistan arc complex, N. W. Himalayas. *Physics and Chemistry of the Earth*, 17, 1-18.

Key words: Structure, tectonics, Kurram, Waziristan, collision, Cretaceous.

K/255. Khan, M.A. & Din, S.M., 1994. Landslide incidences in western limb of Hazara Kashmir syntaxis. Abstracts, Second SEGMENT International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, p.25.

The northwestern limb of Hazara- Kashmir Syntaxis, is an area of high landslide incidences. The valley system is characterized by steep sided river valleys cut into bed rock and river deposits. The steep slopes, undercutting of the Psammatic and Pilitic slates (Hazara Slates), silty and clayey soils, and humid climate of the area. All this area contributes to landsliding in the region. The situation has been further aggravated by road widening, effects of Main Boundary Thrust (MBT), and seismic activities resulting in many major landslides. Slumping, rock-falls, creep and at places earth-flows or combination of these are most common modes of failure.

The dormant and active landslides were investigated in detail because of their large size and proximity to roadways and residential area. Geological and topographic maps were prepared for each site and soil samples were collected to investigate geotechnical properties involved in failure and to establish stratigraphy of the sites.

In addition to the site investigation, a landslide map of the area was prepared using field reconnaissance and aerial photographs. All slope failures were marked on the map according to their damage severity. A high concentration of slope failure occurs on the western limb of Hazara Kashmir Syntaxis and on the eastern side of Kunhar River. The results indicate that slope failure occurs due to high swelling potential of soils, active faults and shear failures.

Key words: Landslides, MBT, Hazara-Kashmir Syntaxis.

K/256. Khan, M.A. & Foster, C.T., 1998. Geothermobarometry in Landakai and Chakdara areas, Swat and Dir Districts NWF Province Pakistan. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.98.

The Landakai and Chakdara areas, occupy the northern part of the Indian Plate south of the Main Mantle Thrust. The oldest rock unit in the area is the metamorphosed Swat granite gneiss of Cambrian age. The schists, marble and amphibolite exposed in the region are believed to be continental shelf sediments of Silurian-Devonian age which have a tectonic contact with gneisses. The rocks of the MMT/Mingora ophiolitic melange were tectonically emplaced upon the metasediments of the Indian Plate during late Cretaceous to early Tertiary time.

Metamorphism in the area ranges from low to medium grade at relatively high pressure. The rocks exposed north of the Swat River belong to the greenschist facies, whereas rocks exposed south of the river fall in the Kyanite zone of the amphibolite facies. Retrograde metamorphism has affected the area throughout but is more intense north of the river.

Geothermobarometry was carried out in pelites and amphibolites south of the Swat River. Applications of the garnet-biotite geothermometer and garnet-aluminum silicate-plagioclase geobarometer in metapelites gave a T and P range from 535° C, 8.3 kb to 662°C, 11kb. In amphibolites, the garnet-hornblende geothermometer and garnet hornblende-plagioclase geobarometer gave a T and P range from 588°C, 10.8 kb to 705°C, 11.9kb.

Key words: Geothermometry, metamorphic rocks, Dir, Swat.

K/257. Khan, M.A. & Foster, C.T., 2000. Pressure-Temperature estimates in rocks around Landakai area, Swat District, NWF-Province, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.67.

Consult the preceding account for further information.

Key words: P-T estimates, metamorphic rocks, Swat.

K/258. Khan, M.A., Habib, M. & Jan, M.Q., 1985. Ultramafic and mafic rocks of Thurlly Gah and their relationship to the Chilas complex, N. Pakistan. Geological Bulletin, University of Peshawar 18, 83-102.

Detailed field and petrographic studies in Thurlly area substantiate the idea of a two-fold subdivision of the Chilas Complex. Much of the area is occupied by the association of "Main Norites" with subordinate pyroxenites and anorthosites displaying only local layering. Apparently intrusive into these is the association of ultramafic-mafic rocks occurring principally in a 2.5×1 km lensoid body. These possess well-developed sedimentary features, especially layering, and comprise dunite, peridotite, pyroxenites, troctolite, norite, anorthosite, and olivine/pyroxene pegmatites. There are distinct differences in the mineralogy of the two associations, especially in the composition of plagioclase and oxide minerals. It is suggested that the ultramafic-mafic association was derived from a picritic magma emplaced in the floor of a crystallizing (main) noritic magma. There is a strong concordance in the planar structures of the two associations and the crystallization of the ultramafic-mafic rocks apparently preceded all deformational events.

Key words: Ultramafics, Thurlly Gah, Chilas complex, Kohistan, Himalaya.

K/259. Khan, M.A., Hamidullah, S., Khattak, M.U.K., Sayab, M. & Jan, M.Q., 1999. Geology and structure of the south-eastern Nanga Parbat Syntaxis, NW Himalaya, Pakistan. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 83-85.

The Nanga Parbat Syntaxes in N. Pakistan marks a crustal-scale structural bend in Himalaya that is accompanied by an unusually fast exhumation and uplift rate and a phase of Pliocene-Pleistocene regional metamorphism and crustal anatexis that is unique in the tire Himalaya. Despite its significance for understanding collision-related crustal geodynamics, the region has remained poorly mapped, particularly in southern and south-eastern parts, mainly because of the inaccessibility but also due to the location in proximity to the border with Indian Kashmir. In this paper, we present results of our new mapping in south-eastern parts of the Nanga Parbat region. Our observations are based on traverses along the Astor valley and its eastern tributaries (i.e., Gurikot, Rupal and Maiche) and a 40-km traverse across the 4564 m high Shontargali Pass, between the villages of Rattu in the Astor valley and Kel in the Neelum valley.

The Astor Section: Mapping in the Astor valley shows a continuation of the Iskere and Shengus gneiss units (Madin et al., 1989) from the Indus valley. These gneisses occupy the core of the massif, with the Iskere unit in the west and the Shengus unit in the east. The contact between the two, in the Astor valley, passes to the west of the village Harchu and is faulted. Whereas, the Iskere gneiss unit is a grey orthogneiss (quartz, k-feldspar, biotite ± garnet), that is often weakly porphyroclastic and migmatitic, the Shengus unit in Astor is a characteristic pink paragneiss (a reflection of garnet and biotite abundance; kyanite and sillimanite locally present) which contains local calc-silicates and quartzite intercalations. The marginal parts of the syntaxis at both sides (east and west) are occupied by a sequence of metasedimentary rocks. The metasedimentary unit at the eastern margin comprises kyanite-sillimanite-garnet schists and paragneisses (derived from calc-pelites), marbles and calc-silicates and together with common amphibolites, is classified as the Rattu Unit (Tahirkheli, 1988). The metasedimentary succession at the western margin is highly attenuated and comprises siliceous schists, marbles and amphibolites. A thin slice of the Rattu unit is observed in the core of the syntaxis near Mushkin that is closely associated with a sequence of amphibolites, together forming part of a narrow (faulted) syncline. The Astor section contains at least two sets of mylonitic gneisses derived from granites. The Mongdoian mylonitic gneiss is characteristically grey with medium-grained feldspar porphyroclasts and occurs enclosed in the metasedimentary unit at the western margin of the massif, while the Harchu pink mylonitic gneiss occurs at the contact between the Iskere and Shengus gneisses. Additionally, a

granite gneiss with characteristic feldspar laths and a pink mylonitic matrix (the lath unit) intrudes the contact between the Shengus and Rattu units. Finally, there is a weakly porphyritic granite in the Astor section that is apparently undeformed and intrudes the grey Mongdoian mylonitic gneiss at the western margin. A partly undeformed granite of similar general characteristics but an extensive geographic distribution has been noticed at the SW margin of the syntaxis in Bunar area (the Jalhari granite of Edwards et al., 1997). Structurally, the Astor section comprises at least two major antiformal fold structures, with a narrow faulted syncline at Dichilli confluence. The strata near the two margins is overturned (dipping inward to the core of the syntaxis) at topographic higher parts, suggesting outward “ballooning” of the syntaxis through crustal-scale fold structures. At the eastern Nanga Parbat-Ladakh terrane contact in Astor section, we have noticed ultramafic lenses that confirm preservation of the Indus Suture melange.

Gurikot, Rupal and Maiche Sections: Traverses along these western tributaries of the Astor river show a continuation of the geology observed in the Astor section. The part of the Gurikot section we covered includes Indus-suture melange comprising ultramafic lenses set in a matrix of basic mylonites, Rattu Unit, a very attenuated ‘Lath unit’, Shengus unit (large kyanites in pink-paragneisses) and Harchu pink mylonite gneiss unit. The entire sequence in the Gurikot section dips steeply to the west and is overturned. The Rupal section that gives access to most central parts of the syntax is in the SE comprises, from margin inward, Indus Suture mylonite melange, Rattu unit and an attenuated Shengus unit. The core of the massif here is occupied by the Rupal augen gneiss, which is unique to the southern parts of the massif. The dominant fabric (SI) in the Rupal augen gneiss trends E-W (dips 60-80° N) in the core of the massif but changes to NNE-SSW in the east near Tarshing. Strong stretching lineation associated with this fabric plunges shallowly to the NNW. Edwards et al. (1996) interpret SI to be associated with a major shear zone which they term Rupal-Chhichi shear zone. A relatively weaker fabric (S2) is superimposed on SI with a constant attitude of NW-SE /~80° SW. The Rupal augen gneiss contains E-W trending screens (several tens of m wide) of low-grade siliceous schists and quartzites at the ridges flanking the Rupal valley to the north and south (Tahirkheli, 1988; this study). The stratigraphic position and contact field relations of these metasediments are not known.

Rattu-Shontargali-Kel Section: The Rattu unit, in the area to the south of Rupal is bifurcated into two, at the limbs of a north-plunging antiform. The eastern limb of this antiform runs along the Indus suture and the western, along the Chhichi valley. The antiform is cored by grey migmatitic gneisses that resemble the Iskere gneiss, followed by a mixture of pink and grey gneisses (the Shengus unit) and finally the Rattu unit at limbs. The traverse along the Mir Malik River crosses obliquely through this antiformal structure. At Rattu, the Indus Suture melange contains abundant lensoid bodies of ultramafic rocks set in greenschist mylonites. The Rattu unit is well exposed at the lower reaches of the Mir Malik valley that is followed by the pink paragneisses in the Shengus unit. Much of the upper reaches of the Mir Malik valley and the Shontargali Pass comprise grey migmatitic gneisses locally intercalated with coarse-grained marbles, calc-silicates and garnetiferous amphibolite sheets. We correlate these gneisses with the Iskere unit. A thick thrust slice comprising tremolite marbles, calc-silicates, calc-pelitic schists and amphibolites (resembling the Rattu unit) occurs enclosed in the Iskere gneisses in the upper reaches of the Mir Malik valley. The paragneisses resembling Shengus unit reappear on the SW side of the Shontargali Pass in the upper reaches of the Shontar valley. These together with a sequence of tremolite-marble, calcsilicates, calc-pelites and amphibolites (the Rattu unit, locally called Nangimahli Formation; Malik, 1995) dominate the Shontar valley. The NW-verging Shontar thrust (Tahirkheli, 1988) runs along the Shontar valley and thrusts Shengus unit on to the Rattu unit. A tight hangingwall anticline and relatively open syncline that are followed to the NW by another pair of NW-verging anticlines and synclines accompany the Shontar thrust. The Shengus unit is in contact with Rupal augen gneisses both to the NW, in the Sarawali glacier area, and to the SW near Kel.

Discussions: The south-central and southeastern Nanga Parbat syntaxis is divisible into three mappable units, Iskere, Shengus, Rattu, that occur in a “stratigraphic” order. Of these the Iskere unit of grey orthogneisses (often migmatitic) is clearly an Early Proterozoic basement gneiss (Zeitler et al., 1993) while the Rattu unit is metamorphosed cover either of Palaeozoic (equivalent Abbottabad Group; Latif, 1970) or Permo-Triassic (equivalent Panjal Group) age. The Shengus unit is interpreted here to be predominantly metasedimentary and may be equivalent of the Precambrian pelites widespread in Lesser Himalayas of N. Pakistan (e.g., Salkhala, Hazara, Attock slates). The Rupal augen gneiss, the Harchu pink mylonites, Mongdoian grey mylonites, the Lath unit and the Jalhari granite are newly recognised units that owe their origin to granite magmatism of discrete but unknown ages. Structurally the Astor section is dominated by two large, N-plunging antiforms intervened by a narrow faulted synform. This fault possibly joins the Rupal-Chhichi shear zone in the south (Edwards et al., 1996). The NW verging Shontar thrust and related fold structures are reworked by SE-verging Rupal-Chhichi shear zone at the high topographic levels marking the drainage-divide between Rupal and Neelam valleys (Figure 1), which we interpret as the southern limit of the affect of Pliocene-Pleistocene exhumation of Nanga Parbat.

Key words: Mapping, structure, metamorphism, Nanga Parbat, Himalaya.

K/260. Khan, M.A. & Jan, M.Q., 1990. Transition from island arc to intra-arc rift tectonics reflected in successive phases of magmatism in the Chilas Complex, Kohistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 24-25.

Two distinct phases of magmatic activity indicating differences in tectonic setting of magma generation have been recognized in the Chilas Complex. The first and main phase crystallized mainly into homogeneous or weakly layered non-cumulate ultramafic and anorthosite rocks. Detailed evaluation of these rocks suggests that the calc-alkaline parental magma was generated and emplaced during mature stages of arc building in Kohistan. The remarkable the Chilas Complex through its entire extent (approximately 8 km²) suggests a peculiar mode of emplacement prob rough a plume-like up rise of magma body in the core of the aruation indicating a component of extensional environments in later stages of arc building.

The second and youngest phase of magmatism is represented swarm of basic dykes which cut across all the other lithologies present the Chilas Complex. These basic dykes have a fractionation trend indicating greater iron enrichment than the host main-phase gabronorities. Comparatively tholeiitic magma character is also supported by rare-earth elements.

Magmatism in island arcs is normally tholeiitic in the initial stages building, switching to a calc alkaline composition in the mature stages. The reverse trend in the Chilas Complex i.e., from calc alkaline to tholeiitic composition in the successive phases of magma is suggestive of intra-arc rifting of compressional environments re with Kohistan Arc- Karakoram plate collision.

Key words: Ultramafics, tectonics, Island arc, Chilas complex, Kohistan.

K/261. Khan, M.A. & Jan, M.Q., 1991. An interpretation of the Himalaya-Karakoram region of Pakistan in the light of plate tectonics and rock ages. *Pakistan Journal of Geography* 1, 1-23.

This paper presents a brief and simplified review of the concept of plate tectonics, continental drift, and methods of radiometric age determination. An attempt has also been made to present the tectonic and magmatic evolution of the NW Himalaya-Karakoram in the light of recent advances in earth sciences. North Pakistan has experienced a complex interplay of continental collision, magnetism, metamorphism, uplift and erosion. The region is envisaged as consisting of the Karakoram and Indo-Pak plates, both of which represent fragments of the Gondwanaland drifted towards north. Sandwiched between these ii the Kohistan- Ladakh tectonic zone, a late Mesozoic to Early Tertiary island arc.

Key words: Plate tectonics, Himalaya, Karakoram.

K/262. Khan, M.A. & Jan, M.Q., 1992a. Some fundamental field and petrographic aspects of the Chilas mafic-ultramafic complex, Kohistan arc, Northern Pakistan. *Acta Mineralogica Pakistanica* 6, 126-147.

Detailed field and petrographic studies of the Chilas Complex, especially around Chilas, suggest that it is principally made up of gabbro-norites with local pyroxenites, anorthosite, quartz diorites and tonalites. These contain, locally, up to 10 km² lensoid bodies of ultramafic rocks with associated anorthosites, troctolites, olivine gabbros, gabbros and gabbro-norites. These latter are commonly layered and contain excellent sedimentary structures. However, the main gabbro-norites are mostly uniform with only sporadic presence of igneous layering. The complex is remarkably coherent with rare evidence of multiple intrusions, suggesting that most of the crystallization took place in one or a few large, continuous magma chamber(s). The contact relations show that the Chilas Complex intruded into a basement comprising metavolcanic amphibolites and paragneisses. The close association of the Chilas complex with arc-related rocks both in space and time, details of mineral and whole-rock geochemistry (presented elsewhere) and the absence of cyclically layered successions negate the possibility for the complex to have developed in mid-oceanic ridge conditions. The Chilas complex may represent rocks of the magma chamber to the Kohistan Island Arc, more likely, it developed from a mantle diapir in an intra-arc rift, similar to that documented in a number of recent island arcs, e.g., Mariana, Fiji.

Key words: Ultramafics, petrography, Chilas Complex, Kohistan, Himalaya.

K/263. Khan, M.A. & Jan, M.Q., 1992b. Magmatic evolution of the lower island arc crust, Kohistan, N Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Deptt. of Earth Sciences, Oxford University, England, 47.

The Eocene obduction of the Kohistan island arc onto the Indian plate exposed a uniquely complete island arc crust in southern Kohistan. Much of the lower arc crust, exposed in the southern Kohistan, is ultramafic to mafic in composition, and is considered to have formed in an intraoceanic island arc setting. A detailed geochemistry, combined with a limited available radiometric age data, yields a three-stage magmatic evolution of the lower-arc crust in Kohistan.

Tora-Tigga, Jijal, Sapatgali, and Babusar ultramafic-mafic complexes occupy the immediate hangingwall of the Indus suture, and are all characterized by a low-K, high-Mg tholeiite geochemical composition. Rocks of this geochemical character are also encountered in the Kamila amphibolite belt as fine-grained metabasalts, and in the Chalt volcanics in the upper arc crust. This early-arc low-K, high-Mg tholeiitic magmatism took place between 120 to 110 Ma. and marks stage-1 magmatic phase in the Kohistan island arc.

The stage-2 magmatism in Kohistan is typically calc-alkaline and is represented by the Chilas Complex, Pattan garnet-granulites and several smaller plutons intrusive in the Kamila amphibolite belt. Trondhjemitic granites, equivalent to 102 Ma. old Matum Das pluton in Hunza valley intrude the stage-2 basic plutons. Some of the calc-alkaline volcanics in the upper arc crust may be equivalent of this stage-2 magmatic phase. An origin in mature island arc with a component of embryonic stages of intra-arc rifting is envisaged for this phase on the basis of trace-element geochemistry. The stage-3 magmatism in the lower-arc crust in Kohistan marks a reversal back to tholeiitic magmatism. It is represented by the intrusion of ultramafic-mafic-anorthosite association in the Chilas Complex, which is distinctly more depleted in incompatible trace elements than the stage-2 gabbro-norite, and is characterised by an enrichment in FeO and TiO₂. The later phases of stage-3 magmatism is also tholeiitic in character and is represented by a suite of ~80 Ma tholeiitic basic dykes which intrude both the Chilas Complex and the Kamila amphibolites. These dykes, representing the last phase of intra-oceanic magmatism in Kohistan, intruded immediately after a major deformation phase related with Kohistan-Karakoram collision. A tholeiite-calc-alkaline-tholeiite temporal evolution of magmatism in the lower arc crust in Kohistan suggests changing tectonic setting of magma generation, in an intraoceanic environment, from an early-arc, through mature-arc, to back or intra-arc rifting in a span of 40 Ma (between 120 and 80 Ma.), prior to Kohistan-Karakoram collision.

Key words: Magmatic evolution, ultramafics, Indus suture, Kohistan, Himalaya.

K/264. Khan, M.A., Jan, M.Q., Qazi, M.S., Khan, M.A., Shah, Y. & Sajjad A., 1995. Geology of the drainage divide between Kohistan and Kaghan, N. Pakistan. Geological Bulletin, University of Peshawar 28, 65-77.

This paper describes the geology of an area of about 1200 km² in the upper Kaghan valley. The area is traversed by Main Mantle Thrust, which juxtaposes the southern part of the Kohistan terrane in tectonic contact with the higher Himalayas of the Indian plate. The Indian-plate sequence in the study area comprises a basement of granitic gneisses (both ortho- and paragneisses) followed by the Domel unit (calcareous schist/paragneisses, garnetiferous marbles, calc silicates and amphibolites) and the Parla Sapat unit (graphitic quartz-mica to garnet staurolite schists). These rocks are in tectonic contact with the mafic-ultramafic rocks of the Sapat complex along the Main Mantle Thrust. The Sapat complex underplates metabasalts of the Kamila amphibolite belts (i.e., Niat metavolcanic unit) and comprises ultramafic cumulates (dunites, peridotites and pyroxenites) at the base, layered gabbros in the middle and isotropic gabbros in the upper levels. The complex is folded through two phases of folding and metamorphosed under greenschist/lower amphibolite facies. The restored thickness of the complex approaches in excess of 2 kms. The Main Mantle Thrust was mapped at several new locations during this study. Our observations show that the MMT at the base of the Sapat complex is younger than the melange /olistostorm preserved in the upper parts of the Parla Sapat unit. The thrust cuts upsection laterally, and to the east of Babusar, occurs at the base of the Niat metavolcanic unit.

Key words: Tectonics, MMT, Sapat, Kohistan, Himalaya.

K/265. Khan, M.A., Jan, M.Q. & Weaver, B.L., 1993. Evolution of the lower arc crust in Kohistan: temporal arc magmatism through early, mature and intra-arc rift stages. In: Treloar,

P.J. and Searle, M.P. (eds.), Himalayan Tectonics. Geological Society of London, Special Publication. 74, 123-138.

The middle to lower island-arc crust in southern Kohistan represents a 40 Ma life-span of subduction-related magmatism in an intraoceanic setting. The Kamila amphibolite belt comprises two varieties of metavolcanic amphibolites. One enriched in high-field strength (HFS) and heavy rare-earth (HRE) elements is transitional in character between N- and E-MORB with a minor subduction-related component, and represents the earliest arc basement in Kohistan. The other variety of the metavolcanic amphibolites, together with deformed and amphibolitised intrusive basic plutons, has a transitional tholeiitic to calc-alkaline nature marked by depleted HFS and HRE elements and a distinct negative anomaly for Nb, suggesting emplacement in the early to mature stages of arc growth. The subsequent magmatism in southern Kohistan took place in two stages. The extensive calc-alkaline gabbro-norites of the Chilas complex were derived from partial melting of a mantle diapir emplaced into a mature arc or, more probably, during the initial stages of sub-arc splitting. This intra-arc rifting, at its advanced stages, generated tholeiitic picrite to high-Mg basalts which crystallized the ultramafic-mafic-anorthosite (UMA) association and basic dykes of the Chilas complex. The Late Cretaceous accretion of the Kohistan island arc with the Karakoram plate in the north ceased the intraoceanic history of magmatism in southern Kohistan.

Key words: Magmatism, island arc, amphibolites, Kamila, Kohistan.

K/266. Khan, M.A., Jan, M.Q., Windley, B.F., Tarney, J. & Thirwall, M.F., 1989. The Chilas mafic-ultramafic complex; the root of the Kohistan island arc in the Himalaya of northern Pakistan. Geological Society of America special Paper 232, 75-94.

The Chilas Complex is a large mafic-ultramafic body closely associated with the Kohistan Arc sequence in the western Himalaya of northern Pakistan. The arc and the Chilas Complex occupy an area of 36,000 km², bounded on the north and south by major sutures. The arc formed close to the margin of Eurasia in response to the northward subduction of neo-Tethyan ocean lithosphere in Late Jurassic to middle Cretaceous time, and consists of intra-arc sediments, calc-alkaline volcanics, and diorite-tonalite-granite plutons. At its base is the Chilas Complex, which extends for more than 300 km and which has a maximum width of 40 km. Most of the complex consists of massive (although locally layered) gabbro-norites, which comprise variable amounts of plagioclase (An 64-40), orthopyroxene (En 76-48), clinopyroxene (mg = 75-55), magnetite, ilmenite, +quartz, tK-feldspar, hornblende, +biotite, +rare scapolite. In the central part of the complex, near the base, there are minor discordant dikes and intrusive bodies as large as 5 km² of a dunite-peridotite-troctolite-gabbro-norite-pyroxenite-anorthosite association that displays excellent layering, graded bedding, slump breccias, and syndepositional faults. These rocks contain olivine (Fo 94-71), relatively Mg-rich orthopyroxene (En 91-65), clinopyroxene (mg = 85-67), and calcic plagioclase (An 98-83), +/- hornblende, +/- chrome spinel, +/- pleonaste, and represent a more primitive magma batch emplaced into the base of the gabbro-norite magma chamber. The mafic complex is not an ophiolite. Rocks of the complex have more petrographic and compositional similarities with plutonic blocks from island arcs and with other major mafic complexes such as the Border Ranges Complex of Alaska and those from the Ivrea Zone in the Alps. Trace-element patterns of the gabbro-norites have marked negative Nb anomalies, positive Sr, Ba, and P anomalies, and high K/Rb ratios, features consistent with melting of a hornblende-bearing sub-arc mantle source. The Chilas Complex either represents the root zone magma chamber of the Kohistan island arc, or magma generated by diapirism in the early stages of intra-arc rifting during formation of a back-arc basin.

Key words: Ultramafics, Chilas complex, Kohistan, Himalaya.

K/267. Khan, M.A., Karim, T. & Iqbal, S., 1987. Bibliography and index of the geology and mineral resources of N.W.F.P., Pakistan. Geological Survey of Pakistan, Record 77, 233p.

This is a detailed document that provides a comprehensive list of contributions to the geology and mineral resources of the North West Frontier Province, now called Khyber Pakhtunkhwa. There is an index for easy access to entries. The document is useful for researchers and those interested in exploration and development of the mineral resources of the province.

Key words: Bibliography, geology, mineral resources, NWFP.

K/268. Khan, M.A. & Khan, A., 1989a. Revised stratigraphy of Paleozoic rocks, Khyber Pass, Khyber Agency, Pakistan. Geological Survey of Pakistan, Information Release 431.

Key words: Stratigraphy, Paleozoic, Khyber Agency.

K/269. Khan, M.A. & Khan, A., 1989b. Geology of Reshun quadrangle, Chitral district, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 430.

Key words: Geology, Reshun, Chitral.

K/270. Khan, M.A., Khan, F.R. & Dawar, A.Y., 1977. Geology of Reshun and Buni area Chitral, N.W.F.P. M.Sc. Thesis, University of Peshawar, 36p.

Key words: Geology, Reshun, Buni, Chitral.

K/271. Khan, M.A. & Khan, I.H., 2001. Geothermobarometry of Oghi area, Mansehra, north Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.3.

The Mansehra area occupies the part of Indian plate south of the Main Mantle Thrust (MMT). The oldest rocks exposed belong to Tanawal Formation's schist, marble and quartzite of various grades. The Mansehra granite of Cambrian age has intruded the Tanawal Formation. The granitic gneisses, porphyritic granite and tourmaline granite are part of the Mansehra granite. The diabasic dykes of Siluro-Devonian age are emplaced into granite and rocks of Tanawal Formation. Some of these dikes are metamorphosed to amphibolite grade surrounding Oghi area and are aligned in an east-west direction. The major and trace element composition by XRF analysis have revealed SiO₂ contents ranging from 45-48% and represent mainly basic compositions.

The metamorphism of these rocks ranges from low to medium grade at relatively high pressure. The exposed lithologies belong to green schist facies and fall in the kyanite zone of the amphibolite grade. The area is affected by retrograde metamorphism and shows sericitized schists of variegated grades. The amphibolitized bodies are aligned east-west parallel to the Oghi shear. The geothermo-barometry was carried out to know the peak metamorphic P-T conditions. The garnet-hornblende-plagioclase geobarometer and garnet-hornblende geothermometer gave 10.8 to 11.9 Kb pressures and 5880C to 7050C temperatures. These amphibolite bodies may have equilibrated at high pressures and low to medium temperatures during the Himalayan collision times (?).

Key words: Metamorphism, geothermobarometry, Mansehra.

K/272. Khan, M.A. & Khan, M.A., & Khan, M.S., 1982. Geology of Gandao quadrangle, Mohmand Agency, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 130, 24p.

Key words: Geology, Gandao, Mohmand Agency.

K/273. Khan, M.A, Khan, M.A. & Jan, M.Q., 1998. Trondhjemites in the southeastern part of the Kohistan Island-Arc Terrane, Pakistan: A product of partial melting. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 97-98.

The Kohistan terrane in N. Pakistan is sandwiched by two major thrusts, the Main Karakorum Thrust (MKT) in the north and Indus Suture or Main Mantle Thrust (MMT) in the south. Recent geological mapping in southeastern part of the terrane, along a N-S transect, provides new and important information about the geology of the area. Hence, the base of the terrane is occupied by a stratiform mafic-ultramafic complex (the Sapat complex), which overrides the crust of the Indian plate along. The complex was intruded into the base of a thick pile of metavolcanics of different environments (the Kamila belt). The Kamila belt is intruded by a suite of granitoid rocks divisible into

three groups. gabbroic association, gabbro-diorite/tonalite-granodiorite-granite association and trondhjemite association.

The trondhjemites occur as thin veins and dykes in the northern part of the Kamila amphibolite belt. Here, the belt is in contact with the Chilas complex along a strong shear zone known as Jal shear zone. Under the microscope the trondhjemites contain feldspar, quartz and amphibole with minor epidote, muscovite, biotite, sphene, garnet and ore, and show parallel alignment of mineral grains in one major direction. They show a very spiked pattern and are depleted in all HFSE, particularly strongly in Ti, P and Nb relative to the other granitoids of the area. The trondhjemites formed by the partial melting are depleted in these elements due to occurrence of amphibole and garnet as the residual phases in the arc basement.

Partial melting of a basaltic source material is considered to be the most viable mechanism for the generation of high-AI trondhjemites similar to those of the area studied by Drummond and Defant (1990). Basalts converted to amphibolites and eclogites when involved in subduction-zone setting are partially fused to generate trondhjemites (De Vore, 1983a, b., Windley, 1984; Martin, 1986, 1987). The geochemical modeling and experimental studies (Drummond and Defant, 1990) favour a hot oceanic crust (20-30 Ma old) subducting and melting to produce trondhjemites. The trondhjemites of the present study are probably a product of partial melting of Kamila amphibolites but a direct role of subduction is not observed.

Treloar et al. (1990) considered that the amphibolite-facies metamorphism and deformation in the Kamila belt is related to the Kamila shear zone of 80 Ma, suggesting a similar age for the trondhjemites. The emplacement of Chilas complex (90-80 Ma) might have played an important role in the genesis of the trondhjemites as a heat source. Field evidence, distinctive geochemical signatures and restricted distribution of trondhjemites close to the Jal shear zone and the lower contact of the Chilas complex support the idea but the exact petrogenesis of the trondhjemites cannot be properly evaluated without data on rare-earth elements.

Key words: Tectonics, volcanics, metamorphism, Kohistan, Himalaya.

K/274. Khan, M.A., Khan, M.A., Qazi, M.S., Khan, T. & Jan, M.Q., 1997. Chalt-Babusar transect across the Kohistan island-arc terrane, N. Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 157.

Kohistan Island Arc terrane in N. Pakistan is a Cretaceous-Tertiary island-arc complex entrapped between collided Indian and Karakoram plates [1]. Several aspects of the crustal geology of the terrane have been refined in the light of our recent mapping along its eastern margin, i.e., Babusar-Chilas-Chalt transect (Fig. 1).

The base of the arc crust in SE Kohistan is occupied by the 2-km thick Sapat mafic-ultramafic complex [2]. Unlike the garnet-granulite facies Jijal Complex exposed in the Indus valley [3], the Sapat Complex is metamorphosed only to lower-amphibolite facies.

The Sapat complex underplates a sequence of amphibolite-facies metabasalts belonging to the Kamila amphibolite belt (KAB). Two compositional types are identified in the KAB. The volumetrically preponderant Niat metabasalts have a geochemical composition similar to the N-MORB, characterized by enriched HFSE and HREE relative to the LILE and REE [4].

These metavolcanics are locally intercalated with metabasalts, which are calc alkaline and have a composition typical of subduction-related magmas. Unlike the Indus-valley section [5], the part of the KAB in SE Kohistan is devoid of metagabbroic amphibolites.

To the north, the KAB is in tectonic contact with the Chilas complex [4]. Much of the northern contact of the Chilas complex is against the relatively younger Kohistan batholith, which more or less completely separates it from a sequence of metabasalts and metasediments exposed near Jaglot. The Chilas complex carries xenoliths of KAB in its southern marginal parts and those of the metasediments of the Jaglot group in its northern marginal parts, suggesting that it was emplaced at the interface of KAB and Jaglot group.

The Jaglot group [6] comprises Gilgit Formation (paragneisses, schists and pillowed metabasalts) at the base, pillowed metavolcanics similar to the Chalt volcanics in the middle and Thelichi Formation (slates, metavolcanics and marble) at the top. There is possibility the Jaglot group is equivalent to the Chalt-Yasin succession exposed adjacent to the Northern Suture, but more geochemical data are needed for evaluation of this aspects.

Key words: Ultramafics, metamorphism, Babusar, Chalt, Sapat, Kohistan, Himalaya.

K/275. Khan, M.A., Khan, M.H., Tahirkheli, T., Treloar, P.J. & Petterson, M.J., 2000. Tectonic Evolution of the Eocene Dosh-volcano-sedimentary basin NW-Kohistan island arc terrane,

Hindu Kush, N Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, 180-181.

In NW Himalayas, the suture zone between the collided Indian and the Karakoram Plates is occupied by crust the Cretaceous Kohistan Island-Arc Terrane (Tahirkheli et al., 1979). Late Cretaceous (about 90 Ma) accretion with the southern margin of the Karakoram Plate the site of the Shyok Suture Zone turned Kohistan to become an Andean-type margin. The Neotethys was completely subducted at the southern margin of Kohistan by Early Tertiary, leading to collision between Kohistan and continental crust of the Indian Plate at the site of the Main Mantle Thrust.

More than 90% of the Kohistan terrane comprised plutonic rocks of (1) ultramafic to gabbroic composition forming the basal crust of the intra-oceanic stage of the island arc, and (2) tonalite-granodiorite-granite composition belong to the Kohistan Batholith occupying much of the intermediate to shallow crust of the terrane mostly intruded in the Andean-type margin stage (Pettersen & Windley, 1985). Both these stages of subduction-related magmatism were associated with volcanic and sedimentary rocks formed in Late Cretaceous and Early Tertiary basins. This study addresses tectonic configuration of Early Tertiary Drosh basin exposed in NW part of the Kohistan terrane, immediately to the south of the Shyok Suture Zone.

Previous studies have shown that Shyok Suture Zone in its immediate southern vicinities comprises a sequence of Late Cretaceous sediments comprising turbidites and subordinate limestone, together constituting the Yasin Group, overlying a sequence of met volcanic rocks called Chalt Group. Recent detailed studies by us confirm that this configuration holds true for the area between the Hunza valley in the east to the Village of Shamran in the west, through the Chalt Volcanic Group increasingly becomes less deformed and more siliceous towards the west. West of Shamran, in the area around the Shandur Pass, there is sporadic presence of rhyolite-rhyodacite dominated green as well as pink volcanic rocks resembling closely with the Eocene Utror Volcanic Group. These rocks, known as the Shamran Volcanic Group. ⁴⁰Ar-³⁹Ar hornblende dating of the Shamran Volcanic Formation has yielded a 58 Ma age. Further west in the area near Drosh, occurrence of two volcanic units; Gawuch and Drosh formations is known previously (Pudsey, et al., 1985). The Gawuch Formation comprises highly tectonic greenschist metavolcanics, with common intercalation of limestone and marble in its upper (northern) part. The Drosh Formation consists of mildly deformed to slightly metamorphosed basalts of tholeiitic character, similar to the Chalt Volcanic group. Our recent mapping in Drosh area finds a third volcanic unit; this unit is andesite to rhyolite in composition, massive; aphyric to hornblende-and/or pyroxene and/or plagioclase phyrlic, undeformed and only mildly metamorphosed and is equated with the Eocene Shamran Volcanic Formation in strike to the east. All the volcanic units in the Drosh area are intruded by the Mirkhani granodiorite pluton. A sequence of red conglomerate, sandstone, siltstone, siltstone and shale of fluvial origin, termed Purit Formation is associated with all the volcanic rocks of the area. Previously this unit was considered to have an unconformable stratigraphic position above the Gawuch Formation and the Mirkhani granodiorite pluton but below the Drosh Formation. Detailed mapping and field-relation studies demonstrate that (1) Mirkhani Pluton is intrusive and thus younger than all the volcanic units in the area, implying that the Purit Formation that rests unconformably on top of the Mirkhani Pluton is the youngest in the area, (2) the occurrence of the Purit Formation unconformably on top of the Shamran Formation suggests a post Early Eocene age for the former.

A comparison between the Early Tertiary Drosh basin with the southerly located Dir basin (Sullivan, et al., 1993) of equivalent age shows a close match in the volcanic rocks in terms of composition and Andean-type setting of origin, but contrast in the sedimentary record. Sediments in the Dir basin are deep-water turbidites (the Baraul Banda Slate Formation) and are considered to have formed in an Andean-type fore-arc setting. In contrast the Purit Formation is typically fluvial and is relatively younger than the Early Eocene Shamran Formation. We equate the Drosh basin with the Reshun basin further to the north and suggest an Andean-type back-arc basin origin for these two basins.

Key words: Tectonics, Eocene, volcano-sedimentary basin, Kohistan island arc, Chitral, Hindu Kush.

K/276. Khan, M.A. & Khan, M.R., 1994. Evaluation of geotechnical properties and deformability of Jura granites, Neelum valley Azad Kashmir. *Kashmir Journal of Geology* 11 & 12, 89-95.

The geotechnical and deformability characteristics of Jura granites are presented. The middle and lower Jura granites are medium textured and takes excellent polish. The upper Jura is coarse textured and also take polish. From geotechnical variations it is apparent that upper coarse textured granites display a behavior markedly different

from lower granites. In the upper weaker rocks, the elastic range is limited to very low stress levels. The sensitivity of the strength to water content has also been discussed.

Microscopic characteristics in particular are outlined, in the areas of grain contact were successfully used to explain strength and deformability of granites: Evaluation of geotechnical properties shows potential as a compliment to the index test of saturated rocks and uniaxial load for weak and strong granites respectively.

The Aggregate Abrasion Value (4%), Aggregate Crushing Value (10%), soundness (1.3 to 6%), porosity (0.1 to 6%), compressive strength (2000-3500 PSI) and slake durability (75% retained) tests were conducted for economic exploitation of the rocks.

Key words: Geotechnical, granites, Neelam valley, Azad Kashmir.

K/277. Khan, M.A. & Khan, M.S., 1989. Engineering characteristics of Nauseri Marble, Azad Kashmir. *Kashmir Journal of Geology* 6 & 7, 125-132.

White, gray and bluish gray marble and brownish gray to whit and dense marble occur in Nauseri area. The deposits were formed at southwestern margin of Kashmir landmass during Permo-Carboniferous times. They were metamorphosed to varying degrees. White crystalline limestones are calcite marbles of inferior quality comprising of a small part of the deposits. Most of these potential sources are not developed so far mainly for lack of technical information. However, on the basis of range of colors, good textures and quality a large and potential quarries could be developed. This paper describes the engineering characteristics of Nauseri Marbles.

A number of mechanical characteristics were determined and most of them are in confirmation to ASTM specifications.

The compressive strength of the marble varies from 3100 PSI to 8100 PSI. Taber Abrasion Index value range from 8.0 to 15.01. The soundness ranges from 0.1 to 5.0% absorption varies from 0.01 to 8%. Specific gravity ranges from 2.65 to 1.73. The porosity of the marble is 0.5 to 8.3%.

Key words: Engineering characteristics, marble, Azad Kashmir.

K/278. Khan, M.A. & Khan, S., 1979. Geology of Pegmatites of Upper Neelam valley, Azad Kashmir. *Geological Survey of Pakistan, Information Release* 112, 27p.

Key words: Geology, pegmatite, Neelum, Azad Kashmir.

K/279. Khan, M.A., Khan, S.F. & Islam, F., 1999. Geology of marbles from District Buner, N.W.F.P., M.Sc. Thesis, University of Peshawar, 91p.

This study of marble deposits of the North West Frontier Province has been carried out in order to update the previous work on the commodity and also to investigate some of the new and the little known occurrences.

The project is located at the central part of Buner district which include areas of Yakh dara, Mirdara, Matwanai, Tursak, Bazargai, Nanser and Bampokha. These are the major marble producing deposits in North West Frontier Province, and different mining corporations are working in these areas.

The marble deposits under study are mostly associated with metasedimentary rocks of Paleozoic age. The marble deposits are located in Kashala, Nikanai Ghar and Saidu Formations. Variation in composition, texture, thickness, and structure displaying a wide array of color shades and grain sizes. The present study include general characteristics of the outcrop exposures, physical and chemical characteristics, petrography and geo-technical properties of these marble. The geology, petrography and geo-technical studies shows that the marble from these deposits has a pleasing appearance, take good polish and meet the standard specification for specific gravity, water absorption, flexural strength and other physical properties.

Key words: Marbles, Buner.

K/280. Khan, M.A., Khan, Z.A., Qureshi, M.S. & Nasim, S., 1994. Evaluation of geotechnical properties of Miocene shales of Muzaffarabad Azad Kashmir. *Kashmir Journal of Geology* 11 & 12, 97-104.

Geotechnical behavior of shale of Murree Formation of Miocene age was observed under static and dynamic tests. It include natural water content, absorption, specific gravity, plasticity, characters, slake durability, point load index, compaction and strength characteristics of mixed samples with varying proportions of shales and sills. This shows improvement in geotechnical behavior of the construction material.

The XRD analysis of the specimens shows montmorillonite and illite as the dominant clay minerals. Generally, the shales tend to have low absorption values, strength after compaction of the samples. Clayey shales showed the best compaction with the lowest void ratio. The void ratio increases with increasing proportions of siltstone in many cases. The unconfined compressive strength decreased with increasing proportions of siltstone (50-65%). The durability seemed to influence by the nature of cementation, degree of lithification and the proportion of silt.

Key words: Geotechnical, shale, Miocene, Muzaffarabad, Azad Kashmir.

K/281. Khan, M.A., Kidd, W.S.F. & Edwards, M.A., 2000. Tectonics of the western margin of the Nanga Parbat-Haramosh syntaxis: Tracing the active Raikot Fault to the SW and modeling its impact on Quaternary exhumation of the massif. Abstracts, Third South Asia Geological Congress, Lahore, 16-17.

Key words: Tectonics, NPHM, Raikot.

K/282. Khan, M.A., Nasir, S. & Malik, I., 1990. Brief geology of the Pegmatites of Jagran area, Neelam valley Muzaffarabad district, Azad Jammu and Kashmir. Geological Survey of Pakistan, Information Release 460.

Key words: Pegmatites, Neelam valley, Azad Kashmir.

K/283. Khan, M.A. & Petterson, M.G., 1992. Magmatic evolution of the Kohistan arc: Geochemical constrains. Abstracts, First South Asia Geological Congress, Islamabad, p.23.

The Kohistan sequence -in N. Pakistan comprises a diverse assemblage of rocks, emplaced during a wide span of time. The recently acquired radiometric ages and whole-rock geochemical data suggest that the sequential magmatism in the Kohistan arc was controlled by changing plate tectonic setting of the region. An early phase of magmatism was exclusively in an intraoceanic island arc setting and was mainly basic in composition (e.g., the Jijal and Chilas Complexes, the Kamila amphibolites, and high-Mg tholeiite volcanics in the Chalt area). The late Cretaceous accretion of the island arc with the Karakoram plate in the north resulted in a major change in the tectonic character of the Kohistan from an intraoceanic island arc to a continental margin. This led to generation of a predominantly acid magmatism which now makes bulk of the Kohistan batholith and volcanics in the upper parts of the arc sequence. Within this broad two-fold division of the arc magmatism, our geochemical data enables us to recognize changes in the tectonic character of the Kohistan arc from an interoceanic early to a mature stage, and from a continental margin to a continent-continent collision zone. In this paper we present geochemical data for these successive phases of magma, and identify changes in the magma character related with changes in the tectonic settings of the Kohistan arc.

Key words: Magmatic evolution, geochemistry, Kohistan arc.

K/284. Khan, M.A., Quddus, A. & Khan, M.F., 1974. Field report on geology of Shakardara area, Swat Pakistan. M.Sc. Thesis., Punjab University, Lahore.

Key words: Geology, mapping, Swat.

K/285. Khan, M.A. & Qureshi, M.S., 1989. Physical characteristics of soil of Muzaffarabad Kohala area Azad Kashmir. Kashmir Journal of Geology 6 & 7, 109-124.

Field and laboratory investigation of physical characteristics related to grades, sediments, water relationship, effect of stress and the amount of strain have been investigate from civil engineering point of view.

The origin of the soils have been studied to summarize the relationship between the soil types and their response to varying condition of moisture, stress response in relation to the grades of the soils.

Key words: Stress, strain, sediments, soil, Muzaffarabad, Azad Kashmir.

K/286. Khan, M.A. & Qureshi, M.S., 1991. Landslide hazards in southern Muzaffarabad Azad Kashmir and southeastern Hazara Pakistan. *Kashmir Journal of Geology* 8 & 9, 121-on ward.

The Jhelum River Valley in southeast of Hazara and southern part of Muzaffarabad are the areas of high landslide hazards. Steep slope, silty, sandy and clayey soils, heavy rains, water seepages all contribute to the landsliding in the region. The instability of the area has been further increased by road widening and effect of the Main Boundary Thrust (MBT) resulting in the form of many major landslides, such as slumping earthflows, rockfall, sinkholes and combination of these.

The active Kohala and Rara landslides were investigated in detail because of their large size and proximity to roadways. Soil samples were collected to evaluate engineering properties of the materials involved in these failures. The investigated area lies in a structurally complex belt of folded and faulted sedimentary rocks which have been further deformed by the locally important Murree Thrust and regionally significant Main Boundary Thrust (MBT).

In addition landslide map of the area was prepared by performing fieldwork and using Ariel photographs. All slope failures were classified according to their movement and state of activity, with variation and change of water content (6.7-45%), liquid limit (22.6-41.5), plastic limit (6-23.7), swellability (8.9-55), compressive strength (2-15 MPa), shear strength (3-10 MPa) and pore water pressure (4-6 MPa). The results suggest that slope failure occur due to high swelling potential of soils, active faults and shear failures.

Key words: Hazards, landslides, Muzaffarabad, Azad Kashmir, Hazara.

K/287. Khan, M.A. & Qureshi, M.S., 1992. Review of geotechnical characteristics of Neelum granites, Neelum valley, Azad Kashmir. *Kashmir Journal of Geology* 10, 141-146.

The Neelum granite of Neelum Valley Azad Kashmir has been investigated to evaluate its geotechnical properties. The geotechnical properties like compressive strength shear strength, soundness, porosity, water absorption and slake durability of the granite show their potential to be used as construction raw material. The compressive strength values ranges from 100-350 MPa. The shear strength varies from 150-950 MPa, soundness 0.1-2%, water absorption 14-20%, slake durability 99.5-99.8%, porosity 0.2-15% and degree of polish good excellent.

An evaluation of geotechnical properties of different granites suggest the rational use of the raw material, considering the deformability characters of the rocks.

Key words: Geotechnical, granites, Neelum, Azad Kashmir.

K/288. Khan, M.A., Rehman, I., Rehman, O. & Abbasi, I.A., 1990. Multiple detachment levels and their control on the deformation style of the Kalachitta Hill Range. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.2.

Detailed mapping in a part of the Kalachitta Hill Range, Attock District (I. Rehman, 1990) has shown two distinct styles of deformation, apparently controlled by two detachment levels. The lower detachment occurs at the base of the Mesozoic strata, and the upper in the Patala Formation of Paleocene age. The deformation in the Mesozoic-Paleocene sequence between these two detachment levels is controlled by thrusting, resulting in the formation of a duplex zone, in which the lower detachment is acting as a sole thrust while the upper detachment as roof thrust. The Mesozoic-Paleocene strata in this duplex zone is repeated, at one place, more than four times in the form of south-verging horses. No folding, except for that related with thrusts (open hanging wall anticlines) has been observed in the sequence between the two detachment levels. In contrast deformation in the Cenozoic strata overlying the upper detachment surface in the Patala Formation is controlled by large scale folds verging both to the north and south, in a fashion similar to that outlined by Cotter (1933) while presenting a model for the tectonic evolution of the Kalachitta Hill Range.

Key words: Deformation, Kalachitta range, Attock.

K/289. Khan, M.A. & Ristic, D., 2001. Swelling potential of sandstones and clays in Himalaya regions. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.47.

Swelling potential of rocks in Himalayan regions is a great problem for civil engineers for designing high rise buildings, bridges, highways, viaducts, overpasses, under passes and other civil engineering structures. This paper covers a broad mechanism of swelling potential of rocks and soils. The rocks were classified in different classes for identification and uses for civil engineering structures. The categories involve mudstone, shales, weakly cemented sandstones, and clays. The engineering aspects of swell are described by the influence of density, in-situ stress and availability of water. The identification of swell-shrink susceptible strata includes testing techniques and the design criteria for subsurface and surface structures in the Himalayan regions of Pakistan and are presented here.

Key words: Geotechnical, sandstone, clay, civil engineering, NW Himalaya.

K/290. Khan, M.A. & Stern, R.J., 1996. Polarity of the subduction system responsible for the Cretaceous Kohistan island arc terrane, N. Pakistan: geochemical and structural constraints. Geological Bulletin, University of Peshawar 29, 27-40.

The Kohistan island arc terrane of N. Pakistan has experienced multiple collisions, resulting in obliteration of the subduction system responsible for its creation. Indirect evidence, based on structural vergences and across-the-arc variations in trace elements (Ti, Zr, Nb, and P) have been combined to interpret the nature of the subduction zones responsible for Kohistan in terms of their location and polarity (i.e., dip direction). Geochemical investigations, from north to south, in the Chalt volcanics, the Chilas complex and the Kamila amphibolite belt indicate a systematic increase in high-field strength elements from north to south. These variations indicate an overall decrease in the degree of melting or degree of source-region depletion, which in either case, give a facing direction for the arc terrane towards north. The structural vergences in the northern parts of the Kohistan terrane are also consistent with a south dipping subduction zone located to its north. Using these observations, a tectonic model is proposed for the origin of Kohistan terrane on a south-dipping subduction zone located at its northern margin. The subduction switched to the southern margin of the arc terrane soon after the Kohistan-Karakoram collision with a reverse polarity (i.e., dip direction towards north). The model has been tested in the light of modern examples of arc-continent collisions in SW Pacific ocean.

Key words: Geochemistry, structure, subduction, Kohistan arc.

K/291. Khan, M.A. & Stern, R.J., 1997. Isotope composition of Sr, Nd and Pb in the Kohistan Intra-Oceanic Arc Terrane of Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 55-56.

The Kohistan terrane of northern Pakistan is a remnant of a Cretaceous-Tertiary island arc crust trapped between collided Indian and Karakoram plates. Two phases of evolution are recognized. Much of the arc crust (i.e., lower-crustal ultramafic-mafic cumulates of Sapat and Jijal complexes, intraoceanic phase. The collision with Karakoram took place at about 90 Ma accompanied by intrusion of the Chilas ultramafic-gabbro-norite Complex. Much of the Kohistan batholith was emplaced in the subsequent continental-margin setting.

We report isotopic composition of Sr, Nd and Pb for the principal units of the island arc crust, i.e., Kamila amphibolite belt, Chalt volcanics and the Chilas complex. Sr and Nd isotopic data for the Kohistan batholith has been published. The Kamila amphibolite belt in SE Kohistan comprises predominantly of metavolcanic rocks metamorphosed under lower-amphibolite facies. Two compositional types are recognized.

The predominant variety is E-type amphibolite, characterized by slight to moderate enrichment in HFSE and HREE over LREE, respectively. Overall composition is not far from type N-MORB. The D-type amphibolite are typically calc-alkaline in composition and show major and trace element composition consistent with a genesis involving strong subduction component. The distinction between the two varieties of the Kamila amphibolite is amplified by the isotope data; E-type contains more radiogenic Nd ($Nd_{120Ma}=+7.0$ to $+7.4$) and less radiogenic initial Sr ($^{87}Sr/^{86}Sr=0.7036-0.7039$) than the D-type ($Nd_{120Ma}=+2.9$ to $+4.7$; $^{87}Sr/^{86}Sr=0.7041-0.7047$). Pb isotope composition for the two varieties shows only subtle differences. The Kamila amphibolites, in SE Kohistan (Thak-Babusar valley), are intruded by a syntectonic suite of Gabbrodiorites-tonalites-granodiorites-trondhjemites. Within this suite three subgroups are identified based on geochemical and isotopic composition. The Gabbro-diorite-tonalite

suite is tholeiite to calc-alkaline in composition with rare-element characteristics common with subduction related rocks. They have highly radiogenic Nd ($^{143}\text{Nd}/^{144}\text{Nd} > 0.51290$), less radiogenic Sr (mean $^{87}\text{Sr}/^{86}\text{Sr} = 0.71380$), comparable to E-type Kamila amphibolites. The granodiorite suite, in contrast, has moderate radiogenic initial Sr and least radiogenic Nd (mean $^{87}\text{Sr}/^{86}\text{Sr} = 0.7037$, $^{143}\text{Nd}/^{144}\text{Nd} < 0.51280$). The trondhjemites have low initial Sr (mean $^{87}\text{Sr}/^{86}\text{Sr} = 0.7037$) and moderately low Nd ($^{143}\text{Nd}/^{144}\text{Nd} = 0.512840\text{--}0.512865$). The Chilas Complex comprises ultramafic cumulates, gabbro-norites and hypersthene diorites with a typical calc-alkaline composition and a strong subduction component [3]. It is characterized by a homogeneous isotopic composition for Sr, Nd and Pb ($^{87}\text{Sr}/^{86}\text{Sr} = 0.70396\text{--}0.70414$, $\text{Nd}_{120\text{Ma}} = 2.8\text{--}4.0$), which is closely comparable with that of the D-type amphibolites from the Kamial belt. The Chalt volcanics are compositionally heterogeneous comprising basalts, boninites and rhyodacites. These have homogeneous isotopic compositions for Nd ($\text{Nd}_{120\text{Ma}} = 6.3\text{--}7.3$) and Pb ($^{206}\text{Pb}/^{204}\text{Pb} = 18.1\text{--}18.4$; $^{208}\text{Pb} = 44\text{--}58$; $^{207}\text{Pb} = 5\text{--}10$), but have highly variable initial Sr ($^{87}\text{Sr}/^{86}\text{Sr} = 0.7040\text{--}0.7055$), probably reflecting alteration accompanying submarine hydrothermal metamorphism. In the Kohistan batholith, Stage I tonalites have radiogenic Nd and low initial Sr ($^{87}\text{Sr}/^{86}\text{Sr} = 0.7039$; $\text{Nd}_{120\text{Ma}} = +6.9$), Stage II granitoids have moderate initial Sr and less radiogenic Nd ($^{87}\text{Sr}/^{86}\text{Sr} = 0.7041\text{--}0.7042$, $\text{Nd}_{120\text{Ma}} = +3.01\text{--}4.09$), and Stage III leucogranites have variable but high initial Sr and low Nd [2]. The isotopic composition of Sr and Nd for various units of the Kohistan arc terrane, when used together, identify two source types. The E-type Kamila metavolcanic amphibolites, Stage I (Matum Das) plutons of the Kohistan batholith, and Thak valley gabbro-diorite-tonalite suite are all characterized by more radiogenic Nd and less radiogenic Sr. The Chalt volcanics have comparable Nd but higher and variable initial Sr. Assuming that higher initial Sr is due to seawater alteration, the Chalt volcanics appear to have a source common with the above mentioned three suites of rocks. The early-arc crust in Kohistan, comprising these four units (and basal cumulates of Jijal and Sapat complexes), is envisaged to have formed from partial melting a mantle source similar to those of N-MORB, with slight but variable modification by subduction related metasomatism.

The mantle source responsible for the Chilas complex, D-type metavolcanic amphibolite and granodiorite and trondhjemite intrusives in the Kamila belt and the Stage-II Kohistan batholith is characterized by less radiogenic Sr and Nd. These suites of rocks formed in the later stages of intraoceanic phase or during Andean-type continental-margin phase, when the arc was in its mature stages of development. A mantle source with higher degrees of subduction-related metasomatism is considered responsible for this crustal component in the Kohistan arc terrane.

An interesting feature of the isotopic compositions of Sr and Pb in Kohistan rocks is the presence of DUPAL signature, suggesting that Kohistan formed at or to the south of equator prior to its northward drift and collision with the Karakoram plate. Independently acquired recent paleomagnetic studies confirm this conclusion.

Key words: Geochemistry, isotopes, paleo-position, Kohistan arc.

K/292. Khan, M.A., Stern, R.J., Gribble, R.F. & Windley, B.F., 1997. Geochemical and isotopic constraints on subduction polarity, magma sources and palaeogeography of the Kohistan Arc, northern Pakistan. *Journal of the Geological Society, London* 154, 935-946.

Geochemical and isotopic data are presented for 18 representative samples from the intraoceanic phase of the Kohistan arc. A restricted range of initial $^{87}\text{Sr}/^{86}\text{Sr}$ ($0.7036\text{--}0.7066$) and $^{\circ}\text{Nd}$ ($+2.8$ to $+7.4$) along with measured $^{206}\text{Pb}/^{204}\text{Pb}$ ($18.0\text{--}18.6$) are consistent with formation of the arc complex in an intra-oceanic setting. The isotopic data demonstrate the involvement of enriched, DUPAL-type mantle, suggesting that the Kohistan arc formed at or south of the present equator. Subduction polarity inferred from geochemical and isotopic data indicate that the Chalt Volcanics and Kamila Amphibolites represent a forearc and backarc basin sequence, respectively. These inferences are most simply resolved with a tectonic model whereby the intra-oceanic Kohistan arc evolved over a south-dipping subduction zone, implying that Kohistan and India moved northwards on the same plate, although separated, during much of Cretaceous time. Collision of Kohistan with the Karakoram caused a new, north-dipping subduction zone to form on the south side of Kohistan, leading to collision with India in early Tertiary time.

Key words: Geochemistry, isotopes, subduction, polarity, palaeogeography, Kohistan arc.

K/293. Khan, M.A., Stern, R.J., Gribble, R.F. & Windley, B.F., 1998. Discussion on geochemical and isotope constraints on subduction polarity, magma sources, and paleogeography of the Kohistan arc, northern Pakistan. *Himalayan Geological Society of London*, 155, 893-895.

Key words: Geochemistry, isotopes, subduction, polarity, Kohistan arc.

K/294. Khan, M.A. & Tahirkheli, T., 1980. Petrography and mineralogy of Tarbela alkaline complex. M.Sc. Thesis, University of Peshawar, 132.

The Tarbela complex comprises gabbroic rocks (oldest), dolerites, melteigites, albitites, normal and sodic granites, albite-carbonate rocks / breccia, and carbonatites (youngest), together covering an area of about 4 sq. km. The rocks have been intruded along a fault zone between the Salkhala and Tanawal formation. Some of the gabbroic intrusions display in situ differentiation with one intrusion grading from pyroxenitic outer margin to leucogabbroic/dioritic interior with a core of intrusive albitites.

Key words: Petrology, alkaline complex, Tarbela.

K/295. Khan, M.A. & Thirlwall, M.F., 1988. Babusar amphibolites: arc tholeiites from the southern Kohistan arc, N. Pakistan. Geological Bulletin, University of Peshawar 21, 147-158.

An imbricate sequence of amphibolites, apparently in the form of a linear belt occurs in the hanging wall of the Indus Suture at Babusar Pass (SE Kohistan). Major-, trace- and a limited rare-earth element data classifies them to be arc tholeiite in composition, in contrast to the bulk of the Kohistan arc, which is predominantly calc-alkaline. Models are discussed about their position with respect to the rest of the Kohistan magmatic sequence, whereas there is a possibility that they represent early tholeiite phases of arc magmatism, a model is presented which considers them (together with a conformable basal ultramafic unit) as crust of a tholeiitic island arc, formed as a separate entity from a predominantly calc alkaline Kohistan arc to the north.

Key words: Petrology, amphibolites, tholeiites, Kohistan island arc.

K/296. Khan, M.A., Treloar, P.J., Khan, M.A., Khan, T., Qazi, M.S. & Jan, M.Q., 1997. Chalt-Babusar transect at the eastern margin of the Kohistan terrane: Implications for the constitutions and thickening of island-arc crust. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.36.

For details consult the following account.

Key words: Tectonics, ultramafics, MMT, Indian plate, Karakoram plate, Kohistan island arc.

K/297. Khan, M.A., Treloar, P.J., Khan, M.A., Khan, T., Qazi, M.S. & Jan, M.Q., 1998. Geology of the Chalt-Babusar transect, Kohistan terrane, N Pakistan: implication for the constitution and thickening of island arc crust. Journal of Asian Earth Sciences 16, 253-268.

The Kohistan island arc terrane is sandwiched between the collided Indian and Karakoram plates in the Himalaya of North Pakistan. Structures related to collision, during which the arc was thrust onto the leading edge of continental India along the Main Mantle Thrust, have resulted in exposure of an almost complete section of arc crust. Mapping along a transect across the east end of the arc terrane provides new data concerning the magmatic emplacement of several of the principal units. The base of the arc here is occupied by a major stratiform ultramafic-gabbroic complex, the Sapat complex. This was intruded into the base of a thick pile of meta-volcanic rocks which make up the Kamila amphibolite belt, and which comprise a varied sequence of basalts some with MORB-type tholeiitic affinities and some with island-arc tholeiitic affinities as well as calc-alkaline andesites. Ultramafic and gabbroic rocks of the Chilas complex are intrusive into the top of the Kamila amphibolite belt. The upper part of the crust comprises meta-sediments and meta-volcanic rocks of the Jaglot and Yasin-Chalt Groups. These were formed in one or more arc-related basins, and host much of the Kohistan batholith. A three-stage history of crustal thickening can be documented for the Kohistan arc. From its initiation at *ca.* 125–120 Ma until *ca.* 90 Ma, the arc grew downward through magmatic emplacement, into its base, of stratiform ultramafic-gabbroic plutonic complexes, and upward through extrusion of volcanic sequences. In Stage 2, the focus of crustal growth shifted upwards from the base of the arc with emplacement of the Chilas complex along the interface between the Kamila amphibolite belt and the overlying volcano-sedimentary cover. This stage of crustal thickening was accompanied by shortening associated

with the 90–80 Ma Kohistan–Karakoram collision. Finally, in Stage 3 (80–45 Ma), the Kohistan batholith was emplaced into deformed cover rocks of the uppermost part of the arc crust.

Key words: Tectonics, MMT, Indian plate, Kohistan island arc.

K/298. Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), 2000. Tectonics of the Nanga Parbat Syntaxis and the western Himalaya. Geological Society of London Special Publication 170, 485p.

This is a compilation of referee-reviewed contributions on the geology, tectonics, erosion and exhumation of the Nanga Parbat-Haramosh massif, and some other neighbouring areas. Individual papers are presented at appropriate places in the present work.

Key words: Tectonics, Nanga Parbat, NW Himalaya.

K/299. Khan, M.A., Turi, K.A. & Abbassi, I.A., 1990. Structures in the hangingwall of the Main Boundary Thrust: post-folding thrust and normal faults from the Kotal-pass area, Kohat Range, N. Pakistan. Geological Bulletin, University of Peshawar 23, 175-186.

The Main Boundary Thrust is a wide, complexly folded and faulted zone which uplifted the Kohat range, and tectonically emplaced the Mesozoic-Cenozoic shelf carbonate succession over the Tertiary molasse sediments. The MBT zone is characterized mainly by major thrust faults both imbricate and duplex type and tight folds. Tight folding along the MBT zone resulted in the formation of out-of the syncline faulting. Late stage (post folding and thrust faulting) development of normal faults at the base of the Paleocene succession further deformed the MBT zone in the Kohat area. The Paleocene strata in the hanging wall of southward propagating normal faults is subhorizontal to shallowly dipping northward, and lies discordantly over the Mesozoic succession. The normal faults are of localized nature in the MBT zone and are reported for the first time from the Kohat range. The normal faults may have exploited the weaker horizons generated during earlier thrusting such as out-of-syncline faults. Presence of thick fault breccia along the fault plane suggests that these structures may have formed close to near surface conditions during uplift of the Kohat range.

Key words: Structure, tectonics, MBT, Kohat.

K/300. Khan, M.A.R. & Hussain, S.H., 1989. Geology of Mirpur area, Azad Kashmir. Geological Survey of Pakistan, Information Release 445.

Key words: Mapping, Mirpur, Azad Kashmir.

K/301. Khan, M.H., 1952. Investigation of the Khewra, Warchha Mandi, Kala Bagh and Mari salt mines. Geological Survey of Pakistan, Records 6(1), 47-51.

Key words: Salt mines, Khewra, Kala Bagh.

K/302. Khan, M.H., 1992-93. Tectonics and structure of Timargara-Lal Qila-Wari areas District Dir N.W.F.P. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 265p.

Key words: Tectonics, structure, Timargara, Dir.

K/303. Khan, M.I., 1958. A preliminary geological map of Pakistan (scale 1: 500, 000). Geological Survey of Pakistan.

This is one of the earlier attempts of preparing a geological map of Pakistan.

Key words: Geological map, Pakistan

K/304. Khan, M.I., 1989. Ablation on Barpu-Glacier, Karakoram Himalaya, Pakistan. A study of melt processes on faceted debris-covered ice surface. M.A. Thesis, Wilfried-Laurier University, Waterloo, Ontario.

Key words: Glaciers, Barpu, ablation, melting, Karakoram, Himalaya.

K/305. Khan, M.I., 1992. Glacial hazards of Northern areas. Culture Area Karakorum, Newsletter 2, p.10, Tübingen.

Key words: Glaciers, hazards, Karakoram.

K/306. Khan, M.I. & Hammad, M., 1978. Petrology of Utla granite, Gadoon area. M.Sc. Thesis, Peshawar University.

Key words: Petrology, granite, Gadoon, Swabi.

K/307. Khan, M.J., 1974. Geological investigation for graphite in Gangarh Range, southern Hazara, Pakistan. Geological Survey of Pakistan, Quetta, Information Release 82.

Key words: Graphite, Gandghar, Hazara.

K/308. Khan, M.J., 1983. Magnetostratigraphy of the Neogene and Quaternary Siwalik Group of the Trans-Indus Salt Range, Northwestern Pakistan. Ph.D. Thesis, Graduate School of Arts and Sciences, Columbia University, 217p.

Part of the information contained in this thesis is presented in summarized form in the following three papers by M. J. Khan.

Key words: Magnetostratigraphy, sedimentation, Quaternary, Trans-Indus Salt Range, siwalik.

K/309. Khan, M.J., 1984a. Brief results of the paleomagnetic studies of the Siwalik group of the trans-Indus Salt range, Pakistan. Geological Bulletin, University of Peshawar 17, 176-178.

Thirteen stratigraphic sections were measured and sampled, from the Siwalik group rocks of the Trans-Indus Salt Range, for Paleomagnetic studies. After measuring Natural Remnant Magnetization (NRM) of all samples, a few were arbitrarily selected for Progressive Alternation Field (AF) demagnetization and Partial Thermal Demagnetization (PTD). The results of these studies show that AF demagnetization is not sufficient for the successful removal of the secondary component of magnetization particularly in case of samples collected from reddish-brown siltstone / claystone units. However, PTD successfully enables to isolate the stable and primary component of magnetization. Therefore, all samples were subject to PTD at 5000C to 6600C, to obtain the stable component of remnant magnetization. These stable directions of remnant magnetization were used to establish a magnetic-polarity reversal sequence of each section, respectively.

Key words: Paleomagnetism, sedimentation, Trans-Indus Salt Range, Potwar.

K/310. Khan, M.J., 1984b. Sedimentation and tectonics of the Trans-Indus Siwalik Group by paleomagnetic methods. Abstracts, First Pakistan Geological Congress, Lahore, p.11.

Paleomagnetic studies of thirteen stratigraphic sections from the Bhattani, Marwat, Khasor, Shinghar, and Surghar Ranges show that the Siwalik Group rocks in this area range in age from 12 Ma. to 0.5 Ma. The basal part of the Siwalik Group in the Bhattani Range could not be dated due to lack of exposure of lower part of the Siwalik Group.

These studies clearly indicate that onset of the Siwalik sedimentation, in the Trans-Indus area, started much later than in the Potwar Plateau, where basal part of the Siwalik Group is older than 15 Ma. Therefore, the Siwalik Group of the Trans-Indus area indicates westward transgression of the Potwar Plateau molasse facies.

Sediment accumulation rates calculated for the Trans-Indus Siwalik Group are generally higher than those calculated for the similar deposits of the Potwar Plateau. These higher sedimentation rates indicate faster subsidence of the Trans-Indus area, and consistent availability of detrital material. The entire stratigraphic sequence is conformable and suggests a lack of tectonic activity, except general subsidence of the basin of deposition, between 12 Ma. and 0.5 Ma. The Siwalik sedimentation was brought to halt at about 500,000 years BP, when the Trans-Indus area was uplifted during the Pleistocene phase of the Himalayan orogeny. Presence of uplifted recent alluvial deposits indicates that uplift is still an active process in this area.

Key words: Sedimentation, paleomagnetism, Trans-Indus Salt Range, Potwar.

K/311. Khan, M.J., 1987. Sedimentation and tectonics of the Siwalik Group of the Trans-Indus Salt Range, northwestern Pakistan. *Geological Bulletin, University of Peshawar* 20, 129-141.

Sediment accumulation rates calculated for fluvial sediments of the Trans-Indus Salt Range in northwestern Pakistan are generally higher than those of the Potwar Plateau. This indicates more rapid subsidence of the Trans-Indus area compared to the eastern Potwar Plateau area, as well as a continued supply of detrital material. The entire stratigraphic sequence, which covers a time span of 12.0-0.5 Ma, is conformable, suggesting that the only tectonic activity in this area over this period consisted of gradual subsidence of the depocenter. However, Siwalik sedimentation ceased at about 500,000 BP when the Trans-Indus region was uplifted during Pleistocene phase of the Himalayan orogeny. The uplift terraces of recent alluvial deposits show that uplift is still an active process in this area.

Key words: Sedimentation, tectonics, Trans-Indus Salt Range, Potwar.

K/312. Khan, M.J. & Ahmad, W., 1987. Clay mineralogy of the Quaternary Lake deposits of Peshawar basin, at Jehangira, district Mardan, NWFP, Pakistan. *Geological Bulletin, University of Peshawar* 20, 143-152.

X-ray diffraction studies of Post-Siwalik Quaternary lacustrine clay deposits exposed near Jehangira suggest the presence of illite, chlorite and montmorillonite. Illite and chlorite show regular and well-formed structure suggesting detrital origin. Whereas montmorillonite may have detrital and/or authigenic origin, If authigenic the depositional environments were alkaline and "non-aggressive". Mafic, ultramafic metamorphites of the Kohistan sequence and Main Mantle Thrust (MMT) melange zone and the schists of the Indo-Pakistan plate south of MMT are inferred as the ultimate source for these clay deposits.

Key words: Clay mineralogy, Quaternary lake deposits, Peshawar basin.

K/313. Khan, M.J., Arif, M., Awais, M. & Iqbal, S., 1987. Depositional environments of the Hissartang Formation Attock-Cherat Range, Peshawar. *Geological Bulletin, University of Peshawar* 20, 99-110.

Hissartang Formation forms the middle part of Silurian-Devonian stratigraphic sequence exposed in the Attock-Cherat Range. Detailed petrographic, textural and structural studies reveal that this formation consists of two facies described as follows.

Argillite facies:

Lower Argillite (99.12m) thin bedded, grey in color.

Upper Argillite (72.73m) thin bedded variegated in color.

Quartzose Sandstone facies:

Lower Quartzose Sandstone: (88.80m), thin to thick bedded, white to light gray in color.

Upper Quartzose sandstone: (105.99m), medium to thick bedded, white to light gray in color.

Only a few stratigraphic horizons of the upper quartzose sandstone show cross beds. Whereas thin to thick strata and thin laminae are commonly present in both, argillites and quartzose sandstone facies. Lack of various sedimentary and biogenic structures, fine grain size of quartzose sandstone and associations of argillites suggest the supratidal to

subtidal environments. Fine grain size of quartz and absence of barrier ridge sandstone suggest the large distance of transport of quartz particles and lesser amount of terrigenous material available.

Key words: Petrography, structure, depositional environment, Hissartang Formation, Attock-Cherat range, Peshawar.

K/314. Khan, M.J., Beck, R.A. & Burbank, D.W., 1992. Depositional diachrony of the Siwalik group between Potwar and Trans-Indus Ranges, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p. 24.

Key words: Depositional diachrony, Potwar, Trans-Indus Salt Range, siwalik.

K/315. Khan, M.J. & Hamidullah, S., 1994. Geochemistry of the seepage water from drain hole 0+53 Down, Adit RAA-2 of Tarbela Dam. Geological Bulletin, University of Peshawar 27, 117-123.

Geochemical parameters of the seepage water from drain hole 0+53 Down, Adit RAA-2 of Tarbela Dam are markedly in contrast with the similar parameters of the reservoir water. TDS and EC values are significantly higher and the amount of dissolved oxygen is lower in the drain hole seepage water than those of the reservoir water. The data suggest addition of soluble salts from the rocks of the right abutment into the seepage water while in transit from reservoir to drain hole. This clearly shows removal of soluble material from the country rocks and thus creation of voids in the right abutment. Lower values of dissolved oxygen in seepage water, as compared to those of reservoir water, indicate its consumption for the oxidation of ferruginous minerals during the transit period. Both gypsum and limestone are present in the country rocks with the former having higher oxidation potential and thus considered a preferred target of removal through dissolution, as compared to the latter. Therefore, proper future monitoring of the geochemical parameters of the seepage water in various drains is very important for evaluating the geotechnical hazards being posed by the dissolution of gypsum from the country rocks of right abutment of Tarbela Dam.

Key words: Hydrogeochemistry, seepage, TDS, Tarbela.

K/316. Khan, M.J. & Jan, M.Q., 1986. Last stages in the closing of neotethys and geotectonic evolution along the Indus suture zone. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 20-21.

Geology of Himalayan mountain chain has been widely attributed to the closing of Neotethys. Permian rifting along northern margin of "Greater India" resulted in the opening of Neotethys and separation of several small continental blocks. Closure of Neotethys had been affected by Early Eocene. Mechanism and timing of various stages of evolution of the ocean basin are still strongly debated. Recent geological data enables us to constrain the evolution in the western and central Himalayas. The data indicate that subduction began earlier in the western Himalayas than along the southern margin of Tibetan block. This was due to late separation (Jurassic) of Lhasa block from northern margin of Gondwanaland. In conformity with the recent radiometric ages and field observations it is proposed that subduction began during Upper Jurassic-Late Cretaceous in the Kohistan-Ladakh Island arcs and simultaneously along a subduction zone north of Lhasa block, probably along the Bangong-Nujiang suture. The process of subduction continued in the western arcs and shifted to south of Lhasa block during Middle Cretaceous. This was accompanied by the development of Trans-Himalayan batholiths (Kohistan-Ladakh-Gangdese belt), rifting of the Indian plate from Gondwanaland and probably a change from steeply dipping to shallow dipping Benioff zone. During this transition the subducting slab intersected the base of magmatic arc and dragged a fragment of the stratiform Chilas complex to depths of more than 40 km. This resulted in the formation of Jijal garnet granulite complex around 103.9 mybp (Sm/Nd age). Continued spreading in the Indian ocean lead to an accelerated rate of subduction. Consequent compression in the island arcs resulted in the closure of the basins located north of the magmatic arcs between 90-75 mybp. The formation of this northern suture (Main Karakorum Thrust) resulted in a major phase of deformation affecting the early plutons of Kohistan-Ladakh batholith. Subsequent magmatism is due to the northward subduction of Neotethys and later anatexis. Contemporaneous formation of the blueschists of the Indus-Zangbo suture is indicated by available radiometric ages. Rapid northward drift of India between 80-55 mybp resulted in complete closure of the Neotethys. Subsequent thrusts and accompanied obduction of the island arcs

resulted in the formation of melanges and emplacement of the tectonic blocks to their present position along the Indus-Zangbo suture.

Key words: Tectonics, Indus Suture, Himalaya.

K/317. Khan, M.J., Jan, M.Q. & Humayun, M., 1986a. A new Neotethyan closure model in western and central Himalayas. Abstracts with Programs, Geological Society of America 18, p. 656.

Recent geologic data indicate that closure of the Neotethys began earlier in the western Himalayas than along the southern margin of the Tibetan block. The data indicate the subduction began during Upper Jurassic-Early Cretaceous epoch along a zone presently occupied by the Kohistan-Ladakh island arcs and probably the Bangong-Nujiang suture, north of Lhasa block. This was due to late separation (Jurassic) of Lhasa block from Gondwanaland and its middle Cretaceous suturing. This resulted in the shift of subduction to the southern margin of the Lhasa block and emplacement of Trans-Himalayan batholiths. Rifting of the Indian plate caused a change from steeply dipping to shallow dipping Benioff zone. During this transition the subducting slab intersected the base of magmatic arc and dragged a fragment of the stratiform Chilas complex to depths of more than 40 km forming the Jijal garnet granulite complex (103.9 mybp). Continued spreading in the Indian ocean led to an accelerated rate of subduction, compression in the island arcs and closure of the basins located north of the magmatic arcs between 90-75 nybp. The formation of this northern suture (Main Karakoram Thrust) resulted in a major phase of deformation effecting the early plutons of the Kohistan-Ladakh batholith. Subsequent magmatism is due to the northward subduction of the Neotethys and crustal anatexis. Contemporaneous formation of the blueschists of the Indus-Zangbo suture is indicated by 84-75 mybp ages. Rapid northward drift of India between 80-55 mybp resulted in complete closure of the Neotethys. Obduction of the island arcs resulted in the formation of melanges and emplacement of tectonic blocks along the Indus-Zangbo suture.

Key words: Neotethys, Himalaya.

K/318. Khan, M.J., Jan, M.Q. & Humayun, M., 1986b. Last stages in the closing of the Neotethys and geotectonic evolution along the Indus suture zone. "Plate Tectonic and Crust of Pakistan". Geology Department, Punjab University, 20-22.

Recent geologic data indicate that closure of the Neotethys began earlier in the western Himalayas than along the southern margin of the Tibetan block. The data indicate that subduction began during Upper Jurassic-Early Cretaceous epoch along a zone presently occupied by the Kohistan-Ladakh island arcs and probably the Bangong-Nujiang suture, north of Lhasa block. This was due to late separation of Lhasa block from Gondwanaland and its middle Cretaceous suturing. This resulted in the shift of subduction to the southern margin of the Lhasa block and emplacement of Trans-Himalayan batholiths. Rifting of the Indian plate caused a change from steeply dipping to shallow dipping of Benioff zone. During this transition the subducting slab intersected the base of magmatic arc and dragged a fragment of the stratiform Chilas complex to depths of more than 40 km forming the Jijal garnet granulite complex (103.9 mybp). Continued spreading in the Indian ocean led to the accelerated rate of subduction, compression in the island arcs and closure of the basins located north of the magmatic arcs between 90-75 mybp. The formation of this northern suture (Main Karakoram thrust) resulted in a major phase of deformation effecting the early plutons of the Kohistan-Ladakh batholith. Subsequent magmatism is due to the northward subduction of the Neotethys and crustal anatexis. Contemporaneous formation of the blueschists of the Indus-Zangpo suture is indicated by 84-75 mybp ages. Rapid northward drift of India between 80-55 mybp resulted in complete closure of the Neotethys. Obduction of the island arcs resulted in the formation of melanges and emplacement of tectonic blocks along the Indus-Zangbo suture.

Key words: Neotethys, tectonics, magmatism, NW Himalaya.

K/319. Khan, M.J. & Opdyke, N.D., 1980. Magnetostratigraphy of the Siwalik sediments in Bhattani-Marwat anticline, Tran-Indus Salt Range, Pakistan. Geological Society of America, Abstracts with Program 12.

Key words: Magnetostratigraphy, Bhattani-Marwat anticline, Trans-Indus Salt Range, Siwaliks.

K/320. Khan, M.J. & Opdyke, N.D., 1981a. Correlation of the Siwalik Group in Trans-Indus Salt Range, Pakistan, based on magnetic polarity stratigraphy. Geological Society of America, Abstracts with Program 13.

Key words: Stratigraphy, magnetic-polarity, Trans-Indus Salt Range, siwaliks.

K/321. Khan, M.J. & Opdyke, N.D., 1981b. The magnetic polarity, stratigraphy, and correlation of the Upper Siwalik Sediments from the Bhattani range, North West Frontier Province, Pakistan. Physics of the Earth and Planetary Interiors 24, 133-141.

Two sections were sampled in Bhattani range, the first at Bain pass consisting of 60 sites through 2200 m of section and the second along the North West Frontier province Road north of Pezu consisting of 25 sites through 100 m/ both sections are in rocks known to range in age from the late Pliocene and Pleistocene based on vertebrate fauna of Pijor age. After partial thermal magnetization a series of magnetozones were established, ten at Bain Pass and six at Pezu, which can be correlated to each other and to the standard magnetic time scale. The sediments from the long section at Bain Pass span the time from the middle Gauss to the upper most Brunhes Chron. The Jaramillo and Olduvai subchrons are present within the Matuyama Chron. A short normal magnetozones is present in the section preceding the Olduvai subchron which correspond in age to the Reunion subchron. Based on the rate of sedimentation during lower Matuyama time which would be 0.95 m/1000 y for Bain Pass section, the Reunion subchron would span at least 25000 y. the section at Pezu Pass begins within the Olduvai and ends between the Jaramillo and Brunhes/Matuyama boundary. The sedimentation rate determined at this section is 0.77m/1000 y. the rate of sedimentation in this region was much higher than over comparable time span previously determined from the eastern Salt Range. The folding of the Bhattani range must have occurred less than 730000 year ago, since Bruchhe age sediments have been deformed.

Key words: Stratigraphy, magnetic-polarity, siwaliks.

K/322. Khan, M.J. & Opdyke, N.D., 1987. Magnetic-Polarity stratigraphy of the Siwalik group of the Shinghar and Surghar Ranges, Pakistan. Geological Bulletin, University of Peshawar 20, 111-127.

Four stratigraphic sequence were measured and sampled from the Shinghar and Surghar Ranges, Pakistan, for detailed magneto-stratigraphic studies of the fluvial Neogene and Quaternary Siwalik Group. The samples were subjected to blanket thermal demagnetization at 500 °C. Some of the samples, particularly those from the pale brown siltstone/claystone units, were further subjected to 600 °C to isolate the stable primary component of magnetization used to establish the magnetic-polarity-reversal sequences. This sequence was correlated to the MPTS with the aid of fossils collected from the nearby Dawood Khel area (Hussain et al., 1977) and from the Shinghar Range during paleomagnetic sampling. This correlation suggests that deposition of the Siwalik Group in this area began during basal Chron 11 (11.8 m.y.B.P.) and continued till the late Matuyama Chron (0.85m.y.B.P.). These indicate that the Siwalik sedimentation in this area started later than that of the Potwar Plateau.

Key words: Magnetostratigraphy, Shinghar, Surghar, siwaliks.

K/323. Khan, M.J., Opdyke, N.D. & Shroder, J.F., 1985. Bain diamictite: lithology, age and the origin. Geological Bulletin, University of Peshawar 18, 53-64.

The Bain diamictite is part of the Plio-Pleistocene Siwalik Group of northwest Pakistan. The type section is exposed in the Bhattani Range on the south edge of the Kurram river drainage basin near its confluence with the Indus. A counterpart section, reported here for the first time, occurs in the Shinghar Range north of the Kurram River. The unit in both areas is an unsorted, unstratified deposit that has heterogeneous lithology, including significantly large volcanic clasts and basal ash stringers. Cooling or drying cracks occur on the upper surface in at least one locality. Clast lithologies indicate a transport direction from the highlands of Afghanistan in the WNW. Previous workers have considered the Bain diamictite to be a tillite, but the low elevation of about 500m and lack of possible glacial

source area prior to main Himalayan orogenesis rule this out. Instead a debris-flow or volcanic-lahar origin from Dasht-i-Nawar caldera 300-400km away in Afghanistan is most likely. The probable volume of $30 \times 10^9 \text{m}^3$ of the deposit is compatible with most probable pre-caldera volcano topography and post- eruption caldera size, but is still perhaps the world's largest known lahar.

Key words: Lithology, diamictite, Kurram River, Plio-Pleistocene, Siwaliks.

K/324. Khan, M.J., Opdyke, N.D. & Tahirkheli, R.A.K., 1988. Magnetic stratigraphy of the Siwalik Group, Bhattani, Marwat and Khisor Ranges northwestern Pakistan and the timing of Neogene tectonics of the Trans-Indus. *Journal of Geophysical Research* 93, 11773-11790.

Nine stratigraphic sections in the Siwalik Group, three from the Bhattani Range, five from the Marwat Range, and one from the Khasor Range, were measured and sampled for magnetostratigraphic studies. Progressive alternating field and partial thermal demagnetization of samples indicated the presence of two components of magnetization. These are a secondary component of low coercivity, which can be removed by alternating field demagnetization in fields up to 40 mT and/or temperatures to 400°C , and a stable primary component of magnetization which has blocking temperatures above 450°C . Therefore all samples were subjected to blanket demagnetization at 450°C and 500°C , and some to temperatures up to 600°C . Positive fold tests from the Bhattani and Marwat ranges indicate the successful isolation of a prefolding characteristic direction of magnetization. A magnetic polarity reversal sequence for each of the sampled sections is determined and correlated to the magnetic polarity time scale utilizing a fission track date and fauna from the sequences which have previously been shown correlated to the magnetic polarity time scale. This correlation shows that the Siwalik Group in the area of study ranges in age from the late Gilbert chron to the early Brunhes chron (about 0.5 m.y. B.P.). Deposition of the thick sandstone units of the Siwalik Group in the Marwat Range began at least by Gauss chron time. The correlation of observed magnetic polarity stratigraphy, of the Khassor Range, with the standard magnetic polarity time scale shows that the Siwalik Group of this area ranges in age from the early Gauss chron (about 3.2 Ma) to the Brunhes chron. The region of this study began to subside prior to 4 Ma and subsided at a rate of from 60 to 100 cm per 1000 years. The tectonism of the region began within the last 1 m.y. and may well be synchronous with folding in the Pabi Hill anticline on the other limb of the syntaxis near Jelum. This orogeny is therefore one of the world's youngest and is undoubtedly still in progress.

Key words: Bhattani, Marwat and Khisor Ranges

K/325. Khan, M.L. & Bangesh, I.H., 1983. Petrography of the Mahak area, Upper Swat. M.Sc. Thesis, University of Peshawar, 71p.

Mahak area in upper Swat lies in the southern amphibolites belt of the Kohistan island arc. The various rock types of Mahak are medium- to coarse-grained amphibolites, hornblendites, hornblende pegmatite, diorites, meta-gabbro, metapyroxenite and quartz-feldspathic veins and dykes. Amphibolites are most abundant rocks of the area. These are distinguished into epidote amphibolite and plagioclase amphibolite.

Key words: Petrography, amphibolites, hornblendites, Mahak, Swat.

K/326. Khan, M.M., Jadoon, K.G. & Khan, A.U., 1990. Selective flotation of lead from lead zinc ore of Kohistan, Hazara, Pakistan. Abstracts, First SEGMIITE Conference on Industrial Minerals, Peshawar, p. 7.

Key words: Lead-zinc ore, floatation, Kohistan, Hazara.

K/327. Khan, M.M., Naseem, T. & Wahid, F., 1994. Beneficiation of North Waziristan copper ore. Abstracts, Second SEGMIITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 21-22.

Key words: Copper ore, beneficiation, Waziristan.

K/328. Khan, M.R., 1972. Geology and petrology of Taghma area, Swat. M.Sc. Thesis, Peshawar University, 57p.

Key words: Petrology, Taghma, Swat.

K/329. Khan, M.R., 1983. The exploitation of iron deposits of Pakistan; great requirement of the time. 2nd National Seminar on Development of Mineral Resources, Peshawar, 12-25.

Key words: Iron ore, exploitation, Pakistan.

K/330. Khan, M.R. & Ali, M., 1994. Preliminary gravity model of Western Himalayas in Northern Pakistan. *Kashmir Journal of Geology* 11 & 12, 59.

The gravity modeling in western Himalayas along SW-NE profile from Fatehjang (southwest) to Kundul Shahi has been developed. Gravity model indicates 8-Km thick sedimentary wedge in the Fatehjang, which gradually increases to 20 km at Kundul Shahi. The thin skin metasedimentary wedge. These thrusts have brought in contact the different stratigraphic units of Precambrian to Mesozoic ages in the area of Hazara Kashmir Syntaxis. The stratigraphic units consist of Hazara Formation (mainly slates of Precambrian), Tanol Formation (pelites/psammities Late Cambrian), Panjal volcanics (Permo Carboniferous), Carbonate (Mesozoic-Tertiary) and Molasse (Miocene to Recent).

The western limb of the syntaxis moves southward over the decollement and formed the low angle thrust while in the eastern limb thrust nappes are uplifted in the absence of decollement and form the high angle thrust. Jhelum strike-slip fault developed by the differential movement marks a boundary between salt and salt areas.

The crystalline crust of 38 Km thick extending all the way from Fatehjang to Kundul Shahi is broken into blocks by the basement faults northeast of Taxila and Abbottabad. These faults are the Hazara lower Seismic Zone and the Bagh Basement Fault. The Main Central Thrust is not detected in the study area; it may be passing from the upper Neelum Valley Azad Kashmir. The results indicate that the differential movement because of the presence and absence of salt and anti clockwise rotation of transport direction are responsible for the formation of Hazara Kashmir Syntaxis. The average crustal thickness of 46 Km in Fatehjang gradually increases to 49 Km at Kundul Shahi.

Key words: Geophysics, gravity model, Himalaya.

K/331. Khan, M.R. & Ali, M., 1997a. Tectonic study of the Hazara and its adjoining areas of northern Pakistan based on gravity data. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 37.

Consult the following account for more information.

Key words: Tectonics, gravity, Hazara, Himalaya.

K/332. Khan, M.R. & Ali, M., 1997b. Tectonics of the Hazara and adjoining areas, based on gravity data, Northwest Himalaya, Pakistan. *Geological Bulletin, University of Peshawar* 30, 273-283.

Gravity data in the Hazara-Kashmir Syntaxis of northern Pakistan has been incorporated into interpretation of the gross crustal structure of the area. In this area, due to the continued northward migration of Indian plate, the Indian plate has been overridden by slices of its own northern margin and activity has caused the slight thickening of crust in the northeast and northwest of the Hazara-Kashmir Syntaxis. In the sedimentary wedge, the thinskin structures have been developed by the southward migration of the sedimentary wedge. In northern Pakistan, Late Precambrian to Early Cambrian strata constitutes the zone of decollement. It is absent in eastern side in Kashmir and India. In the eastern limb of the Hazara-Kashmir Syntaxis, the Main Boundary Thrust (MBT) and the Panjal Thrust (PT) are developed. Here the strong coupling between sediments and basement occurred due to the absence of decollement which caused the high topography of the Hazara-Kashmir Syntaxis range front. In the western limb the MBT and the Nathiagali Thrust (NT) are developed. These thrust sheets moved southward over this decollement. The thrust

system of eastern and western limbs are converging near the apex of Hazara-Kashmir Syntaxis. The differential movement resulted due to presence and absence of salt in the area developed the Jhelum fault. Jhelum fault cuts the PT, MBT and the Kashmir Boundary Thrust (KBT) in the Kashmir side and the MBT and NT in the western side in northern Pakistan. The sedimentary wedge of the western limb of the Hazara-Kashmir Syntaxis moves southward along this fault.

Key words: Tectonic modelling, gravity, Hazara, Himalaya.

K/333. Khan, M.R. & Ali, M., 1997c. Tectonic modeling of western Himalaya in northern Pakistan based on gravity study. *Geological Bulletin, Punjab University* 31 & 32, 103-113.

Gravity data in the Hazara and its adjoining areas of northern Pakistan have been incorporated for the interpretation of the gross crustal structure of the Hazara-Kashmir Syntaxis in western Himalayas. In this region two types of deformation have been observed. One is in the crystalline basement and other is in the sedimentary wedge. The crystalline crust of 38 Kms thickness faulted into blocks in the northeast of Taxila and Abbottabad. These faults are Hazara Lower Seismic Zone and Bagh Basement Fault. These predeveloped faults have been reactivated after collision of Indian and Eurasian Plates. Some of the normal faults trending in the NE-SW, also appeared to exist in the upper crystalline basement near Rawalpindi. These faults were developed by the extensional stresses, which are caused by the bending of Indian crystalline basement.

In the sedimentary wedge the thin-skin structures have been developed by the southward migration of the sedimentary wedge. In the area under study the thin-skin structures consist of thrust faults, strike slip faults and the salt/incompetent state (decoulement). In the eastern limb of Hazara Kashmir Syntaxis there is strong coupling between sediments and basement consequently the materials is uplifted. In Pakistan Late Precambrian to Early Cambrian age strata constitute the uplifted zone of decollement. Over this decollement the western limb of Hazara-Kashmir Syntaxis move southward between Jhelum and Kalabagh strike slip faults.

Key words: Tectonic modelling, gravity, NW Himalaya.

K/334. Khan, M.R., Ali, M. & Ashraf, M., 1998. Crustal study in lesser and Sub-Himalayas of northern Pakistan based on gravity modelling. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 101.

In lesser and sub-Himalaya in Northern Pakistan the deformations have been observed in crystalline crust and sedimentary and metasedimentary wedge using gravity technique. The crystalline crust of 38-km thickness extended all the way in the study area and faulted into blocks under the western limb of Hazara-Kashmir Syntaxis. These faults are Hazara Lower Seismic Zone (HLSZ) and Bagh Basement Fault (BBF). These predeveloped faults have been reactivated after collision of Indian and Eurasian plate. The HLSZ has been associated with the basement fault under Northern Potwar trending NW-SE. Along this fault 6 Km relative movement of the blocks have been observed. In the gravity modelling best fit of the observed and calculated curves in the northeast of Abbottabad also suggested 4-km relative movement of the blocks. This fault has been named as the Bagh Basement Fault which is existing between HLSZ and Indus Kohistan Seismic Zone (IKSZ).

In the sedimentary and metasedimentary wedge the deformations have been developed by the southward migration of this wedge. The thrust faults have brought in contrast the different stratigraphic units in sedimentary and metasedimentary wedge of the Hazara-Kashmir Syntaxis. From north to south in Lesser Himalaya Nathiagali Thrust (NT) brings the Hazara Slates of Precambrian age over the Eocene to Cretaceous marine rocks. The Main Boundary Thrust (MBT) is the major southern most lineament along which the pre-collisional marine sediments are thrust over post-collisional molasse in the Sub-Himalaya. The fault plane of MBT is steeper near surface and becomes gentle in depth, and joins the low angle detachment. The fault plane of the NT does not join the MBT, which indicates that NT is not a part of MBT Zone. The MBT at present is active in the north of Kohat and in the eastern limb of Hazara-Kashmir Syntaxis. The present gravity investigations suggested the presence of the Panjal thrust between Panjal volcanics and Tanol Formation in the eastern limb and do not pick the Main Central Thrust up-to the Kundul Shahi. This may exist in the upper Neelum Valley. The thrust system of eastern and western limbs were converging near the apex of Hazara-Kashmir Syntaxis. The Jhelum Fault cuts Panjal Thrust (PT), MBT and the Kashmir Boundary Thrust in the Kashmir side and the Hazara Thrust System in the western side in northern Pakistan. The dips of the Hazara Thrust system increase towards northeast. The differential movement exists in the Hazara-Kashmir Syntaxis due to the presence and absence of decollement (salt). In the western limb thrust nappes

are thrusting southward over the decollement, whereas, in the eastern limb the thrust nappes are uplifted in the absence of decollement. These differential movements developed the Jehlum Fault. The sedimentary and metasedimentary wedge of the western limb of Hazara-Kashmir Syntaxis moves southward along the Jehlum Fault. The Kuldana Shales are acting as a secondary decollement, in the sedimentary wedge. The average crustal thickness or Moho depth in the area seems to vary from 46 km (southwest) in Fatehjang to 59 km in Kundul Shahi (northeast). It seems that the total crustal thickness from Potwar plain (Fatehjang) to the Neelum Valley (Kundul Shahi) Azad Kashmir increases by 13 Km.

Key words: Gravity modelling, deformation, NW Himalaya.

K/335. Khan, M.R. & Khan, M.S., 2001. Study of shallow geological structures in the core of Hazara Kashmir syntaxis based on residual gravity data in Azad and Jammu Kashmir, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 69-70.

The residual gravity data has been incorporated for the interpretation of shallow geological structures in the core of Hazara Kashmir Syntaxis. In the western periphery of the area Jhelum fault is running along the river Jhelum. The contours trend on residual granite maps from Muzaffarabad to Tam follows the trend of Jhelum fault. The negative contours closure on the residual gravity map in Bagh area shows the low-density sedimentary basin of recent age. The modelling of residual gravity data indicates 1.3 km deep sedimentary basin. The contours trend from Bagh to Chikar and from Chikar to Muzaffarabad delineate the Kashmir Boundary Thrust (KBT). The KBT is running from Bagli to Chikar between the Murree Formation and the Siwaliks whereas on the northeastern side from Chikar to Muzaffarabad the Siwaliks have been eroded and the Murree Formation is exposed. The gravity modelling also envisages the KBT as a shallow thrust, which penetrates upto the depth of the Kuldana Formation. The shales of the Kuldana Formation are acting as decollement for the overlaying sedimentary wedge of the Murree Formation which is thrusting over the Siwaliks along the KBT.

Key words: Structures, tectonics, geotechnical, gravity, Hazara Kashmir syntaxis.

K/336. Khan, M.S., 1986. Pleistocene sediments and chronology of Middle Indus and Lower Gilgit Valleys between Shatial and Dainyar. M.Phil. Thesis, University of Peshawar, 101p.

Thick valley-fill deposits preserved in deep valleys in Indus, Gilgit and Hunza river areas and a variety of age dates allow new definition of Quaternary events in Karakoram Himalaya. Three glacial stages of Pleistocene are recognized with several advances in Holocene. The early stage is indurated lower Jalipur tillites and heterogeneous upper Jalipur valley-fill sedimentary rock younger than 1 to 2 myr and folded, overturned or overridden by movement of Raikot fault associated with rapid overall uplift rates of Nanga Parbat-Haramosh massif. Middle stage is two tills intercalated with invariable sediments, including thick lacustrine units dipping upto 43° along fault. Indus-Shatial tills record the farthest advance down Indus of Pleistocene glacier at this time, Late stage consists of three or more separate advances that retain moraine topography; the Dianyor moraine near Gilgit was produced by a major longitudinal glacier from Hunza. Downstream at Jaglot, Nanga Parbat, Shatial and elsewhere, transverse glaciers blocked Indus to produce lake deposits now dipping upto 6° along the fault. Catastrophic breakout floods emplaced some Punjab erratics and sediments that was reworked into loesses in the Himalayan fore land.

Key words: Sedimentology, Quaternary, Pleistocene, Jalipur, Chilas.

K/337. Khan, M.S., 1997. Gold mineralization in the Carboniferous-Permian rocks in the Neelum valley, Azad Kashmir, Lesser Himalayas. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

The agglomeratic slates and the Panjal volcanics (lava flows) and associated carbonate rocks are sandwiched between the Main Boundary Thrust and the Panjal Thrust in the Neelum valley. Muzaffarabad, the Lesser Himalayas. The Panjal volcanics have been altered and metamorphosed to lower greenschist facies metamorphism. Major alteration minerals are chlorite, epidote, albite, actinolite, quartz and sphene. The Panjal volcanics are mainly tholeiitic to slightly alkalic rocks. They are dominantly basalts to basaltic andesites. The alteration has also been revealed from their high LOI values and high Na₂O and K₂O contents and by other mobile elements.

Reconnaissance geochemical “grab” sampling along two mapping and petrographic traverses across the strike of the volcanic sequence encountered Au and Ag mineralized units. The host rocks are dioritic and andesitic in composition exposed along and within the Panjal volcanics. The Panjal volcanics are closely associated with the Nauseri granite-granite gneiss terrain. The gold mineralization is located at two horizons. The lowest is a dioritic rock which is foliated and mylonitized. This rock is at the contact of the lava flows and chemically consists of SiO₂ 60.30, MgO 1.28, CaO 1.04, TiO₂ 0.80 Wt.%, Ni 1241ppm, Pb 1588ppm, Cu 49 ppm, Zn 80ppm and Au 11 ppm. The second horizon is a sulfide zone containing pyrite and chalcopyrite and located within the lava flows of the Panjal volcanics in an andesitic rock. The chemical constituents of this rock are SiO₂ 61.69, MgO 2.06, CaO 7.62, TiO₂ 1.4 Wt%, Ni 99ppm, Cu 5639ppm and Ag 8ppm. Both zones represent altered parent lithologies. Rocks have altered to chlorite, sericite, epidote and clay minerals. The foregoing results of only few samples in reconnaissance indicate that a follow-up comprehensive geochemical exploration programme in the areas comprising agglomeratic slates and the Panjal volcanics would be worthwhile.

Key words: Mineralization, gold, carboniferous, Permian, Neelam valley, Azad Kashmir.

K/338. Khan, M.S., 1998. Estimation of contaminants in the groundwater establishment of protection zones in Wah Cantt. Area. Ph.D. Thesis, Punjab University, Lahore.

Key words: Groundwater, contamination, Wah cantt, Attock.

K/339. Khan, M.S., Ahmad, M. & Anwar, M., 1970. Morphological comparison of the heavy minerals of Manki Slate and Attock Shale of the Attock Group. M.Sc. Thesis. Geol. Dept., Peshawar University, 28p.

Key words: Morphology, heavy minerals, Manki slates, Attock shale, Peshawar.

K/340. Khan, M.S. & Ashraf, M., 1989. Panjal volcanics: geochemistry and tectonic setting in Azad Jammu & Kashmir & Kaghan valley NW Himalaya. Kashmir Journal of Geology 6 & 7, 61-80.

Panjal Volcanic rocks, with maximum upto 1400 m thickness, occur within a system of Main Boundary Thrust and Panjal Thrust in the NW Himalayas from Kahuta to Kaghan. The geotectonic evolution of these volcanic have been studied by field investigations, petrography and geochemistry. Petrographic study of the Panjal rocks show that they are basalts to basaltic andesites and are tholeiitic to slightly alkaline in character. They were formed mostly in submarine environments showing alteration of their minerals to epidote, chlorite and sodic Plagioclase.

Major elements data for the Panjal Volcanics are plotted on different tectonomagmatic geochemical discriminate diagrams, to infer their tectonic environment. The data largely plot in the oceanic fields. The geology of the area, geochemistry and inferred tectonic setting show that Panjal Volcanics were erupted in a rift to oceanic, environments.

Key words: Geochemistry, tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/341. Khan, M.S., Ashraf, M. & Chaudhry, M.N., 1991. Geochemical evidence for an oceanic affinity of the Panjal volcanics in Kaghan valley, Pakistan. Kashmir Journal of Geology 8 & 9, 1-18.

The Panjal volcanic rocks in Kaghan area have been analyzed for major and trace elements. These rocks have been altered and spilitized considerably because Na₂O varies from 0.38 to 6.4 wt. %. In spite of alteration of these rocks the whole rock composition retains a strong igneous imprint (TiO₂ 1.28 to 2.34 % P₂O₅ 0.1 to 0.24 %, Zr 77 to 179 ppm and Y 19 to 39 ppm). The abundance of incompatible and immobile elements when plotted on discrimination diagrams of infer tectonic setting, indicate geochemical signature of ocean floor basalts. These rocks are transitional between within-plate to ocean floor basalts on major and trace element abundance.

Key words: Geochemistry, Panjal volcanics, Azad Kashmir, Kaghan.

K/342. Khan, M.S., Ashraf, M. & Chaudhry, M.N., 1992. Geochemical evidence for an oceanic affinity of the Panjal volcanic in Azad Kashmir and Kaghan area. Abstracts, First South Asia Geological Congress, Islamabad, p. 24.

For more information on the topic, consult M. S. Khan et al. (1991, 1997).

Key words: Geochemistry, tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/343. Khan, M.S., Ashraf, M. & Chaudhry, M.N., 1997. Geochemical evidence for the tectonic setting of the Panjal volcanics in Azad Kashmir and Kaghan areas. Geological Bulletin, Punjab University 31 & 32, 43-52.

The Permian to Early Triassic age Panjal volcanics in Azad Kashmir and Kaghan areas are exposed along Main Boundary Thrust. Studies of the major and trace elements in the Panjal volcanic rocks indicate that they formed in a tectonic setting transition from within plate to oceanic conditions. These rocks show TiO_2 contents from 1.08 to 1.59 wt. %, SiO_2 from 47.93 to 51.24 wt. %, MgO from 5.05 to 9.07 wt. % and P_2O_5 from 0.09 to 0.19 wt. %. $\text{Mg\#}$ varies from 59.7 to 66.10 Na_2O contents range from 1.11 to 4.99 wt. %, K_2O from 0.11 to 2.67 wt. %. Major elements especially Na_2O and K_2O indicate alteration of these rocks.

Trace element contents of the Panjal volcanics also show variation. Zr contents range from 53 to 110 ppm, Ni 56 to 229 ppm and Cr from 54 to 677 ppm. Major and trace elements and $\text{Mg\#}$ of the rocks indicate that the Panjal magma has been evolved as tholeiitic to slightly alkalic in composition with geochemical characteristics similar to enriched mid ocean ridge (P-type) basalts or ocean island tholeiites. The interbedded chert, limestone and associated turbidite deposits indicate shallow marine environment during the time of eruption of magma. The volcanics represent range of the northern margin of Indian continent and development of shallow marine oceanic conditions during Upper Paleozoic.

Key words: Geochemistry, tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/344. Khan, M.S., Ashraf, M. & Raja, M.K.K., 1994. Petrology of the Nauseri granite gneisses in lower Neelum valley state of Azad Jammu and Kashmir. Kashmir Journal of Geology 11 & 12, 29-42.

The Nauseri granite gneisses occur in the lesser Himalaya of Azad Jammu and Kashmir. The granite gneisses are sheared, mylonitized, deformed and occur in the metamorphic assemblages of biotite to kyanite grades. The field relations of these rocks characterized by peraluminous and S-type nature. On the basis of available data i.e. their intrusive character in the field, petrography and major element chemistry, partial melting origin is envisaged and large scale subsequent granitization for the granitic rocks. These rocks have been resulted from the emplacement of the anatectic melt into the low-grade metasediments, which had been uprooted and transported southwards from their original place.

Key words: Petrology, granite, gneisses, Neelum valley, Nauseri, Azad Kashmir.

K/345. Khan, M.S. & Chaudhry, M.N., 1997. Tectonic-magmatic environment of the Panjal volcanics in Azad Kashmir and Kaghan areas, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.37.

For more information on the topic, consult M.S. Khan et al. (1991, 1997).

Key words: Tectonics, Panjal volcanics, Azad Kashmir, Kaghan.

K/346. Khan, M.S., Mateen, A. & Tufail, M., 1997. Investigations of radioactivity in Hazara phosphate deposits for fertilizer applications. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Natural radioactivity due to ^{40}K , ^{226}Ra and ^{232}Th has been investigated in the phosphate rock deposits of Hazara division of Pakistan. Gamma measurements of the radionuclides were carried out using a high purity germanium (HPGe) detector. Data acquisition and activity analysis was done by a PC based MCA. A common index, called Radium Equivalent Activity that incorporates ^{40}K , ^{226}Ra and ^{232}Th activity values, was found to be considerably higher than the permissible limit of 370Bq.Kg^{-1} . That can result in significant radiation exposure in the environment of fertilizer making plants and in its storage places where radon is accumulated. Radioactivity is also spread in the agriculture land along with fertilizers. Removal of radioactivity from the phosphate rock and ventilation of storage places of the fertilizers affect the economic value of the phosphate products.

Key words: Radioactivity, fertilizer, phosphates, Hazara.

K/347. Khan, M.S., Shah, H. & Saeed, G., 1995. Geological Map of Thana quadrangle (Toposheet No. 43 B/2, Scale 1:50,000), NWFP, Pakistan. New Geosc. No. 1038 (Old Sheet No. 70), Geological Survey of Pakistan NWFP Geological Map Series, vol. III.

Key words: Mapping, Malakand Agency.

K/348. Khan, M.S.Z., Abdullah, S.K.M. & Offield, T.W., 1966. Reconnaissance geology of the Mansehra quadrangle, Hazara district, West Pakistan. Geological Survey of Pakistan and U.S.G.S Project Report PK (IR)–10, 31p.

Key words: Reconnaissance, Mansehra.

K/349. Khan, M.S.Z., Shah, S.H., Khan, N.A., Latif, M. & Khan, K.S.A., 1999. Geological Map of the Gilgit quadrangle (Toposheet No. 43-I/5; Scale, 1:50,000), Northern Areas, Pakistan. Sheet No. 1310, Geological Survey Pakistan. Geological Map Series.

Key words: Geological map, Gilgit.

K/350. Khan, M.Y., 1974. Geological investigation for graphite in Gandghar Range, southern Hazara, Pakistan. Geological Survey of Pakistan, Information Release 28.

Key words: Exploration, graphite, Gandghar, Hazara.

K/351. Khan, M.Y. & Ahmad, Z., 1974. Geology of Barwa quadrangle (Toposheet No. 38 N/9), Dir State, West Pakistan. Geological Survey Pakistan. Information Release 79.

Key words: Geology, mapping, Dir.

K/352. Khan, M.Y. & Hussain, A., 1974. A note on the occurrence of iron ore near Mazari Tang, Peshawar District, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 72, 8p.

The iron ore occurrence near Mazari Tang Payan village in Peshawar district has been investigated. The ore is hematite and is of sedimentary origin. It occurs in two to three lenticular beds in the lower part of Jurassic limestone. The hematite is good quality and contains more than 50% of Fe_2O_3 . The extent of the deposit is limited and its reserves, calculated to a dip depth of 400 feet, are 450000 tons.

Key words: Iron, Mazari Tang, Peshawar.

K/353. Khan, M.Z., 1983-85. Geology and petrology of Burawai area upper Kaghan valley District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 125p.

Nearly 114 sq. km. in the vicinity of Burawai, upper Kaghan valley has been geologically mapped, at the first time. This thesis presents first time accounts of geomorphology, lithostratigraphy, petrography and economic geology of the area. The area constitutes rocks representing old Indo-Pak basement rocks, comprising pelites, calc-pelites and marbles have been metamorphosed to kyanite and sillimanite grades. These are intruded by para-autochthonous sheet granites also metamorphosed. Major structure comprises an open synform possibly part of a larger structural basin. The western part comprises the nose of a larger antiform. Marble, biotite mica and kyanite are important mineral deposits which deem further exploration and evaluation. This thesis also includes petrogenesis of the rock units as well as numerous sketch sections and photographs, illustrating the geology of the area.

Key words: Petrology, mapping, Kaghan valley.

K/354. Khan, M.Z., 1991. Petrology and Geochemistry of melange zone and southern amphibolite belt rocks from Gantar area. Allai-Kohistan, Hazara, N. Pakistan. M.Phil. Thesis, University of Peshawar.

Petrographic and geochemical study was performed for the Kohistan island arc (KIA) rocks, Main Mantle Thrust (MMT) mélangé zone and Indian plate rocks at Gantar and Kalalota, Allai Kohistan, Hazara, in order to envisage the petrogenetic history of these rocks. Field and petrographic data shows that the KIA is composed of amphibolites (mainly epidote amphibolite) together with hornblend pegmatite. The mélangé zone include blue schist, green schist, meta-gabbro/norite, ultramafic and pillow lavas while the Indo-Pak plate comprises quartz-muscovite-chlorite-carbonate schist, quartz-actinolite schist calcareous schist graphite schist and siliceous marble.

Amphibolites of the Kohistan arc are derived mainly from the basic magma of non-alkaline characters (transitional between tholeiitic and calc-alkaline) through crystallization differentiation of ferro-magnesian minerals with plagioclase. This protolithic material was the subjected to a metamorphism of amphibolites facies followed by retrogression into epidote amphibolite facies and green schist facies.

Mineral chemistry of amphibolites reflects maximum metamorphic temperature i.e. 600 c for tschermakitic hornblend and 500 c for the actinolite under a metamorphic PH₂O of 4-5 kb. The hornblend pegmatite appears to be of possible metasomatic origin.

It is concluded that the mafic/ultramafic rocks, meta-gabbro/norites, blue schist, pillow lavas and other basic rocks (metamorphosed to green schist) envision the normal ophiolitic sequence being offset by intensive multiple episodes of tectonic deformations (subduction and obducting environment).

Key words: Petrology, geochemistry, amphibolite belt, Allai-Kohistan.

K/355. Khan, M.Z. & Khattak, N.N., 1989. Hydraulic characteristics of the aquifers of Haripur area, District Abbottabad. M.Sc. Thesis, University of Peshawar, 67p.

Key words: Groundwater, aquifer, Haripur, Abbottabad.

K/356. Khan, N., 1990-91. Structure, stratigraphy and petrography of the western limb of the Hazara-Kashmir Syntaxis, Abbottabad and Manglaur areas, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 138p.

The Abbottabad and Manglaur area lies along the western extremity of the Hazara-Kashmir syntaxis. The area has been divided into two zones on the basis of structure and stratigraphy. Because the rocks of the blocks belong to different stratigraphic provinces and have become in contact with each other tectonically, these zones are Garhi Habibullah-Abbottabad (east of Panjal thrust) and Mansehra zone (west of Panjal thrust).

Rocks east of Panjal thrust in the area consist predominantly of Precambrian to Paleocene sedimentary and very low-grade metasedimentary rock units (Hazara Formation) that represents the first deformation and metamorphism in the Hazara area. Whereas, in west of Panjal thrust, the area consists of Cambrian granite gneisses and very low to low-grade metasedimentary (Tanol Formation) that represent D2 deformation and metamorphism associated with the Himalayan deformation phases. The grade of metamorphism varies from chlorite-grade in the south to biotite-grade in the north. The Mansehra zone is intruded by the Permian Panjal mafic dykes and sills of dolerite and basalts. These dolerite and basalts are mostly fresh. The sedimentary, metamorphic and intrusive igneous rocks of

these zones are classified and characterized by petrographic studies. The stratigraphy of the area has been developed in which the Abbottabad group has been divided into three formations which are Sobrah, Kakul and Sirban formations. The redivision was marked by an unconformity between Sangargali and Mahmdagali of the Sobrah and Kakul formations.

The rocks have undergone at least three phases of deformation (D1, D2 & D3) and have been metamorphosed to greenschist facies. The first deformation D1 took place as a result of Hazaran orogeny and produced first fabric (S1) in the Hazara Formation which is generally parallel or slightly oblique to the original lithologic layering S0. D2 is associated thrusting and folding phase. Himalayan orogeny folded S1 into open and closed F2 folds that range in size from small kink bands to larger map scale folds. It caused development of penetrative S2 foliation axial planar to F2 folds. D3 deformation phase associated with the formation of Hazara-Kashmir syntaxis and formed F3 cross folds.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir syntaxis.

K/357. Khan, N. & Ilyas, T., 1995-96. Geometric analysis of mesoscopic shear zones in the Gandghar Range, N.W. Himalaya; Pakistan, M.Sc. Thesis, 66p.

Key words: Structure, Gandghar Range.

K/358. Khan, N.A. & Khan, T., 1998. Geology of the Chilas quadrangle (Toposheet No. 43 I/3), Diamir district, Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 548, 10p.

The mapped area lies within the southern Kohistan island arc terrane. The Kohistan arc terrane has been considered to form due to the northward subduction of the Neo-Tethyan oceanic lithospheric plate under the Eurasian plate during Cretaceous time. Two suture zones delineate the arc from the continental plates, viz., the Main Mantle Thrust (MMT) and the Main Karakoram Thrust (MKT). The Main Mantle Thrust (MMT) passes through the southeastern part whereas the MKT is exposed to the north" of the mapped area.

Rock formations ranging in age from Cretaceous to Recent include Thak amphibolites, Sunal greenstone, metasediments and metavolcanics of the Jaglot group, Chilas complex, Kohistan batholith and glaciofluvium, alluvium and colluvium deposits. Thak amphibolites occupy Jal shear zone which are sheared and deformed. Sunal greenstone include metabasalt and metaandesite with minor dacite and rhyolite, volcanic breccia and tuff. Amphibolites, metagabbroic and metadioritic in composition occur in Kiner Gah area. They have intrusive contacts with the Chilas complex and the Kohistan batholith. Metasedimentary and metavolcanic (amphibolites) of the Jaglot group occur as xenoliths within the Chilas complex. The Chilas complex comprises mafic, ultramafic and feldspathic rocks. The complex is dominantly composed of gabbro-norite and pyroxene quartz diorite. Dunite, peridotite, pyroxenite, anorthosite (ultramafic-mafic-anorthositic association; cumulates) are also characteristic of the Chilas complex. Blastomylonite diorite and tonalite are also present. Kohistan batholith includes tonalite which intrudes the Thak amphibolites.

Tectonically, the area is characterized by a number of northwest dipping high angle faults and shear zones which are truncated in the east by the Raikot fault. The ultramafics of Chilas complex have chromite, PGE and copper mineralization. Small patches of the sulphide zones occur within the Chilas complex and the Thak amphibolites.

Key words: Mapping, Chilas Complex, Kohistan Island Arc.

K/359. Khan, N.A., Khan, T., Mujtaba, G., Hussain, H. & Khan, R., 1999. Geology of the Kiner Gah quadrangle (Toposheet No. 43 I/2), Diamir district, Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 684, 13p.

The mapped area lies within the southern Kohistan island arc terrane. The Kohistan arc terrane has been considered to form due to the northward subduction of the Neo-Tethyan oceanic lithospheric plate under the Eurasian plate during Cretaceous time. Two suture zones delineate the arc from the continental plates, viz. the main Mantle Thrust (MMT) and the Main Karakoram Thrust (MKT). The Main Mantle Thrust (MMT) passes through the southeastern part whereas the MKT is exposed to the north of the island arc.

Rock formations ranging in age from Cretaceous to Recent include Kiner amphibolite, metasediments and metavolcanics of Jaglot group, Chilas complex, Kohistan batholith and glaciofluvial deposits. Kiner amphibolites

(metagabbro and metadiorite) occur in Kiner and Hadar gah which are sheared and deformed in Dang Phhar area. They have intrusive contact with the Chilas complex and the Kohistan batholith. Metasediment and metavolcanics of the Jaglot group occur as xenoliths within the Chilas complex and Kohistan batholith.

They are schists and paragneisses interlayered with amphibolites. They are hybridized and at places migmatized. The Chilas complex comprises gabbro-norite, pyroxene quartzdiorite, hornblendite with minor ultramafic rocks. This sequence intruded by the Kohistan batholith which occupies about 70% of the northern part of the mapped area. It is composed of multiphases plutons of diorite, tonalite, quartzdiorite, granodiorite, adamellite, granite and leucocratic dykes. The diorite and tonalite show deformation whereas quartzdiorite, granodiorite and granites are partly deformed.

Tectonically, the area is characterized by a number of northeast dipping high angle faults and many shear zones are developed which accommodate the neotectonic uplift of the NPHM

Key words: Geology, Kiner gah, Diamir.

K/360. Khan, N.A., Latif, M., Bakht, M.S. & Fayaz, A., 1999. Geology of the Guner quadrangle (43 I/7), Diamir District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 683.

The investigated area lies on the SSW of the Nanga Parbat Haramosh Massif (NPHM) and southern part of Kohistan island arc. The oldest formation is Nanga Parbat group of paragneisses, schists and orthogneisses of Precambrian age. These are polycyclic metamorphic facies which consist of garnet-microparagneisses, mica schists, migmatites, augen-gneiss, orthogneiss and retrograde chlorite schists. These rocks are intruded by granitoid of Cambrian age. These rocks updomed from a cover of thrust amphibolites/meta volcanic of Kohistan island arc and formed the Nanga Parbat syntaxis.

The Raikot shear zone is mostly amphibolite green schist and actinolite schist having faulted contact with Nanga Parbat group and Kohistan island arc. The Kohistan sequence has the oldest rocks of the Thak and Kiner amphibolites. They were formed from the early volcanics and plutonic rocks of calc-alkaline nature. The Chilas complex is a large mafic-ultramafic body intruded into the arc sediments and amphibolite and represent the root zone of magma chamber of the Kohistan island arc.

All these rocks are intruded by Kohistan batholith. Latest intrusions are tonalite stocks, garnet-tourmaline granitic sheets and granitic pegmatites after the collision during Miocene. Small deposits of molasse occur along the Indus River. However, the unconsolidated sediments are found along the Indus River and its major tributaries which are moraine, terrace and scree. Sulphide veins are associated with the Nanga Parbat gneiss and gneissic-schist, have mineralization of gold and silver. Detailed exploration may be carried out and geochemical studies are further recommended. The Indian plate collided with Kohistan island arc during 55 to 50 Ma along the Main Mantle Thrust (MMT). Later on due to reverse faulting the Raikot shear zone was formed and protruding of NPHM towards north. Many ductile and brittle shear zones are developed which accommodate the neotectonic uplift of the NPHM. The area is characterised by a number of high angle faults which are truncated the Raikot shear zone.

Key words: Geology, NPHM, Kohistan island arc.

K/361. Khan, N.A., Latif, M. & Shah, S.H., 1999. Geology of the Thurgoh-Gol quadrangle (43 M/15), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 687.

The mapped area lies within the Kohistan-Ladakh island arc near the Asian mass and separated by the Main Karakoram Thrust (MKT). The rock units are Katzarah formation, Shigar volcanics, Yasin group, mafic and ultramafic rocks, intruded by multiphase diversified plutons of Ladakh batholith. The Katzarah formation of Early Cretaceous age consists of intra-arc flysch deposit of various grade phyllite, schists, hornfels and para-gneiss interlayered with epidote amphibolite and marble lenses. The Shigar volcanics consist of basalt, basaltic andesite, andesite and pyroclastic volcanics which have turbidite beds and green schist. The Yasin group of Early Cretaceous age consists of slate, sandstone, green schist, massive algal limestone, marble and turbidite beds.

The mafic-ultramafic rocks comprise of layers of altered peridotites, changed into serpentinite near northern suture zone and the scattered outcrops of mostly metagabbro with pockets and patches of peridotite, gabbroic monzonite and diorite. Ladakh batholith of early Paleocene to Miocene consists of granodiorite and granite associated with

quartz diorite. It occupies southern and eastern parts of the mapped area. Leuco dykes and sills of aplite and pegmatite are also present.

The unconsolidated sediments consist of low and high altitude moraines and also terraces along the Indus River and its other tributaries. Shigar volcanics have faulted contact with the overlying Yasin group, the folds and faults of varying magnitudes are common in the mapped area, with major fold axis plunging toward west.

The gold showings are present in the quartz veins of Katzarah formation and Shigar volcanics. Some pockets and lenses of serpentinite occur in the remote areas of the Yasin group.

Key words: Geology, tectonics, ultramafics, MKT, Skardu.

K/362. Khan, N.A., Mujtaba, G. & Khan, T., 1998. Geology and mineral investigations of the Gupis quadrangle (Toposheet No. 42 H/8), Northern Areas, Pakistan. Geological Survey Pakistan. Information Release 546.

The Gupis quadrangle 42-H/8 is bounded by latitudes 36° to 36° 15'N and longitudes 31° 4' to 73° 30'E. It comprises mainly the Kohistan batholith which contains xenoliths of Chalt volcanics and the metasediments. The Chalt volcanics are considered to be of early Cretaceous age and consist of basalt, andesite, rhyolite, tuff with marble and quartzite intercalation. It shows metamorphism from amphibolite to greenschist grades. The Kohistan batholith is composed of multiphased plutons of diorite, granodiorite, granite, pegmatite and aplite. The diorite shows deformation whereas granodiorite and granites are mildly deformed and undeformed. Economically the area is not so much promising except the occurrences of a small sulphide zone and quartz veins which contain at places some transparent to translucent quartz crystals.

Key words: Mapping, minerals, Kohistan.

K/363. Khan, N.A., Shah, S.H., Khan, F. & Laghari, A.L., 1999. Occurrence of gold in Garesh area, Gilgit District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 692.

Key words: Gold, Gilgit.

K/364. Khan, N.A., Shah, S.H., Laghari, A.L. & Mujtaba, G., 1987. A preliminary report on occurrence of sulphide mineralization in Singal area (42 H/16), Gilgit District, Pakistan. Geological Survey of Pakistan, Information Release 288.

Massive sulphide mineralization zone has been found in volcanic and metasedimentary rocks of lower Cretaceous age in Singal area about 50 km northwest of Gilgit (Toposheet No. 42 H/16). The mineralization occurs in Rakaposhi volcanic complex and is exposed in an area of 2.5 sq. km approximately. This sulphide zone can be recognized as an altered product of original rocks that weathers to pale, brownish, reddish and dark grey material in the superficial part of the outcrop. The mineralization is also observed in the form of dissemination in the volcanics and dolerite dikes mostly along the surface of joints and fractures. During the geological investigations of the area, 15 representative samples were collected and chemically analysed, Majority of samples show encouraging results of anomalous massive sulphide mineralization. The metallic content of analysed samples generally indicate the presence of Fe, Zn, Cu, Mn, Co and Mo in above-average quantities.

This report is based on field investigations and chemical analyses and may be suggested to be followed by a more comprehensive field and laboratory studies to prove the economic potential of sulphide mineralization.

Key words: Sulphide mineralization, Gilgit.

K/365. Khan, N.A., Shah, S.H. & Khan, M.S., 1988. Geology and mineral investigations of the Single quadrangle, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 362, 20p.

The investigated area is a part of the Kohistan island arc sequence lying adjacent to the south of the Main Karakoram Thrust (MKT), and falls in the Survey of Pakistan Toposheet No. 42 H/16.

The project area is typified by meta-volcano-sedimentary rocks which are intruded by multi phases intrusions of the Ladakh-Kohistan granitoids with subordinate gabbroic intrusions, acidic and hornblendic pegmatites. Magmatic segregation and differentiation are noted within the granitic rocks. The contact metamorphic effects are more pronounced along the marginal zones of the intrusive bodies thus resulting schist, amphibolite and gneisses. Owing to the presence of the collision boundary between the Asiatic mass and Island arc, the rocks of the investigated area are severely disturbed resulting a number of upright tight folds and faults.

Copper showings have been found in the Japuka and Hamuchal areas. Besides, altered massive sulphide mineralization and pyrite crystals as sparse dissemination are also located in the mapped area.

Key words: Volcanics, MKT, Kohistan island arc, Gilgit.

K/366. Khan, N.M., 1950. A survey of coal resources of Pakistan. Geological Survey of Pakistan, Records 2(2), 10p.

Key words: Hydrocarbons, coal, Pakistan.

K/367. Khan, N.M., 1962. Geology of coal fields in Pakistan. CENTO Symposium on Coal, Zonguldak, 1961, 97-102.

Key words: Hydrocarbons, coal, Pakistan.

K/368. Khan, N.M. & Reinemund, J.A., 1962. Industrial rocks and minerals in Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 21-27.

Key words: Industrial rocks and minerals.

K/369. Khan, N.M. & Reinemund, J.A., 1963. A cooperative mineral exploration and development program in Pakistan. UN Conference on Application of Science and Technology for the benefit of less developed areas, Geneva. Natural Resources (Karachi University) 2, 71-89.

Key words: Mineral exploration.

K/370. Khan, R., Hussain, H. & Saleem, M., 1984. Cement raw material around Muzaffarabad, Azad Kashmir. Geological Survey of Pakistan, Information Release 225.

During September, October and Novanber,1982, the investigation of cement raw materials around Muzaffarabad was undertaken by the authors on the request of the Government of Azad Kashmir and the Chairman, AKMIDC, to establish a cement plant near Muzaffarad, Azad Kashmir.

In the investigated area the metasedimentary and sedimentary rocks, ranging in age from Precambrian to Quaternary, are exposed. The sedimentary rocks are mainly limestone, shale and sandstone ranging in age from Cambrian to Pliocene. The metasedimentary rocks of the Hazara formation, probably of Precambrian age, consist of slate, phyllite, shale, limestone with lenticular bodies of gypsum are exposed in the west of Muzaffarabad.

Although the cement raw materials are available at different places between 2-8 kilometers around Muzaffarabad, but the most suitable deposits on the basis of quality and quantity are the Batmang deposits of the Chhalpani formation located at about 8 kilometers north of Muzaffarabad. During the course of investigation over sixty limestone, shale and gypsum samples were collected for chemical analysis on the basis of which a deposit was found to be suitable.

Key words: Limestone, cement, Muzaffarabad.

K/371. Khan, R., Shah, S.H. & Khan, N.A., 1999. Investigation of the geothermal springs of the Tatta Pani area, District Kotli, Azad Jammu and Kashmir. Geological Survey of Pakistan, Information Release 701.

Key words: Geothermal springs, Tatta Pani, Azad Kashmir.

K/372. Khan, R.A., 1973. Field report on geology and petrology of Thakot–Shang area, Hazara and Swat. M. Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, Thakot-Shang, Hazara, Swat.

K/373. Khan, R.M.K., 1976-78. The geology and petrology of Jura-Bandi Area Muzaffarabad, Azad Kashmir. M.Sc. Thesis, Punjab University, Lahore, 97.

Jura Bandi, an igneous and metamorphic complex, is a part of Nanga Parbat-Haramosh zone. The area is highly disturbed being in the region of syntaxial influence i.e. involvement in Himalayan orogeny. The metamorphic rocks are the oldest marking of Salkhala series which includes granitic rocks (Quartz-o-feldspathic rocks) along with prominent foliated structure with development of augen gneisses at places. Lithologically the oldest metamorphic rocks present are as following:

i) Chlorite mica schist.

ii) Garnet mica schist.

The metamorphism extends up to garnet grade yet retrograde metamorphism is commonly observed especially in the chlorite mica schist. Among Quartz-o-feldspathic rocks two granites (Granite gneiss and granite porphyritic) lying side by side extending in NE and NW direction. Mineralogically both granites are rich in Potash feldspar. Pegmatites and Aplites are present as dykes. The basic rocks among the minor bodies are diorite and diabases dykes. The report submits a detailed map on scale 1pp-789 miles or 1:50,000 of about twenty seven square miles along with details of field and laboratory investigation, the petrogenesis of both the granites (Granite gneiss and granite porphyritic) is derived on the strelleson's triangle method. The Petrography is discussed slide wise.

Key words: Petrology, igneous rocks, Muzaffarabad, Azad Kashmir.

K/374. Khan, R.N., 1987. Feldspar deposits in NWFP. Geological Survey of Pakistan, Information Release 283.

Key words: Minerals, feldspar, NWFP.

K/375. Khan, R.N., Afridi, A.G. & Shah, H., 1986. Geology of Charbagh Quadrangle, Swat. Geological Survey of Pakistan, Quetta. Information Release 132.

Key words: Mapping, geology, Swat.

K/376. Khan, R.N., Iqbal, S., Khan, S. & Khan, M.A., 1995. Geological Map of Murghzar quadrangle (Toposheet No. 43 B/2, Scale 1:50,000), NWFP, Pakistan. New Geoscience No. 1073 (Old Sheet No. 71), Geological Survey Pakistan. NWFP Geological Map Series, vol. III.

Key words: Mapping, Murghuzar.

K/377. Khan, R.N. & Saleemi, B.A., 1972. Geology of Kotegram and Akhagram quadrangle, District Dir and Swat, Pakistan. Geological Survey of Pakistan, Information Release 80, 28p.

Key words: Mapping, geology, Dir, Swat.

K/378. Khan, R.S., 1986-88. Geological studies of Jabri Area with special emphasis on sedimentology of carbonate rocks. M.Sc. Thesis, Punjab University, Lahore, 134p.

Key words: Sedimentary rocks, carbonates, Hazara.

K/379. Khan, R.S., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1992. A reconnaissance microfacies studies of Margala Hill Limestone Jabri area, southern Hazara, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.54.

Key words: Metamorphic, limestone, reconnaissance, Margalla Hill, Hazara.

K/380. Khan, S., 1965. Notes on the dolerite dykes in Northern Hazara. Zamaka, Peshawar University Geological Bulletin 2b, 1-4.

The northern regions of Hazara consist mostly of metamorphic and plutonic rocks of Palaeozoic and Mesozoic times. The plutonic rocks consist of granites and gneisses which are part of the great Himalayan batholiths. The metamorphic rocks consist of almost all grades from chlorite schists to staurolite schists passing further north into sillimanite gneisses in Hazara Kohistan. A little south of Oghi, big crystals of kyanite can be seen in a small portion of Susal Gali granite gneiss. These rocks of different metamorphic grades show all sorts of mineralogical, textural, and structural variation. Almost the whole of the region is isoclinally folded. Analysis of the structural data indicates that this area has been subjected to more than two phases of tectonic events. The granites and gneisses are also extremely variable, mostly have faulted contacts, and contain accessory minerals such as andalusite, sillimanite, kyanite, and garnet, etc., all of which are generally of metamorphic affinities. There is ample evidence that they are products of assimilation (Shams, 1961). Some granites are also very rich in tourmaline. These granites are of a later time and are generally very massive. Some of them for example the Hakale granite in Mansehra proper is extremely rich in volatile components and has intrusive relations with Mansehra granite. These rocks are profusely intruded by dolerite dykes and sills at different intervals of geological time. They have a tendency to be more abundant in plutonic than metamorphic rocks. The majority of these dykes and sills occurring in metamorphic rocks are regionally metamorphosed with well developed schistose planes striking parallel to the regional strike. The present notes are a short discussion of the various types of these dolerite veins, their optical characters and a review of their possible relation to the granites.

Key words: Metamorphic rocks, plutonic rocks, dolerite dykes, Hazara.

K/381. Khan, S.A., 1981-83. Geology of Para-Bela-Jared Area Central Kaghan Valley. M.Sc. Thesis, Punjab University, Lahore, 145p.

This report covers a comprehensive study of a part of central Kaghan Valley. The principal emphasis has been on detailed litho-structural mapping of the area of the scale 1:8333. The rocks range in age from Precambrian Salkhalas to Miocene Murrees. Stratigraphically, the geology is in many ways different from that in the Abbottabad-Murree-Tarbela-Attock area further south. Part of the Mesozoic and part of the Tertiary sequence is missing in the project area. Furthermore, the equivalents of Panjal Trap and associated limestone are not found in the above mentioned area southwards. Structurally except for some folding in the blocks and nearly all contacts are faulted. The succession in the area is overturned. A fairly detailed account of the stratigraphy is being given and the report also includes a detailed account of the Petrography of all units based on extensive sampling. Tectonically the area is very interesting and the Panjal Traps appear to represent Ophiolites while the Agglomerate Slates appear to indicate Volcano-sedimentary material with island arc affinities. There is thus some evidence of a Paleozoic subduction zone in this area. Numerous photographs and sketches have also been included to illustrate the geology of the area.

Key words: Geology, petrology, Kaghan valley.

K/382. Khan, S.A.Q. & Munir, A., Undated. Mineralogy and economic geology of Lahor-Pazang area, Swat Kohistan. M.Sc. Thesis, Geology Department, Peshawar University.

Key words: Economic geology, lead-zinc, Lahor-Pazang, Swat Kohistan.

K/383. Khan, S.D., 1973. Stratigraphy of Chail group in Hazara. M.Sc. Thesis, Punjab University, Lahore.

Key words: Stratigraphy, Hazara.

K/384. Khan, S.H., 1997a. Neotectonic Map of Pakistan, 1:5,000,000 scale. Geological Atlas Pakistan. Geological Survey Pakistan.

Key words: Mapping, neotectonics, Pakistan

K/385. Khan, S.H., 1997b. Map showing major faults of Pakistan. Geological Atlas of Pakistan. Geological Survey Pakistan.

Key words: Mapping, fault zones, Pakistan.

K/386. Khan, S.H. & Ahmad, S.A., 1994. Publication Catalogue of Geological Survey of Pakistan. Geological Survey Pakistan. Record 104.

This is a catalogue that lists all publications (Memoirs, Records, Information Releases, etc.) of the Geological Survey of Pakistan (GSP) up to the year 1993.

Key words: GSP.

K/387. Khan, S.N., 1961. Survey of radioactive minerals. Natural Resources (Karachi University) 1, 63-66.

Key words: Radioactive minerals, Pakistan.

K/388. Khan, S.N., 1964. Geology of Rajdhawari pegmatites, Oghi sub-division, Hazara District, West Pakistan. Geological Survey of Pakistan, Information Release 19, 18p.

The detailed study of Rajdhawari pegmatites was completed on December, 30, 1961. In this study an attempt has been made to classify the pegmatites on the basis of their size, shape, internal structure, and mineralogy. An area covering 21 square miles around Rajdhawari has been geologically mapped. Longitudinal cross sections and radiometric grid maps of two productive pegmatites have also been prepared.

Out of a total of 74 pegmatite bodies studied in Rajdhawari area, less than three per cent contain traces of billibinitc and other unidentified radioactive minerals. Nearly fifteen percent pegmatites contain beryl. The two productive pegmatite bodies have an approximate reserves of 1500 pounds of beryl, 225 tons of mica, and 2500 tons of feldspar. Total reserves of feldspar to a depth ranging from 20 to 50 feet in five bigger pegmatites have been estimated as 6200 tons.

Key words: Pegmatites, beryl, Hazara.

K/389. Khan, S.N., 1970. Search for radioactive minerals in Pakistan. National Seminar on Mineral Development, Lahore.

Key words: Radioactive minerals.

K/390. Khan, S.N., 1985. Publication catalogue, Geological Survey of Pakistan. Geological Survey Pakistan. Records, 48, 57p.

This is a listing of the geological Survey of Pakistan (GSP) publications up to the year 1984.

Key words: Publication catalogue, GSP.

K/391. Khan, S.N., 1995. Mineral resources and metallogenic zonation of Pakistan. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 43-45.

Key words: Mineral resources, metallogeny.

K/392. Khan, S.N., Khan, I.A., Abbas, S.G. & Khan, A.L., 1992. Coal resources potential of Pakistan. Geological Survey of Pakistan, Information Release 533.

Per capita power consumption is an indicator of the development stage of a country, and normally developed countries are using vast quantities of coal for power generation. In the USA 63 million tonnes of coal is used annually for power generation. In East Germany 220 million tonnes and in Western Europe 182 million tonnes of coal is used for power production every year. Pakistan, unfortunately has not been able to utilize its coal resources and the share of coal in the energy mix has declined from about 60% at the time of independence to less than 5% at present. Pakistan at present is using imported oil and natural gas for almost total thermal power generation. However, fast depleting gas resources and sharp increase in already scarce foreign exchange bill for import of oil are pressing hard to develop indigenous coal resources for generation of power.

GSP, from its own resources and aided by USAID and USGS, has continued its efforts to explore and establish the coal resources of the country. The efforts of the department have resulted in the recent discovery of two new large coal fields with coal quality suitable for power generation. The coal resources of the country are now projected at 22 billion tonnes.

Out of these 637 million tonnes are measured, 2440 million tonnes indicated 855 million tonnes inferred and 10646 tonnes hypothetical. Over ninety seven percent of these resources occur in Sindh Province, not very far from Karachi, the biggest industrial centre of the country.

The Pakistan coals are lignite A to Hv sub B and generally high in sulphur. However, the latest discovered coal field of Thar desert contains low sulphur coal. with the erection of two power plants of 50 M.W each, based on Lakhra coal, a beginning to utilize indigenous coal for large scale power generation has been made and it is expected that discovery of low sulphur coal in Thar will encourage the investment on development of huge coal resources of the country for power generation.

Key words: Hydrocarbons, coal, Pakistan.

K/393. Khan, S.N., Khattak, M.U.K. & Ahmad, W., 1997. Significant gold base-metal anomalies associated with Tirich Mir Fault zone, Chitral, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

The Chitral region geographically occupies the eastern terminations of Hindukush ranges and geotectonically the western extremities of the Himalaya sedimentary rocks of Karakoram and Asia to the north and a dominantly Cretaceous volcano-sedimentary sequence of Kohistan arc in the south. The Paleozoic to Mesozoic rocks are strongly sheared, folded and faulted during the Cretaceous-Tertiary orogenesis and are subjected to subduction related ~oIcanopIutonic complexes.

This paper describes anomalous concentrations of gold and base-metal in the rock formations north and south of the Tirich fault zone. This research is part of a systematic regional exploration comprising drainage geochemical survey and remote sensing through the study of satellite imageries and aerial photographs together with use of information on ground geology (petrography. petrology and geochemistry) and mineral occurrences. Tirich Mir fault zone is typically associated with mafic-ultramafic rocks and probably represents a suture zone between the Karakorum and the Asian plates.

Key words: Minerals, base metal anomalies, gold, Tirich Mir fault zone, Chitral.

K/394. Khan, S.R., 1989. An introduction to Ophiolites of Waziristan. Geological Survey of Pakistan, Information Release 435.

The Waziristan ophiolite is a prominent feature of the geology of Pakistan and delineates the suture at the northwest edge of the Indian plate. It comprises all the component lithologies of a typical ophiolite. This paper is amongst the earliest descriptions of it. For details, see description under S. R. Khan (2000) and Khan et al. (2001).

Key words: Waziristan ophiolite, Pakistan.

K/395. Khan, S.R., 1992a. Stratigraphy and structural set up of Swabi and adjoining areas, NWFP, Pakistan. M.Phil. Thesis, University of Peshawar, 42p.

The present work has resulted in the recognition of a well developed stratigraphic succession of the Tethyan Himalayas exposed in the mountain ranges fringing the northeastern Peshawar basin (Swabi, Mardan, and Buner districts of the NWFP, Pakistan). The rocks range in age from Precambrian through Paleozoic to Early Mesozoic and are composed of igneous, metamorphic and sedimentary rocks. A Precambrian succession comprising of Salkhala and Tanawal formations makes a basement to about 400 metres thick Paleozoic succession, comprising Ambar Formation (Cambrian), Misri Banda Quartzite (Early to Late Ordovician), Panjpir Formation (Late Silurian), Nowshera Formation (Early Devonian), and Jafar kandao Formation (Early Carboniferous). These metasedimentary rocks provide evidence for Late Paleozoic (Carboniferous Permian) intracontinental rifting, the onset of which is indicated by north derived clasts in the jafar Kandao Formation and together with extrusion of rift related volcanism in the form of alkaline acid porphyries and tholeiitic to alkaline basalt horizons. A much greater variety of hypabyssal and plutonic rocks including carbonatite, ijolite etc., are associated with this phase of magmatism. Post Permian thermal subsidence and marine transgression led to the deposition of the Early Mesozoic carbonate rocks which unconformably overly the Karapa Greenschist. The whole stratigraphic succession is considered to be developed in a northward dipping epicontinental basin while the magmatism is related to the rifting episode. Most of the rocks have yielded fossil evidences regarding their ages, while a few have been dated by radiometric determination. The present work describes some of the new evidences relating to the Paleozoic-Mesozoic rocks of the study area and their interpretation and implication in the reconstruction of the regional geological framework of this part of Tethyan outer Himalayas.

Key words: Stratigraphy, structure, Precambrian, Paleozoic, Swabi.

K/396. Khan, S.R., 1992b. Ophiolites in Pakistan. Abstract volume International Symp. Himalayan Geology, 3–9 Sept., 1992, Shimane, Japan, p.22.

This general account includes ophiolites from the area of this work of ours.

Key words: Ophiolites, Pakistan.

K/397. Khan, S.R., 1992c. Paleozoic stratigraphy and intracontinental magmatism, northern Pakistan. 29th International Geological Congress, Kyoto, Japan. Abstract volume 1 of 3, p.122.

Key words: Magmatism, stratigraphy, Paleozoic.

K/398. Khan, S.R., 1995. A preliminary geological report on part of Waziristan ophiolitic mélangé, North Waziristan Agency, NW Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.4.

The Waziristan ophiolite is a prominent feature of the geology of Pakistan and delineates the suture at the northwest edge of the Indian plate. It comprises all the component lithologies of a typical ophiolite. This paper is amongst the earliest descriptions dealing with the tectonic mélangé which contains components of the ophiolite.. For details, see description under S. R. Khan (2000).

Key words: Ophiolite, geology, Waziristan.

K/399. Khan, S.R., 1999a. Stratigraphy of the passive margin of the Indian Plate, Waziristan, N.W. Pakistan. *Geologica* 4, 47-68.

Key words: Tectonics, stratigraphy, Indian plate.

K/400. Khan, S.R., 1999b. First discovery of Mesozoic fauna from Waziristan and its stratigraphic significance. Abstract book, Peshawar meeting IGCP 421 (8-26 September 1999) – additional abstract. National Centre of Excellence in Geology, University of Peshawar.

Key words: Stratigraphy, fauna, Mesozoic, Waziristan.

K/401. Khan, S.R., 2000. Petrology and geochemistry of part of the Waziristan Ophiolite Complex, Pakistan. Ph.D. Thesis, University of Peshawar, 253p.

This work presents for the first time a detailed geological mapping, petrologic, geochemical and stratigraphic synthesis of a part of the Waziristan Ophiolite Complex and part of shelf-slope sediments of the Indian plate in North Waziristan, northwest. Pakistan. The study area is presently sandwiched between the Afghan block to the west and Indian plate to the east and divisible into two blocks. These blocks from east to west are the shelf-slope sediments and Waziristan Ophiolite Complex. The shelf-slope sediments are thrust over by the Waziristan Ophiolite Complex to the west, whereas a thick pile of Tertiary sediments unconformably overlies the ophiolite complex.

The shelf-slope sediments based on detailed geologic mapping, section measurement and fauna discoveries are divisible into seven stratigraphic units. These units from older to younger are Raghzai formation of Middle Triassic, Kishai formation of Late Triassic, Zehe formation of Early Jurassic, Alexandra formation of Middle Jurassic, Zargar Khel formation of Late Jurassic-Early Cretaceous (?), Sinai formation of Early Cretaceous and Marni Rogha limestone of Late Cretaceous (Campanian) age.

The Waziristan Ophiolite Complex is also divisible into three thrust sheets/ nappes, each characterised by distinct lithologies and style of deformation. These nappes from east to west are the Vezhda Sar, Boya and Datta Khel. The Vezhda Sar nappe forms the eastern edge of the ophiolite complex, is composed entirely of pillow basalts and intermixed with the shelf-slope sediments. It contains exotic blocks of serpentinised ultramafic rocks. The central nappe called the Boya nappe contains an intact normal ophiolite sequence, starting from ultramafic cumulates followed by isotropic/homogeneous gabbros and pillow basalts and is capped by pelagic sediments. The central part of this nappe is strongly deformed and contains fault bounded blocks of all sort of ophiolitic rocks. The Datta Khel nappe forming the western part of the ophiolite complex is characterised by the presence of sheeted dykes and isolated outcrops of ultramafic-mafic cumulates and, pillow basalts. A thick pile of Tertiary sediments unconformably overlies this nappe. The Tertiary sequence is comprised of Ghazij Formation of Early Eocene and Kirthar Formation of Early to Middle Eocene age. The geochemical characteristics, such as LILE enrichment, HFSE depletion, and non-depletion of Nb indicate that the ophiolitic rocks are transitional between island-arc tholeiites and mid-ocean ridge basalts type affinities. Rocks displaying such a transitional characteristics are thought to have involvement of some sort of subduction component brought by fluids along subduction zone to the source region and interpreted to have formed above a subduction zone in a back-arc basin or suprasubduction zone setting.

The pelagic sediments intercalated and stratigraphically overlying the pillow basalts, contain radiolarian fauna of Late Jurassic to Early Cretaceous (Tithonian-Valanginian) age. Based on the age of the radiolarian fauna, the formation age of the ophiolite is interpreted to be Late Jurassic or older. The ^{40}Ar - ^{39}Ar isotopic dates on hornblende of an amphibolised gabbro from the Waziristan Ophiolite Complex indicate 93.57 ± 1.01 Ma. This - 93 Ma age may represent the first phase intraoceanic obduction of the Waziristan Ophiolite Complex. The ophiolite complex contains exotic blocks of Marni Rogha limestone of Late Cretaceous (Campanian) age and is also thrust over similar limestone, suggesting late Cretaceous or most probably Paleocene secondary obduction of the ophiolite over the shelf-slope sediments of the Indian plate. The K-Ar whole rock radiometric dates (- 75 Ma) of the gabbroic and trondhjemitic rocks further support this interpretation. The K-Ar whole rock radiometric dates ("" 60 Ma) of the Waziristan volcanics may suggest the accretion of the Indian plate with the Afghan block. The deformation of the Tertiary sediments overlying the Waziristan Ophiolite Complex, those of the Katawaz Basin and thrusting of the Mesozoic rocks of Kirthar and Sulaiman ranges over the foredeep molasse sediments, suggest collision between Indian plate and the Afghan block during Pliocene-Pleistocene.

Key words: Petrology, geochemistry, ophiolite, Waziristan.

K/402. Khan, S.R. & Fatmi, A.N., 1999. Discovery of Mesozoic fauna from Waziristan and its stratigraphic significance. Additional abstracts, IGCP 421 (North Gondwanan mid-Palaeozoic Bioevent/ Biogeography Pattern in Relation to Crustal Dynamics), Peshawar Meeting, 1p.

Key words: Fauna, stratigraphy, Mesozoic, Waziristan.

K/403. Khan, S.R., Jan, M.Q. & Khan, M.A., 2001. Tectonic evolution of the Waziristan ophiolite, NW Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.8.

The Waziristan ophiolite is located in the northwest Pakistan, demarcating a suture zone between the Indian plate to the east and Afghan block to the west. It is highly dismembered and divisible into three nappes. These nappes from east to west are: Vezhda Sar nappe entirely comprising of pillow basalts; Boya nappe, made up of ophiolitic mélange with an intact sequence in the basal part; and Datta Khel nappe, consisting of sheeted dykes along with variable proportions of other components. The intact Ophiolite sequence from bottom to top consists of i) the ultramafics (harzburgite, wehrlite and dunite), ii) the mafics (isotropic gabbros), and iii) the volcanics (pillow basalts), capped by pelagic sediments (limestone, shale and chert). The layered gabbros, sheeted dykes and trondhjemites are found as isolated fault bounded bodies in the highly dismembered central and western parts of the ophiolite suite. The ophiolite is unconformably overlain by sedimentary rocks of Early to Middle Eocene age to the west and thrust over the Mesozoic shelf-slope sedimentary rocks of the Indian plate to the east.

Major and trace elements geochemistry is used in specifying the petrogenetic and tectonic evolution of the Waziristan ophiolite. All the ophiolitic rocks are of N-MORB type and give a similar geochemical characteristics indicating to be comagmatic. These rocks are characterized by higher LILE/HFSE ratios and non-depletion of Nb. The various geochemical parameters based on high-field strength elements reveal that the ophiolitic rocks are transitional between island-arc tholeiites and mid-ocean ridge basalts. Their transitional characteristics, non-depletion of Nb, higher LILE/HFSE ratios and presence of sheeted dykes suggest that the Waziristan ophiolite may have originated in back-arc basin environment.

Based on the age of radiolarian fauna (Tithonian±Valanginian) recovered from the pelagic sediments (chert), the age of the Waziristan ophiolite is interpreted as Late Jurassic or older. The presence of tectonic blocks of Campanian limestone (Mami Rogha Limestone) in the ophiolite and thrusting of the ophiolite onto Maastrichtian shale, suggest post-Maastrichtian, most probably Paleocene, emplacement of the ophiolite.

Key words: Tectonics, ophiolites, Waziristan.

K/404. Khan, S.R., Jan, M.Q., Khan, M.A. & Khan, T., 2001. Geochemistry and petrogenesis of the sheeted dykes in Waziristan Ophiolite, NW Pakistan and their tectonic implications. 16th Himalaya Karakoram Tibet International workshop, Journal of Asian Earth Sciences 19, p.36.

This paper presents the petrologic and geochemical aspects of the sheeted dykes as well as isolated mafic dykes from the Waziristan Ophiolite, northwest Pakistan. The ophiolite occurs in the suture zone between the Indian plate to the east and Afghan block to the west. It is divisible into three main sheets or nappes which, from east to west are: Vezhda Sar nappe entirely comprising of pillow basalts; Boya nappe made up of ophiolitic mélange with an intact sequence in the basal part; and Datta Khel nappe consisting of sheeted dykes along with small proportions of other components. The sheeted dykes are an important component of the Waziristan Ophiolite and their excellent exposure is found in the hanging wall of the Datta Khel Thrust, ENE of Datta Khel. The ophiolite is thrust over the Mesozoic shelf-slope sediments of the Indian plate to the east and unconformably overlain by sedimentary rocks of Early to Middle Eocene age to the west. Major and trace element geochemistry indicate that the dykes (both sheeted and isolated) contain higher contents of Na₂O, FeO/MgO and LILE/HFSE ratios, and lower TiO₂ (0.1 wt%) and K₂O (Figs. 1 and 2). Non-depletion of Nb and high LILE/HFSE ratio negate an island-arc or mid-ocean ridge settings for these dykes, respectively. The enrichment of LILE rather suggests involvement of crustal components driven by fluids along a subduction zone. The various geochemical parameters used in specifying the tectonomagmatic setting of the Waziristan dykes reveal a transitional characteristic between mid-ocean ridge basalt and island-arc tholeiite. It is suggested that the Waziristan dykes may have originated in a back-arc basin tectonic set-up. Based on the age of the radiolarian fauna (Tithonian±Valanginian) recovered from the pelagic sediments (cherts), the age of the Waziristan Ophiolite is interpreted as Late Jurassic or older. The presence of exotic blocks of

the Campanian limestone in the ophiolite coupled with overthrusting of the ophiolite onto Maastrichtian rocks suggest post-Maastrichtian, most probably Paleocene, emplacement of the Waziristan Ophiolite.

Key words: Geochemistry, sheeted dykes, sea floor spreading, ophiolites, Waziristan.

K/405. Khan, S.R. & Karim, T., 1989. Geological map of Drazinda. US Geological Survey, Geological Map Series 775, 170A (39 I/2).

Key words: Mapping, Drazinda, D.I. Khan.

K/406. Khan, S.R. & Khan, M.A., 1994. Late Proterozoic stratigraphy of Swabi area, NWFP, N. Pakistan. Geological Bulletin, Peshawar University 27, 57–68.

A succession of weakly metamorphosed unfossiliferous sedimentary rocks has been described in terms of lithostratigraphy from an area north of Swabi. The succession unconformably underlies the Cambrian Ambar (Dolomite) Formation (=Abbottabad Formation) and represents the supra-crustal sediments of a probable Late Proterozoic age from the Indian- Plate basement. A WNW plunging cylindrical anticline controls the disposition of stratigraphic units. The succession is divisible into two formations; Salkhala and Tanawal. The basal part of the Sulkhala Formation, exposed at the west bank of the Tarbela dam, is classified as the Gandaf unit and comprises pelitic and graphitic schists, brown dolomite and white and grey-black marble. The upper part, exposed at the apex of the Kundal anticline, is predominantly argillaceous and contains black mud- and siltstone which grade upward into pebbly green phyllite. The overlying Tanawal Formation is conglomeratic at its base and comprises three units, two of which are quartzitic, while the one, in the middle, is argillaceous. It is suggested that the Tanawal Formation may be a time-equivalent facies change of the Hazara, Manki and Landikotal Slate formations, rather than being younger as suggested in the existing literature. This may explain some of the discrepancies in the existing regional tectonic framework of the Indian plate in northern Pakistan.

Key words: Stratigraphy, Proterozoic, Swabi.

K/407. Khan, S.R., Khan, M.A., Jan, M.Q. & Khan, T., 1998. Trondhjemites from the Waziristan ophiolitic melange, NW, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 98-99.

Small amounts of leucocratic intrusions composed of quartz, feldspar, and accessory ferromagnesian minerals are associated with most ophiolites. These, commonly called trondhjemite or plagiogranite, are soda-rich and potash-deficient as compared with normal granite. These rocks are generally found in the upper part of mafic cumulates of the ophiolite sequences, but the trondhjemites in the Waziristan Ophiolitic Melange are associated mostly with ultramafic cumulates and only locally with mafic cumulates. In both the cases they have sharp intrusive contacts with the host rocks. They occur in the form of veins, pods and plugs, ranging from a few centimetres to four metres in width and six to ten metres in length. The rocks are light-grey to milky-white, medium-to coarse-grained, equigranular, non-foliated, and composed of quartz, albite (An₈₋₁₀) and minor biotite and hornblende. The constituent minerals, especially plagioclase, show alteration to chlorite, calcite, sericite, epidote and muscovite.

The rocks are characterized by relatively high SiO₂ (60.47 - 79.70 wt.%), Na₂O (3.04 - 6.06 wt.%), CaO (0.52 - 6.95 wt.%), and low K₂O (< 1 wt.%), TiO₂ (< 1 wt.%), P₂O₅ (< 1 wt.%) and MgO (0.23 - 2.82 wt.%). They are sub-alkaline in composition and classify as trondhjemite on the basis of normative albite, orthoclase and anorthite contents [1]. The Rock/Primordial Mantle spider diagram pattern (Fig. 1) shows enrichment in LIL elements (K, Rb, Ba, Sr) relative to HFS (Ti, Y, Nb) elements [2]. The geochemical pattern for the trondhjemites is transitional between those of island arc and mid-oceanic ridge granites.

K/Ar whole rock ages of trondhjemites (77 ± 2 - 70 ± 1 Ma) are much younger than the overlying radiolaria (Late Jurassic to Early Cretaceous) found in the pelagic sediments lying on top of the ophiolite [3]. From these dates we conclude that the ophiolite was generated by the Late Jurassic and emplaced during the Latest Cretaceous-Paleocene.

Key words: Ophiolites, geochemistry, Waziristan.

K/408. Khan, S.R., Khan, M.A., Jan, M.Q. & Khan, T., 1998. Tectonic implications of major and trace elements geochemistry of volcanic rocks from the Waziristan ophiolitic melange, NW. Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.100.

Volcanic rocks are the most voluminous component of the ophiolite segments in the Waziristan Ophiolitic Melange (WOM). They are divided into two-groups, i) Vizhda Sar Complex volcanics (VSCV), and ii) Waziristan Ophiolitic Melange Volcanics (WOMV). The VSCV are erupted along the western periphery of the Mesozoic shelf sediments of the Indian plate, in Waziristan, Pakistan. Their most excellent outcrops are found between Vizhda Sar to the south and Baba shaga to the north. The name Vizhda Sar Complex is proposed after Vizhda Sar, the second highest peak in the area and is composed entirely of pillow basalts. The VSCV contain exotic blocks of limestone and shale ranging in age from Lower-Middle Triassic to Late Cretaceous. They are basaltic in composition, and are not associated with dykes. To the west they are obducted by the Waziristan Ophiolitic Melange (WOM). The WOMV form the uppermost segment of the ophiolite sequence overlying the mafic cumulate and underlying the pelagic sediments, respectively. In the normal ophiolite sequence they found as pillow lavas, while in the ophiolitic melange part, they are sporadically distributed over a considerable area and found as pillow lavas, sheet flows, agglomerates and breccias. Contrary to the VSCV, the WOMV are intruded by dolerite dykes, showing chilled margins. The WOMV have a wide range in composition varying from basalt to rhyolite. Geochemically, the VSCV are more primitive as evidenced by their higher content of MgO, Cr, and Ni than the WOMV, which are more fertile in LIL (K, Rb, Ba, Sr) elements. Both types are soda-rich, potash deficient, sub-alkaline and tholeiitic in composition. The VSCV are mid-ocean ridge basalt, whereas the WOMV are transitional between mid-oceanic ridge basalt and island arc tholeiite. Field and geochemical data suggest back-arc basin affinity for the formation of WOMV.

The radiolaria found in the cherts lying on top of the ophiolite sequence are of Late Jurassic to Early Cretaceous age, suggesting Late Jurassic age for the generation of WOM. The presence of tectonic blocks of Globotruncana-bearing limestone of Late Cretaceous age in the WOM, the K/Ar radiometric dates of gabbroic rocks ($77 \pm 2 - 75 \pm 1$ Ma) and trondhjemitic ($77 \pm 2 - 70 \pm 1$ Ma) and Early-Middle Eocene strata unconformably overlying the ophiolite sequence, suggest Latest Cretaceous-Paleocene as the time of emplacement of the WOM. This is consistent with the emplacement of Khost ophiolite to the north in Afghanistan and Muslim Bagh ophiolite to the southwest in Pakistan. The high scale deformation of the Tertiary (Early to Middle Eocene) sequence unconformably overlying the ophiolite sequence and the serpentinite splinters cross-cutting the Oligocene-Miocene flysch sediments of the Katawaz basin west of Muslim Bagh propose Pliocene age as the time of India-Afghanistan collision.

Key words: Tectonics, geochemistry, volcanics, Waziristan.

K/409. Khan, S.R., Khan, M.A., Nawaz, R. & Karim, T., 1990. Stratigraphic control for the age of Peshawar-Plain magmatism, northern Pakistan. Geological Bulletin, University of Peshawar 23, 253-263.

Recent mapping and stratigraphic analyses in the area at the north-eastern edge of the Peshawar plain has resulted in the recognition of a bimodal suite of basic and acidic volcanics. These volcanics occupy specific stratigraphic horizons in the Jafar Kandao Formation, whose age is well constrained between Carboniferous and Early Permian, on the basis of conodont studies. It is suggested that the basic volcanics are extrusive equivalents of the extensive suite of basic dykes and sills found in the internal zone of the Indian plate, while the acid volcanics are counterpart of the A-type granites of Warsak, Ambela, and Shewa-Shahbazgarhi. This study provides a stratigraphic control for the age of the Peshawar-plain magmatism.

Key words: Mapping, stratigraphy, magmatism, Peshawar Plain.

K/410. Khan, S.R., Khan, M.S., Afridi, A.J. & Nasir, S., 1976. Petrographic study of Samana Suk Formation, Kohat. M.Sc. Thesis, Peshawar University.

Key words: Petrography, Samana Suk Formation, Kohat.

K/411. Khan, S.R., Khan, R.N. & Shah, H., 1989. Geology of Rustam quadrangle, Mardan and Swat districts, NWFP., Pakistan. Geological Survey of Pakistan, Information Release 443.

Key words: Geology, stratigraphy, petrography, Rustam, Mardan.

K/412. Khan, S.R., Khan, R.N., Shah, H. & Saeed, G., 2000. Geology of the Rustam quadrangle, Mardan district, NWFP., Pakistan. Geological Map Series, vol. III

Key words: Geological map, Rustam, Mardan.

K/413. Khan, S.R., Khan, R.N. & Karim, T., 1990. Field relationship: Stratigraphic and structural position of the Shewa-Shahbaz Garhi “porphyritic microgranite”. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 36-37.

Recent field studies carried out by the GSP in and around Rustam area in the Mardan District, NWFP, have shown, contrary to the previously thought structurally restricted extent (Martin 1962 & Kemp 1973)), that the “Porphyritic Microgranite” of the Shewa-Shahbaz Garhi area has a much larger areal extent showing cyclic intercalations with the host rocks.

The emplacement of the “Porphyritic Microgranite” and the deposition of the enclosing sediments seem to have taken place contemporaneously in an oscillating basin. The whole sequence is now treated as a separate, distinct and mappable time-rock unit. The name ‘Jafar Kandao Formation’ is proposed after the surveyed type locally at Jafar Kandao, about 5 km southeast of the Rustam village. In addition to the type locality and the better known Shewa-Shahbaz Garhi areas, the formation is also exposed in the Banda-Buner areas of the lower part of the Swat District. In most of these areas, it is found in the cores of the anticlines where the younger strata have been eroded.

The ‘Jafar Kandao Formation’ consists of argillites, limestone, quartzite, amphibolite, and “Porphyritic Microgranite”. The formation has been assigned Early Carboniferous age on the basis of conodonts found in the limestone lenses (Pogue, Pers. Commun.).

Key words: Stratigraphy, field relations, granite, Shewa Shahbaz Garhi, Mardan.

K/414. Khan, S.R., Nakagawa, M., Khan, I.H., Kausar, A.B. & Shirahase, T., 1996. PGE mineralization in the Jijal complex, Kohistan, north Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 15, 103-125.

A GSP-JICA joint collaborative project for the investigation of PGE mineralization in the Jijal mafic-ultramafic complex, north Pakistan had been initiated in 1991, and carried out geochemical exploration, mineralogical and petrochemical investigations. During the course of works, restricted areas showing remarkable positive anomaly of Pt and Pd were found, and also merenskyite; (Pd,Pt)Te₂ hosted by pyrrhotite was discovered from massive sulfide ore of the Kolai stream which showed a considerable content of Pd (> 22 g/t). Follow-up petrochemical analysis revealed that the disseminated sulfide mineralization in the garnet pyroxenite and/or hornblendite of the Kolai area contained 1.4 g/t of Pt + Pd which is more than thousand times concentration compared to the host rock background. However, from the comparative study with sub-economical occurrence of PGE in the Ivrea-Verbano Complex, Italy, the tectonic setting of which is similar to that of the Jijal Complex representing a root of paleo-island arc, high grade (> 10 g/t) PGE mineralization would not be expected in the complex except the massive sulfide ore presumably in the garnet hornblendite located close to the Kolai stream.

Key words: PGE, Jijal, Kohistan.

K/415. Khan, S.R., Pogue, K.R., Hussain, A., Saeed, G. & Babar, F., 1995. Geological Map of Topi quadrangle (Toposheet No. 43 B/12, Scale 1:50,000), NWFP., Pakistan. New Geosc. No. 1142 (Old Sheet No. 95), Geological Survey Pakistan. NWFP. Geol. Map Ser., vol. III.

Key words: Geological map, Topi, Swabi.

K/416. Khan, S.R., Saeed, G. & Khan, F., 1984. Geological map of Tarbela (43 B/12), Hazara District, Sheet No. 94, Scale 1:50,000. Geological Survey of Pakistan, Quetta. Map Series.

Key words: Mapping, Tarbela.

K/417. Khan, S.R. & Sano, S., 1994. Geology and petrography of the Landi Raud chromite deposits: A part of the Malakand ultramafic complex, N.W.F.P., Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 9, 5-16.

Key words: Petrography, ultramafics, chromite, Malakand.

K/418. Khan, S.R. & Suzuki, M., 1997. Geochemical exploration for gold mineralization in northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

The study area includes part of the Karakoram plate and the Kohistan arc terrane, which are separated from each other by the Main Karakoram Thrust (MKT). The Karakoram plate to the north of the MKT consists mainly of Paleozoic-Cenozoic sedimentary rocks, which are further intruded by Jurassic to Tertiary plutonic rocks. The island arc terrane contains metavolcanic and metasedimentary rocks intruded by Kohistan Batholith ranging in age from 102 to 30 Ma.

Detailed geochemical exploration, including stream sediments and panned concentrates as media, was conducted along the main streams of the Hunza and Gilgit rivers and their major tributaries. Sampling density was slightly enhanced in the neighbourhood of Gilgit where a number of alteration zones have been found. 120 samples of stream sediments were analyzed for gold, whereas 92 samples of panned concentrates underwent chemical assays for Au, Ag, As, Bi, Cu, Mo, Pb, Sb, and Zn in Chemex Laboratories, Canada. Gold contents in the study area are generally higher than the average of the earth crust, implying a high probability of some gold mineralization in this area. The univariate analysis demonstrates high concentrations along the MKT and on the northern side as a whole, except Cu and Mo. Gold shows particularly high concentrations along the MKT.

Factor analyses have led to the extract of the following two factors related to gold mineralization: i) a factor represented by a combination of Au-Ag-As-Sb (Factor 1) ~ their high factor scores are found along the MKT and ii) a factor represented by a combination of Bi-As-Ag-Au (Factor 2). High-scored points for the Factor 2 are distributed mainly around the glacier areas. The present survey succeeded in demarking areas showing high content of 11 ppm and 50.5 ppm Au as well as high scores for Factor 1 that suggest a follow-up survey on priority basis in these areas.

Key words: Geochemistry, gold, Karakoram, Kohistan arc.

K/419. Khan, S.R., Suzuki, M. & Khan, T., 1996. Gold mineralization in the Kohistan arc terrane and Karakoram continental plate, Gilgit and Ghizar areas, northern Pakistan. *Geologica* 3, 23-67.

Key words: Gold mineralization, Kohistan arc, Karakoram.

K/420. Khan, S.U., 1995-96. Structure, stratigraphy, micropaleontology and petrography of Dardhan, Narota & Karwali areas District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 89p.

The Dardhan, Narota and Karwali area are part of Attock-Hazara fold-and-thrust belt of the northwest Himalaya of Pakistan. The lithographic units exposed in the area are mainly sedimentary in nature and range in age from Mesozoic to Cenozoic. The area is deformed by folding and faulting during the Tertiary-Himalayan collision. The Early Cretaceous Lumshiwal Formation has disconformable contact with the overlying Late Cretaceous Kawagarh Formation. The presence of glauconite in the Lumshiwal Formation reveals that the formation was deposited in marine condition during regressive as well as transgressive phases. The Late Cretaceous subduction of the Indian plate below the Kohistan Island arc caused the deepening of the Tethyan shelf in the subduction zone and initiated

the deep marine deposition of the Kawagarh Formation. The contact between Kawagarh Formation and Early Paleocene Hangu Formation is marked by break in deposition which is evidenced by the presence of laterite/haematite and sandstone. The abrupt change in facies from deep water marine environment of Kawagarh Formation to terrestrial deposition of Hangu Formation indicates the initial Early Paleocene collision of the Indian Plate and Kohistan Island arc.

The Lower Tertiary sequence exposed in the area is Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margala Hill Limestone, Early Eocene Chorgali Formation and Early to Middle Eocene Kuldana Formation. The Lower Tertiary sequence marks the complete cycle of transgression and regression of the Tethyan Sea. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockhartia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show the tropical sub-tropical open sea upper slope to outer shelf environments. The Kuldana Formation is composed of marine limestone, continental variegated clay, shales and evaporitic gypsiferous bands. These variegated lithologies show that the Early to Middle Eocene Kuldana Formation deposited in transitional environment. The Kuldana Formation marks the end of transgressive cycle and initiation of regression of the Tethyan ocean. The Paleocene-Eocene boundary cannot be marked due to the lack of microfossils in Patala Formation. However, a tentative Paleocene-Eocene boundary marked at the base of Margala Hill Limestone on the basis of first appearance of Early Eocene fossils in the Margala Hill Limestone. Two sets of folds have been recorded which indicate two separate phases of deformation. These deformation phases are D_1 and D_2 which are related to Himalayan orogeny. D_{1a} is associated with the southeast-directed thrusts and southeast vergent F_1 folds. D_{1b} is related with the backsteepening of the major thrusts and northwest overturning of the major F_1 folds. This phase is well documented by the northwest vergent Chak Jabbi syncline and Khui-Marl syncline. D_{1b} is also related with backsteepening of MBT due to folding. The D_2 deformation phase is related with the folding of earlier northeast-southwest trending D_1 structures along northwest plunging F_2 cross folds. The F_2 cross folds are antiforms and synforms. These F_2 cross folds are related with the development of the Hazara-Kashmir syntaxis.

Key words: Structure, stratigraphy, micropaleontology, petrography, Haripur, Hazara.

K/421. Khan, S.Z., Shah, S.H., Khan, N.A. & Khan, K.S.A., 1999. Geological map of Gilgit quadrangle (43-I/5) northern areas, Pakistan. Geological map series no. 1310, Geological Survey of Pakistan Quetta.

Key words: Maps, Gilgit.

K/422. Khan, T., 1986. Geology of the Pegmatite Belt in Chitral, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 266, 16p.

The rock units of the investigated area are the metamorphites and granitoids, which range in age from Devonian to Tertiary. The pegmatite belt comprising simple and complex pegmatites, trending in northeast and southwest direction are the youngest intrusions (85-20 Ma) within the granites. Gemstone mineralization confined to the complex pegmatites has been found at several localities in the high altitudes. Beryl/ aquamarine, schorlite, indicolite, garnet, and mica may get economic significance. Sulphide mineral association, scheelite, graphite and fluorite mineralization has also been observed.

Key words: Pegmatites, Chitral.

K/423. Khan, T., 1991. Geochemistry of the Warsak igneous complex, N. Pakistan. M.Phil. Thesis, University of Peshawar, 103p.

The Warsak Igneous Complex (WIG) is a bimodal suite of granite and basic rocks, with no or little intermediate compositions. The field relations are ambiguous because of shearing and metamorphism, however, there are indications that the basic rocks are older than the granites. The granites, occurring in three petrographic varieties are closely similar in geochemical composition, in particular, in terms of incompatible trace elements. They have all the characteristics of A-type within-plate granites. The basic rocks are typically tholeiitic formed in intracontinental setting, probably in the initial stages of rifting event. The close similarity of the Warsak granites with Ambela and

Koga, suggests a Palaeozoic age of the WIC. The magmatism in the Warsak area (including both basic and alkaline acidic) was probably related with the Paleozoic fragmentation of the Gondwanaland and the separation of India.

Key words: Geochemistry, granite, alkaline complex, Warsak.

K/424. Khan, T., 1992. Geology and tectonics of the Hindukush Range in the north Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 3, 84-90.

Hindukush (also called Nuristan) is a NE-SW striking range straddling parts of the countries including Pakistan, Afghanistan and the former U. S. S.R. The range is bounded by major faults except for in the NE where it may continue with the Karakoram Range (Figure 1: After Desio, 1979). The southern boundary of the Hindukush range is defined by the Main Karakoram Thrust (MKT) which separates the Hindukush range from the Kohistan arc. To the west the Hindukush range is bounded by the Sarobi fault which separates it from the Kabul block in the west. To the north the boundary of the Hindukush is defined by the Herat Fault that separates it from the Badakhshan block in the north. The Hindukush or the Noristan block is itself divisible into two structural domains, separated by the Reshun fault. The Reshun fault is a northward dipping thrust fault, which is locally defined along the Yarkhun River by a narrow belt of metavolcanics with (?) ophiolitic affinity (Pudsey et al., 1985). Thus there is a possibility that the Reshun fault is a palaeosuture between two continental blocks within the Hindukush range.

Key words: Tectonics, Hindukush.

K/425. Khan, T., 1994. Evolution of the “upper and middle crust in Kohistan island arc”, northern Pakistan. Ph.D. Thesis, Peshawar University, 225p.

This thesis presents a geological map of 4,000 km² area between Chilas and Gilgit on a scale of 1:250,000, together with details of geochemistry and petrology. The area is occupied by > 1 km thick basal turbiditic sediments (the Gilgit paragneisses), followed upward by > 0.5 km thick Chait metavolcanics and, finally the Thelichi formation = Yasin group comprising a volcanic base and > 1 km thick overlying turbidites with local intercalations of marble volcanoclastics and lava flows. Other lithologies in the area include, Chilas mafic ultramafic complex (8,000 km²), and the Kamila amphibolites. The Kohistan batholith of mostly Paleocene-Eocene age, consists of quartz diorites, tonalities, trondhjemites, gabbroic, diorites, quartz monzonites, granodiorites, granites, aplites and pegmatites. The batholith contains tholeiitic and calcalkaline mafic dykes; such dykes in the Chilas complex are tholeiitic. Metamorphism up to sillimanite grade has been recorded in the Gilgit paragneisses. The rocks of the Chait volcanic group, mafic dykes of the Chilas complex and early phases of the Kohistan batholith show amphibolite facies metamorphism. The Thelichi formation contains greenschist facies mineral assemblages. The geochemical signatures of the Gilgit paragneisses support passive continental margin setting for their deposition. The Chait volcanics demonstrate island arc and back arc type affinities, whereas the Kamila volcanics resemble back-arc tholeiites and mid ocean ridge basalts. These volcanics show transition from arc volcanism to back-arc spreading. The Kohistan batholith is calcalkaline, and gives island arc and continental margin types configurations.

The 36,000 km² Kohistan terrane is divisible in three tectonic zones, (i) the southern (Kamila) zone comprises principally amphibolitised basalts, underplated by cumulate mafic-ultramafic plutons which occupy the hangingwall of the Indus suture, (ii) the central zone comprises the Chilas complex, and (iii) the northern (Gilgit) zone, the Gilgit paragneisses and the overlying rocks. The Gilgit zone was welded to the Karakoram plate 90 Ma ago along the Shyok suture. The northern two zones are complexly folded and faulted (in a divergent pop up structure), while the southern zone is folded and imbricated with a persistent southward vergence. Much of the Kohistan batholith cuts across these structures in the Gilgit zone. Previous tectonic models for Kohistan consider the southern two zones as the basal crust and the northern as the upper crust of a Cretaceous island arc. The present investigation shows that in the Gilgit zone there are two stages of turbidite deposition intervened by basaltic volcanism, an assemblage probably formed in a back-arc basin. These findings have resulted in a completely new interpretation for the Kohistan terrane. It is suggested that only the southern or the Kamila zone represents an island arc crust, while the assemblage to the north of the Kamila-Jal shear zone, including the Chilas complex and the overlying sequence of metamorphosed turbidites and basaltic volcanics, represents a folded and imbricated back-arc basin.

Key words: Ultramafics, metamorphism, volcanics, Chilas.

K/426. Khan, T., 1996. Geological excursion guide along the Karakoram Highway, North Pakistan. In: Geo-traverse along Karakoram Highway, Field Excursion Guide, Geological Survey Pakistan. Proceeding Geoscience Colloquium 15, 1–19.

Key words: Field geology, KKH.

K/427. Khan, T., 1998. Geochemistry, mineralogy and petrology of the sulfide mineralization and associated rocks in the area around Drosh, north Pakistan. Ph.D. Thesis, University of Peshawar.

Copper mineralization in the Drosh-Shishi area is localized in the upper crust of the Kohistan arc terrane in Chitral, northern Pakistan. It is confined to the Gawuch Formation in the area, comprising variably metamorphosed volcanics and sediments intruded by the plutons of diorite and granodiorite composition. The metavolcanics of the Gawuch Formation and the diorite-granodiorite minor plutons have calcalkaline compositional characteristics. In comparison, the metavolcanics of the Drosh Formation, occupying the top of the succession, are island-arc tholeiites. Copper mineralization in the area is related to hydrothermal activity and is mainly associated with altered diorites and quartz veins. It occurs in different forms; in the quartz veins, along the foliation planes, in dissemination and as supergene enrichment. Tetrahedrite, chalcopyrite, pyrite and galena are the dominant ore minerals along with subordinate amounts of sphalerite, magnetite, malachite and azurite. Fluid inclusion studies indicate that the salinity of the hydrothermal solution is <26 equivalent wt% NaCl and the homogenization temperature is in the range of 160 to 350°C. Oxygen isotope data suggest that the quartz in the mineralized quartz veins has $\delta^{18}O$ values ranging from 14.49 to 18.32 per mil. with mean value of 16.63 ‰. This, when combined with the homogenization temperature obtained from the fluid-inclusion studies, indicates involvement of magmatic fluids ($\delta^{18}O = 5.79$ – 9.42 ‰) in the formation of quartz veins and associated copper mineralization. The lead isotopic compositions of three galena samples suggest that $^{206}Pb/^{204}Pb$ ranges from 18.728 to 18.793, $^{207}Pb/^{204}Pb$ from 15.658 to 15.72, and $^{208}Pb/^{204}Pb$ from 39.040 to 39.285. These Pb-isotope ratios yield model ages of 42 – 142 Ma with the M values of 9.86 to 10.01. The minimum age (i.e., 42 Ma) is in close agreement with ^{40}Ar - ^{39}Ar age of the Lowari pluton, which is considered to be the source of hydrothermal solutions. The lead isotopic composition of studied galena samples indicate involvement of lead derived from older sources. These sources could be the arc volcanics or pelagic sediments of oceanic crust of Neotethys or the continental crust of the subducting Indian plate. It is concluded from these studies that the copper mineralization in Drosh- Shishi area was produced by the hydrothermal activity related with syntectonic dioritic magmatism.

Key words: Geochemistry, mineralogy, petrology, sulphides, Drosh, Dir.

K/428. Khan, T., Ali, I., Siddiqui, R.H. & Kamal, H., 1987a. Occurrence of Pink zoisite at Nomal, Gilgit District, Pakistan. *Acta Mineralogica Pakistanica* 3, 159-160.

Key words: Zoisite, Gilgit.

K/429. Khan, T., Ali, I., Siddiqui, R.H. & Kamal, H., 1987b. Pink zoisite (thulite) occurrence at Nomal, Gilgit District, Pakistan. Abstract with Programs, Mineral Resources and Geology of Pakistan, Quetta, Pakistan.

Key words: Zoisite, Gilgit.

K/430. Khan, T. & Humayun, M., 1980. Geology of the Shangla-Alpurai area. M.Sc. Thesis, University of Peshawar, 68p.

The Shangla area is a mélange between the Kohistan island arc and the Indian Plate. It contains pelitic and psammitic rocks, and components of ophiolite, including the main Alpurai ultramafic body. The rocks are described in this thesis.

Key words: Ultramafics, Shangla-Alpurai, Swat.

K/431. Khan, T., Karim, T., Rehman, H., Haider, N. & Naseem, M., 2000. The sheeted dykes: An evidence of sea floor spreading in the Kohistan arc terrain, Northwestern Himalaya, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 168-170.

Key words: Sheeted dykes, sea floor spreading, Kohistan Island arc.

K/432. Khan, T., Karim, T., Yoshida, M. & Khan, S.R., 1997a. Petrochemistry of the Ambela–Koga–Naranji Kandao Granite–Syenite Complex, northern Pakistan–Petrogenesis with reference to trace and rare–earth elements. In: Rare–Earth Elements Exploration of alkaline Rocks in Koga Area, Peshawar basin, NWFP, Pakistan. Karim, T. and Yoshida, M. (Eds.), Geological Survey Pakistan. Proceedings Geoscience Colloquium, Geoscience, Special Issue, 17, 11-30.

Key words: Petrogenesis, granite, syenite, carbonatite, Buner, Swat.

K/433. Khan, T., Karim, T., Yoshida, M. & Khan, S.R., 1997b. Petrogenesis of the Ambela–Koga–Naranji Kandao Granite–Syenite–Carbonatite Complex, North Pakistan. *Geologica* 5, 1–19.

Key words: Petrogenesis, granite, syenite, carbonatite, Buner, Swat.

K/434. Khan, T. & Kausar, A.B., 1996. Peridot occurrence with ferromagnetic mineral in the dunite of the Sapat ultramafics sequence, Naran-Kohistan, Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, p.130.

We report for the first time the peridot occurrence associated with a ferromagnetic mineral in the sheared dunite body of the Sapat ultramafic sequence, Naran-Kohistan (Survey of Pakistan toposheet Nos. 43E and 43F). The Sapat ultramafic sequence comprises dunite-pyroxenite-gabbro- (anorthosite), thinly layered dunite pyroxenite, dunite with thin chromite layers, homogeneous dunite and serpentinized dunite. It is part of the Sapat layered complex, making the tectonic base of the Kohistan island arc. The ultramafic sequence occupies the Indus suture or the Main Mantle Thrust, with the Indian plate in the south. Peridot-magnetite-bearing dunite is sheared cataclastically, and as a result, the dunite is randomly and intensely jointed. Peridot occurs in the joints, and the cavities. Other minerals associated with the peridot include talc, serpentine, magnesite, chromite and ferromagnetic opaque mineral of which Curie temperature marks 585°C, and the specific gravity up to 5.08. The ferromagnetic mineral occurs as subhedral grains, black-coloured with metallic luster. Talc and/or magnesite is the host and cementing material for the peridot and the ferromagnetic mineral. Peridots of the Sapat area are green, and yellowish green. They are euhedral to subhedral, and transparent but translucent and opaque peridots are also mineralized. Hydrothermal activity is responsible for the mineralization of peridot, ferromagnetic and the associated minerals. Magnetic method is applicable for prospecting the peridot. The association of ferromagnetic mineral with peridot may indicate path finder signatures of the former with the latter. Due to the brilliance and green colour, the peridots of the Sapat ultramafic sequence can be used as gemstones.

Key words: Mafic-ultramafics, peridot, Sapat, Kohistan.

K/435. Khan, T., Kausar, A.B. & Khan, I.H., 1997a. Peridot mineralization in the dunite of the Sapat ultramafic sequence, Naran-Kohistan, Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

For details consult the following account.

Key words: Geochemistry, mafic-ultramafics, peridot, Sapat, Kohistan.

K/436. Khan, T., Kausar, A.B. & Khan, I.H., 1997b. Peridot mineralization in the Sapat ultramafic sequence of the Indus suture zone, Naran-Kohistan area, Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 159-164.

The Sapat mafic-ultramafic complex of Jan et al. (1993) lies north of the Kaghan valley and to the northeast of Naran (N 34° 54' 17" and E 73° 38' 51") and north of Sochh village (N 34° 56' 29" and E 73° 42' 40") along the Naran-Babusar road. It comprises layered gabbro, gabbro-norite and massive to layered ultramafics with basal serpentinitic mylonites (Fig. 1). The layered ultramafics include dunite-pyroxenite-gabbro- (anorthosite) layers, thinly layered dunite pyroxenite, dunite with thin chromite layers, homogeneous dunite and serpentinized dunite (Fig. 2). The Sapat ultramafic sequence is part of the Sapat mafic-ultramafic complex, making the tectonic base of the Kohistan island arc, and marks the boundary, the Indus Suture with the Indian Plate to the south. Peridot mineralization has been spotted for the first time in the serpentinized dunite (minor), homogeneous dunite and the dunite with thin chromite layers (Fig. 2). Peridot occurrence has also been reported at the Zeberget, Island of St. John, in the Red Sea where the host rock is serpentinite dunite (McIntock, 1951; Reed, 1991), and Fo90 (Strunz, 1962; Wilson, 1976). In the Ross Island Antarctica the peridots occur in nodules in basalt with Fo92 (Wilson et al., 1974). Other localities where the peridot mineralization is known include Upper Myanmar (Burma), Australia, Brazil, China, Mexico (light green peridot, Fo91, and a more iron rich light greenish-brown variety, Fo88.6, Dunn, 1978), Norway (Fo90.6; Bank et al., 1970) and USA (Deer et al., 1982; Reed, 1991).

Peridots (Fo91 at the average, and occasionally Fo92 and Fo95) of the Sapat are green to yellowish green in color. They are euhedral to subhedral and 0.5 cm to 4 cm long. They are generally transparent, translucent, and occasionally opaque. The green-colored, transparent, and fracture-free varieties are used as good-quality gemstones. In the Sapat area peridot mineralization occurs in 250-m wide zone, bounded by a 3-m thick mylonite zone in the lower part towards the Indus Suture. They are mineralized in the crosscutting joints, joint cavities, and veinlets. The width of the cavities range up to about 7 cm (Fig. 3). Other minerals associated with peridots include clinochrysotile, antigorite, talc and magnetite (Curie temperature 585°C in heating curve and 595°C in cooling curve). Clinochrysotile is the main mineral wrapping the peridot crystals and magnetite grains (Fig. 4). As evident from the antigorite inclusions in peridots and the mode of occurrence of peridots, it seems that they are developed from antigorite, and the magnetite grains associated with peridots are inherited from the serpentinite, indicating high oxygen fugacity conditions during the progressive metamorphism of serpentinites or deserpentinization (Deer et al., 1982), and the processes related to the shearing along the Indus Suture.

Key words: Geochemistry, mafic-ultramafics, peridot, Sapat, Kohistan.

K/437. Khan, T., Kausar, A.B. & Khan, I.H., 2000. Peridots of the Sapat, Naran-Kohistan areas, Himalaya, Pakistan: An evidence of mantle thrust sheet deposit. Abstracts, Third South Asia Geological Congress, Lahore, 167-168.

Consult the preceding account.

Key words: Geochemistry, mafic-ultramafics, peridot, Sapat, Kohistan.

K/438. Khan, T., Kausar, A.B., Takahashi, Y. & Takahasi, Y., 1993. Geochemistry of the mafic and ultramafics rocks of Chilas complex, Chilas, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 4, 51-61.

Chilas Complex is a layered magmatic complex of the Kohistan island arc which is 300 km long and 40 km wide. It comprises pyroxene quartz diorites, tonalites, gabbros, gabbro-norites, layered dunites, peridotites and amphibolites. Geochemical studies conducted on the ultramafic and basic to intermediate plutonic rocks of the complex reveal their island arc affinities. Various discrimination diagrams have been used to define these rocks. These are mainly gabbros and pyroxene quartz diorites, tonalites and peridotites. The basic and intermediate rocks are low-K to medium-K and calc-alkaline. The geochemical patterns identify the rocks as developed in the island arc environments. These rocks are depleted in Nb giving typical "V" shape pattern. Positive anomalies at Sr and Zr (in more acidic ones) are also significant. The geochemical pattern support the compatible behaviour of the HFS

elements in olivine, pyroxene and spinel. High degree of partial melting of the metasomatised mantle peridotite is considered the source for the Chilas Complex.

Key words: Geochemistry, mafic-ultramafics, Chilas complex, Kohistan.

K/439. Khan, T., Khan, M.A. & Aziz, A., 1992. Petrogenetic comparison between the mafic dykes of Chilas complex and Kohistan batholith, Northern Pakistan. *Acta Mineralogica Pakistanica* 6, 118-125.

Kohistan Island Arc is formed due the northward subduction of oceanic plate in Cretaceous. The arc sequence contains two major magmatic complexes: the layered mafic and ultramafic Chilas Complex at the base, and the Kohistan Batholith in the middle part. Mafic dykes intrude the gabbro-norite and pyroxene diorites of the Chilas Complex, north of Chilas and the diorites of the Kohistan Batholith west and south of Gilgit. Petrography and geochemistry divided the mafic dykes into three distinct groups. The mafic dykes of the Chilas Complex are rich in plagioclase, hornblende and ilmenite and/or magnetite. These are metamorphosed to amphibolites except the dykes intruding the batholith at shallower part. The Chilas Complex dykes are picobasalt and basalt whilst in the batholith they are basaltic andesite and trachyandesite. Trace element geochemical patterns are similar for all the three type of dykes but the Chilas Complex dykes are more depleted in LIL elements with marked negative Nb and positive Sr anomalies. The Kohistan batholith dykes are comparatively enriched in the LIL elements and the trachyandesites are more enriched. The former is considered "D-type" and the later "E-type" dykes. They all show island arc affinities but the trachyandesite shows continental margin signatures. The three groups also reflect three different magmatic episodes, derived from the partial melting of less and more heterogeneous mantle sources, respectively.

Key words: Petrogenesis, mafic dykes, Chilas complex, Kohistan batholith.

K/440. Khan, T., Khan, M.A. & Jan, M.Q., 1993. Kohistan, a collage of island arc and back-arc basin assemblages in the Himalaya of Pakistan. *Geological Society of America, Abstract Program*, A-122.

Trapped between the collided Indian and Karakoram Plates, the 38000 km² Kohistan terrain in N. Pakistan is divisible into three tectonic zones. The southern (Kamila) zone comprises principally amphibolitized basalts, underplated by cumulate ultramafic-mafic plutons, which occupy the hangingwall of the Indus suture. The central zone comprises gabbro-norites, pyroxene diorites and ultramafics, forming a ~ 8000 km² coherent plutonic body. The northern (Gilgit) zone comprises > 1 km thick basal (turbiditic) sediments (the Gilgit paragneisses) metamorphosed up to sillimanite grade, followed by > 0.6 km thick Chalt (meta)volcanics (commonly pillowed) and finally > 1 km thick turbidites locally interbedded with marble of Albian-Aptian age (Yasin group). The Gilgit zone was welded to the Karakoram plate - 90 Ma ago along the Shyok suture characterized by up to 4 km thick olistostrome. The northern two zones are complexly folded and faulted in a divergent pop-up structure, while the southern zone is folded and imbricated with a persistent southward vergence. The Kohistan batholith of mainly Palaeocene-Eocene age cuts across the structures in the Gilgit zone.

Previous tectonic models for Kohistan consider the southern two zones as the basal crust and the northern zone as the upper crust of a Cretaceous island arc. Subsequently we suggested that the Chilas complex was probably emplaced during an episode of back arc rifting. Recent mapping, stratigraphic reconstruction and geochemistry in the Gilgit zone has resulted in the recognition of two stages of turbidite deposition intervarved by basaltic volcanism, an assemblage probably formed in a back-arc basin. These findings have resulted in a completely new interpretation for the Kohistan terrane. We suggest that only the southern or the Kamila zone represents an inland arc crust, while the assemblages to the north of the Kamila-Jal shear zone, including the Chilas complex and the overlying sequence of metamorphosed turbidites and basaltic volcanics, represents a folded and imbricated back-arc basin.

Key words: Kohistan, Island arc, Back arc basin.

K/441. Khan, T., Khan, M.A. & Jan, M.Q., 1994. Geology of a part of the Kohistan terrane between Gilgit and Chilas, northern areas, Pakistan. *Geological Bulletin, University of Peshawar* 27, 99-112.

More than 4000 Km² area of Kohistan terrane, exposed between Gilgit and Chilas, is mapped and described in this paper. A variety of plutonic and metamorphosed volcanic and sedimentary rocks are encountered in the mapped area, which have been classified into Kamila amphibolite, Chilas complex, Kohistan batholith and Jaglot Group. The Jaglot Group, comprising a succession of metasediments and metavolcanics, is divided into three stratigraphic units, which, from base to top, include Gilgit Formation [~ 1 Km thick succession of schists, paragneisses, calc-silicates and amphibolites (some derived from the pillowed basalts) and Thelichi Formation (comprising a volcanic basal part, overlain by >1 km thick turbidites with a thick marble unit in the middle). The rocks of the Jaglot Group are regionally metamorphosed in amphibolite-and greenschist facies; the highest grade is depicted by the occurrence of sillimanite in the paragneisses of the Gilgit Formation. A pair of crustal-scale anticline (the Gilgit anticline) and syncline (Jaglot syncline) control the structure of the area. These, together with their parasitic folds, repeat the stratigraphy of the area several times. The Jaglot Group is regionally correlated with the succession of metasediments and metavolcanics exposed along the Northern Suture (i.e., Yasin Group Sediments and Chalt Volcanics) and is considered to have been deposited in an oceanic basin (probably of a back-arc affinity) on the basis of the predominance of turbidites in the metasediments and pillowed basalts in the volcanics.

Key words: Kohistan island arc, Gilgit, Chilas, Himalaya.

K/442. Khan, T., Khan, M.A. & Jan, M.Q., 1995. Back-arc basin assemblages in Kohistan, Himalaya, north Pakistan. Spec. issue, Mitt. Geol. Inst., Zurich, 4p.

The 36,000 km² Kohistan sandwiched between the Karakoram and Indian continental plates in the north and south, respectively. In the north the contact is defined by the Shyoke suture or Main Karakoram Thrust and in the south by the Indus suture or Main Mantle Thrust. The whole rock sequence of Kohistan is considered to represent an intra-oceanic island arc with a narrow marginal sea in the north (Pettersen & Windley 1985; Pudsey 1986). It was formed due to northward subduction of the Neo-tethyan Lithospheric plate (Coward et al. 1987; Honneger et al., 1982; Tahirkheli & Jan, 1979).

This manuscript includes a geological map of the investigated area together with a brief description of petrology and geochemistry. The area is occupied by >1 -km thick basal turbiditic sediments (the Gilgit paragneisses), followed upward by >0.5 -km thick Chalt volcanics and, finally the Thelichi formation = Yasin group of Ivanac et al. (1956), comprising a volcanic base and >1 -km thick turbidites with local intercalations of marble, volcanoclastics and lava flows. Other lithologies in the area include, Chilas mafic-ultramafic complex (~ 8000 km²), and the Kamila amphibolites (Bard et al. 1980; Jan et al. 1984; Jan 1988; Khan & Coward, 1990; Khan et al., 1993). The Kohistan batholith (Pettersen & Windley, 1985) mostly Paleocene-Eocene cuts across the structure in the Gilgit zone. The batholith contains tholeiitic and calc-alkaline mafic dykes; such dykes in the Chilas complex are tholeiitic.

Metamorphism up to sillimanite grade has been recorded in the Gilgit paragneisses. The rocks of the Chalt volcanic group, mafic dykes of the Chilas Complex, and early phases of the Kohistan batholith show amphibolite facies metamorphism. The Thelichi Formation contains greenschist mineral assemblages.

The geochemical signatures of the Gilgit paragneisses support igneous provenance, derived from mainly the oceanic island arc (Roser & Korsch 1988; Condie et al. 1992). Evidences for the existence of the continental basement and fore-arc basin are lacking for the Gilgit paragneisses. The metavolcanic rocks namely the Chalt, and the Majne volcanics are tholeiitic basalts, which show a composite trace elements geochemical signatures. The Chalt volcanics are mainly HFS elements depleted with Nb trough where as the Majne volcanics are HFS elements enriched with positive Nb anomaly. Both the island arc-and MORB-like signatures are found in these two volcanic formations (Alabaster & Storey, 1990). As evident from the stratigraphical setup the Chalt volcanics are older than the Majne volcanics, and enriched in the incompatible elements derived from the subducting lithospheric plate during the initial stages of back-arc rifting (Pearce et al. 1984; Saunders & Tarney, 1991). The Majne volcanics are MORB-like back-arc basin tholeiitic basalts, and are low in MgO and high in TiO₂ contents and FeO(total) / MgO ratio where as the Chalt volcanics are high-Mg tholeiitic basalts with low TiO₂ content and FeO(total)/MgO ratio at a given SiO₂ concentrations. Fractional crystallization and low degree of partial melting of the enriched mantle, and high degree of partial melting of the subduction modified mantle are the possible sources for the Majne and Chalt volcanics, respectively (Pearce & Norry, 1979; Wilson 1989). Moreover, these volcanic formations show transition between arc-like and MORB-like magmatism during back-arc rifting.

The establishment of a new stratigraphy in the middle Indus valley of Kohistan and the recognition of the sillimanite-bearing metasedimentary rocks and the back-arc basin tholeiitic basalts for the first time, divides the Kohistan in three tectonic zones. The southern (Kamila) zone comprises principally amphibolitised basalts, underplated by cumulate mafic-ultramafic plutons, which occupy the hanging wall of the Indus suture. The central

zone comprises the Chilas complex, and the northern (Gilgit) zone, the Gilgit paragneisses and the overlying rocks. The Gilgit zone was welded to the Karakoram plate-90 Ma ago along the Shyoke suture. The northern two zones are folded and faulted (in a divergent pop-up structure), while the southern zone is folded and imbricated with a persistent southward vergence. Much of the Kohistan batholith cuts across these structures in the Gilgit zone.

Previous tectonic models for Kohistan consider the southern two zones as the basal crust of a Cretaceous island arc. The present investigation shows that in the Gilgit zone there are two stages of turbidite deposition intervened by basaltic volcanism, an assemblage formed in a back-arc basin. These findings have resulted in a completely new interpretation for Kohistan. It is suggested that only the southern or Kamila zone represents an island arc crust, while the assemblage to the north of the Kamila-Jal shear zone, including the Chilas complex and the overlying sequence of the metamorphosed turbidites and basaltic volcanics represents a folded and imbricated back-arc basin.

Key words: Back arc basin, Kohistan arc, Karakoram, Himalaya.

K/443. Khan, T., Khan, M.A., Jan, M.Q. & Latif, M., 1996. The Kohistan between Gilgit and Chilas, northern Pakistan: regional tectonic implications. *Journal of Nepal Geological Society* 14, 1-10.

In this paper, we present geological description of an area located between Gilgit and Chilas within the Kohistan terrane. This terrane has been considered an intra-oceanic island arc, formed due to northward subduction of the Neo-tethyan lithospheric plate. At present, it is squeezed between the Karakoram-Asia and Indian continent plates. Both the contacts are marked by suture zones, that is, Shyok (MKT) in the north and Indus (MMT) suture in the south, respectively. The investigated area consists of plutonic, metamorphosed volcanic and sedimentary rocks, the Chilas Complex, and the Kamila Amphibolite. The metamorphosed volcanic and sedimentary rocks are packaged into the Jaglot Group. This group comprises basal turbiditic sediments, intercalated with amphibolites and calc-silicates (the Gilgit Formation), followed upward by the Gashu-Confluence Volcanic=Chalt Volcanic Group, and finally the Thelichi Formation=Yasin Group of Aptian-Albian age. The Thelichi Formation comprises a volcanic base (Majne volcanics) and overlying turbidites, local intercalation of marble, volcanoclastics and lava flows. Greenschist and amphibolite facies are common in the Jaglot Group, and particularly the sillimanite in the Gilgit Formation. A pair of anticline (the Gilgit anticline) and syncline (the Jaglot syncline) make up the structural scenario. On the basis of field geology, we conclude that the entire Jaglot Group and its equivalent, Yasin Group, Chalt Volcanic Group in Kohistan, and Burjila Formation, Bauma Harel Formation and Katzarah Formation in Ladakh show intra-oceanic back-arc basin rather than island arc affinities as suggested in the past.

Key words: Tectonics, Kohistan island arc, MKT, MMT, Himalaya.

K/444. Khan, T., Khan, M.A., Jan, M.Q. & Naseem, M., 1996. Back-arc basin assemblages in Kohistan, northern Pakistan. *Geodynamica acta* 9, 30-40.

The east central part of the Kohistan magmatic arc is made up principally of the Jaglot Group. From bottom to top it consists of I) paragneisses and schists intercalated with amphibolites and calc-silicates (Gilgit Formation), II) Gashu-Confluence Volcanics (GCV) and III) the Thelichi Formation comprising a volcanic base (Majne volcanics) and turbidites, marble, volcanoclastic sediments and lava flows. Metamorphic grade varies up to the sillimanite zone. The GCV are correlated with the Chalt volcanics and the Thelichi Formation with the Yasin Group. Other lithologies include the Chilas Complex, the Kohistan Batholith and part of the Kamila Amphibolite. Metavolcanics show a broad range in chemical composition. Geochemical parameters used to specify the tectonomagmatic regime suggest affinities of both island arc and MORB-like back-arc basin basalts. Kohistan can be divided into three tectonic zones, I) the southern (Kamila) zone comprises amphibolitized basalts, and mafic and ultramafic rocks, II) the central Chilas Complex, and III) the northern (Gilgit) zone i.e., the Jaglot Group. Previous tectonic models considered the southern two zones as the crust of a Cretaceous island arc. This investigation concludes that only the southern zone represents a true island arc. The Jaglot Group derives from back-arc basin assemblages and the Chilas Complex is a magmatic diapir emplaced in the back-arc basin.

Key-words: Island arc, back arc, geochemistry, Kohistan.

K/445. Khan, T., Khan, N.A. & Khan, M.S., 1988. A short note on the occurrence of turbidite at Sikanderabad, along Karakoram Highway, Northern Areas of Pakistan. *Geological Survey of Pakistan, Information Release* 387, 5(+8)p.

In the Hunza valley, rock units belonging to Kohistan Island arc, Main Karakoram Thrust zone and Eurasian continent are exposed along the Karakoram Highway. A turbidite unit has been identified at Sikandarabad in the melange zone of the MKT along with slates, phyllitic schist, calcareous schist, limestone, green schist pyroclasts, talc carbonate, serpentinite, peridotite, andesite/basalt and rhyolite as the melange constituents. The turbidite of the area is composed of interlayered siltstone, sandstone and mudstone. The mudstone is changed into schist, containing upto 25 cm long pebbles of sandstone, siltstone, limestone, quartz, slate and andesite. These pebbles are flattened and oriented in the northwestern directions. This turbidite of the melange zone may represent deep-seated sedimentary origin in the oceanic island arc environments.

Key words: Turbidites, Hunza, Shyoke suture, Karakoram.

K/446. Khan, T., Khan, N.A. & Shirahase, T., 1998. Geology of the Kohistan batholith in Kar Gah and Gor sectors, Kohistan arc terrane, Gilgit, North Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 102-103.

Kohistan arc terrane lies between the Asian and Indian continental plates (Fig. 1). Both the northern and southern contacts of the arc are marked by suture zones commonly known as Main Karakoram Thrust (MKT) and Main Mantle Thrust (MMT). The Kohistan batholith which is one of the major rock components of the arc and the Trans-Himalayan batholith extends for more than 2700 km along the length of Himalaya and Karakoram. The Kohistan batholith in Kohistan arc extends for 300x50 km between the Afghan border on the west and the western flank of the Nanga Parbat massif on the east (Fig. 1). The batholith is an ENE-SSW elongated body consisting of many plutons which intrude the Jaglot group and Chilas complex of the Kohistan arc. The Kohistan batholith, south of Gilgit, in Kar Gah and Gor sectors comprises multiphase plutons forming Shinghai and Gor plutonic belts. The Shinghai plutonic belt is basic to intermediate in composition comprising gabbro, gabbroic-diorite and diorite along with younger intrusions of granodiorite and granite (minor). The belt also contains serpentinite, pyroxenite? and paragneiss as xenoliths. The Gor plutonic belt is the principal occurrence of the Kohistan batholith along the drainage divide between the Indus and Gilgit Rivers. It is a coherent body of mainly quartz diorite composition but also contains intrusions of tonalite, granodiorite, adamellite and granite along with ample aplite and subordinate pegmatite. The main pluton contains abundant xenoliths and/or autoliths of basic composition. Both the northern and southern contacts of the Gor pluton are intrusive into the metasedimentary succession of the Jaglot group and the Chilas complex, respectively.

Major and trace element geochemical patterns and petrological characteristics of the Kohistan batholith in the study area reveal that (i) chemical variation seen in the batholith is not due to high level differentiation but can be better explained by partial melting, (ii) much of the Kohistan batholith appears to be the product of mantle wedge above the subduction zone, (iii) some of the leucogranite and aplite seem to be derived by partial melting of the crust of the Kohistan arc, and (iv) there are certain plutons which are alkaline in nature and contain a higher amount of K₂O over Na₂O which may be derived from crustal material such as Gilgit paragneisses and/or from a possible basement of the Indian plate crust underplating the arc. The Frequency of C twins in the Kohistan batholith is mostly 10 to 20% showing igneous features and shallow depth of emplacement for the batholith.

Key words: Kohistan batholiths, petrography, Gilgit, Kohistan arc.

K/447. Khan, T., Latif, M., Khan, N.A. & Shah, S.H., 1989. Geology and petrography of the rock outcrops in Shinghai Gah and Kiner Gah, Gilgit-Chilas Districts, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 446, 15p.

Reconnaissance geological investigation and petrographic study on the rocks of the Shinghai gah and Kiner Gah have revealed that the Kohistan Island arc in these nallahs is composed of plutonic, metavolcanic and metasedimentary rocks belonging to Ladakh-Kohistan granitic belt, greenstone complex, Chilas complex and Thelichi beds. Granodiorites and diorites are the dominant plutonic rocks with granite, pegmatite and aplite as minor associates with norite the bottom most unit exposed at Thak area in Kiner gah. The older granitoids are metamorphosed and mylonitized along the sheared contacts. Volcanics (greenstone/greenschist) occur in an elongated belt underlain by the marble beds, schists, andalusite slate and micaceous sandstone at Shinghai gah. The metasediments have sheared contacts. The older volcanics are metamorphosed into amphibolites and occur as

xenoliths and screens within the intrusive rocks. All the rocks units exposed in Shinghai gah and Kiner gah range in age from Recent to Jurassic and trend mostly in NW-SE direction.

Key words: Petrography, Central east Kohistan, Gilgit-Chilas districts.

K/448. Khan, T., Nakajima, T., Khan, S.R. & Sano, S., 1994. Occurrence of blueschists at Tuwa near Charbagh, NWFP, Pakistan. *Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad)* 8, 94-99.

A new occurrence of blueschists within the Indus Suture near Charbagh has been reported. There is intermixing of blueschists and greenschists, representing single lithology. The coexistence of glaucophane- crossite, actinolite/tremolite and epidote may suggest high pressure intermediate series metamorphism of the rocks. Thus, blueschists melange and greenschists melange represent a coherent melange group extending from Shangla towards Tuwa.

Key words: Blueschists, greenschists, Indus suture, melange, Charbagh, Swat.

K/449. Khan, T., Nakajima, T., Seki, Y., Khan, N.A. & Khan, S.Z., 2001. Turbidite occurrence at Sikandarabad (Chalt) along the Karakoram Highway, Northern areas of Pakistan. *Abstracts, 4th Pakistan Geological Congress, Islamabad*, p.70.

In Hunza valley, rock units belonging to Kohistan island arc, Main Karakoram Thrust zone and Karakoram-Asian continent, are, exposed along the Karakoram Highway. A turbidite unit resembling conglomerate has been identified at Sikandarabad (Chalt) in the mélangé zone of the Main Karakoram Thrust along with slates, phyllitic schist, calcareous schist, limestone, greenschist pyroclastics, talc-carbonate, serpentinite, peridotite, andesite/basalt and rhyolite as the mélangé constituents. The turbidite of the area is composed of interlayered siltstone, sandstone and mudstone. The mudstone is changed into schist, containing up to 25 cm long pebbles of sandstone, siltstone, limestone, quartz, slate and andesite. These pebbles are flattened and oriented. This turbidite of the melange zone may represent deep-seated sedimentary origin in the ocean basin.

Key words: Turbidite, Karakoram thrust zone, KKH.

K/450. Khan, T., Ogasawara, M. & Oeta, E., 1992. Electron probe study of pink zoisite of Nomal, Gilgit District, Pakistan. *Abstracts, First South Asia Geological Congress, Islamabad*, p.23.

Key words: Mineralogy, zoisite, Nomal, Gilgit.

K/451. Khan, T. & Shirahase, T., 1996. Evolution of the Kohistan terrane with reference to the Jaglot Group and the Chilas complex, Gilgit-Chilas, northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad*, 15, 15-36.

In this manuscript, we present geological description of an area located between Gilgit and Chilas within the Kohistan terrane. This terrane has been considered an intra- oceanic island arc, formed due to northward subduction of the Neo-tethyan lithospheric plate. At present, it is squeezed between Karakoram-Asian and Indian continental plates. Both the contacts are marked by suture zones, that is, Shyok (MKT) in the north and Indus (MMT) sutures in the south, respectively. The investigated area consists of plutonic, metamorphosed volcanic and sedimentary rocks (Jaglot Group), the Chilas Complex, and the Kamila Amphibolite. The Jaglot Group comprises basal turbiditic sediments, intercalated with amphibolite and calc-silicate (Gilgit Formation), followed upward by Gashu-Confluence Volcanics which is the equivalent of the Chalt Volcanic Group, and finally the Thelichi Formation, equivalent of the Yasin Group of Aptian-Albian age. The Thelichi Formation comprises a volcanic base (Majne volcanics) and the overlying turbidites, local intercalation of marble, volcanoclastics and lava flows.

Greenschist and amphibolite facies metamorphism are common in the Jaglot Group. A pair of anticline (Gilgit anticline) and syncline (Jaglot syncline) makes up the structural scenario. On the basis of field geology and petrology, we conclude that the entire Jaglot Group and its equivalents, the Yasin Group, the Chalt Volcanic Group in Kohistan, and the Burjila Formation, Bauma Harel Formation and the Katzarah Formation in Ladakh show intra-oceanic back-arc basin rather than island arc affinities as suggested in the past. The Chilas Complex exhibits a mantle diapir which ensued during the subduction related back-arc rifting processes.

Key words: Geology, ultramafics, Jaglot group, Chilas complex, Gilgit.

K/452. Khan, T.M., 1992. Uranium distribution in graphitic metapelites in the Pre-Cambrian Formation of Azad Kashmir and NW Pakistan. M.Phil. Thesis, University of Peshawar, 133p.

The graphitic metapelites of NW Pakistan and Azad Kashmir are exposed in a zone of thrust tectonics, and are scattered in the form of continuous beds and lenses in various nappes. These are highly radioactive at places but the equivalent chemical uranium is found to be lower than its radiometric equivalents. This form of negative disequilibrium is produced due to the presence of daughter products of U, Th and K40. The chemical composition of the graphitic metapelites indicates that the rocks from Tarbela area are more siliceous and contain more organic carbon compared to the rest of the exposures of the graphitic-metapelites. Due to their fine grain-size, dark colour, and Fe oxidation along fractures, the rock types are classified as black shales. According to the classification of Stribny et al. 1988, the graphitic metapelites from Tarbela area are siliceous and those from other area are dominantly argillaceous, siliceous with high normative quartz. Uranium associated with other elements is concentrated in the upper part of the graphitic metapelites and unlike typical black shale deposits, do not indicate any correlation with organic carbon. The absence of relationship is primarily caused by the dissolution of some of the elements in ground water circulating freely in the otherwise impermeable rock made permeable by the structural movements in the region. Compared to metal rich black shale deposits these rocks are enriched in U, V, Ba and Pb. The enrichment of one of the elements took place in association with the detrital fraction of the rock while the rest of the enriched elements were concentrated from normal seawater in oxygenated transitional environment close to the continent. The graphitic metapelites were probably deposited in a basin fed by different source material.

Key words: Radioactive minerals, Precambrian, Azad Kashmir.

K/453. Khan T.M. & Shah, M.S., 1979. Petrography of the Shilman Carbonatite Complex, Khyber Agency. M.Sc. Thesis, Peshawar University, 72p.

This is a description of the field and petrographic aspects of the Shilman carbonatite. The rock-types of the complex include altered (meta) gabbros / dolerite, followed by amphibole-apatite-, biotite/phlogopite-, and dolomitic carbonatites, syenites and lamprophyric rocks, and Fe-rich hydrothermal veins.

Key words: Petrography, carbonatite, Shilman, Khyber Agency.

K/454. Khan, T.N., Khan, M.M. & Mohammad, N., 1994. Upgradation of Kakul rock phosphate by reverse flotation. Abstracts, Second SEGMENT International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, p.21.

Laboratory scale flotation studies were conducted on North Waziristan Copper Ore to enhance the copper content in the final concentrate product. Process parameters such as type of collector effect of activator/depressant, effect of pH were investigated. In the final product copper content was enhanced from 0.386% (in feed) to nearly 20 percent (in the concentrate) in a single stage flotation process.

Key words: Phosphate, Kakul, Hazara.

K/455. Khan, W., 1986. Geology and petrography of the metamorphic and ultramafic rocks of Shergarh Sar area, Allai Kohistan, Hazara Division, N.W.F.P. Geological Survey of Pakistan. Information Release 254, 29p.

The area investigated, lies along the main Mantle Thrust and constitutes the southernmost obducted part of Kohistan Island Arc sequence, which developed due to the collision of the northward moving Indo-Pakistan continent with Eurasian plate. The area is occupied mostly by metamorphic and ultramafic rocks. The metamorphic rocks consist of epidote amphibolites, garnet-epidote amphibolite and garnet amphibolites. The ultramafics are peridotite, pyroxenite, dunite and their equivalent serpentinite. The amphibolites are the part of north east trending southern amphibolite belt of Kohistan and represent the metamorphosed Tethyan oceanic crust, while the ultramafics are considered to be the pieces of the underlying upper mantle and show the chromium mineralization.

Key words: Geology, petrography, metamorphic rocks, ultramafics, Shergarh Sar, Alai Kohistan.

K/456. Khan, W., Aslam, M., Begum, I. & Shah, A., 1982. Geology of Shergarh Sar complex Alai Kohistan, Hazara. M.Sc. Thesis, University of Peshawar, 55p.

Key words: Geology, Shergarh Sar, Alai Kohistan.

K/457. Khan, W.M., 1965. The main Malakand granite. Geological Bulletin, University of Peshawar 2, 8-10.

The best exposures of this beautiful rock are seen along the main road from Malakand to Bat Khela. It is a dazzling white, coarse grained rock, mainly composed of quartz, biotite and alkali feldspar, but there are local variation in color, texture and composition. It is without foliation in the main part but where traced to the surrounding rocks, gneissic structures come in. the country rocks surrounding it are mainly slates and gneisses, but various kinds of schist may also be seen. Quartz, aplite and pegmatite veins are common, especially, where the adjacent rocks are slates. Rafts and xenoliths of slates are common in the granites.

Key words: Granite, Malakand.

K/458. Khan, Z.A., 1997. Nature and Genesis of India-Asia Suture. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 165-166.

The paper reviews the field data from the Chaman and the Indus-Tsangpo regions and points out that currently available evidence does not support the plate tectonic concept that these are sutures zones of the Indian and northern landmasses. Instead, it is suggested that the Indus-Tsangpo is a rift valley. Presumably it came into being in Triassic, which continue to deepen and receive sediments, became dormant in the Cretaceous after a spurt of volcanic activity long before the supposed suturing in the Eocene.

Attention is drawn on the occurrence of extensive Carboniferous fluvioglacial deposits in northern Tibet, and the presence of typical Gondwana flora and fauna bespeak unequivocally that there was a continuity from Peninsular India to northern Tibet in Carboniferous times. Tapponnier et al., (1980) and Acharyya (1990) admitted the existence of Carboniferous tillite with distinct Gondwana affinities underlying Permo—Carboniferous beds in the Lhasa block, but later, the former committed a somersault calling it a rift in—fill to continent to support plate tectonic data. Furthermore, consistent palaeocurrent-directions towards the northwest in Peninsular India, Lesser, and Tethys Himalayas (Sakai, 1991) indicate a continuity from Peninsular India to northern Tibet and may be beyond.

The ophiolite eruptions along the Indus-Tsangpo suture have yielded two different ages of emplacements i.e. emplacement took place about 100 Ma before the supposed collision in the Eocene-Miocene. Whereas, the Tibetan glacial indicate that India and Tibet were together in Carboniferous, Lystrasaurus fauna suggests for the Lower Triassic and the ophiolites for the Jurassic-Cretaceous. Thus, India and Tibet were together all the time.

Also, Indian plate is believed to have underthrust the Tibetan plate by about 500 km, however, if this is correct and if 500 km of shortening along the Himalaya is added to it there should be a displacement of about 1000 km on the Baluchistan coast. Instead, the coast is straight. Similarly, there is no explanation for the fact that, if this underthrusting has taken place, why did Himalayan uplift occur some 500 km from the Indus-Tsangpo suture instead of being along Collision zone itself The collision of suture is therefore, a consequence of misinterpreted evidence and distorted arguments offered by supporter of plate tectonic hypothesis. Likewise, the double thickness of crust in Tibet, is not unique in that it continue south of the so-called suture, as also in Pamir. It is of about the same order in Andes available evidence strongly suggests that the Tethys was entirely epi-continental. It may be noted that the

rivers flowing out of the Tibet area onto the Indian plate must have existed before the Himalaya rising, which means that India-Tibet area was a landmass, and Tethys did not exist. Evidence in support of the points indicated above is discussed in this study.

Key words: Tectonics, Indus-Zangbo suture.

K/459. Khan, Z.A., Dawar, N.A. & Ahmad, M., 1997. Geology of area south of Bahadur Khel District Karak, N.W.F.P. M.Sc. Thesis, University of Peshawar, 43p.

Key words: Geology, Bahadurkhel, Karak.

K/460. Khan, Z.K., 1978. Study of landslide problem along the Murree Kohala road, District Rawalpindi, Punjab. Part 1: General Study. Geological Bulletin, University of Punjab 15, 52-61.

Along 10 miles long stretch of road, from lower Topa to Phagwari village has been surveyed to study the major landslides in detail, namely the so called Kasserli, Norgali, Seher Bagla and Aliot slides. The landslides have been mapped on contour map of scale 1:2400 and 1:4800 on basis of surface geology, characteristics of the slope, types of movement and the material involved. Majority of the failures mainly occurs due to lack of proper drainage facilities all along the road. Engineering properties like Atterberg's limit, specific gravity, density, cohesive strength, angle of friction and grain size analysis of the soil present on unstable slopes are tested to know behavior of the soil under different conditions. Suggestion for improving present conditions of the road and to minimize possibility of its failure are purposed.

Key words: Landslides, Murree-Kohala, Rawalpindi.

K/461. Khan, Z.K., 1991. A Geologic Study of Basha Dam and its appurtenance in Diamir District, Northern area, Pakistan. Kashmir Journal of Geology 8 & 9, 181-184.

The Basha dam site is situated on the Indus River about 45 km downstream of the town of Chilas. This is purely meant for hydel power. Rocks exposed at the dam site are predominantly igneous complex, comprised of norite with subordinate peridotite, hornblende and quaternary deposits. Geological map is presented with the possible location of main dam and its essential appurtenances. The locations of appurtenances are essentially examined and discussed.

Key words: Geology, igneous complex, Basha, Chilas.

K/462. Khattak, A., Nawaz, A. & Khattak, M.T., 1996. Soils and materials testing for road construction; Indus Highway Project Phase II (Karappa-Karak Section), N.W.F.P. M.Sc. Thesis, University of Peshawar, 55p.

Key words: Geotechnical, material testing, Indus Highway.

K/463. Khattak, A.K. & Aslam, M., 1974. Emeralds deposits of Tora Tiggera, Mohmand Agency, N.W.F.P., Pakistan. Geological Survey of Pakistan, Quetta. Information Release, 71, 13p.

Key words: Gems, emerald, Tora Tiggera, Mohmand Agency.

K/464. Khattak, A.S.K., Yousafzai, A.S. & Khan, N.A., 1977. Geology and structure geology of part of the area North of Kohat District. North West Frontier Province. M.Sc. Thesis, Peshawar University, 91p.

Key words: Structure, stratigraphy, Kohat.

K/465. Khattak, G.A., 1997. Sedimentological and environmental studies of loess deposits, Nowshera area, Peshawar basin, N.W.F.P. M.Sc. Thesis, University of Peshawar, 114p.

Key words: Sedimentology, environment, loess deposits, Nowshera.

K/466. Khattak, M.A., Aziz, S. & Shah, R.A., 1979. Exploration, beneficiation and utilization of Hazara rock phosphate. International Seminar on Mineral Exploration and Technology, 1979, 59p.

Key words: Exploration, beneficiation, phosphate, Hazara.

K/467. Khattak, M.A., Husain, V. & Qureshi, K.M., 1990. Prospects for development and utilization of some industrial minerals of N.W.F.P. Proceedings, First SEGMITE Conference on Industrial Minerals, Peshawar, 62-67.

The province is endowed with rich reserves of industrial minerals such as rock phosphate, magnesite, gypsum, limestone, soapstone, silica sand, etc. Selected minerals are discussed in terms of reserves and grade. Large deposits of silica sand occur in Pezu, Paniala in DI Khan contain iron, but it can be reduced to use the sand in colorless container glass. At Munda Kucha near Mansehra, 53 million tons of silica sand has been estimated. Very large deposits of limestone occur in the province. Large deposits of gypsum Karak-Kohat belt, and sizable deposits of barite, rock phosphate and magnesite occur in several places.

Key words: Industrial mineral, prospects, NWFP.

K/468. Khattak, M.U.K., Ahmed, I., Ahmed, J. & Ahmed, A., 1984. A note on the occurrence of blue quartz in Rustam, Mardan District, Pakistan. Geological Bulletin, University of Peshawar 17, 174-175.

The Swabi-Chamla sedimentary group of Martin et al. (1962) is generally borders the Ambela granite along its western and southern margin. The main lithologies include shales, quartzites, limestones and dolomites. The low grade regionally metamorphosed phyllitic rocks of Chamla are pelitic to semi pelitic in composition and contain the so-called quartzitic and graywacke layers and zones of elongate pebbles of generally psammitic composition (Martin et al., 1962). The rocks are locally schistose in character. We report here an occurrence of blue quartz in quartz-rich shaly lenses enclosed in the Chamla phyllitic shales. The lenses represent either a layer in the phyllitic country rocks as described by Martin et al. (1962), or quartz veins associated with the Ambela granite. Further data on detailed petrography, tectonic setting and correlation of the rocks in the area and the origin of the quartz will be given elsewhere.

Key words: Ambela granite, metasediments, blue quartz, Mardan.

K/469. Khattak, M.U.K., Ahmed, I., Parvez, M.K., Ahmed, J. & Ahmed, A., 1984. Carbonatite body near Khungai, Rustam area, District Mardan, north Pakistan. Geological Bulletin, University of Peshawar 17, 175-176.

A small carbonatite body is located on the eastern edge of the Ambela granitic complex at Khungai village in Rustam area of Mardan District. The Carbonatite is medium-coarse-grained and has a sharp contact with the Ambela granite. The granite is commonly medium-grained and is generally gneissose at the contact with the carbonatite. The granite is sheared along the contact with the carbonatite, however, in one occasion the contact between the granite and carbonatite contains enrichments of pyroxenes, pyrite, tourmaline, and garnet. At the eastern contact of the carbonatite the granite is very fine-grained and seems more felsic due to metasomatism. Fenetization seems to accompany the emplacement of carbonatite body.

Key words: Carbonatite, granite complex, Rustam, Mardan.

K/470. Khattak, M.U.K., Jan., M.Q. & Khan, M.A., 1998. Nature of Indus suture (MMT) and Astak Fault east of Nanga Parbat-Haramosh Massif. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 103-104.

Recent studies have shown that in much of the Himalaya the Indus suture (IS) demarcates the boundary between the Indian plate and the "Asiatic" mass with local occurrences of ultramafic rocks and ophiolitic melanges. In the northwestern Himalaya, however, a more complicated scenario has been documented due to the presence of an extensive zone, the Kohistan-Ladakh island arc (KLIA), between the Indian plate and Asia. The contact between the Indian plate and the KLIA is an extension of the IS and locally (i.e. within Pakistan) named as the Main Mantle Thrust (MMT).

The MMT is quite variable in nature. It is razor sharp in some places (e.g. Sapat; Jijal; Timargara), consists of ophiolitic melanges (e.g. Shangla; Alai; N of Peshawar), or of melanges containing elements of the Kohistan arc and Indian plate with or without components of the neo-Tethyan crust-mantle (e.g. Babusar; E of NPHM). In some places high-P rocks have been reported in the MMT zone (Patan; Kaghan; N of Astak; Le Fort et al., 1997).

The IS on the eastern margin of the NP is a good example of a melange zone containing all three components. The Indian plate is represented by metasediments and gneisses, the KLIA by amphibolites, and the neo-Tethyan oceanic crust by mafic-ultramafic assemblages. Individual blocks range from a few to hundreds of meters in dimension and show varying degree of deformation and alteration.

West of the Astak river confluence with the Indus river (~3 km W of Astak police station), a series of pelitic and possibly some psammitic rocks, variably deformed and boudinaged, contain lenses of amphibolite (meta-gabbros), semi-pelites, calc-silicate and ultramafic rocks. The mafic-ultramafic assemblages include meta-gabbros (now garnet amphibolite), altered chromite-bearing dunite, peridotite and pyroxenite, and are enclosed in biotite-rich matrix. This biotite-rich matrix probably formed from a mud-rock. The pelites are garnetiferous and have streaky bands and veins of quartz and feldspathic material. Some muscovite pegmatite are highly boudinaged (upto 15 cm thick). Some amphibolite occurs in cm-scale bands. Amphibolite lens may contain 1/2 mm garnet porphyroblasts. The mafic-ultramafic lithologies are highly altered and mostly consist of ?tremolitic green amphibole with or without talc, boudinaged within biotite-rich band. The biotite-rich 'beds' are also boudinaged and in rare cases, reach ~1.4 m in width. These 'beds' consist of abundant biotite and subordinate green amphibole, with possibly a small amount of quartz. These green amphibole-bearing pockets in biotite-rich matrices, normally not more than a few meters across probably represent olistostromes formed at the surface of the neo-tethyan oceanic crust. The mafic-ultramafic lenses are upto a third of a meter in length and some 10-13 cm thick. One ultramafic lens (1/2 m x 20 cm) contains poorly defined layers as well as disseminated grains of chromite in an altered green ultramafic matrix. The outermost 1-2 cm crust of the 'nodule' is very dark, rich in amphibole, possibly some olivine and some orthopyroxene.

Also contained in the zone are lenses of a dense rock consisting of garnet, ?opx, ?cpx, and Qtz. One disc shaped, 2 x 3/4 m in size, ultramafic lens contains, from core outward, talc, talc+tremolitic amphibole, and ~1 cm rim of tremolitic green amphibole, enclosed in biotite-rich band. The largest ultramafic lens (~20 m broad), consists of grey/brown material in a greenish to yellowish serpentinitic matrix. In the interior of this lens, there is a biotite-rich zone ~1/2 m across which contains altered nodules of the ultramafic. These nodules may have talcose interiors surrounded by colorless and/or green fibrous amphibole. Adjacent to the ~20 m ultramafic lens, the biotite band passes into grey to white fibrous amphibole ± talc-bearing band with a green inner and a grey outer zone. Locally this ultramafic lens is grey serpentinitic. Alteration zones in the ultramafic main lens contain upto ~3 cm long green mica, prisms of upto ~2 cm long green amphibole, and ?magnetite. The ultramafic lithologies are hosted by metasedimentary rock which gets more and more gritty to conglomeratic westwards. Well-bedded siltstone and sandstone lithologies are exposed ~250-300 meters west of the eastern-most ultramafic lens. Some of these gritty rocks contain over 1 cm rotated garnet porphyroblasts. Local biotite-rich bands with greenish material continue westwards for at least several 100s of meters. This melange zone extends over ~2 km to the west from the Astak River confluence with the Indus river. Further west, associated with these rocks are greyish orthogneisses, garnet-kyanite gneisses and banded amphibolites and granitic sheets, all intruded by deformed quartzo-feldspathic material (aplites and pegmatite dikes). Similar melange zone has been found some 25-30 km to the south along Astore river east of Harchu, although the scale of the mafic-ultramafic 'pockets' here is several orders of magnitude smaller. Geochemistry is in progress to sort out details and tectonic locale of the various mafic-ultramafic lithologies.

Key words: Indus Suture, melange, petrography, Astak fault, NPHM.

K/471. Khattak, M.U.K., Khan, M.L., Bangash, M.I. & Jan, M.Q., 1985. Petrography of hornblendites and associated rocks at Mahak, upper Swat. *Acta Mineralogica Pakistanica* 1, 78-82.

An 8-km² area around Mahak consists of amphibolites, metamorphosed gabbros and pyroxenite, hornblendites, and minor dykes and veins of hornblende-plagioclase pegmatite and quartzo-feldspathic rocks. These are described here petrographically, with a brief discussion on their origin. The amphibolites are meta-igneous and essentially composed of amphibole, plagioclase and /or epidote; the gabbros and pyroxenites are relictual and partially amphibolitized; the hornblendites are essentially monomineralic, variable in grain size and may grade into amphibolites through a plagioclase-bearing variety.

Key words: Petrography, hornblendites, pyroxenites, amphibolites, Mahak, Swat.

K/472. Khattak, M.U.K., Khan, S. & Ahmed, W., 1997. Tirich Mir Fault zone of Chitral. Northern Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, p. 167.

This paper describes geology of the Tirich Mir fault zone of Chitral in northern Pakistan. The fault zone follows a NE-SW direction from Arkari towards Tirich Gol, passes through Rich and Shah Jinali and enters Afghanistan. The fault zone is typically associated with mafic-ultramafic rocks and probably represents a suture zone between the Hindukush-Karakoram and the Asian plates. The mafic-ultramafic rocks form thin to thick lenticular bodies of fine to coarse grained, locally foliated to banded, gabbro-diorite, homogenous to banded amphibolites, hornblendite, and serpentinite. The serpentinite is strongly shattered, has a typical tectonized appearance and commonly contains veins of asbestos and locally pseudomorphs of pyroxene recognizable in hand specimen. The largest of the mafic-ultramafic bodies is ~20 km long and up to ~2 km thick and is exposed in the Arkari valley. To the northwest, the Wakhan Formation consists of Permian to Jurassic terrigenous sequence of dark gray slate to siltstone with less common fine grained quartzite and intercalations of calcareous schist, dolomite and marble. Drainage geochemical exploration along the Tirich Mir fault zone shows significant gold, nickel, zinc, cobalt, lead, copper, iron, and molybdenum values. Complex mesoscopic scale deformation (folding and faulting) is common along the fault. The fault zone is intruded by hornblende-biotite-granodiorite pluton of Tirich Mir and Kafiristan. No blueschists or eclogitic rocks have been found associated with the fault. To the southeast of the Tirich Mir fault zone is a thick sequence of dark gray slate-siltstone with minor gray argillaceous-arenaceous-calcareous schist, fine grained quartzite, and green metavolcanic and volcano-sedimentary rocks.

The occurrence of the typical alpine-type (as opposed to stratiform-type) mafic-ultramafic rocks along the fault zone on a regional scale probably indicates the existence of a major tectonic contact i.e. a suture between the Asian and Karakoram plates. This is supported by the fact that geochemical signature of the Tirich Mir fault zone resembles that of the Main Karakoram Thrust which is a well established suture between the Kohistan arc and the Karakoram plate in northern Pakistan. Another possibility is that the fault zone may have originated as an intraplate rift zone which probably developed as a result of extensional regime generated within the Hindukush-Karakoram plate and then gave way to a fault (suture) during the compressional phase developed by the northward subduction along the MKT and by the southward subduction along the Reshun Pshart suture in the Pamirs.

Key words: Tirich Mir fault zone, mafic-ultramafics, Chitral.

K/473. Khattak, M.U.K. & Parvez, M.K., 1980. A petrographic account of the east-central part of the Chilas complex, Northern Pakistan. M.Sc. Thesis, University of Peshawar, 83p.

The Chilas complex is mainly composed of gabbro-norites. In the eastern part (Astor-Chilas section), it contains many bodies of ultramafic-mafic-anorthosite association. Olivine gabbros and troctolites associated with the later display excellent reaction coronas between olivine and calcic plagioclase. This work presents details of field aspects and petrography of the rocks.

Key words: Petrography, gabbro-norites, ultramafics, Chilas complex, Kohistan.

K/474. Khattak, M.U.K., Shervais, J.W. & Jan, M.Q., 1999. Petrology of the layered mafic-ultramafic lenses from the Nanga Parbat-Haramosh massif. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 85-86.

Recent studies have shown that in much of the Himalaya the Indus suture (IS) demarcates the boundary between the Indian plate and the "Asiatic" mass characterized by local occurrences of ultramafic rocks, ophiolitic melanges, and high-P metamorphism. In the northwestern Himalaya, however, a more complicated scenario has been documented due to the presence of an extensive zone, the Kohistan-Ladakh magmatic arc (KLMA), between the Indian plate and Asia. The contact between the Indian plate and the KLMA is an extension of the IS and locally (i.e. within Pakistan) named as the Main Mantle Thrust (MMT). The MNIT is quite variable in nature. It (a) is razor sharp at some places (e.g. Sapat, Jijal, Timargara), (b) consists of ophiolitic melanges (e.g. Dargai-Harichand, Shangla, and Alai, north of Peshawar), or (c) consists of melanges containing elements of the Kohistan arc and Indian plate with or without components of the neo-Tethyan crust-mantle (e.g. Babusar, E of NPHM). In some places high-P rocks have been reported in the MMT zone (Shangla, Allai, Kaghan, N of Stak). The IS on the eastern margin of the NPHM is a good example of a melange zone containing all three components. The Indian plate is represented by metasediments and gneisses, the KLMA by ortho-amphibolites and tonalites, and the neo-Tethyan sediments by biotite-rich gneisses containing lenses of rocks, which contain mafic-ultramafic assemblages. Individual blocks range from a few to hundred of meters in dimension and show varying degree of deformation and alteration/metamorphism (Fig. 1). This article presents data on the mafic-ultramafic assemblages along the eastern margin of the NPHM, which probably represent Tethyan shelf sediments caught up during subduction of the oceanic crust, subjected to elevated pressures and metasomatic changes, and finally thrust upward along with the rest of the sequence of the NPHM.

At the eastern margin of the NPHM, west of the Stak river confluence with the Indus River, there occurs a melange zone of strongly deformed and boudinaged biotite-rich bands with highly altered mafic-ultramafic lenses (Fig. 1). The mafic-ultramafic lenses consist of amphibolite, garnet amphibolite, pyroxenite, serpentinite, and carbonate- and talc-bearing ultramafic rock. The biotite-rich matrix probably formed from a mudstone, whereas the mafic-ultramafic lenses probably represent carbonate enclaves or portions of carbonate interlayers incorporated within the muds, which were later metasomatized and metamorphosed to their present state. Microprobe analyses of clinopyroxene from one banded pyroxenite lens show almost pure diopsides, characteristically impoverished in TiO₂ (<0.03 wt.%) Al₂O₃ (0.3 wt.%), Na₂O (0.3 wt.%), Cr₂O₃ (nil) and NiO (<0.06 wt.%) and enriched in MnO (0.4-0.6 wt.%), MgO (15.55-16.44 wt.%), and CaO (23.72-24.46 wt.%). The low Cr and high Mn content of Mg-Ca rich diopsides may be a consequence of metasomatic metamorphism. An iron oxide (hematite or magnetite) analysis contains appreciable amount of TiO₂ (0.8 wt.%), Cr₂O₃ (0.4 wt.%), and Al₂O₃ (0.4 wt.%), whereas an ilmenite analysis contains 2.5 wt.% MgO and 0.5 wt.% Al₂O₃, (Table I). The absence of chromite, the presence of Fe-Ti oxides and the occurrence of carbonate in some lenses further supports the view that the rocks may have been chemically modified during metamorphism.

Key words: Petrology, layered ultramafics, NPHM.

K/475. Khattak, M.U.K., Shervais, J.W. & Stakes, D.S., 1996. Counter-Clockwise P-T-t paths in garnets from the Nanga Parbat-Haramosh Massif and the Ladakh island arc terrane, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 79.

High pressure, upper amphibolite facies metamorphic rocks of the Nanga Parbat-Haramosh Massif (NPHM) in northern Pakistan record the Tertiary metamorphism and dynamics of the Himalayan collision, and subsequent overthrusting of the Kohistan-Ladakh island arc terrane onto the Indo-Pakistan plate. At the time of collision, the Kohistan-Ladakh island arc may have formed the southern margin of the Asia, or may have formed a separate terrane. In our study area, the NPHM is separated from rocks of the Ladakh island arc by the Astak Fault Zone, a NNE-trending high-angle fault that forms the eastern margin of the NPHM.

Metamorphic rocks of the NPHM are represented by an intercalated sequence of para- and orthogneisses, with minor metabasics, calc-silicate rocks, and post-metamorphic pegmatite dikes. Garnets from two gt-bi-sill paragneisses in the NPHM are characterized by three distinct textural zones: (1) an inclusion-free core (2) an inclusion-filled intermediate zone, and (3) inclusion-free rims. These garnets are characterized by distinct chemical zoning profiles from core to rim (Figure 1). Equilibration temperatures for these garnets, calculated with the garnet-biotite geothermometer, are ~650°C in the inclusion-free core, ~725°C in the inclusion-filled intermediate zone, and ~500°C

in the inclusion-free rim. Garnets in a paragneiss adjacent to the Astak Fault Zone and the Ladakh arc terrane are inclusion-free throughout, and have nearly flat, unzoned chemical profiles. Equilibration temperatures for these annealed garnets are ~700-684°C. The dominance of relatively high equilibration temperatures in all of these garnets is confirmed by oxygen isotope partitioning studies, which show that most grant-quartz, feldspar-quartz, biotite-quartz mineral pairs equilibrated at ~700°C in the NPHM (Khattak, 1995).

The Ladakh arc terrane, east of the Astak Fault Zone, consists largely of meta-volcanic rocks, but also contains minor paragneiss horizons. Garnets found in gt-bi-sill paragneisses from the Ladakh arc terrane contains minor inclusions in the core but have inclusion-free rims. These show a sharp step-like change in chemistry at the boundary between core and rim (Figure 1), with relatively high temperatures in the inclusion-filled cores (~720-650°C) and lower temperature rims (~580°C).

The chemical zoning, P-T estimates, and the textural features of these garnets are interpreted as indicative of the tectonic history of the area. The flat chemical zoning indicates annealing (re-equilibration) of the garnets during or after the peak of upper amphibolite facies metamorphism. The occurrence of inclusion coincides with the preservation of the original growth zoning under dynamic, rapid growth conditions. The following tectonic history is proposed: (1) the inclusion-free core of the NPHM garnets may represent collision of the Indian plate with the Ladakh arc; (2) the higher temperature inclusion-filled intermediate zone in the NPHM garnets and the inclusion-filled core of the Ladakh garnets indicates growth during collision of the India-Ladakh package with the Asian plate; (3) the outermost inclusion-free zones in garnets from both the terrains probably formed during unroofing/cooling. Annealed garnets of the NPHM adjacent to the Astak Fault Zone probably reflect heating by hot base of the over-riding Ladakh arc.

Key words: Garnets, metamorphism, NPHM, Ladakh island arc, Himalaya.

K/476. Khattak, M.U.K. & Stakes, D.S., 1993. New data on the metamorphism of the Nanga Parbat-Haramosh massif, and the adjoining Ladakh island arc terrain, northern Pakistan. *Geological Bulletin, University of Peshawar* 26, 1-16.

The Nanga Parbat-Haramosh Massif in northern Pakistan records the Tertiary metamorphism and dynamics of the Himalayan collision and subsequent overthrusting of the Asian plate onto the Indian plate. The massif consists of an intercalated sequence of paragneisses derived from the Precambrian Salkhala series, of orthogneisses from Precambrian and early-Paleozoic granites, of minor metabasites and calc-silicate rocks, and of post-metamorphic pegmatite dikes. The adjacent part of the Ladakh arc consists of metasediments intruded by younger massive tonalites. The massif and the Ladakh arc are metamorphosed under high pressure, upper amphibolite facies condition. P – T estimates and P – T paths have been determined for the metapelitic samples from the massif and from the adjacent areas of the Ladakh arc along two cross-strike transects (Indus and Astore rivers) through the massif. Results show that the massif followed a compressional (counter-clockwise) and the Ladakh arc a decompressional (clockwise) P – T path, consistent with the tectonic history of the Himalaya of northern Pakistan.

Geothermobarometry on garnet-biotite and garnet-plagioclase pairs from pelites in the massif indicates that the rocks started their metamorphic history at ~ 5.5 kb and ~ 625°C. During collision, the pressure and temperature rose ~ 9kb and about 725°C. The Ladakh garnets started to grow at ~ 10 kb and ~725°C with subsequent decrease in metamorphic pressure and temperature to ~8.5 kb and ~650°C. After the collision, the massif and the adjacent areas equilibrated at ~ 8 kb and ~ 700°C.

Key words: Metamorphism, P-T data, NPHM, Himalaya.

K/477. Khattak, M.U.K., Stakes, D.S. & Khaliq, A., 1997. Late stage isotopic resetting in the Nanga Parbat-Haramosh massif. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p. 38.

Consult Khattak et al. (1997) for further information.

Key words: Isotopes, NPHM.

K/478. Khattak, M.U.K., Stakes, D.S. & Shervais, J.W., 1995. P-T-t paths of garnets from the Nanga Parbat – Haramosh massif, the Kohistan and the Ladakh island arc terranes, northern Pakistan. *Geological Bulletin, University of Peshawar* 28, 97-108.

Metamorphic rocks of the Nanga Parbat-Haramosh Massif (NPHM) are represented by an intercalated sequence of para- and orthogneisses, with minor metabasites, calc-silicate rocks, and post-metamorphic pegmatite dikes. Garnets from two gar-bio-sill paragneisses in the NPHM are characterized by three distinct textural zones: (1) an inclusion-free core, (2) an inclusion-filled intermediate zone, and (3) inclusion-free rims. These garnets are characterized by distinct chemical zoning profiles from core to rim. Equilibration temperatures for these garnets, calculated with the garnet – biotite geothermometer, are ~ 650°C in the inclusion-free core, ~725°C in the inclusion-filled intermediate zone, and ~500°C in the inclusion-free rim. Garnets in a paragneiss adjacent to the Astak Fault Zone and the Ladakh arc terrane are inclusion-free throughout, and have nearly flat, unzoned chemical profiles. Equilibration temperature for these annealed garnets are ~ 700-684°C, with thin rims ~ 610°C. The dominance of relatively high equilibration temperature in all of these garnets is confirmed by oxygen isotope partitioning studies, which show that most garnet-quartz, feldspar-quartz, biotite-quartz mineral pairs equilibrated at ~700°C in the NPHM (Khattak, 1995).

The Ladakh arc terrane, east of the Astak Fault Zone, consists largely of meta-volcanic rocks, but also contains minor paragneiss horizons. Garnets found in gar-bio-sill paragneisses from the Ladakh arc terrane contains minor inclusions in the core but have inclusion-free rims. These show a sharp step-like change in chemistry at the boundary between core and rim, with relatively high temperature in the inclusion-filled cores (~ 720-650°C) and lower temperature rims (~580°C).

The chemical zoning, P-T estimates, and the textural features of these garnets are interpreted as indicative of the tectonic history of the area. The flat chemical zoning indicates annealing (re-equilibration) of the garnets during or after the peak of upper amphibolite facies metamorphism. The occurrence of inclusion coincides with the preservation of the original growth zoning under dynamic, rapid growth conditions. The following tectonic history is proposed: (1) the inclusion-free core of NPHM garnets may represent collision of the Indian plate with the Ladakh arc; (2) the higher temperature inclusion-filled intermediate zone is the NPHM garnets and the inclusion-filled core of the Ladakh garnets indicates growth during collision of the India-Ladakh package with the Asian plate; and (3) the outermost inclusion-free zones in garnets from both the terranes probably formed during unroofing /cooling. Annealed garnets of the NPHM adjacent to the Astak Fault Zone probably reflect heating by the hot base of the over-riding Ladakh arc.

Key words: P-T-t path, garnets, metamorphism, collision, NPHM.

K/479. Khattak, M.U.K., Stakes, D.S. & Shervais, J.W., 1997a. Metamorphism of the Nanga Parbat - Haramosh massif - I: Stable isotope thermometry. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 169-170.

The Nanga Parbat-Haramosh Massif in northern Pakistan represents the northernmost exposure of the Indian plate that have been metamorphosed in the Late Tertiary subsequent to the Himalayan collision and overthrusting of the Asian plate onto the Indian plate. The massif is a complex mixture of para- and orthogneisses, of minor metabasites and calc-silicate rocks, and of post-metamorphic pegmatite dikes. The 180 geothermometry results indicate that these gneisses are metamorphosed under peak temperatures of upper amphibolite to granulite facies conditions (< 700°C).

The 180 isotopic compositions of the rocks and their constituent minerals in the massif and adjacent areas of the Kohistan and Ladakh arc along the Indus and Astore Rivers varies as following (Table 1): whole rock $\delta^{18}\text{O}_{\text{SMOW}}=7.4-15.3\%$; quartz =7.4-16.4%; feldspar =7-16. 10/ac; garnet 5.3-13.7%; biotite =3.9-12.6%; muscovite =6.7-12.7%; and hornblende amphibole =4.4-7.256g. 180 thermometry results were calculated from 180 fractionations among quartz, garnet, feldspar, biotite, muscovite and amphibole. Fifteen of the sixteen fractionations of Qtz-Gar pairs (aQG) vary from 2.89Gm to 3.8% giving a range of temperatures from 764°C to 599°C respectively. The 1.00/ac variation in fractionation is greater than the expected error and thus indicates a real variation in the maximum temperatures. Among the analyzed minerals, the feldspars, which are isotopically least stable, indicate isotopic resetting during a later metamorphic event.

Key words: Thermometry, metamorphism, stable isotopes, NPHM, Indian plate.

K/480. Khattak, M.U.K., Stakes, D.S. & Shervais, J.W., 1997b. ^{18}O fractionation in feldspars from the Nanga Parbat-Haramosh massif, Northern Pakistan. Geological Bulletin, University of Peshawar 30, 219-225.

The Nanga Parbat-Haramosh Massif in northern Pakistan represents the northernmost exposure of the Indian plate that has been juxtaposed against the Kohistan-Ladakh island arc along Raikot-Sassi and Astak faults. The massif is a complex mixture of paragneisses, orthogneisses, minor metabasics, calc-silicate rocks, and post-metamorphic pegmatite dikes. These gneisses are metamorphosed under high pressure upper amphibolite facies conditions (5.5-10 kb, 650-750°C; Khattak, 1990).

The ^{18}O SMOW isotopic compositions of the rocks and their constituent minerals in the massif and adjacent areas of the Kohistan-Ladakh arc along the Indus and Astore Rivers varies as following: whole rock $\delta^{18}\text{O}$ SMOW = 7-15.3‰; quartz = 7.4-16.4‰; feldspar = 7-16.1‰; garnet = 5.3-13.7‰; biotite = 3.9-12.6‰; muscovite = 6.7-12.7‰; and hornblende amphibole = 4.4-7.2‰ (Khattak, 1994). Feldspars isotopic compositions show maximum scatter indicating refractory nature of the minerals. ^{18}O thermometry results based on coexisting quartz-feldspar fractionation curves show disequilibrium in some of the samples. Calculation of the ^{18}O composition of fluids that were in equilibrium with different minerals in the temperature range of 500-700°C reveals that there is one pre-metamorphic and one post-metamorphic fluid activity affecting the isotopic composition of the rocks of the massif. The pre-metamorphic fluids probably originated from an igneous parent, depleting the rocks in -2‰, especially along the major faults. The post-metamorphic fluids probably originated from prograde metamorphic reactions and were heavy enough to enrich the feldspars up to ~1.8‰. Retrograde paths indicate that the massif was probably quick in its upward flight from depths of around 35 kms as shown by pressure estimates of Khattak and Stakes (1993).

Key words: ^{18}O fractionation, feldspar, metamorphism, NPHM.

K/481. Khattak, M.U.K., Stakes, D.S., Shervais, J.W., Arif, M. & Shah, M.T., 1995. Stable isotope thermometry of the Nanga Parbat-Haramosh Massif and the Kohistan-Ladakh arc, northern Pakistan. *Geological Bulletin, University Peshawar* 28, 109-126.

The Nanga Parbat-Haramosh Massif in northern Pakistan represents the northernmost exposure of the Indian plate that have been metamorphosed in the Late Tertiary subsequent to the Himalayan collision and overthrusting of the Asian plate onto the Indian plate. The massif a complex mixture of para- and orthogneisses, of minor metabasics and calc-silicate rocks and of post-metamorphic pegmatite dikes. The ^{18}O geothermometry results indicate that these gneisses are metamorphosed under peak temperature of 700°C.

The ^{18}O isotope compositions of the rocks and their constituent minerals in the massif and adjacent areas of the Kohistan and Ladakh arc along the Indus and Astor Rivers vary as following: whole rock $\delta^{18}\text{O}$ SMOW = 7-15.3‰; quartz = 7.4-16.4‰; feldspar = 7-16.1‰; garnet = 5.3-13.7‰; biotite = 3.9-12.6‰; muscovite = 6.7-12.7‰; and hornblende amphibole = 4.4-7.2‰. The majority of the mineral δ -values follow the "normal" sequence. ^{18}O thermometry results were calculated from ^{18}O fractionations among quartz, garnet, feldspar, biotite, muscovite and amphibole. Fifteen of the sixteen fractionations of Qtz-Gar-pairs (α_{QG}) vary from 2.8 ‰ to 3.8 ‰ giving a range of temperature from 764°C respectively. The 1.0- ‰ variation in fractionations is greater than the expected error and thus indicates a real variation in the maximum temperatures. Among the analyzed minerals, the feldspar, which are isotopically least stable, indicate isotopic resetting during a later event.

Key words: Thermometry, metamorphism, NPHM, Indian plate.

K/482. Khattak, N.U., Qureshi, A.A., Akram, M., Hussain, S.S. & Mehmood, K., 2001. Classification and petrogenesis of the Loe-Shilman carbonatite complex Khyber Agency, North West Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.4.

The Loe-Shilman Carbonatite Complex is the western extension of a 200 km long belt of alkaline rocks. The alkaline belt is situated on the northern side of the Peshawar Plain in an arcuate fashion. It consists of sills-like bodies of carbonatite and related alkaline rocks. These sill-like bodies have been emplaced along a fault zone in metasedimentary rocks of Palaeozoic to Precambrian age.

Using petrographic techniques the sedimentary and metasedimentary carbonate country rocks of the Loe-Shilman carbonatite were classified as dolomite and dolomitic limestone, while the carbonatites were classified into (a) calcite-carbonatites and (b) dolomite-carbonatites. The carbonatites were also classified into (a) calcio-carbonatites, (b) magnesio-carbonatites and (c) ferro-carbonatites on the basis of geochemical data. Field relationships, petrography and geochemical data indicate that the carbonatite magma originated by direct melting of the partly carbonated, metasomatized mantle peridotites. Calcite-carbonatite, the most widespread variety of the carbonatites

in the complex, appears to represent the first phase of carbonatitic magmatic activity, followed by dolomite (and ferroan dolomite)-carbonatite as a separate intrusion. Fission track dating on apatite crystals indicates that emplacement of the carbonatites took place prior to about 20 Ma, probably in the Oligocene (31 ± 2 Ma).

Key words: Carbonatite, petrogenesis, Loe Shalman, Khyber Agency.

K/483. Khattak, N.U., Qureshi, A.A., Hussain, S.S., Akram, M., Mehmood, K. & Khan, H.A., 1998. Emplacement time and tectono metamorphic history of the Sillai Patti granite gneiss using fission track dating technique. *The Nucleus* 35, 159-162.

The Peshawar Plain Alkaline Igneous Province (PAIP) consist of a group of alkaline rocks. It occurs in the north of Peshawar from Tarbela in the east through Koga-Ambela, Shewa-Shahbazgarhi, Malakand, Sillai Patti, and Warsak up to Loe Shilman in the west. The alkaline rocks mainly consist of granites, syenites, gabbros, ijolites, carbonatites etc. The granitic rocks cover a major part of the Alkaline Province. This paper presents an account of fission track age data on zircon as a paleotemperature indicator, recognition of the emplacement time and tectonic uplift history of the Sillai Patti Granite Gneiss in combination with the other radiometric ages. The field relationships show that the Malakand Granite and Sillai Patti Carbonatites are younger than the Sillai Patti Granite Gneiss. However, our fission track age of the Sillai Patti Granite Gneiss is less than absolute ages of Malakand granite (U - Pb age approx. equal to 270 Ma) and Sillai Patti Carbonatite (K - Ar age approx. equal to 31 ± 2.00 Ma). Therefore, the fission track age of 24.32 ± 2.80 Ma on zircon from Sillai Patti Granite Gneiss, based on present work, represents a time of post metamorphic uplift history of the area, when these rocks pass through the 210 deg. C isotherm, corresponding to depth of about 6.7 km inside the earth crust from their present position

Key words: Metamorphism, tectonics, carbonatite, granite gneiss, fission track dating, Sillai Patti.

K/484. Khattak, R., Inamullah, Ahmad, S. & Ahmad, J., Undated. Geology of western part of Attock-Cherat Range north of Nizampur District Nowshera. M.Sc. Thesis, University of Peshawar, 51p.

Key words: Attock-Cherat Range, Nizampur, Nowshera.

K/485. Khawaja, I.A., 1979. Geology of Khaki area, Mansehra and Hazara. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Khaki, Mansehra.

K/486. Khawaja, M.I., 1978-80. Bangang-Palana Area, District Kotli Azad Jammu Kashmir. M.Sc. Thesis, Punjab University, Lahore, 84p.

The project area has been mapped on 1:9000 scale and covers about 20 miles². Stratigraphic units from Dogra Slates to Siwalik Group have been identified studied and described. Micropaleontological identification reveals the presence of 18 species of foraminefera. Some invertebrate fossil encountered has also been recorded. It has been noted that unlike Hazara the unconformity has enlarged to bring Paleocene rocks in contact with Cambrian rocks. In this process some of the Lower Paleocene rocks are also absent with the result a new unit representing unconformity has been introduced. On the structural side, Main Boundary Thrust has been noticed passing through the southwestern part of the area. On the economic side minerals like fireclay, bauxite, soapstone, dolomite and coal have been recorded.

Key words: Mapping, stratigraphy, palaeontology, foraminifera, Azad Kashmir.

K/487. Khizr, K.M., 1979-81. Geology of Sawni Sheringal Area, Dir District, NWFP. M.Sc. Thesis, Punjab University, Lahore, 92p.

Sawni-Sheringal area is mainly composed of metamorphic rocks of sedimentary origin, with igneous intrusions. The main rock units in the area are calcareous quartzites, chlorite schists, biotite schists and amphibolites.

Calcareous quartzites are believed to be the oldest rock unit of the area. Chlorite schists, biotite schistose and amphibolites have formed as a result of progressive regional metamorphism of calcareous quartzites. The contacts of calcareous quartzites with the schistose and the contacts between chlorite and biotite schistose are gradational. Amphibolites are developed as formless patches in the schistose.

The area is tectonically highly disturbed being involved in Himalayan Orogeny. The report presents a detailed geological and petrological investigation of about 40-km² area. A detailed map of the investigated area on a scale of 1:10,000 are presented, along with its cross-section along X-Y line. Succession of Rocks of the area has been worked out. Detailed petrography of all the major units of the area is described. Petrogenesis of the rocks of the area is interpreted. Major and minor structures of the area are discussed in brief. Economic minerals found in the area are listed.

Key words: Amphibolites, metasediments, Sheringal, Dir.

K/488. Khosa, F.M., 1983-85. Engineering geological mapping and site investigations of Kohala Hydal Project with special reference to appertinances fitness. M.Sc. Thesis, Punjab University, Lahore, 104p.

The detailed geological map of the Kohala damsites No. 1 and No. 2 have been prepared. This field report consists of two Parts. Part "A" deals with the General Geology of the Area. Introduction, Physiography, Stratigraphy, Structure, Tectonics and Economic Geology of the area has been discussed in this part. In Part "B" various Engineering Geological Aspects have been discussed in detail. In this part, different factors of site investigation have been discussed. Recommendations and conclusions have been given at the end.

Key words: Engineering geology, mapping, hydel power, Kohala.

K/489. Khurshid, A., Yeilding, G., Ahmad, S., Davidson, I., Jackson, J.A., King, G.C.P. & Zuo, L.B., 1984. The seismicity of northernmost Pakistan. *Tectonophysics*, 109, 209–226.

A portable seismic network was operated in the Karakoram area of northern Pakistan for over two months during the summer of 1980. The principal objectives were to record possible subcrustal earthquakes beneath the Karakoram Range, and to monitor crustal activity throughout northernmost Pakistan. We confirm the existence of intermediate-depth seismicity (at a depth of about 140 km) beneath the Karakoram Mountains. Shallow crustal activity also occurs in the Karakoram Range, with events recorded from near the northwest end of the Karakoram Fault and near a number of smaller lineaments in Baltistan. Seismicity in Kohistan appears to be largely confined to the upper crust, though occasional earthquakes at 65 km depth (approximately the base of the crust) occur beneath areas of higher topography (Nanga Parbat, Rakaposhi). An area close to the Hamran (1972) and Darel (1981) earthquakes showed intense activity in the depth range 0–25 km, similar to that involved in the mainshocks themselves. Focal mechanisms for events in this area show thrusting on NW-trending planes, indicating NE-SW compression.

Key words: Seismicity, earthquake, Karakoram, Northern Pakistan.

K/490. Khwaja, A.A., 1987. Natural resources potential of Pakistan. *Earthview*, 14–45.

Key words: Natural resources.

K/491. Khwaja, A.A. & Anwar, J., 1969. Stratigraphic studies of the Nowshera reef complex, Nowshera Tehsil, West Pakistan. *Geological Bulletin, University of Peshawar* 4, 33–43.

A belt of Siluro-Devonian limestone and quartzite, pink or yellowish-pink in color is exposed on either side of the Nowshera-Risalpur road. This belt was identified as a 'Reef Complex' in 1965, and is the first of its kind to be discovered in the Indo-Pak sub-continent. Prior to this discovery, the limestone belt had been erroneously assigned a Precambrian age and regarded as part of the Attock Slates.

The entire belt unconformably overlies the Kandar Phyllite and is divisible into four definite units: 1. Carbonate Rocks, 2. Reef Core, 3. Reef Breccia, and 4. The Misri Banda Quartzite. The first three collectively are known as the

Nowshera Formation. With the exception of the last, these units represent the characteristics structural layers of a reef.

The age of the reef complex on the basis of its fossil assemblage ranges between Upper Silurian and Devonian. However, there is no fossil present which may pinpoint an exact age. The uncertainty about the precise age of the reef is largely due to the destruction of many organisms by the process of dolomitization. In the opinion of the writers, the Nowshera Formation and the Misri Banda Quartzite were deposited in the southernmost extremities of the basin in which the Muth Quartzite, of Siluro-Devonian age, was formed. In their opinion, the Nowshera formation and the Misri Banda Quartzite, can be correlated with the middle and upper parts of the Muth Quartzite.

Key words: Stratigraphy, reef complex, Nowshera.

K/492. Khwaja, A.A., Jadoon, I.A.K., Ghazi, G.R., MonaLisa & Hashmi, S., 1997. Nature of faults and focal mechanism solutions of a part of northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.39.

Key words: Structure, focal mechanism, Northern Pakistan.

K/493. Khwaja, I., 1959-61. Mansehra, Susal Gali (Hazara District). M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, Mansehra.

K/494. Khwaja, S.A., Murtaza, G., Masood, M.T. & Musa, S., 1976. Petrographic study of Kawagarh Formation, Kohat, North West Frontier Province. M.Sc. Thesis, Peshawar University, 97p.

Key words: Petrography, geology, Kawagarh Formation, Kohat.

K/495. Kichi, E.M.K., 1988-90. Petrography and geology of Fatehpur-Shin Area (District Swat). M.Sc. Thesis, Punjab University, Lahore, 93p.

Rocks of Fatehpur Shin area (Lower Swat) are part of metamorphic hornblende complex. The area lies within the Southern portion of Lower Swat. These rocks are probably the extensions of rocks of Dir in the form of belt running approximately in East-West direction. The area given fieldwork comprises 30 miles in the North-West of Saidu Sharif. The area mainly comprises the main rock units are amphibolite, Norite, Diorite, Quartz-O-feldspar and pegmatite veins. Amphibolites have been metamorphosed basic rocks probably Norite gabbro. As the field evidences, and the laboratory study shows that the amphibolites were formed from basic magma, which has undergone regional metamorphism under the intense orogenic conditions. Quartz-O-feldspathic and pegmatite veins are extensively distributed all over the area indicating the evidence of Diorite magma. Major minerals are plagioclase, Hornblende, epidote and quartz with accessories as sphene and magnetite. These are products of regionally metamorphosed igneous rocks.

Key words: Petrography, Fatehpur, Kohistan.

K/496. Kick, W., 1956. Chogo Lungma Glacier, Karakoram. Geographical Journal 122, 93-96.

I was expecting in the autumn of 1954 to accompany as topographer the expedition of Dr. K. Herrligkoffer, which had for its objective Broad Peak in the upper Baltoro region. But during the summer months of that year the scientists of Professor Desio's successful K2 expedition had been at work on the Baltoro glacier, and I decided to go to another region of the Karakoram. I chose the Chogo Lungma glacier, which had only once before been investigated, and that half a century ago.

Although it is one of the very big valley-glaciers, Chogo Lungma is not situated in the zone of the main crest, but southwards at the bifurcation of the Rakaposhi and Haramosh ranges in the Lesser Karakoram. From Skardu on the Indus, it self only four days by air from Europe, the valley can now be reached by a further four days journey. The

ease and relatively low cost of access may promote more activity by mountaineers and scientists in this region: last summer a Frankfort Himalayan Expedition went to Chogo Lungma, accompanied by the meteorologist Dr. Untersteiner.

Easy access was also the reason that this glacier was the first of all the big Karakoram glaciers to be discovered by a European, G. T. Vigne in 1835. He found the lower end "a short distance from the village Arindu," the height of the ice wall there being nearly 100 feet. The next explorer was Godwin Austen in 1861 who wrote from the small village of "Arundu at its (the 'Chogo Loombah's) termination, its fields touching the ice." As these statements are still roughly accurate, it would seem that the length of the Chogo Lungma has not changed much during the last 120 years.

However, although the glacier may not have changed much in its length, the thickness of the ice has varied greatly at different times. Godwin Austen carried out the first plane-table survey of this area in the space of only two days. But the result, a part of his "Sketch map of the glaciers of the Mustakh Range" on a scale of 1 / 506,880 (1 inch = 8 miles), shows the form of "Chogo Ganse" much better than the map on 1 / 150,000 of the Workman expedition of 1903. This second map was based on a "theodolite survey by B. H. Hewett, corrected and supplemented by the authors (Fanny B. and William H. Workman) from actual observation and photographs." They supposed, erroneously, that the given highest intersected point "Indus-Nagar-Watershed-Peak No.2" (= Peak 46/42L = Malubiting) was fixed wrong during the Kashmir triangulation, as they thought Pyramid Peak, which they had almost climbed to the top, was at least 300 feet higher than Malubiting. Meanwhile, during the triangulation of the Indo-Russian Connection Series in 1912/13 Malubiting (24,470 feet) was checked and found correct and a new point was intersected: this was Peak 68/42L (23,056 feet) for which the Karakoram Conference Report suggests the name Yengutz Har, because of the glacier with this name on the northern side. The peak which the Workman tried to climb is really Yengutz Har. Oestreich had already made this suggestion, and last year's triangulation confirmed it. The Workmans' mistake was quite understandable; it is very easy to be wildly out when comparing the height of peaks without instruments. In fact "Pyramid" is 1400 feet lower than Malubiting, not 300 feet higher. Indeed many sketch-maps of this region are wrong, some even make 2 Siebentauser (peaks over 7000 metres or about 23,000 feet) out of one, partly as a result of the many names existing for this mountain: Yenguta Har or Pyramid is the same as "Ghenish Chish" (Burushaski for "Gold Mountain") of the official quarter-inch map, and is the top of the ridge shown on Conway's map (1894) as the Golden Parri. The people of Arandu showed me the same peak as "Spantik," probably because of a highest single spot with grass at the foot of the south-eastern ridge of it (in Balti, spang = meadow, grass, tik = spot).

Key words: Glaciers, Chogo-Lungma, Karakoram.

K/497. Kick, W., 1956 Der Chogo-Lungma Gletscher im Karakoram. Zeitschrift für Gletscherkunde und Glazialgie 3, 335-347.

Consult the preceding account for further information.

Key words: Glaciers, Chogo-Lungma, Karakoram.

K/498. Kick, W., 1956/57. The people of Arandu and their Chogo Lungma Glacier. The Mountain World 4, 163-172.

Key words: Glaciers, People of Arandu, Chogo-Lungma, Karakoram.

K/499. Kick, W., 1958a. Exceptional glacier advances in the Karakoram. Journal of Glaciology, 3(23): 229.

Key words: Glaciers, Karakoram.

K/500. Kick, W., 1958b. An Nanga-Parbat Gletschern. Mitteilungen des Deutschen Alpenvereins, 12, 194.

Key words: Glaciers, Nanga Parbat.

K/501. Kick, W., 1960. 100 Jahre Nanga Parbat-gletscher. *Urania-Universum* 6, 42-50.

Key words: Glaciers, Nanga Parbat.

K/502. Kick, W., 1962. Variations of some Central Asiatic glaciers. In: *Proceedings of the Symposium of Obergurgl, September 1962*. IAHS Publication 58, 223-229.

Key words: Glaciers, Central Asia.

K/503. Kick, W., 1964. The Chogo-Lungma Glacier, Karakoram. *Zeitschrift Gletscherkunde und Glazialgeologie* 5, 1-59.

Key words: Glaciers, Chogo-Lungma, Karakoram.

K/504. Kick, W., 1967. Experiences in comparing geometric elements of glacier variations. *Abstracts of the Commission of Snow and Ice Journal Assembly of Bern, September – October, 1967*, 173-180.

Key words: Glaciers.

K/505. Kick, W., 1977. Eisgeschwindigkeitsmessungen an Gletschern Hochaisens: Geschichte-Technik-Ergebnisse. *Zeitschrift für Gletscherkunde* 13, 7-22.

Key words: Glaciers, ice measurements.

K/506. Kick, W., 1980. Material for a glacier inventory of the Indus drainage basin - the Nanga Parbat massif. In: Clarke, R.T., (ed.), *International Workshop on the World Glacier Inventory, Aletsch Ecological Centre, Riederalp, Ct. Valais, Switzerland, 17-22 September 1978*. *Proceedings. International Association of Hydrological Sciences. IAHS/AISH Publication*, 126, 105-109.

Key words: Glaciers, Indus, drainage, Nanga Parbat.

K/507. Kick, W., 1985. Geomorphologie und rezente gletscheränderungen in Hochasien. In: Hartl, M. & Engelschalk, W. (eds.), *Geographie-Naturewissenschaft und Geisteswissenschaft. Regensburger Geographische Schriften* 19/20, 53-78.

Key words: Glaciers, geomorphology, High Asia.

K/508. Kick, W., 1986a. Glacier mapping for an inventory of the Indus drainage basin: current state and future possibilities. In: Richardson, E.L. (ed.), *Symposium on Glacier Mapping and Surveying*, University of Iceland, Reykjavik, 26-29 August 1985. *Proceedings. Annals of Glaciology*, 8, 102-105.

Key words: Mapping, glaciers, Indus, Drainage basin.

K/509. Kick, W., 1986b. Hundert jahre sachengletscher am Nanga Parbat-Kein ausnahmeverhalten? In: Kuhle, M. (ed.), Internationales Symposium uber Tibet und Hochasien vom 8. bis 11. Oktober 1985. Gottingen Geographische Abhandlungen 81, 11-17.

Key words: Glaciers, Nanga Parbat.

K/510. Kick, W., 1989a. Bericht 1989 uber das Chogo-Lungma-Gletscherende im Karakorum. Zeitschrift fur Gletscherkunde und Glazialgeologie 25, 139-145.

Key words: Glaciers, Karakoram.

K/511. Kick, W., 1989b. The decline of the Last Little Ice Age in High Asia compared with that in the Alps. In: Oerlemans, J. (ed.), Glacier Fluctuations and Climatic Changes. Kluwer Academic Publisher, Dordrecht, 129-142.

Key words: Ice age, Alps, Asia.

K/512. Kick, W., 1994. Gletscherforschung am Nanga Parbat 1856-1990. Munchen: Deutscher Alpenverein (=Wissenschaftliche Alpenvereinshefte 30).

Key words: Glaciers, Nanga Parbat.

K/513. Kick, W., 1997. Forschung am Nanga Parbat-Geschichte und ergebnisse. Beitrage und Materliene zur Regionalen Geographie 8.

Key words: Nanga Parbat, Tectonics.

K/514. Kidd, W.S., Edwards, M.A., Khan, M.A., Schneider, D.A., Zeitler, P.K. et al., 1998. Structure and chronology of Nanga Parbat Haramosh Massif. 1998 Fall meeting EOS, 79(45), suppl., F909.

Consult the following account for further information.

Key words: Structure, geochronology, uplift, Nanga Parbat.

K/515. Kidd, W.S., Edwards, M.A., Schneider, D.A. & Khan, M.A., 2001. New geological map of the Nanga Parbat-Haramosh massif. Journal of Asian Earth Sciences 19, p.36.

We present a newly compiled detailed geological map (1:100 000 scale) of the Nanga Parbat±Haramosh massif based on our field work during the 1995-8 continental dynamics collaborative project, building from previous work by others (references on the map, and below), and supplemented by interpretation from an excellent cloud-free Landsat thematic mapper image taken in October 1995. Major geological features relevant to the young rapid uplift and denudation of the NPHM include the Raikhot fault and its precursor shear zone, first identified by Madin (1986), which is the main structure developed by the W- to WNW- directed thrusting and exhumation of the NPHM over the past 5±10 Ma. Our work has extended the identification and location of this fault and shear zone from Raikhot Bridge to the southwest through the Diamir valley, and shown the coincidence of this zone with the young Jalhari granite from the Diamir valley southwards (Edwards et al., 2000). Our work also documents the extent and shear sense of ductile shear associated with the Diamir± Raikhot shear zone (DRSZ) and distinguishes older ductile shear and mylonite zones, originally developed by S- to SW-directed thrusting, and some subsequent N-directed low angle normal sense motion, during the earlier 'Himalayan' events. The map also documents that the eastern NPHM-Kohistan contact is in most places only folded by the NPHM event, with local young faults in this zone being much

less abundant and not a continuous 36 Abstracts: 16th Himalaya-Karakorum-Tibet Workshop, Austria Fig. 1. N MORB-normalized spider diagram for the Waziristan dykes (after Pearce, 1983). Fig. 2. Primordial mantle-normalized spider diagram for the Waziristan dykes (after Wood et al., 1979) zone, unlike the Raikhot fault on the western margin. Our mapping shows that there is significant E- to NE- directed, mainly ductile displacement on the eastern margin of the main antiform of the Nanga Parbat part of the NPHM, expressed by a wide S/C ductile shear zone in the Chhichi and central Rupal valleys, which continues northwards as a narrower tightly pinched synclinal/shear zone structure at least to Shengus village in the Indus gorge (Schneider et al., 1999b). This Rupal±Chhichi shear zone (RCSZ) and its northward continuation is well within the NPHM, and does not directly affect the eastern NPHM-Kohistan contact. Some younger brittle faulting is associated with this zone in the Rupal valley, but it is not nearly as prominent as that associated with and defining the Raikhot fault on the western margin of the massif. The RCSZ forms the secondary part of a crustal-scale popup structure conjugate to the DRSZ and Raikhot fault. Besides the quaternary fault along surface trace of the Raikhot fault, some other active fault traces are developed in the Kohistan block to the west, up to as much as 15 km from the Raikhot fault. The map includes the newly discovered Himalayan leucogranite of Miocene age in southernmost Chhichi Nullah (Schneider et al., 1999a).

Key words: Mapping, NPHM.

K/516. Kidwai, A.H. & Immam, A., 1958. Magnetite deposits of Dammer Nissar, Chitral state, West Pakistan geological Survey of Pakistan, Information Release 7.

Large bodes of magnetite are present three to four miles southeast of Dammer Nissar, Chitral state. The magnetite is massive, it is found in lenses ranging from 20 to 425 in length and from 5 and 75 feet in width.

A total reserve of 3.7 million tons of magnetite ore has been calculated on the basis of dimensions measured on the surface and on estimated extensions of ore to depths averaging 150 feet below outcrops of individual lenses.

The grade of the ore in general is high; near the contacts of the ore bodies iron content ranges from 45 to 55 per cent whereas main bodies contain 55 to 65 per cent. An alternate route of ore transport through Afghan territory is suggested.

Key words: Magnetite, Dammer Nissar, Chitral.

K/517. King, B.H., 1961. A new fossil locality in Swat. Geological Bulletin, Punjab University 1, p. 65.

The author has been engaged on the detailed mapping of the granitic gneisses, schists, amphibolites, and marbles of the Lower Swat Valley and adjoining area of Buner. It was *in* this latter area that, in November 1960, fossil remains were discovered in two outcrops on Nikanai (one of the two synclinal island mountain masses which rise abruptly from the Buner Plain) near the village of Tursak (34°31'; 72°22'). This is the first known .discovery of fossils in the crystallines of the region. The .fossils occur in the marbles which are wholly crystalline, usually well bedded, and with bluish-grey and white bands. Some parts, however, are more massive and bedding is obscure, or absent; here the marble tends to be lenticular in form, although often several hundred feet thick and up to one mile in length.

The fossils were found at the following two localities:-

1. on the crest of the spur directly above Tursak (43 B/6 grid 373533). They occur in several discontinuous bands which conform to the bedding of the well bedded marbles. Most of the fossils are highly distorted and only identifiable as such when referred to the few less distorted specimens.

Three types can be recognized;

(a) A small low-spined gastropod up to 1 cm. in diameter.

(b) A small pelecypod up to 2 cm. in diameter, with an oval valve.

(c) A larger pelecypod up to 10 cm. in diameter, with a more symmetrical valve than (b).

2. Just north of the summit of Nikanai (43 B/6 grid 346548). The fossils are less distorted than at the first outcrop, and are seen on a relatively small weathered surface. They display a coralline type of structure.

Thin sections of the collected material show only a mosaic of calcite crystals of two grain sizes and 110 internal structures, although the main outlines are fairly clear. No identification, even on a generic level, can be made of the available specimens. Therefore, it is only possible to put a very questionable Upper Palaeozoic (or possibly younger) age to the rocks. The evidence does, however, show that their age is not Pre-Cambrian, as had been generally assumed, previously.

Key words: Paleontology, fossils, Swat.

K/518. King, B.H., 1964. The structure and petrology of part of Lower Swat, West Pakistan, with special reference to the origin of the granite gneisses. Ph.D. Thesis, University of London.

This Thesis concerns the structure and stratigraphy of Lower Swat, Buner and adjacent area of Swabi, northern Pakistan. There is a considerable discussion on the primary (igneous) versus secondary origin of the granitic gneisses of Lower Swat. Much of the details of stratigraphy and structure are similar to those given in Martin et al. (1962).

Key words: Structure, petrology, Buner, Swat.

K/519. King, G. & Jackson, J., 1984. Tectonic studies in the Alpine-Himalayan belt. In: Miller, K.J. (ed.), The International Karakoram Project, 1, 215-220. Cambridge University Press.

Plate tectonics has successfully explained the behaviour of the major ocean Basins. However, it has proved to be less successful in describing the processes of continental collision and its associated deformation. Seismic studies proved crucial in providing information on which plate tectonics was established. Recent developments in the study of seismic signals recorded on distant instruments and on portable seismographs temporarily installed in the Alpine-Himalayan belt are beginning to reveal the relation between extension, sedimentation, compression and major strike slip faulting such as the Karakoram fault.

Key words: Tectonics, Alpine-Himalaya.

K/520. Kinniburgh, W., 1969. Technical feasibility of producing light-weight aggregates from clays of West Pakistan. Building Research Station, London, K264, 1-9.

Key words: Feasibility, light weight aggregate, Clay.

K/521. Klebelsberg, R. von, 1938. Visser's Karakorum-glaziologie. Zeitschrift für Gletscherkunde 26, 307-320.

Key words: Glaciers, Karakoram.

K/522. Klinger, F.L., Reinemund, J.A. & White, M.G., 1963a. Status of information concerning indigenous raw materials and process for making iron and steel in Pakistan. Proceedings, Symposium on Industrial Rocks and Minerals, Lahore, 1962, 101-111.

Key words: Economic minerals, iron ore, steel.

K/523. Klinger, F.L., Reinemund, J.A. & White, M.G., 1963b. Status of information concerning indigenous raw materials and process for making iron and steel in Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-52, 113p.

Key words: Economic minerals, iron ore, Steel.

K/524. Klinger, F.L., Reinemund, J.A. & White, M.G., 1963c. Geology of the iron ore deposits of Pakistan. Symposium on Iron Ore. CENTO, Iran, 101-110.

Key words: Economic minerals, iron ore.

K/525. Klootwijk, C.T. & Conaghan, P.J., 1979. The extent of greater India, 1. preliminary palaeomagnetic data from the Upper Devonian of the Eastern Hindukush, Chitral (Pakistan). *Earth and Planetary Science Letters* 42, 167-182.

Samples of Upper Devonian sedimentary ironstones from the eastern Hindukush, Chitral (Pakistan), give a characteristic palaeomagnetic direction: declination $D = 318^\circ$, inclination $I = -6.5^\circ$; believed to represent the primary magnetization direction. The samples come from an area which lies north of a major ophiolite zone that recent workers suggest is the southwestern continuation of the Indus Suture. As the present palaeomagnetic results are in fair agreement with palaeomagnetic data from the Siberian platform but not with data from Gondwanaland they can be taken as additional evidence that this suture does indeed constitute the main collision zone between the Gondwanic Indian subcontinent and Asia. The palaeomagnetic data presented here from the Devonian of Chitral suggests additionally: (1) in excess of 100° of counterclockwise rotation of the area, associated most likely with the formation of the regional Hindukush-Pamir-Karakoram syntaxial bend; (2) more than 2000 km of crustal shortening between Chitral and the Siberian platform due to the northward indentation of the Indian Gondwanaland fragment subsequent to collision.

Key words: Paleomagnetism, Devonian, Hindukush, Chitral.

K/526. Klootwijk, C.T., Conaghan, P.J., Nazirullah, R. & DeJong, K.A., 1994. Further paleomagnetic data from Chitral (Eastern Hindu Kush): Evidence for an early India Asia contact. *Tectonophysics*, 237, 1–25.

The Eastern Hindukush forms part of an elongate belt ("Central Domain", collage of Cimmerian microcontinents) that encircles the northern part of the Indian subcontinent. A Gondwanan origin is commonly assumed for this belt, but a "Laurasian" origin for the Chitral region has been argued on palaeontological (Talent and Mawson, 1979) and palaeomagnetic (Klootwijk and Conaghan, 1979) grounds. The "Laurasian" view was based on a pilot study we undertook of Upper Devonian pisolitic ironstones from a thrust sheet at Kurāgh Spur in Chitral. Preliminary results showed a characteristic magnetization component [$D = 318^\circ$, $I = -6.5^\circ$, $N = 7$ (block samples), $k = 14$, $\alpha_{95} = 16.5^\circ$] indicating an equatorial palaeoposition. This component was thought to be of primary origin and was interpreted in terms of a Late Devonian "Laurasian" affinity of the Kurāgh Spur rocks. This controversial conclusion has been tested in the present more comprehensive study of the thrust pile of sedimentary rocks in the Reshūn-Kurāgh-Būni region of Chitral and the primary origin of the characteristic magnetization component refuted. Thermal demagnetization of 333 block samples from Middle to Upper Devonian variegated sediments, Permian quartz flysch, Permo-Triassic carbonates, and mid-Cretaceous redbeds showed two interpretable components. A softer component of recent origin (A); and a harder characteristic component (B) of both normal and reverse polarity whose mean direction [$D = 314.1^\circ$, $I = 6.0^\circ$, $N = 4$ (thrust sheets), $k = 198.2$, $\alpha_{95} = 6.5^\circ$] is comparable to the characteristic component observed in our preliminary study. However, the universal presence of this component throughout the thrust pile proves its overprint origin, which we attribute to initial India-Asia contact. Palaeomagnetic information pertinent to the controversy of a "Laurasian" versus a Gondwanan origin of the Chitral region has not been obtained in this further study because primary magnetizations could not be identified beyond doubt. Hence, we retract herewith our original conclusion of a Late Devonian "Laurasian" affinity of the Chitral region on the basis of the palaeomagnetic evidence. The secondary component (B) comprises a suite of secondary magnetizations, acquired at equatorial-to-low-northern palaeolatitudes, and is attributed to initial contact between Greater India and southern Asia. Component B has been observed previously in the Himalayan-Tibetan region, both north and south of the Indus-Tsangpo Suture zone. Identification is herein extended to the Hindukush region north of the Northern Kohistan (or Shyok) Suture zone, which is a western continuation of the Indus-Tsangpo Suture. Comparison of this suite of collision-attributed equatorial palaeolatitude data from the India-Asia convergence zone with new palaeolatitude constraints from the Ninetyeast Ridge on the northward movement of the Indian plate, constrained additionally by a recent minimal estimate of the palaeogeographic northern extent of Greater India, indicates that initial contact between northwestern Greater India and southern Asia was established at, or before, the Cretaceous-Tertiary boundary. The overprint origin of component B at about this time is further supported by observations by Zeitler (1985) on rocks from the sampled area in Chitral of partially reset zircon fission-track ages around 68-55 Ma. The NW-SE declination axis of component B indicates a $60-70^\circ$ counterclockwise rotation of the sampled thrust pile with respect to Eurasia and a counterclockwise rotation between 10 and 30° with respect to India. Some of the

recent field components (A) show a comparable rotation and indicate that the tectonic activity that led to the formation of the Hindukush-Pamir-Karakorum syntaxial zone has continued into recent times.

Key words: Paleomagnetic data, collision, India-Asia, Chitral.

K/527. Kneneu, Ph.H., 1929. Petrographic description of the rock from the Hunza valley in the Karakorum. *Leidsce Geologie Mededeelingen* 3.

During his second Karakoram expedition in 1925 Mr. Ph. C. Visser collected some 70 rock specimens from the valley of the Hunza and its tributaries. The following is a petrographic description of these specimens and I gladly take this opportunity of thanking Mr. Visser for entrusting me with his valuable material. Geologists are much indebted to this energetic explorer for bringing together such a considerable number of samples under circumstances in which all carriage had to be reduced to a minimum and when so many other calls were being made on his time and energy. A collection made by a layman and therefore taken without many observations on mode of occurrence, must naturally be of limited value. When, however, it concerns a region that is almost terra incognita from a geological as well as from a geographical point of view, it may serve to give us an insight into the more salient features, especially petrographic and to some extent structural as well, and therefore constitute an important contribution to geological knowledge. Geologists will all hope that Mr. Visser will soon be in a position to add to the collections he has already made.

Key words: Petrography, Hunza, Karakorum.

K/528. Knowlton, E., 1933. Nanga Parbat 1932. *The American Alpine Journal* 2, 18-31.

Key words: Geology, geomorphology, Nanga Parbat.

K/529. Koivula, J.I. & Fryer, C.W., 1986. Blue-green zircon in Pakistani beryl. *Zeitschrift der Gemmologischen Gesellschaft* 35(3-4), 101-103.

Key words: Gemmology, zircon, beryl.

K/530. Koivula, J.I., Kammerling, R.C. & Fritsch, E., 1992. Gem news. *Gems & Gemology* 28, 268-279.

Key words: Gemology.

K/531. Koivula, J.I., Kammerling, R.C. & Fritsch, E., 1994a. Gem news. *Gems & Gemology* 30, 191-201.

Key words: Gemology.

K/532. Koivula, J.I., Kammerling, R.C. & Fritsch, E., 1994b. Gem news. *Gems & Gemology* 30, 271-280.

Key words: Gemology.

K/533. Kojima, J., 1965. Metamorphic and plutonic rocks of the Karakorum and Hindu Kush. In: *Geology of the Karakorum and Hindu Kush. Results of the Kyoto University Science. Exped. 1955*, VII, 93-119.

The specimens of metamorphic and plutonic rocks collected through the Japanese Expeditions of 1955, 1956 and 1957 have been studied petrographically. The results for 250 samples from Swat, Ghizar, Yasin, Ishkuman, lower

Hunza, Indus gorge east of NPHM and Braldu are listed in a useful and informative petrographic table in the Appendix. The principal rock types include acid to intermediate plutonic rocks, gneiss, basic igneous rocks, impure calcareous rocks, calcareous rocks, siliceous rocks, and psammitic and politic rocks. Based on petrography, the charts showing the metamorphic facies, type of anatexis, preservation of basement crystalline rocks in the area concerned have been constructed. From these charts the zonal arrangement of the terrains with different characters in the NW-Karakoram and East Hindu Kush, together with the northern extension of the Nanga Parbat gneiss dome, has been discussed. The distribution and the petrographic characteristics of the plutonic rocks show intimate relationship with the geotectonic division of the basement. The Nanga Parbat basement is considered to have passed through polymetamorphism.

Key words: Metamorphism, metasediments, granitoids, Nanga Parbat, Hindu Kush, Karakoram.

K/534. Kolati, T., Ali, S. & Muhammad, H.M., 1986. Groundwater conditions of Sangau area Mardan. M.Sc. Thesis, University of Peshawar, 60p.

Key words: Groundwater, Mardan.

K/535. Kordos, L., 1997. A comparative environmental and hominoid history in the Neogene of Carpathian basin and Siwalik. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p.56.

Both Carpathian Basin and Siwalik region rich in Late Miocene Hominoid remains and have a great importance on the early phase of human evolution. The range of Hominoids in the Carpathian Basin 15-9 Ma, and in the Siwalik 12-7 Ma.

At the same time significant global and local environmental changes happened in the two areas, a transition from wet tropical-subtropical to dry temperate climate. However, the Late Miocene geological history of Carpathian Basin and Siwalik region are basically different. During the Early and Middle Miocene the Carpathian Basin was a member of the Paratethys (Central Paratethys) and separated as a large lake system (Pannonian Lake) during the early Late Miocene (11-10 Ma). The Pannonian lake and swamp gradually disappeared until the Mio-Pliocene boundary. The large body of water caused a long, generally warm and wet permanent environment. During this process the palynological data are showing two cooling periods during the Late Neogene. First is between 11 and 10 Ma, and the second between 8 and 7 Ma. Carbon isotopic analyses of 10 Ma old sediment of Rudabanya Hominoid site indicate purely C3 ecosystem. These climatic and ecological data are showing similar global environmental events at 7-8 Ma, both in Kenya, in Pakistan, and in the Carpathian Basin.

Comparative palaeoecology of Neogene terrestrial mammal faunas of the Carpathian Basin generally support previous analyses and help to answer one of the most interesting question, why Hominoids disappeared during Late Miocene from Eurasia?

Key words: Environment, neogene, hominoid history, Carpathian, siwaliks.

K/536. Kothe, A., Khan, A.M. & Ashraf, M., 1988. Biostratigraphy of the Surghar Range, Salt Range, Sulaiman Range and the Kohat area, Pakistan, according to Jurassic through Paleogene calcareous monnofossils and Paleogene dinoflagellates. *Geologie Jahrbusch* 71: 3-87, 32 figs., tabs., 17 pls.; Hannover.

Key words: Biostratigraphy, Jurassic-Paleogene, Surghar Range, Salt Range, Sulaiman Range, Kohat.

K/537. Kovak, C., 1986. Minerals and gemstones of Pakistan. *The Australian Gemmologist* 16, 57-59.

Key words: Economic geology, gems, Pakistan.

K/538. Kravchenko, K.N., 1964. Soan formation - upper unit of Siwalik group in Potwar. *Science & Industry* 2(3), 230-233.

Key words: Soan Formation, siwalik, Potwar.

K/539. Kravchenko, K.N., 1979. Tectonic evolution of the Tien Shan, Pamir and Karakoram. In: Farah, A. & DeJong, K. A., (Eds.), *Geodynamics of Pakistan*, Geological Survey Pakistan, Quetta, 25-40.

In the Tien Shan, Pamir and Karakorum the southward migration of the mobile belts reflects the growth of the Eurasian continent during the Phanerozoic. Geosynclinal development in the mobile belts began with rifting and drifting of Pre-Baikalian continental crust during five periods: 1) in the Middle Tien Shan during the Proterozoic (Pre-Late Rifean); 2) in the North Tien Shan during the Late Proterozoic-Early Cambrian; 3) in the South Tien Shan during the Cambrian-Early Carboniferous; 4) in South Ghissar and North Pamir during the Early Carboniferous; and 5) during the Early Carboniferous-Triassic in Central and Southeast Pamir. The Caledonian orogeny occurred in the North Tien Shan, the Hercynian orogeny in the Middle Tien Shan, South Tien Shan, South Ghissar and North Pamir, and the Alpine orogeny during the Mesozoic and the Cenozoic in Central and Southeast Pamir and the Karakorum. The latest orogenic phase, which began in the Late Oligocene, is very widespread and is the result of the collision between the Eurasian and Indian plates.

Key words: tectonics, Tien Shan, Pamir, Karakoram.

K/540. Krishnan, M.S., 1936. A look at marble samples from Swabi Tehsil, North West Frontier Province. *Geological Survey of India, Record* 70, p.414.

Key words: Marble, Swabi, India.

K/541. Krishnan, M.S., 1960. *Geology of India and Burma*, 604 p. Higginbothams, Madras.

This is a revised edition of the geology of the sub-continental India and Burma by the same author. Like the *Geology of India* by Wadia, this book also covers all aspects of geology, stratigraphy and mineral deposits, etc., of the region stretching from western margin of Pakistan to eastern Burma..

Key words: Geology, Burma, India, Pakistan.

K/542. Krol, M.A., Zeitler, P.K. & Copeland, P., 1994. Temporal and spatial variations in the cooling history of the Kohistan island arc terrane, Pakistan: Implications from Ar/Ar K-feldspar thermo chronology. *Geological Society of America, Annual Meeting*, A-136, p.7.

Consult krol et al., 1996, for further information.

Key words: Ar-Ar thermochronology, cooling history, Kohistan island arc.

K/543. Krol, M.A., Zeitler, P.K. & Copeland, P., 1996. Episodic unroofing of the Kohistan batholith, Pakistan: implications from K-feldspar thermochronology. *Journal of Geophysical Research* 101, 18149-18164.

New $^{40}\text{Ar}/^{39}\text{Ar}$ and U-Pb mineral ages from plutonic rocks help constrain the thermal and tectonic evolution of the Kohistan island arc terrane following its collision with India in early Tertiary time. Kohistan has experienced a prolonged tectonomagmatic history extending from the Early Cretaceous through the Tertiary. Thermal histories derived from multi diffusion domain analyses of K-feldspar within the Kohistan batholith reveal rapid cooling events (70–140°C/m.y.) distributed through space and time. The cooling histories show a systematic variation along the length of the batholith suggesting that Kohistan experienced differential unroofing. An episode of rapid cooling in the middle Eocene is recognized in western Kohistan, whereas rapid cooling occurs substantially later, during the middle and late Miocene, in eastern Kohistan. Rapid cooling in western Kohistan might have been caused by postemplacement cooling of hot magma against cold country rocks at relatively shallow crustal levels. Within the NW region of eastern Kohistan, rapid cooling at 13–12 Ma is recorded in K-feldspars ~60 km from the contact with

the Nanga Parbat-Haramosh Massif (NPHM), whereas cooling does not occur until 11 Ma only 2.5 km from the contact. This temporal and spatial variation in cooling histories may record differential unroofing in response to the development and propagation of the NPHM structure beneath Kohistan. The NPHM has experienced rapid cooling and unroofing over the last 10 m.y., and our results are consistent with this mid-late Miocene event.

Key words: Tectonics, Kohistan batholith.

K/544. Krol, M.A., Zeitler, P.K., Poupeau, G. & Pecher, A., 1996. Temporal variations in the cooling and denudation history of the Hunza plutonic complex, Karakoram Batholith, revealed by $^{40}\text{Ar}/^{39}\text{Ar}$ thermochronology. *Tectonics*, 15 (2), 403–415.

The $^{40}\text{Ar}/^{39}\text{Ar}$ thermochronology of the Late Cretaceous Hunza plutonic complex reveals an episodic cooling and denudation history for this regional-scale pluton. The $^{40}\text{Ar}/^{39}\text{Ar}$ analyses of biotites from a vertical relief section of >3200 m reveal a pulse of rapid cooling at ~20 Ma. In the interval of 110–27 Ma, age-elevation distributions suggest denudation rates of the order of 0.02 ± 0.003 mm/yr. At ~20 Ma, denudation rates increased significantly to 2.7 ± 0.7 mm/yr, then returned to much slower rates until 12 Ma. A second pulse of rapid cooling beginning at 12 Ma is revealed by inverse numerical modeling of multidiffusion domain alkali feldspars from a vertical section of 1700 m. Decreasing in elevation, these samples record the onset of rapid cooling at 12, 9, and 7 Ma, respectively. All of the alkali feldspars record a period of nearly isothermal conditions prior to the onset of rapid cooling when rates increased to $30^\circ\text{C}/\text{m.y.}$ Assuming a geothermal gradient of $30^\circ\text{C}/\text{km}$, these cooling rates translate into denudation rates of 1.0 mm/yr. Apatite fission track analysis indicates denudation rates of 0.7 ± 0.1 mm/yr over the interval of 6.6 Ma to 2.4 Ma in agreement with the alkali feldspar data. These data suggest denudation of 2.9 ± 0.4 km since the Plio-Pleistocene. Together, the alkali feldspar and apatite data indicate that a minimum of 10 km of overburden has been removed since the mid-late Miocene.

Key words: Ar-Ar thermochronology, cooling history, Kohistan island arc.

K/545. Kruseman, G.P. & Naqavi, S.A.H., 1988. Hydrogeology and groundwater resources of the North West Frontier Province, Pakistan. WAPDA Hydrogeology Directorate, Peshawar, Pakistan/Institute of Applied Geosciences, DELFT, The Netherlands. 191p.

This account gives details of the water resources of NWFP. It comprises 1. Introduction, 2. Hydrogeology, 3. Groundwater behaviour, 4. Groundwater investigations, 5. Groundwater development, 6. Groundwater development potential, 7. Groundwater management: a look ahead, 8. The regional groundwater resources, which include 9. the intermontane basins of Dir, Swat and Chitral districts, 10. The left bank areas, 11. the intermontane basins of Peshawar and Mardan districts, 12. the intermontane basins of Kohat and Karak districts, 13. the Bannu basin, 14. The Dera Ismail Khan district, and 15. Groundwater in the Federally Administered Tribal Areas. At the end, references and glossary are given. The document is supported by 32 tables and 88 figures.

Key words: Groundwater, hydrogeology NWFP.

K/546. Kubo, K., Khan, T., Kausar, A.B., Sawada, Y., Takahashi, Y. & Takahashi, Y., 1998. Origin of ultramafic-felsic association in the Chilas Igneous Complex, Kohistan Arc, North Pakistan. Exotic block derived from oceanic crust. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 107-108.

The Chilas Igneous Complex is one of the major geologic units in the Kohistan Arc region, located in the western Himalaya of northern Pakistan. It is a huge gabbroic body, 300 km long, intruding the Kamila amphibolites which occur widely in the southern half of the Kohistan Arc region. The Chilas Igneous Complex is composed mainly of gabbro-norite with minor two-pyroxene quartz diorite and two pyroxene granodiorite. The complex contains several small xenolithic bodies of ultramafic-felsic association (UFA), layered two pyroxene gabbro and amphibolites. The layered two pyroxene gabbro is the cumulus facies of the gabbro-norite (Kubo et al., 1997).

Within the Chilas Igneous Complex, several bodies of UFA exist. Of these, the body cropping out along the Karakoram Highway (KKH) to the east of Chilas village (named as Thak body) is described in detail. The Thak body extends 2.8 km along the KKH, enclosed and intruded by gabbro-norite of Chilas Igneous Complex. The Thak body consists of cyclic units of layered cumulate rocks. The layered rock units are younging from west to east

throughout the body. The cumulates are classified into olivine cumulate and pyroxene-dominant cumulate. Olivine- dominant cumulate consists mainly of olivine cumulate (dunite), associated with minor amount of olivine-clinopyroxene cumulate (wehrlite). It occurs as 10 to 400 m thick layers, alternating with thin layers of plagioclase dominant cumulate. Plagioclase-dominant cumulate occurs as layers several meters to several tens of meters thick. It consists of plagioclase olivine-clinopyroxene cumulate, though the modal ratio of each mineral changes greatly within a layer. The amount of clinopyroxene occurring as primocryst is very low. At the basal part of plagioclase dominant cumulate, a trough structure develops. It crosscuts the underlying olivine dominant cumulate. The boundary between the top of the plagioclase-dominant cumulate layer and the overlying olivine dominant cumulate layer is generally straight, and is parallel to the rhythmic layering or lamina in the upper part of plagioclase-dominant cumulate. This suggests that the plagioclase-dominant cumulate was covered conformably by the olivine-dominant cumulate and the boundary plane represents a horizontal plane during the crystal accumulation.

Under the microscope, the plagioclase-dominant cumulate shows adcumulus texture. Plagioclase, olivine and clinopyroxene occur as granular primocrysts. Olivine is sometimes partly rimmed by clinopyroxene, orthopyroxene and/ or hornblende embedded by vermicular spinel. A similar texture is also recognized rarely in the olivine-dominant cumulate. The characteristics are as follows, i) frequently, olivine is in direct contact with plagioclase without the interception of other crystals, and ii) the rock has an igneous texture and keeps the normal compositional zoning of primocrysts though very weak. Effects of regional metamorphism are not recognized. These characteristics and mineral chemistry data indicate that the vermicular spinel within clinopyroxene, orthopyroxene or hornblende was formed by the reaction between olivine and plagioclase, under the condition of the inconstant existence of a liquid phase among the primocrysts, i.e., the reaction between plagioclase and olivine proceeded during the magmatic stage, instead of during the metamorphic stage.

Pyroxene-dominant cumulate occurs as a layer 18 m in thickness. The upper boundary of the layer is straight and covered concordantly by olivine-dominant cumulate, and the lower boundary is cut by gabbro. It consists of orthopyroxene-clinopyroxene cumulate (websterite) and clinopyroxene cumulate (clinopyroxenite). Pyroxene-dominant cumulate occurs also near the eastern margin of the Thak body as platy blocks, 20 m in thickness, intruded by gabbro. EPMA data show that the compositional variation of each mineral is very small within and among the layers, and systematic changes through the Thak body are not recognized, i.e., cryptic layering does not exist. The Thak body and gabbro of the Chilas Igneous Complex are very different in petrologic and mineralogical characteristics, indicating that these rocks have different origin. The crystallization process of UFA is summarized into, i) olivine and small amounts of clinopyroxene crystallized continuously near the central part of a magma reservoir and settled on the bottom. The settled crystals made up the homogeneous cumulate (olivine-dominant cumulate). During this process, the chemical composition of crystallizing minerals and the magma (liquid) above the cumulate was kept constant,, ii) at the same time, crystallization of pyroxenes and plagioclase occurred at other portions of the same magma reservoir. Some accumulated plagioclase and pyroxenes flew down along the bottom of magma chamber (like a mudflow in water) toward the place where olivine was accumulating. Thus the plagioclase-dominant and pyroxene-channeled or eroded olivine dominant cumulate, iii) plagioclase, olivine and interstitial liquid could not coexist stably, and a reaction rim was formed between plagioclase and olivine, and iv) as the downward flow of plagioclase and pyroxene occurred intermittently, plagioclase dominant and pyroxene-dominant cumulates were covered by olivine-dominant cumulates conformably until the next flow arrived. This magma reservoir is characterized by open system crystallization. That is, primitive magma is continuously supplied into the magma reservoir and differentiation proceeds from the center to margin of the reservoir. Such a magma reservoir is not known except for that supposed for the generation of oceanic crust. Therefore, the ultramafic-felsic association is considered to be derived from the oceanic crust.

Key words: Ultramafic-felsic association, oceanic crust, Chilas complex, Kohistan.

K/547. Kubo, K., Sawada, Y., Takahashi, Y., Kausar, A.B. & Khan, T., 1992. Geological survey of the Chilas igneous complex in 1991 (short note). Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 3, 92-94.

This report describes the mafic-ultramafic rocks of the Chilas complex, which range from dunite, wehrlite, pyroxenite to norite and gabbro. Also given is columnar lithological section of the complex.

Key words: Petrology, Chilas complex, Kohistan.

K/548. Kubo, K., Sawada, Y., Takahashi, Y., Kausar, A.B., Seki, Y., Khan, I.H., Khan, T., Khan, N.A. & Takahasi, Y., 1992. The Chilas igneous complex in the western Himalaya of northern Pakistan. Abstracts of Symposium on Himalayan Geology, Shimane '92.

This is a summarised account of the field aspects, petrography and petrology of the Chilas complex.

Key words: Petrology, Chilas complex, Kohistan.

K/549. Kubo, K., Sawada, Y., Takahashi, Y., Kausar, A.B., Seki, Y., Khan, I.H., Khan, T., Khan, N.A. & Takahasi, Y., 1996. The Chilas igneous complex in the western Himalaya of northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 14, 63-68.

This note describes briefly the occurrence of the Chilas complex and gives a columnar section across the mafic-ultramafic body near Chilas. It is assumed that the complex represents a part of subducted oceanic plate that was obducted during the collision and captured by the norite magma as a xenolith.

Key words: Chilas complex, oceanic crust, Kohistan arc.

K/550. Kuhle, M., 1986a. Die obergrenze der gletscher hohensstufe-oberflächentemperaturen und vergletscherung der Himalayaflanken von 5000, bis 8000m. Zeitschrift für Gletscherkunde und Glazialgeologie 22, 149-162.

Key words: Glaciers, surface-temperatures, Himalaya.

K/551. Kuhle, M., 1986b. Schneegrenze Berechnung und topologische klassifikation von gletschern anhand spezifischer reliefparameter. Petermanns Geographische Mitteilungen, 41-51.

Key words: Topography, relief,

K/552. Kuhle, M., 1988. Letzte eiszeitliche gletscherausbildung vom NW-Karakorum bis zum Nanga Parbat (Hunza-, Gilgit- und Indusgletschersystem). In: Tagungsbericht und Wissenschaftliche Abhandlungen des 46. Deutschen Geographentages 1987 in München. Franz Steiner, Stuttgart, 606-607.

Key words: Ice age, glacier expansion, Karakoram, Nanga Parbat, Hunza, Gilgit, Indus glacier system.

K/553. Kummel, B., 1966. The Lower Triassic Formations of the Salt and Trans-Indus Ranges, West Pakistan. Museum of Comparative Zoology, Harvard University, Bulletin 134(19), 161-429.

The Triassic formations in the Salt Range of West Pakistan have played a particularly important role in the development of our Triassic zonal scheme, especially for the Scythian stage. In addition, interest in these formations is heightened because they conformably overlie late Permian formations, and the Triassic formations in the Salt Range have occupied the attention of nearly every student of the causes of abrupt faunal breaks. This great interest has not been matched by many modern detailed stratigraphic or paleontologic studies of these Permo-Triassic formations. Waagens (1895) great monograph on the Fossils of the Ceratit Formation was the first large scale report on a Triassic fauna from the eastern region of Tethys. In the same year Mojsisovics, Waagen, and Diener (1895) published their proposal for a classification of the Triassic System. In that paper the name Scythian was introduced for the lower series of the Triassic and the Salt Range sequence of zones presented as the type section. Later, Noetling (1901) reaffirmed the Pre-eminent importance of the Salt Range sequence in Scythian chronology, at the same time modifying somewhat the scheme of zones proposed by Waagen. It was not until 30 years later that it was

generally recognized that the Triassic fossilbearing formations in the Salt Range studied by Wynne (1878), Waagen (1895), and Noetling (1901, 1905) encompassed only the lower half or so of the Scythian. Waagen's Salt Range ammonites, however, have continued to play a dominant role in our interpretation of the evolution and systematics of Scythian ammonoids.

Key words: Stratigraphy, Lower Triassic, Salt Range, Trans-Indus Ranges.

K/554. Kummel, B. & Teichert, C., 1966. Relation between the Permian and Triassic Formations in the Salt Range and Trans-Indus Ranges, West Pakistan. *Neues Jahrbuch Geologica Palaeontologia, Abhandlungen* 125, 297-333.

Key words: Permian, Triassic, Salt Range, Trans-Indus Ranges.

K/555. Kummel, B. & Teichert, C., 1970. Stratigraphy and Paleontology of the Permian- Triassic boundary beds, Salt Range and Trans-Indus Ranges, West Pakistan. In: Kummel, B. & Teichert, C. (eds.), *Stratigraphic Boundary Problems, Permian and Triassic of West Pakistan*. Geology Department, University of Kansas, Special Publication 4, 1-110.

It has been known for about a hundred years that the sedimentary series of the Salt Range and some of the Trans-Indus ranges of West Pakistan encompass a concordant succession of marine, fossiliferous rocks of Late Permian and Early Triassic age. After a brief introduction to geology and geography of the area, the history of research on this sequence and on the problem of the Permian-Triassic boundary is reviewed.

The detailed stratigraphy of the beds immediately above and below the Permian-Triassic boundary is described from nine localities in the Salt Range, two in the Surghar Range, and two in the Khisor Range. The uppermost lithological unit of the Permian Chhidru Formation ("Upper *Productus* limestone") is a white sandstone unit which is as much as 17 feet thick and in the Khisor Range has yielded brachiopods indicating a Late Permian age. It also contains conodonts, a rich palynological assemblage, and acritarchs.

The white sandstone unit is conformably overlain by a dolomite unit, about 5 to 14 feet thick, containing *Ophiceras*, *Glyptophiceras*, *Miocidaris*, and few other megafossils associated with rich assemblages of conodonts, acritarchs, and spores and pollen. This unit forms the base of the Triassic System. It is gradational with an overlying limestone unit that also contains *Ophiceras* and other fossils, including conodonts and palynomorphs. The dolomite and limestone units together form the Kathwai Member which represents the *Ophiceras* Zone, the lowest ammonoid zone of the Triassic System. This is overlain by thin-bedded limestone containing *Gyronites* and other ammonoids (the "Gyronitan" assemblage of Spath) the "Lower Ceratite limestone" of Waagen, which most previous observers believed to form the base of the Triassic System in the Salt Range.

The nature of the boundary between the Permian and Triassic systems in the Salt Range and the Trans-Indus ranges is discussed from the point of view of lithology, diagenesis, sedimentary structures, and fossil content. The abrupt litho-facies change indicates a sharp change of sedimentary environment. Sedimentary structures, such as mudcracks and capped ripple marks, in combination with dolomitization and dedolomitization patterns, suggest that a period of emergence intervened between the deposition of the white sandstone unit and the dolomite unit, and that the contact between the Permian and Triassic systems in the Salt Range and Trans-Indus ranges, therefore, is a paraconformity which may represent a gap equivalent to as much as, or more than, a stratigraphic stage.

Key words: Stratigraphy, palaeontology, Permian, Triassic, Salt Range, Trans-Indus Ranges.

K/556. Kummel, B. & Teichert, C., 1973. The Permian-Triassic boundary beds in Central Tethys. In: Logen, A. & Hills, L.V. (Eds.), *The Permian and Triassic system and their mutual boundary*. Canadian Society of Petroleum Geology, Memoir 2, 17-34.

The classical and most important areas for the study of Permian-Triassic boundary beds, with the exception of that at Kap Stosch, East Greenland, are in central Tethys. This report discusses the stratigraphy and paleontology of these boundary beds in the Salt Range and Trans-Indus ranges of West Pakistan, the Julfa region of northwest Iran, and at Guryul Ravine near Srinagar, Kashmir.

The Permian-Triassic contact in the Salt Range and Trans-Indus ranges is interpreted as a paraconformity reflecting a recession of the sea and an emergent condition in latest Permian time followed by a transgression in the earliest

Triassic as defined by the first appearance of *Ophiceras*. These earliest Triassic strata also contain a variety of Permian-type brachiopods which are interpreted as short-lived survivors from the underlying Permian.

The controversial strata of the Dzhulfa region of Soviet Armenia, and now known from the adjacent region of northwest Iran that contains the so-called mixed faunas, are considered to be of Late Permian age. New finds of ammonites, especially genera known previously only from the Changhsing Limestone of Kwangsi, China, are part of the basis for this interpretation. In Guryul Ravine are strata with *Claraia* that contain Permian-type brachiopods. We interpret these beds as of Early Triassic age.

Key words: Permian, Triassic, Tethys.

K/557. Kureshy, A.A., 1970. The larger Foraminifera of lower Eocene of Azad Kashmir. Pakistan Journal of Science 22, 164-165.

Key words: Paleontology, foraminifera, Eocene, Azad Kashmir..

K/558. Kureshy, A.A., 1975/77. Texanomic studies of Tertiary larger foraminifera of Pakistan. Geological Survey of Pakistan, Record 38, 47p.

Key words: Paleontology, foraminifera, Tertiary.

K/559. Kureshy, A.A., 1977a. The Cretaceous planktonic foraminiferal biostratigraphy of Pakistan. Paleontological Society of Japan, Special Paper 21, 223-231.

Key words: Paleontology, foraminifera, Cretaceous.

K/560. Kureshy, A.A., 1977b. The Cretaceous larger foraminiferal biostratigraphy of Pakistan. Journal of the Geological Society of India 18, 662-667.

Key words: Biostratigraphy, palaeontology, foraminifera, Cretaceous.

K/561. Kureshy, A.A., 1978. Tertiary larger foraminiferal zones of Pakistan. Revista Espanola de Micropaleontologia 10, 467-483.

Key words: Palaeontology, foraminifera, Tertiary.

K/562. Kureshy, A.A., 1979. The Cretaceous/Tertiary boundary in Pakistan. Proceedings of Cretaceous/Tertiary Symposium, Copenhagen, 1, 214-221.

Key words: Palaeontology, Cretaceous-Tertiary boundary, Foraminifera.

K/563. Kureshy, A.A., 1980a. Foraminifera of Belemnite Formation (Early Cretaceous) of Pakistan. Geology and Palaeontology of Southeast Asia, University of Tokyo Press, 21, 101-108.

Key words: Foraminifera, Early Cretaceous, belemnite.

K/564. Kureshy, A.A., 1980b. The Miocene-Pliocene boundary in Pakistan. Revista Espanola de Micropaleontologia 12, 41-46.

Key words: Palaeontology, Miocene-Pliocene boundary.

K/565. Kureshy, A.A., 1981. The Plio-Pleistocene boundary in Pakistan. *Revista Espanola de Micropaleontologia* 13, 267-272.

Key words: Palaeontology, Pliocene-Pleistocene boundary.

K/566. Kureshy, A.A., 1982a. The Paleogene-Neogene boundary of Pakistan. *Revista Espanola de Micropaleontologia* 14, 221-229.

Key words: Palaeontology, Paleogene-Neogene boundary.

K/567. Kureshy, A.A., 1982b. Paleobiogeography of Tertiary larger foraminifera of Tethys region. *Proceedings of the North American Paleontological Convention*, 3:16.

Key words: Palaeontology, forminifera, Tethys.

K/568. Kureshy, A.A., 1983. Pakistan. In: Moullade, M. & Nairn, A.E.M. (eds.), *The Phanerozoic Geology of the World II: The Mesozoic B*. Elsevier, New York, 353-374.

Key words: Geology, Phanerozoic.

K/569. Kureshy, A.A., 1984. Quaternary palaeobiogeography and biostratigraphy of Pakistan. *Mezhdunarodnyj Geologicheskij Kongress* 27, Mascow, 1, 380-381.

Important contributions have been made on paleontology and biostratigraphy of Pakistan (including the area of this monograph) in series of papers by A.A. Kureshi. Unfortunately, we have not been able to access these papers, therefore, no annotation is given for these except the key words.

Key words: Paleontology, biostratigraphy, Quaternary, Pakistan.

K/570. Kureshy, K.U., 1986. *Geography of Pakistan*. National Book Service, Lahore, 263p.

This is a detailed account of the geography of Pakistan. It covers nicely the varied physiography of the country as well as other geographic subjects with the help of maps and statistical detail.

Key words: Geography.

L/1. Labonne, B., 1995. Geological endowment and mining potential of Pakistan: An overview. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 31-42.

Key words: Mineral deposits, exploration, mining.

L/2. La Fortune, J.R., 1989/8. Geology and geochemistry of Indian plate rocks south of the Indus suture, Besham area, northern Pakistan. MS Thesis, Oregon State University, Corvallis, 70p.

Consult the following account for further information.

Key words: Geochemistry, structure, Indian Plate, Indus Suture, Besham.

L/3. La Fortune, J.R., Snee, L.W. & Baig, M.S., 1992. Geology and geochemistry of Indian plate rocks south of the Indus suture zone, Besham area, Northwest Himalaya, Pakistan. *Kashmir Journal of Geology* 10, 27- 52.

The Himalayan mountains are the geologic manifestation of continental collision, and in North Pakistan the Main Mantel Thrust (MMT) is major suture along which the collision occurred. The basement rock near Besham Village in southern Kohistan, adjacent to MMT, are bounded on the east and west by north-trending high-angle faults. These basement rocks that are significantly different from any of the other plutonic and metamorphic rocks of the southern Kohistan and that are not seen elsewhere in the Pakistan Himalaya west of the Nanga Parbat-Haramosh massif (NPHM).

Rocks of the Besham area are subdivided from oldest to youngest into five groups. The oldest rocks of the Besham area are; (1) the metasediments and heterogeneous gneisses of the Besham group. In conjunction with field evidence, major, trace and rare earth element analysis of Besham gneisses suggest that the quartzofeldspathic gneisses formed in situ from a sedimentary protolith. The presence of both quartzofeldspathic gneiss and sodic quartzofeldspathic gneiss in the Besham group may be attributable to variable protolith composition or more likely, the sodic gneiss was derived from intrusive protolith that was strongly transposed during deformation. These sodic gneisses are equivalent to the previously named Lahor granite. The Besham group was intruded by (2) mafic dikes that were subsequently metamorphosed to amphibolites. Geochemical data suggest that these tholeiitic dikes have island arc geochemical affinities. (3) The third group rocks comprise cogenetic, small granitic intrusions and associated pegmatites; the Shang granite, the Dubair granodiorite and the Shorgara pegmatite. Unconformably lying upon these three units is (4) the Karora group, which comprises conglomeratic, calcareous and carbonaceous sedimentary rocks. The Karora group provides evidence for more than one metamorphic event in the Besham area, i.e., the Karora group is metamorphosed to lowergreenschist facies, in contrast, the underlying Besham group is metamorphosed to epidote amphibolite facies. The youngest unit observed in the Besham area is (5) a relatively undeformed leucogranite that intrudes both the Karora group and the Besham group. The metamorphic and granitic rocks of the Besham area may be correlative with the basement rocks of the Nanga Parbat-Haramosh Massif. Specifically, the quartzofeldspathic gneisses of the Besham group may correlate with the Nanga Parbat gneisses and the amphibolites found in the Besham area may correlate with mafic dikes of the massif. Further study of both the Besham area and the Nanga Parbat-Haramosh Massif can provide a better understanding of Precambrian basement rocks of northern Pakistan.

Key words: Stratigraphy, geochemistry, structure, Indian Plate, Indus Suture, Besham.

L/4. Laghari, A., 1945. The occurrence of bitumen in the Punjab Salt Range and the Kohat area and its bearing on the age of Saline Series. Proceedings, Indian National Academy of Sciences, Section B, Volume 14(6), 329-333.

Key words: Coal, Kohat, Salt Range, Punjab.

L/5. Landis, E.R., Reinemund, J.A., Cone, G.C., Schlick, D.P. & Kebblish, W., 1971. Analyses of Pakistan coals. USGS Project/GSP Information Release, PK-58, 71p.

Between 1952 and 1969, a total of 71 samples of Pakistan coals were collected, described, and analyzed by standardized methods and procedures. Descriptions of all the samples as reported by the collectors and complete coal analyses as reported by the U. S. Bureau of Mines are presented in this report.

Key words: Coal, Pakistan.

L/6. Latham, M.H., 1939. Some Eocene ostracoda from North West India. Proceedings, Royal Society of Edinburgh 59(1), 38-84.

Key words: Ostracoda, Eocene.

L/7. Latif, A., 1977. Groundwater conditions in Paharpur area, District Dera Ismail Khan. M.Sc. Thesis, Peshawar University.

Key words: Groundwater, Paharpur, D.I. Khan.

L/8. Latif, M. & Fayaz, A., 1987. Road alignment studies along Gilgit-Gupis road, Northern Areas. Geological Survey of Pakistan Information Release 292.

Road alignment and related studies along Gilgit – Gupis roads were carried out during the field season of 1986. The road which 110 km long is jeepable in fair weather conditions. Geological mapping and study of seven bridge sites from the engineering geological point view was done. The entire road was divided into 20 sectors and a comparative statement showing the material exposed, problems, remedial measures and blasting pattern was prepared. At certain places realignment of road was also proposed. proper execution and implementation of recommendation made, may help to great deal in construction, of better road and bridges.

Key words: Engineering geology, Gilgit-Gupis road.

L/9. Latif, M. & Hussain, H., 2002. Limestone quarry sites around Islamabad and Kohat. Geological Survey of Pakistan Information Release 721.

The beautified and green Margalla Hills of Islamabad are being eaten up by limestone mining and crushing which in addition to the destruction of the natural landscape, is causing large scale environmental degradation and air pollution. To find out the alternate limestone reserves, the investigation in the surrounding areas of Islamabad was carried out in April, 2000. As a result of this investigation six different sites have been identified. These new sites are Khairi Murat, Kala Chitta Pathargarh Khanpur, Ganghar and Kohat ranges. The Margalla range which is already being mined has been studied as a reference site, The new sites have been selected in view of their relatively more favorable occurrences in sufficient quantity and their easy accessibility. Brief description of locations, accessibility, reserve estimates and geology of the six new sites and the existing mining area of the Margalla Hills range are given in the report.

Key words: Limestone quarry, Margalla hills, Islamabad, Kohat.

L/10. Latif, M. & Khan, N.A., 1999a. Geological Map of Gahkuch-Roshan quadrangle (Toposheet No. 42 H/12, Scale 1:50,000) District Ghizer, Northern Areas, Pakistan. Sheet No. 1227, GSP. Geological Map Series.

Key words: Geology, Gahkuch, Ghizar.

L/11. Latif, M. & Khan, N.A., 1999b. Geological Map of Bara Pani quadrangle (Toposheet No. 43 M/8, Scale 1:50,000), District Skardu, Northern Areas, Pakistan. Sheet No. 1404, GSP. Geological Map Series.

Key words: Geology, Bara Pani, Skardu.

L/12. Latif, M., Khan, T., Fayaz, A. & Shah, S.H., 1998. Geology of Kargah quadrangle, District Gilgit, Northern Areas of Pakistan. GSP Information Release 675.

The KarGah quadrangle (43 1/1) lying in the district Gilgit has been mapped on 1:50,000 scale. Mapped area shows variety of rocks including metasedimentary, metavolcanic and plutonic. Metasedimentary and metavolcanic rocks are classified as Gilgit formation (parapeisses and schists together with amphibolites), Thelichi formation (turbidites, marble, green schist and basic dyke) and Greenstone complex (metavolcanics and metatuffs). The plutonic rocks are named as the Kohistan batholith which consists of diorite, granodiorite, granites aplite and pegmatite.

Structure of the mapped area is depicted by a syncline which is occupied by the rocks of the Thelichi formation. The mapped area contains mineral showings of insignificant economic importance.

Key words: Mapping, Kargah, Gilgit.

L/13. Latif, M.A., 1962. An Upper Cretaceous limestone in the Hazara District. Geological Bulletin, Punjab University 2, p.57.

In the Hazara District of West Pakistan, there occurs a limestone, 300 to 400 feet in thickness, above the Giumal Sandstone and below the un-doubted Tertiary sequence. It was described by Middlemiss (pp. 39-40) who was not sure of its age, but placed it at the base of his Nummulitic Series (Eocene), primarily for the convenience of mapping. At the base of the limestone is a bright orange yellow sandy limestone, about 6 to 10 feet thick, which contains a rich assemblage of definite Cenomanian fossils (op. cit. pp. 35 - 38). The top of the limestone is strongly lateritized, generally to a depth of 5 feet, and even more; and usually marks the small time-break to the overlying carbonaceous shales with inferior coal bands of early Tertiary age.

The limestone is very fine grained and pale grey on the freshly broken conchoidal fracture surfaces. It usually weathers creamy white, and occasionally dark grey. It is more thickly bedded at the base than the top, where it develops an uneven platy appearance due to the frequent alternations of limestone and very thin marly layers. This gives the rock a rather distinctive appearance compared with other limestones in the succession.

During the recent remapping of the region, a rich assemblage of small pelagic Foraminifera was found at a number of localities (Darband 33 56', 72 19' : Dungagali 34 3', 73 22': and Khan 34 8', 73 19').

Detailed work on these microfossils is in progress and the results will be published in full later. From the preliminary investigations of thin sections, however, the Foraminifera Globotruncana, Heterohelix, Rugoglobigerina and Pseudotextularia have been seen to occur, frequently, particularly in the upper part of the limestone. These genera are characteristic of the Upper Cretaceous, and, therefore, the limestone may be assigned definitely to this Series. It is interesting to note that the Parh Limestone of Baluchistan is of same age, and bears a striking similarity in the field.

Key words: Limestone, Cretaceous, Hazara.

L/14. Latif, M.A., 1963. Stratigraphy of the Hazara District, West Pakistan. 15th All Pakistan Science Conference, Lahore, p.15.

Key words: Stratigraphy, Hazara.

L/15. Latif, M.A., 1964. Criteria used in identification of various limestones in Hazara. 16th All Pakistan Science Conference, Lyallpur.

Key words: Limestone, Hazara.

L/16. Latif, M.A., 1968. Contributions to the geology and micro-palaeontology of Hazara, West Pakistan. *Sond. Verh. Geol. Bund. Austria* 3, 92-94.

Key words: Palaeontology, Hazara.

L/17. Latif, M.A., 1969. The stratigraphy of southeast Hazara and parts of the Rawalpindi and Muzaffarabad districts of West Pakistan and Kashmir. Ph.D. Thesis, London University, England.

Key words: Stratigraphy, Hazara, Rawalpindi, Muzaffarabad.

L/18. Latif, M.A., 1970a. Micropaleontology of the Chanali Limestones. Upper Cretaceous of Hazara, West Pakistan. *Jahrbuch der Geologische Bundesanstalt (Wien)* 15, 25-61.

A sequence of limestones, considered as the basal beds of Eocene, have been identified as a mappable, lithostratigraphic unit and given a new formation name, the Chanali Limestone. The microfaunal studies of 5 samples, further reveal the presence of more than 30 species, 16 belonging to planktonic and 15 to benthonic foraminiferida and 3 to Ostracoda. An Upper Coniacian to Campanian age for the formation is established.

Key words: Micropaleontology, Chanali Limestones, Cretaceous, Hazara.

L/19. Latif, M.A., 1970b. Explanatory notes on the geology of southeastern Hazara, to accompany the revised Geological Map. *Wein Jahrb. Geol. Bundesanst., Sonderb. Austria* 15, 5-19.

This is a brief account of the stratigraphy of over 1000 square miles of south eastern Hazara, West Pakistan, supported by a geological map on a scale of one inch to one mile. The mapping is based on the recognition of lithostratigraphic units, which are briefly described with modernization of nomenclature. The rocks are divided into 7 groups and subdivided into 21 formations, some provisional. The strata range from Eo-Cambrian?/Cambrian to Recent. Diagnostic fossils evidence wherever available is given. A correlation with adjoining areas is attempted.

Key words: Geology, geological map, Hazara.

L/20. Latif, M.A., 1970c. Micropalaeontology of the Galis Group, Hazara, West Pakistan. *Wein Jahrb. Geol. Bund. Austria* 15, 63-66.

Key words: Micropaleontology, Galis group, Hazara.

L/21. Latif, M.A., 1970d. Lower Carboniferous rocks near Nowshera, West Pakistan. *Geological Society of America, Bulletin* 81, 1585-1588.

No abstract available for this account.

Key words: Carboniferous, Nowshera.

L/22. Latif, M.A., 1972a. Lower Palaeozoic (? Cambrian) hyolithids from the Hazara Shale, Pakistan. *Nature, Physical Science* 240(100), 92-93.

The age of rocks forming the Lower Himalayas of Nepal and of the Kumaon, Garhwal, Simla, Kashmir and Hazara areas in the northwestern part of the Indo-Pakistan subcontinent has long been the subject of considerable controversy. The rocks include the Simla Slates, the Chandpur and Nagthat beds, as well as the Hazara Group and Tanol Formation of the Hazara District in northern Pakistan, which are separated from the overlying clastic and carbonate sediments by a disconformity marked by a glacial conglomerate known as the Blaini boulder bed in Nepal

and India and the Tanakki boulder bed in Hazara, Pakistan. The post-Blaini or post-Tanakki sequence is known as the Infra-Krol and Krol beds in Nepal, Kumaon and Simla, and as the Abbottabad Group in Hazara^{1,2}. In the absence of fossil evidence, both the Blaini and Tanakki boulder beds have been correlated with the fossiliferous Talchir boulder bed and, accordingly, considered to be of Upper Carboniferous-Permian age.

Key words: Palaeontology, Hazara.

L/23. Latif, M.A., 1972b. An occurrence of Paleozoic phosphate rocks in Hazara District, West Pakistan. Transaction Institute of Mining and Metallurgy (Section B: Applied Earth Sciences) 81, 850-853.

Key words: Paleozoic, phosphate, Hazara.

L/24. Latif, M.A., 1973. Partial extension of the evaporite facies of the Salt Range to Hazara, Pakistan. Nature, Physical Science 244(138), 124-125.

The age of the Salt Range Formation (formerly the Saline Series of Wynne) has long been controversial. The problem of age has revolved around two factors-the fossil evidence and the contact with the overlying Palaeozoic sequence. A third factor-the presence of Slate Series in other areas of the Indo-Pakistan subcontinent-has not been considered, despite the fact that both the Salt Range Formation and the Slate Series mark the oldest known rocks of enormous thickness and with an unknown base^{6,7} in their respective areas of development.

Key words: Evaporites, Salt range, Hazara.

L/25. Latif, M.A., 1974a. A Cambrian age for the Abbottabad Group of Hazara, Pakistan. Geological Bulletin, Punjab University 10, 1-20.

The Lower Himalayas all along are dominantly composed of a thick sequence of quartzites, sandstones and dolomites overlying what are known as Slate Series named variously at different localities. One such sedimentary sequence mapped earlier (1970) by the author as Abbottabad Group is the subject of study in this article. Like similar other rocks sequences in other parts of Indo-Pakistan the age has been unknown for want of fossil evidence. The majority of previous workers have for reasons of glaciated Tanakki conglomerate proposed a post carboniferous age for the problematic sequence. The rock sequence has been described starting with the Hazara Group followed by the Tanol Formation. These are considered to be from Eo-Cambrian to Basal Cambrian. Abbottabad Group follows after a break marked by Tanakki Conglomerate followed by Sangargali Member, Mahmadagali Member and Mirpur Member all belonging to Kakul Formation. These are followed by a dolomite sequence, the Sirban Formation, which in upper parts is cherty and phosphatic. After a break, said to be gradational in few sections, (?), the Abbottabad Group is followed by Tarnawai Formation composed of Galdanian and Hazira members, known to be facies equivalents of each other. Galdanian Member is composed of red haematitic mudstones, clay-stones etc. and Hazira Member of yellowish sandstone and siltstone rich in glauconite in lower parts. The Tarnawai Formation is followed by the Thandiani Group of Jurassic age.

Fossil, Hyoliths and Chencelloria have been recorded from the Hazira Member and a Cambrian age is assigned to the rock sequence lying above Tanol Formation and below Hazira Member. The sequence has been correlated partly with the Cambrian sequence of Salt Range and Iran. The lithologically similar sequence in other parts of Indo-Pakistan are suggested to be the possible equivalents of Abbottabad Group.

Key words: Cambrian, Abbottabad, Hazara.

L/26. Latif, M.A., 1974b. A review of the study of phosphatic rocks in Hazara District, Pakistan. Geological Bulletin, Punjab University 10, 91-94.

Key words: Phosphates, Hazara.

L/27. Latif, M.A., 1974c. A new evidence to solve the controversy of paleo-glaciation in Indo-Pakistan. Geological Bulletin, Punjab University 11, 1-6.

Evidences show that unconformity is not restricted to Tanakki Member horizon; the conglomerate occurs at levels other than Tanakki Member; the Tanakki Member is composed entirely of rocks of local origin, mainly sedimentary, as against Talchir Boulder Bed where these have been transported from far off distances and are mainly composed of crystalline rocks; the red and purple sandstones, quartzites and dolomites always occur younger than Tanakki Member whereas lithologically identical rock units always occur older than Talchir Boulder Bed; fossil Hyolithes, Chancelloria etc. of Cambrian age are found to occupy a younger position in sequence than Tanakki Member and there is a possibility of the presence of globular organisms of Algonkian affinities in the Blaini Beds of Simla India. It is suggested that Tanakki Member and Talchir Boulder Bed belong to two different phases of glaciation, the former being older, possibly Cambrian or topmost Pre-Cambrian.

Key words: Paleo-glaciation, Tanakki conglomerate, Cambrian.

L/28. Latif, M.A., 1976. Stratigraphy and micropaleontology of the Galis Group of Hazara, Pakistan. Geological Bulletin, Punjab University 13, 1-64.

The Galis Group is composed of 6 distinct mappable units recognized as formations. The gray limestone considered as Eocene by Middlemiss (1896) in fact of Upper Cretaceous age and has been separated as Kawagarh Formation at the top of the Hothla Group. The contact between Hothla and Galis groups is marked by a break in deposition followed by laterite/limonite/hematite/ and coal/bituminous shales. The group contains 75 species of Foraminifera and genera of Ostracoda, recorded and described from Hazara for the first time. The Group ranges in age from Lower Paleocene to basal Middle Eocene. The southeastern parts of the area indicate relatively shallower conditions of deposition. During the deposition of the Galis Group, intermittent phases of transgression and regression are recorded with a tendency towards a complete withdrawal of marine conditions upward in the succession.

Key words: Stratigraphy, micropaleontology, Galis Group, Hazara.

L/29. Latif, M.A., 1980. Overstep by Thandiani Group, Jurassic over older rock sequences in Hazara. Contributions to the Geology of Pakistan 1, 1-8.

Of the seven unconformities recorded in the sequence of rocks in Hazara the lower three disconformities merge into one composite unconformity. This leads to an overstep by Toarcian rocks over, the Eo-Cambrian rocks. An attempt has been made to elaborate the varied effect of various unconformities on the underlying sequences in various parts of Hazara which led to the formation of the composite unconformity.

Key words: Stratigraphy, Thandiani, Hazara.

L/30. Latif, M.A., 1992. Tectonic control of stratigraphic and facies variations in the Mesozoic and Paleogene rocks, in Hazara, Islamabad & Kashmir. Abstracts, First South Asia Geological Congress, Islamabad, p.26.

Key words: Tectonics, stratigraphy, facies, Mesozoic, Hazara, Kashmir.

L/31. Latif, M.A., Afzal, M.S., Qureshi, M.N., Munir, M.H. & Ahmed, N., 1991. Geological setting and landslide Hazara at Kalabun and Riala south-east Hazara, NWFP. Kashmir Journal of Geology 8 & 9, 133-138.

Location of Kalabun and Riala in the vicinity of regional thrusts; presence of extensive faulting and folding; very high relief; denudation of softer shales at the toe of high ridge by local streams and chemical and mechanical action together seem to be responsible for sliding in the area.

Key words: Structure, geography, hazards, landslides, Hazara.

L/32. Latif, M.A., Lodhi, S.A.K., Qureshi, M.N. & Munir, M.H., 1991. Geological, mineralogical and geotechnical investigations of laterite from Changlagali area of Hazara division. *Kashmir Journal of Geology* 8 & 9, 165-172.

Indian plate movement after the deposition of Cretaceous Kawagarh Formation and prior to the Paleogene deposition created conditions suitable for the formation of Hangu Formation which the product of lateritization of old limestone surface. The laterite beds exposed near Changlagali, on Murree-Abbottabad road were measured and sampled for this study. The samples dominantly consist of gray colored pisoliths embedded in a gray to creamish brown matrix. Mineralogically, goethite and boehmite are the two distinct phases in laterite. Geochemical analyses show that the percentage of alumina decreases in the upper parts of the beds, whereas, the percentage of iron increases with the decrease of alumina in the beds. The general trend is desilicification in the middle of the beds. In the upper part of the beds the percentage of silica is increasing because of leaching out of the elements due to weathering phenomenon. The firing of samples at above 900 °C produces beautiful red colors. It is deduced that materials are suitable for the manufacturing of surface tiles.

Key words: Mineralogy, petrology, laterite, Changlagali, Hazara.

L/33. Latif, M.A., Munir, M.H., Qureshi, M.A., Ahmed, N. & Tareen, M.S., 1992. The facies control of mineralization of the Hangu Formation in Hazara, Islamabad and Azad Kashmir. *Kashmir Journal of Geology* 10, 161-168.

The Hangu Formation (Paleocene) reveals a range of lithologies in Hazara – Islamabad, northern Rawalpindi District and Azad Kashmir areas. Five lithologies comprise, the Hangu Formation i.e., bauxite facies (Azad Kashmir), laterite facies (Southern Hazara), haematite facies (central regions of Hazara), laterite cum arenaceous facies (mid northwestern Hazara region) and arenaceous/quartzite facies (northwest Hazara region). The five facies are delimited by thrust and have been recognized as the member of the Hangu Formation.

Key words: Mineralogy, lithology, Hangu Formation, Hazara.

L/34. La Touche, T.D., 1892. Report on the oil springs at Moghal Kot in Shirani Hills. *Geological Survey of India, Record* 25(4), 171-175.

Key words: Hydrocarbons, oil, Shirani Hills.

L/35. La-Touche, T.D., 1893. Geology of the Shirani Hill. *Geological Survey of India, Record* 26(3), 77-96.

Key words: Geology, Shirani Hills.

L/36. La Touche, T. D., 1917. *Bibliography of Indian Geology and Physical Geography; with an Annotated Index of Minerals of Economic Value*, 2 Vols: 571 + 490 + 143 p. Geological Survey of India, Calcutta.

Key words: Bibliography, geography, economic minerals.

L/37. Laurs, B.M., Dilles, J.H. & Snee, L.W., 1996a. Geologic origin of gem-bearing pegmatites, Stak Nala, Haramosh massif, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 83-84.

Gem-bearing pegmatites and associated leucogranite bodies are widely distributed in rocks of the Pakistan Himalaya, within both the Nanga Parbat-Haramosh Massif of the Indian Plate and in the Asian Plate to the north. The Stak Nala pegmatites are located (ca. 35°59'; 75°02'E) near the eastern portion of the massif, where late tectonic

Himalayan leucogranites (U/Pb zircon ages of 2 to 13 Ma) were emplaced during late Neogene uplift (Zeitler and Chamberlain, 1991). The pegmatites are hosted by granoblastic-textured ortho- and para-gneiss (Shengus gneiss of Verplanck, 1986) metamorphosed at granulite facies (8 to 13 kb, 650-700°C) (Pognante et al., 1993). In the mine area, cm- to m-scale banded biotite-muscovite±garnet granitic gneiss dominates.

The Stak Nala pegmatites contain the only known economic concentration of gem quality pink-green tourmaline in the region. The pegmatites are mined west of and 400 m above the Stak Nala valley over a 0.5 km distance, but similar pegmatites extend 3 km south. Pegmatites are typically <1-m thick and locally up to 5-m thick. Most pegmatites are emplaced along the gently dipping S1-foliation (& F1 folds with top-to-south shear) of the Shengus gneiss, but in detail are slightly discordant sills. The pegmatites also cross-cut a series of N60°W striking, 60°N-dipping monoclinical F2-flexural shears with gneissic layers attenuated within the dipping limbs. These fold-shears are interpreted to be deep, ductile normal faults related to Neogene uplift of the massif. The pegmatite emplacement locally deforms gneissic wall-rock foliation and hence occurred while the gneiss was hot enough to allow ductile deformation of quartz (>300°C). Late brittle normal faults reactivate the F2-shears, offset pegmatites, and contain local sericite-pyrite hydrothermal alteration inferred to have formed at ca. 250°C. Two ⁴⁰Ar/³⁹Ar plateau ages on white micas (closure temperature ca. 325°C) yield 5.80±0.05 Ma for wall-rock gneiss and 4.63±0.12 Ma for the pegmatite. If the micas have the same structural state, these data suggest the gneissic wall-rock cooled to 325°C at 5.8 Ma slightly prior to pegmatite emplacement.

In the mine area, at least six pegmatites separated by 3 to 20 m occur within a 100 m section of gneiss. All these pegmatites have complex mineralogic zonation, microlitic cavities, coarse grain-size, and quartz, orthoclase, sodic plagioclase, muscovite, and schorl tourmaline. The most productive pegmatite has been mined in a zone 100 m by 60 m. The thickest portion of the pegmatite (1.0 to 1.2 m) is most productive; the northern thin (<0.7 m) portion is non-productive. The productive zone is bounded on the north by an F2 fold, which forms an anticline that may have trapped volatile components to produce gem tourmaline. The pegmatites display a simple internal zonation from the wall-rock contact inward; border and intermediate zones symmetrically enclose a central core zone (Fig. 1). The border zone is ca. 10 cm thickened characterized by coarse-grained (1 to 7 cm) albite, orthoclase, and quartz, and medium-grained schorl, garnet, and loellingite. Large (15 to 30 cm) perthite crystals nucleate within the border zone and flare into the intermediate zone, accompanied by locally abundant schorl prisms. Schorl, albite and quartz form irregular coarse-grained intergrowths which are rarely graphic in texture; loellingite (<0.1 vol.%) is widespread. The core zone is at or slightly above the pegmatite centerline, and is marked by an abrupt increase in blocky, commonly albitized, and perthite crystals. Albite, quartz, schorl, muscovite (rare lepidolite), and green fluorite of variable grain size (1 mm to 10 cm) are essential.

Gem tourmaline-bearing pockets occur sporadically within the core zone. The pockets range in size up to 2*3*0.5 m, and are lined by albite (wedge-shaped crystals and cleavelandite), topaz, green fluorite, and pink-brown fluorapatite; columbite-tantalite, pyrochlore, and hambergite form rarely. A thin layer of hypogene fine-grained illite partially covers pocket minerals, and together with soil fills the remaining pocket cavity. Associated with some pockets are irregular bodies of sugary albite, garnet, and tourmaline, which locally extend into the surrounding intermediate zone. These may be pressure-quench aplite derived from abrupt fluid escape during pocket rupture, as described at pegmatites in San Diego County, California (Ford, 1976).

The wall-rock is bleached up to 7 cm from the pegmatite and contains metasomatic albite, muscovite, and tourmaline. Wall-rock alteration increases with pegmatite thickness and amount of pocket mineralization, and is most extensive in biotite-rich gneisses where tourmaline extends up to >50 cm along foliation. Pegmatite-derived fluids have added, B, Fe, Rb, Zn, Zr, and Nb, and leached K, Ba, and Sr from the wall-rocks.

We conclude that pegmatite gem mineralization at Stak Nala formed during the late Neogene uplift of the Nanga Parbat-Haramosh Massif, probably after the granulite-facies host rocks have cooled to 300 to 350°C at pressures of <2 kb (based on microlitic cavities). The pegmatites are derived from leucogranite magmas enriched in Si, Al, Na, K, B, F, Li, Rb, and H₂O that formed from low degrees of partial melting of a metapelite source during decompression (?). The high concentration of rare elements in the narrow pegmatite dikes is probably due to extreme fractionation of vapor-saturated magma.

Key words: Gems, pegmatites, granites, Stak Nala, Nanga Parbat-Haramosh.

L/38. Laurs, B.M., Dilles, J.H. & Snee, L.W., 1996b. Emerald mineralization and metasomatism of amphibolite, Khaltaro granitic pegmatite-hydrothermal vein system, Haramosh Mountains, northern Pakistan. *Canadian Mineralogist* 34, 1253-1286.

Emerald mineralization is found within 0.1- to 1-m-thick hydrothermal veins and granitic pegmatites cutting amphibolite within the Nanga Parbat-Haramosh massif, in northern Pakistan. The amphibolite forms a sill-like body within garnet-mica schist, and both are part of a regional layered gneiss unit of Proterozoic (?) age. The $^{40}\text{Ar}/^{39}\text{Ar}$ data for muscovite from a pegmatite yield a plateau age of 9.13 ± 0.04 Ma. Muscovite from mica schist and hornblende from amphibolite yield disturbed spectra with interpreted ages of 9 to 10 Ma and more than 225 Ma, respectively, which indicate that peak Tertiary metamorphism reached 325 to 550 degrees C prior to 10 Ma. Pegmatites were emplaced after peak metamorphism during this interval and are older than pegmatites farther south in the massif. At Khaltaro, simply zoned albite-rich miarolitic pegmatites and hydrothermal veins containing various proportions of quartz, albite, tourmaline, muscovite, and beryl are associated with a 1- to 3-m-thick heterogeneous leucogranite sill, that is locally albitized. The pegmatites likely crystallized at 650 to 600 degrees C at pressures of less than 2 kbar. Crystals of emerald form within thin (<30 cm) veins of quartz and tourmaline-albite, and more rarely in pegmatite, near the contacts with altered amphibolite. The emerald-green coloration is produced by Cr and Fe. The Cr and total Fe contents, expressed as Cr_2O_3 , and Fe_2O_3 , respectively, decrease systematically from emerald (>0.20, 0.54-0.89 wt%), to pale blue beryl (< or = 0.07, 0.10-0.63%), to colorless beryl (<0.07, 0.07-0.28%). The amphibolite is metasomatized in less than 20-cm-wide selvages that are symmetrically zoned around veins or pegmatites. A sporadic inner zone containing F-rich biotite, tourmaline, and fluorite, with local albite, muscovite, quartz, and rare beryl, gives way to an intermediate zone containing biotite and fluorite with local plagioclase and quartz, and to an outer zone of amphibolite containing sparse biotite and local quartz. The inner and intermediate zones experienced gains of K, H, F, B, Li, Rb, Cs, Be, Ta, Nb, As, Y and Sr, and losses of Si, Mg, Ca, Fe, Cr, V and Sc. The outer alteration zone has gained F, Li, Rb, Cs, and As. Oxygen isotope analyses of igneous and hydrothermal minerals indicate that a single fluid of magmatic origin with $\delta^{18}\text{O} = 8$ per mil produced the pegmatite-vein system and hydrothermal alteration at temperatures between 550 and 400 degrees C. The formation of emerald result from introduction of HF-rich magmatic-hydrothermal fluids into the amphibolite, which caused hydrogen ion metasomatism and released Cr and Fe into the pegmatite-vein system.

Key words: Emerald mineralization, amphibolites, metasomatism, pegmatites, granites, Stak Nala, Nanga Parbat Haramosh.

L/39. Laurs, B.M., Dilles, J.H., Warraich, Y., Kausar, A.B. & Snee, L.W., 1998. Geological setting and petrogenesis of symmetrically zoned, miarolitic granitic pegmatites at Stak Nala, Nanga Parbat-Haramosh massif, northern Pakistan. *Canadian Mineralogist* 36, 1-47.

Miarolitic granitic pegmatites in the Stak valley in the northeast part of the Nanga Parbat-Haramosh Massif, in northern Pakistan, locally contain economic quantities of bi- and tricolored tourmaline. The pegmatites form flat-lying sills that range from less than 1 m to more than 3 m thick and show symmetrical internal zonation. A narrow outer or border zone of medium-to coarse-grained oligoclase--K-feldspar-quartz grades inward to a very coarse-grained wall zone characterized by K-feldspar-oligoclase-quartz-schorl tourmaline. Radiating sprays of schorl and flaring megacrysts of K-feldspar (intermediate microcline) point inward, indicating progressive crystallization toward the core. The core zone consists of variable mixtures of blocky K-feldspar (intermediate microcline), oligoclase, quartz, and sparse schorl or elbaite, with local bodies of sodic aplite and miarolitic cavities or "pockets". Minor spessartine-almandine garnet and lollingite are disseminated throughout the pegmatite, but were not observed in the pockets. The pockets contain well-formed crystals of albite, quartz, K-feldspar (maximum microcline+ or - orthoclase overgrowths), schorl-elbaite tourmaline, muscovite or lepidolite, topaz, and small amounts of other minerals. Elbaite is color-zoned from core to rim: green (Fe^{2+} and Mn^{2+})-bearing), colorless (Mn (super 2+) -bearing), and light pink (trace Mn (super 3+)). Within approximately 10 cm of the pegmatites, the granitic gneiss wallrock is bleached owing to conversion of biotite to muscovite, with local quartz and albite added. Schorl is disseminated through the altered gneiss, and veins of schorl with bleached selvages locally traverse the wallrock up to 1 m from the pegmatite contact. The schorl veins can be traced into the outer part of the wall zone, which suggests that they formed from aqueous fluids derived during early saturation of the pegmatite-forming leucogranitic magma rich in H₂O, F, B, and Li. Progressive crystallization resulted in a late-stage sodic magma and abundant aqueous fluids. Two late stages of volatile escape are recognized: the first stage caused pressure-quenching of the last magma, which produced aplite and caused albitization (An 3 to An 8) of earlier crystallized K-feldspar and oligoclase. The second stage, released during the rupture of miarolitic cavities, produced platy albite ("cleavelandite," An 1) locally associated with F-rich muscovite and elbaite. Albitization is likely due to cooling of alkali-fluoride-dominated fluids at less than 2 kbar pressure. The pegmatites are derived from Himalayan leucogranitic magma emplaced prior to 5 Ma into granulitic gneiss that was at 300 degrees to 550 degrees C and 1.5

to 2 kbar. The pegmatites were emplaced during uplift of the Haramosh Massif, since they cross-cut ductile normal faults but are cut by brittle normal faults. Economically important pink tourmaline mineralization formed in pockets concentrated near the crest of a broad antiform, as a result of trapping of late magmatic aqueous fluids that had become Fe-poor owing to the prior crystallization of schorl.

Key words: Petrogenesis, zoned pegmatites, granites, Stak Nala, Nanga Parbat-Haramosh.

L/40. Lawrence, L. & Malinconico, Jr., 1989. Crustal shortening in the west Himalaya. *Geological Bulletin, University of Peshawar* 22, 55-64.

The main collision between the Indian and Asian lithospheric plates occurred during the late Eocene (40 million years ago) and continued closure at the rate of 5 cm/yr has resulted in approximately 2000 km of crustal shortening between the two plates (Molnar and Tapponnier, 1975; Molnar, 1984). In northern India it has been suggested that while some of the shortening is by underthrusting (Molnar and Tapponnier, 1975) much may be the result of diffuse deformation in China (Tapponnier, 1982). However, in northern Pakistan the problem is complicated because there is no Tibetan plateau analog and no evidence of strike-slip structures that could have removed significant amounts of crustal material.

In order to place tighter constraints on tectonic models for the Indian-Asian collision in the western Himalaya it is important to be able to estimate the amount of crustal shortening that has occurred. Current estimates of 500 to 700 km of convergence in northwestern Pakistan (Butler, 1986), are calculated from balanced cross-section methods. This is significantly less than the 2000-km required by closure models based on paleomagnetic data (Powell, 1979, Molnar and Tapponnier, 1975; Molnar, 1984).

An important step in estimating the amount of shortening that has occurred is to determine the volume of crust that remains in the orogen. The crustal models based upon observed gravity profiles presented in this paper suggest that there may be enough crustal volume to account for between 550-1100 km of shortening. This is still significantly less than the 2000 km of closure that has presumably occurred. The balance of the closure might be account for by erosion and/or diffuse deformation or it might suggest that less than 2000 km of closure has occurred in the northwestern Himalaya.

Key words: Structure, tectonics, collision, Himalaya.

L/41. Lawrence, R.D., 1982. West and Tibetan collision zone in Pakistan. *EOS* 63, p1112.

The northwestern margin of the subcontinental India in Pakistan is characterized by two major suture zones. The one on the west juxtaposes the Afgan block with India. That in the north (commonly referred to the Indus Suture) juxtaposes the Kohistan island arc terrain against India. These are described in this note. Major tectonic features record the transition from convergence in the Himalaya and Tibet to transform on the Chaman fault system in northern Pakistan. The Main Boundary thrust can be traced to the south side of the Safed Koh where it overrides the Sulaiman fold belt. It ends abruptly where the Sarubi tear fault abuts the Heart fault. The Main Central thrust becomes obscure in eastern Kashmir. Beyond the Hazara-Kashmir Syntaxis (HKS) its only possible expression is a deep seismic zone (IKSZ) under "flack tectonic" thrust sheets of Kohistan & Swat (Kohistan flakes). The Indus suture continues as the Main Mantle thrust to the Kunar fault, reappears around the Kabul block, and into the Quetta line; all marked by latest Cretaceous/Paleocene obduction. The Kabul block is a fragment of Lesser Himalayan terrain of the Indian subcontinent displaced by interactive motion on the Herat & Chaman faults. Significant stratigraphic contrasts subdivide the Lesser Himalayan terrain. The HKS & Nanga Parbat loop are neotectonic features on the eastern border of the Kohistan flakes with centers of rotation at their apices. Microplate line of Afghanistan-Nuristan-Pamirs-South Tibet is wrapped around the Kohistan flakes by rotation in the west, thrusting in the north (Pamir thrusts), & right-lateral translation in the east (Karakorum fault). Unscrambling of tectonic development requires (1) reverse translation and rotation of relatively rigid blocks, (2) unfolding and thrusting of marginal belts, and (3) reconstruction of areas concealed by over-thrusts. Key is reversal of motion on Chaman & Herat faults and reversal of rotation of Kohistan flakes.

Key words: Collision zones, tectonics, Tibet, Pakistan.

L/42. Lawrence, R.D., 1984a. An expedition to Pakistan. *Science* 226, p.1414.

This gives a brief account of the two volumes of the International Karakoram Project (K.J. Miller editor, 1984). Papers in these are annotated at appropriate places in this work.

The International Karakoram Project, K. J. Miller, Ed. Cambridge University Press, New York 1984. In two volumes. Vol. 1, xxx, 412 pp., Vol. 2, xxviii, 635 pp., From two conferences, Islamabad, June 1980, and London, Sept. 1981.

This two volume set contains papers delivered at conferences which that took place before and after the International Karakoram Project (IKP). The IKP was a major expedition into the remote Karakorum Mountains of northern Pakistan using the recently completed Karakorum Highway, which follows the old silk road between India and China. The project was undertaken, in a two-month period, during the summer of 1980s as part of the Royal Geographic Society's 150th anniversary celebration. It brought together earth scientists mainly from three cooperation nations, the United Kingdom, Pakistan, and the People's Republic of China. The principal studies involved glaciology, topography, seismology, housing as it relates to natural hazards, geomorphology, and geology. The first volume contains papers delivered at the conference preceding the expedition. About a third of the volume is thus devoted to descriptions of techniques for gathering desired data. About a fourth is devoted to descriptions of the results of studies in distant areas that used techniques intended to be used in the IKP. The remainder of the book mainly describes projects planned in Pakistan and neighboring areas. Six papers report new results from previous work in Pakistan that are of lasting value. Four papers report the results of glaciological studies by Chinese scientists. Israr-ud-Din of Pakistan reports the results of his studies of house construction in Chitral in relation to the geographic setting. H. M. Rendell reports new work on the Quaternary history of the Potwar plateau. This volume is largely superseded by the second volume.

The second volume contains the results obtained by the IKP, Much information is published here for the first time and not all of it can be reviewed. One of the most ambitious efforts of the IKP was a resurvey of the 1913 triangulation connection between India and Russia in an effort to detect tectonic deformation across the Karakoram. This effort entailed major mountaineering, for the stations to be reoccupied were mostly mountain peaks between 4000 and 6000 meters high. The survey itself was successfully accomplished, but significant tectonic deformation was not detected. A substantial effort was made in glaciology, and many new data were obtained that will be increasingly useful as these baseline studies are replicated. A micro-earthquake survey was made with a portable seismic network. Most of the seismicity was under the Hindu Kush to the west. However, important seismicity was observed for the first time in the Kohistan area of northern Pakistan (south of Karakorum) and will provide guidance to future neotectonic studies. A large part of the volume is devoted to the study of housing and natural hazards. Many data on house construction and family use of homes were gathered that will interest ethnologists and anthropologists. A key element of the success of these studies was the presence of a female, F. D'Souza, for non-family males are not allowed inside the homes in this area. The housing team devoted considerable effort to attempts to determine the role of natural hazards in locating houses. Surprisingly in this area of very great natural hazard, they found that agricultural considerations, specifically preservation of cultivatable land and availability of irrigation supplies, essentially exclude natural hazards such as rock-fall, mudflow, flood, and earthquake from consideration when new houses are located.

The longest part of the volume deals with geomorphology. Extensive data on current processes are reported. Perhaps the most unexpected result here is that a dissolved load yielding sediment of 90 tons per square kilometer per year was measured on the Hunza River, indicating that substantial chemical weathering occurs even in a high, cold, arid area where it had always been considered to be negligible. One of the best papers in the collection deals with the Quaternary history of the Hunza Valley. Eight separate glacial phases are recognized, the older of them more than 139,000 years old. The oldest stages are recorded by remnants several thousand meters above the Hunza Valley floor. The sole weakness of the study is a failure to consider the effects of tectonic uplift interacting with glacial episodes. With uplift rates of over 1' centimeter per year recorded in the area, the interaction must be significant. This is the first modern study of glacial chronology in northern Pakistan and will be of great value to other workers.

The IKP was an ambitious undertaking. Much was accomplished, but the project has the inherent weaknesses of short-term projects. In numerous instances previous work is not adequately recognized. Little effort was apparently made to assist Pakistani colleagues to continue the studies, particularly those that established baseline data. These proceedings volumes are not as tightly edited as one would wish, but they do contain substantial amounts of valuable information.

Key words: Reconnaissance, expedition, Karakoram.

L/43. Lawrence, R.D., 1984b. Suture tectonics in Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, p.49.

In Ladakh the Indus suture divides. A minor northern suture, the MKT, records a back arc basin north of the Kohistan-andesite arc. The major suture, which records the location of the Neotethys, is south of the arc. It is made up of a complex set of terrains and structures. Ultramafic rocks of three derivations can be distinguished in this suture, namely: (1) those emplaced by obduction, (2) those imbricated into subduction zones, and (3) those basal to the arc complex. Obducted material is present as an infolded klippe at Dargai and associated with emerald mineralization from Mohmand to Mingora. Subduction complex with blueschist, serpentinite, piemontite schist, and phyllite is preserved at Shangla. Fossils of probable early Cretaceous age are present in subduction material near Mingora. Initial emplacement of subduction and abduction material in Swat occurred prior to continental collision. Ophiolite material of diverse origin is mingled by collision and its complex earlier history is obscured. This is demonstrated better in Pakistan than elsewhere in the world. As the suture is followed west and south from Swat, the subduction and obduction complexes become separated by the Khojak flysch. Subduction melange occurs at Khost, in the Altimur Range, and in the southern Ras Koh. Obduction masses occur at Waziristan, Muslimbagh, and Las Bela. The enormous Khojak flysch mass separates these, and collision has not gone to completion as is the case in the Himalayan Ranges.

Key words: Structure, tectonics, ultramafics, MKT.

L/44. Lawrence, R.D., Baig, M.S., Dilles, J.H., Lafortune, J.R., DiPeitro, J., Huges, S.S., Palmer, Rosenberg, P.S., Pogue, K., Snee, L.W., Tahirkheli, R.A.K., Ghauri, A.A.K., Jan, M.Q., Ahmad, I., Rafiq, M., Kazmi, A.H. & Hussain, A., 1989. Tectonics south of the Suture, northern Pakistan. *Geologique Internationale Resumes – 28th International Geological Congress Section 2*. No. 28, p.265.

In Pakistan the Indus suture zone is known as the Main Mantle Thrust zone (MMT) and separates the Kohistan andesitic arc complex from rocks of the Indian subcontinent portion of Gondwana. The latter, south of the MMT, are the hinterland of the Himalayan thrust system in Pakistan. In Swat and Besham areas pre-Himalayan deformation and early Himalayan metamorphism complicate interpretation of these rocks.

The MMT zone contains three separately mappable melanges in the Swat region. Mingora melange consists of ophiolite blocks and slabs in or on a metamorphosed talc-carbonate or serpentinite matrix that is tectonically interleaved with graphite schists at the base. Klippe of Mingora melange may be found 40 km south of the MMT. Charbagh melange is composed of greenschist of possible andesitic arc origin. The Shangla melange contains blueschist, serpentinite, and other exotic blocks in a sheared matrix of low grade metasediments and metavolcanoclastics. On the Indus River north of Besham the MMT is a fault at the base of the Jijal complex (peridotites and pyroxene granulites of the base of the Kohistan arc); suture melanges are absent. In Allai Kohistan east of the Indus River, blueschist and serpentinite melanges similar to those of southern Swat reappear in southern Swat the rocks under the MMT are stratigraphically divided by a significant unconformity. Below the unconformity are quartzofeldspathic and calc-silicate metasediments, Manglaur schist (MS). Above the unconformity are the members, quartz-mica schists, amphibolites, calc-schists, marbles, graphite schists, etc. of the Alpurai formation (AF) of late(?) Paleozoic age. Member 5 maps south to stratigraphically overlie conodont-bearing lower Carboniferous rocks near Rustum. This Rustum Paleozoic section is fossiliferous from Ordovician to Carboniferous. The Paleozoic section of the SE Peshawar basin margin overlies with angular unconformity Precambrian Tanawal formation, a largely quartzose sequence probably correlative with MS. Granitic rocks of the Swat region were intruded at several different times. The Swat porphyritic granites (SPG) are unconformable beneath AF and intrude MS. These are peraluminous coarse-grained granites containing biotite, muscovite, garnet. SPG correlates (?) with Mansehra granites east of Indus River (516 My Rb/Sr isochron). Small bodies of syntectonic Swat tourmaline granite (STC) intrude mainly along major contacts. These are peraluminous non-porphyritic rocks containing muscovite, tourmaline, epidote group minerals. STG REE patterns are similar to those of the SPG, but a factor of 5-10 less enriched; this is compatible with partial melting of the SPG to form the STG. About 20 km south of SPO outcrops, the Ambela granite (AG), associated with numerous small bodies of alkaline granites (Rb/Sr isochrons of about 300 My) intrudes Carboniferous sediments. These granites may reflect late Paleozoic rifting along northern Gondwana. Major and trace element chemistry confirm that the STO, AO, and STG are distinct magmatic entities. The youngest granites include the small post-tectonic Malakand biotite granite whose intrusive contacts cross cut Himalayan age metamorphic foliation. The upper rocks of Swat probably form a roof thrust 75 km. Marker units can be traced in overlapping sequence from the MMT to the Swabi region. AF Member 2 forms a regional marker

allowing detailed analysis of folding within this unit. The first two fold sets are synmetamorphic at or before Ar closure in hornblende at about 40 My. and have north-south or northwest-southeast axes. The first set is recumbent and west verging; the second set upright and west verging. Neither comprises sheath folds or other structures rotated into the direction of elongation; their axes do not define a stretching lineation. They occur only in the 20-30 km wide zone of high grade metamorphism, are associated with initial collision, and suggest left lateral strike slip along the suture with limited west-directed overthrusting (50 - 30 My). The youngest set of folds in the Swat area has eastwest axes associated with the onset of major south-directed thrusting. Folds of this pattern are present from the MMT south to the Salt Range. East of the Indus River stratigraphy and intrusive history are similar to Swat, but an imbricate pattern of south-directed thrusts developed in the Hazara Hills east of the Indus River. The most probable interpretation is an extensive roof thrust in Swat that overlies the imbricate duplexes revealed by deeper erosion to the east in Hazara. The Besham block is a stratigraphically and structurally distinct block along the Indus River. North-south, steeply dipping faults separate this block from its neighbors. Reconnaissance mapping suggests 'that these faults also cut the MMT itself and separate the portion of the MMT marked by the Jijal complex from the Swat and Allai Kohistan melange-bearing portions of the MMT.

Besham block stratigraphy consists of heterogeneous quartzofeldspathic banded gneisses and metasediments, the Besham Group (BG), representing early Proterozoic(?) crystalline basement. Major and trace element variability in the gneisses suggests both paragneisses and in situ anatexitic melts of pelitic sediments as the origin of these rocks. The BG is intruded by Labor granite (LG) which is clearly crustal melt. Pegmatites of LG intrude all lithologies of the BG. BG gneissic foliation and LG pegmatites are truncated by an angular unconformity at the base of marine metasediments of the Karora Group (KG). Fragments of all basement lithologies are found in the Karora Group (KG). Fragments of all basement lithologies are found in the basal conglomerate of the KG. Above this unit the KG consists of graphitic phyllite overlain by siliceous dolomite. Metamorphic grade of the KG is middle greenschist. The higher metamorphic grades and anatexitic events of the BG developed before the unconformity between these units. The KG can probably be traced into equivalent Precambrian phyllites unconformable under the Tunawal near Turbela. A common structural history for Besham and Swat blocks probably began with the younger north-south fold set. Recently the entire area was arched on a north-south axis to form the syntaxial bend of the MMT. The limbs of this structure are partly formed by brittle motion on steeply dipping north-south trending faults. Some of these faults contain mafic and ultramafic slivers derived from suture melanges. In summary the Swat and Besham regions record different structural and metamorphic histories: in the former, late Precambrian to Paleozoic granites and sediments are deformed and intruded by tourmaline granites during Himalayan metamorphism and deformation; in the latter, an earlier Proterozoic metamorphism and magmatism are preserved below the suture.

Key words: Tectonics, Southern Suture, Himalaya.

L/45. Lawrence, R.D. & Ghauri, A.A.K., 1983a. Observations on the structure of the Main Mantle Thrust at Jijal, Kohistan, Pakistan. *Geological Bulletin, University of Peshawar* 16, 1-10.

Structures in the lower plate of the MMT at Jijal include a blastomylonite zone, Z-folds in the blastomylonite, and abundant slickensides in a breccia block. Blastomylonite foliation is cross-cut by intermediate granitic intrusive. A multi-stage history of the MMT involving (1) SE thrust motion on a deep shear zone, (2) uplift and granitic intrusion, (3) renewed thrust faulting and breccia formation at a shallow crustal level, and (4) folding of the MMT and cessation of thrust motion is suggested.

Key words: Tectonics, structure, MMT, Jijal, Kohistan, Himalaya.

L/46. Lawrence, R.D. & Ghauri, A.A.K., 1983b. Evidence of active faulting in Chilas District, northern Pakistan. *Geological Bulletin, University of Peshawar* 16, 185-186.

About 10km northeast from the town of Jalipur, a zone of breccia, 5-10km thick, is located along the Karakorum Highway. The breccia is found in Holocene fan-gravels developed at the foot of the Nanga Parbat massif. It is present at several locations along the road up to Raikot bridge, and also north of the confluence of the Indus and Astor River. Slickensides are developed in this breccia zone. Most of these appear to plunge along the dip of fault surfaces on which they are found. The trace of the fault is delineated by a line of hot springs, some right on the road and some on the river side. The ones located along the road can be easily spotted by the rising steam. The hot springs south of Raikot bridge are closely spaced and have a definite linear arrangement.

Key words: Structure, KKH, Nanga Parbat, Nanga Parbat.

L/47. Lawrence, R.D. & Ghauri, A.A.K., 1984. Tectonics of the western Indus suture in Pakistan. EOS 65, p.1094.

The Indus suture extends from southern Tibet to northwestern Pakistan. This is a brief account of the tectonics of the western part of the suture in Pakistan. The suture is associated by mélanges at places. In Ladakh, the Indus suture bifurcates. A minor northern suture, the MKT, records a backarc basin north of the Kohistan andesitic arc. The major suture is south of the arc. It is made up of a complex set of terrains and structures. Ultramafic rocks initially emplaced by obduction, imbricated into subduction zones, and basal to the arc complex can be distinguished. At Dargai, A klippe of obducted material is intricately infolded into metasediments. In Swat, obducted material contains emerald mineralization in ophiolite metamorphosed to talc-carbonate. Subduction complex with blueschist, serpentinite, piemontite schist, and phyllite is preserved at Shangla. From Dargai to Shangla, the southern marginal fault of the suture zone is older than the northern fault mid-Cenozoic metamorphism of the northern margin of the Indian subcontinent occurred under the overriding Kohistan arc. Three units of metasediments are tentatively recognized: twice metamorphosed crystalline schists of probable Precambrian age, once metamorphosed shelf sediments of probable Paleozoic age, and one metamorphosed possible Indus flysch equivalent. The crystalline schists are intruded by augen gneisses, and both are unconformably overlain by the metamorphosed shelf sediments. The entire complex rides south on the Himalayan sole thrust as a tectonic flake. At Jijal, peridotite and garnet granulite are basal Kohistan arc complex; other elements are completely overridden. East of Chilas, the suture complex is cut by the active Rakhiot fault which trends north-south. Plio-Pleistocene Jalipur fluvial sandstones are preserved along the fault. Talus cones, alluvial fans, and glacial sediments are cut by the Rakhiot fault. It brings the psammitic gneisses of the Nanga Parbat-Haramosh complex to the surface. It extends north-south from Sassi to Chilas and probably continues to the Hazara-Kashmir syntaxis. We interpret it as a displacement transfer structure offsetting the Himalayan sole thrust. The MCT terminates against this fault. The Indus suture reappears east of the Nanga Parbat-Haramosh massif in the relatively well known Ladakh area. Previous workers have interpreted the suture zone to loop around the Nanga Parbat-Haramosh loop; we find that it is interrupted and displaced by the loop. The Nanga Parbat-Haramosh massif is not an ancient basement high of the Indian rock, but rather an active Himalayan structure that records the offset on the Himalayan sole thrust.

Key words: Tectonics, Indus Suture, Himalaya.

L/48. Lawrence, R.D., Kazmer, C. & Tahirkhelli, R.A.K., 1983. The Main Mantle Thrust; A complex zone, northern Pakistan. Geological Society of America, Abstracts with Program 15, p.624.

The Main Mantle Thrust, northern Pakistan, brings the Kohistan andesitic arc terrain against the Indo-Pakistani subcontinent and links the Indus suture zone (east) with the paired ultramafic complexes of Waziristan/Zhob/Las Bela and Altimur/Ras Koh (west). It is composed of melange, blueschist, and ultramafic rocks between major bounding faults. Ultramafic rock of three sources is present: that (1) obducted onto the leading, rifted margin of the Indo-Pakistani subcontinent, south side of the Neotethys, in latest Cretaceous/Paleocene, (2) emplaced within the subduction margin of the Kohistan arc, north side of the Neotethys, during Late Cretaceous, and (3) formed as the base of the late Jurassic Cretaceous, 7-8 km thick, Kohistan arc slab. Examples: (1) Dargai klippe and Swat Emerald Mine talc-carbonate slab, (2) Shangla Pass blueschist and Jawan Pass area, (3) Jijal Complex. Types (1) and (2) brought in contact during middle Eocene (?) suturing. Type (3) thrust over suture later during continuing collision. Resultant MMT complex is on top of Precambrian medium-grade metasediments (Salkhala?) with no intervening shelf or deep marine sediments. West of Nanga Parbat Haramosh massif MMT complex is replaced by a single active fault that brings a Tertiary migmatized and metamorphosed slab (High Himalayan slab?) over the Kohistan area.

Key words: Indus suture, MMT, Himalaya. Pakistan.

L/49. Lawrence, R.D., Kazmi, A.H. & Snee, L.W., 1989. Geological setting of the emerald deposits. In: Kazmi, A.H. & Snee, L.W., (eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 13-38. Van Nostrand Reinhold, New York.

In Pakistan emeralds are found in fascinating surrounding. The spectacularly rugged Himalayan ranges (photo. 2.1) capped by the lofty snow-capped peaks of Nanga Parbat (8128m), Rakaposhi (7790 m) and Haramosh (7406 m) are dissected by awe-inspiring canyon of the Indus River which reaches over 6100 meters of relief in places. Farther south the verdant, picturesque Swat valley between pine-clad mountains give way to the barren, hilly and hostile terrain of the Malakand, Mohmand and Bajaur agencies. Though today the emerald occurrences are spread over a fairly extensive belt, their presence was not known until 1958 when the first emerald deposit was discovered at the northern edge of the city of Mingora in Swat (Kazmi, 1983). Since then, a number of deposits or showings of emeralds have been located in Mohmand Agency at Nawe Dand, Gandao (actually green beryl), Pranghar, Bucha, and Khanori; in the Bajaur Agency at Aman Kot and Maimola; in Swat District at Charbagh, Makhad and Gujarkili and in the Gilgit Agency at Khaltaro (fig. 2.1).

Detailed geological prospecting of the Mingora mines (Kazmi, 1983; Kazmi and others, 1984. 1986), has shown that they contain at least three distinct types of emerald deposit which differ in quality. Thus, Pakistan emeralds offer a wide range of color and quality, with the best ones coming from Gujarkili and Mingora mines (Kazmi and others. this volume).

Exquisite as these emeralds are as gems; their geological setting is also wonderful: they are the products of collision between the Indian and Asian continental crustal plates. This history has been briefly described in the previous paper (Kazmi, this volume). The present study indicates that all the emerald deposits and showing in Pakistan except the Khaltaro occurrence are located exclusively in the metamorphosed ophiolitic melange of the suture zone. Although the Khaltaro emerald occurrence is within the Nanga Parbat gneiss, it also is found in close proximity to the suture zone. The geological setting of these deposits is briefly described.

Key words: Gems, gemology, emerald, ophiolites, Swat, Mohmand.

L/50. Lawrence, R.D. & Shroder, J.F., 1984. Active fault northwest of Nanga Parbat. Abstracts, First Geological Congress, Lahore, 50-51.

The Rakhiot fault is a newly identified active fault along the western margin of the Nanga Parbat-Haramosh massif. This active fault offsets the suture zone (MMT) and produces a gap in the trace of the suture. It is an oblique fault with a combination of reverse and right-lateral slip. Active fault features include crystalline basement overriding Quaternary sediments, fault scarps in fan gravels, lines of hot springs, sheared glacial till, offset glacial terraces, and slickensides in fan gravels. The scarp of the famous 1841 landslide is along the trace of the Rakhiot fault. The landslide was triggered an earthquake, presumably associated with the fault, in December 1840 or January 1841, and it dammed the Indus into a lake up to 300 m deep that broke out in June to overwhelm the Sikh army downstream at Attock. The still fresh scar of the landslide is located on the east side of the Indus south of the mouth of the Astor River. The to on the west side of the Indus preserves pressure ridges from the high-velocity movement. The rockslide diamicton is a chaotic mixture of pulverized rock fragments in a friable sandy matrix; the larger clasts are dominantly light colored gneisses. This diamicton is quite distinct from adjacent older semi-consolidated tills and the consolidated Jalipur diamicton that it overlies. The association of massive landslides with active reverse faults is well known and suggests possible future hazard in the area.

Key words: Structure, active faulting, Nanga Parbat.

L/51. Lawrence, R.D. & Shroder, J.F., 1985. Tectonic geomorphology between Thakot and Mansehra, Northern Pakistan. Geological Bulletin, University of Peshawar 18, 153-161.

Geomorphic features between Thakot and Mansehra include, 1) bedrock terraces and an associated knickpoint on Nandihar Khwar, an Indus tributary, 2) deeply weathered residual soils on a relict upland surface called the Chhattar plain, 3) an escarpment developed at the edge of headward erosion into this upland surface, and 4) an incised intermontane sedimentary basin north of Mansehra. Together these features provide new data to be used in reconstructing the history of recent uplift of the Himalaya in Pakistan. They reflect a period of relative tectonic stability during tropical soil development on a surface of rolling hills between about 25 and 5 m.y. ago followed by uplift and erosion of that surface. These residual soils may be an important sediment source for the young intermontane basins developed in association with foreland thrust fault motion during the last 5 my.

Key words: Tectonics, geomorphology, Thakot, Mansehra.

L/52. Lawrence, R.D., Snee, L.W. & Rosenberg, P.S., 1985. Nappe structure in a crustal scale duplex in Swat, Pakistan. Geological Society of America, Abstracts with Programs 17, p.640.

Key words: Structure, duplex, Swat.

L/53. Lawrence, R.D. et. al., (including Tahirkheli, R.A.K. & Ghauri, A.A.K.) 1986. Deformation of crustal rocks beneath suture in western Himalaya, Pakistan. Geological Society of America, Annual Meeting . 18.

Key words: Deformation, Indus suture, Himalaya.

L/54. Leahy, T., 1993. Fluid flow, metamorphism, and magmatism at Nanga Parbat, Pakistan Himalaya. M.S. Thesis, Dartmouth College, Hanover, New Hampshire.

Key words: Metamorphism, magmatism, Nanga Parbat, Himalaya.

L/55. Leake, R.C., Fletcher, C.N., Haslam, H.W., Khan, B. & Shakirullah, 1989. Origin and tectonic setting of stratabound tungsten mineralization within the Hindu Kush of Pakistan. Journal of the Geological Society of London 146, 1003-1016.

Key words: Tectonics, mineralization, Hindukush.

L/56. Leake, R.D., 1983a. Mineralization in the area around Besham, Kohistan, Pakistan. Natural Environmental Research Council, Institute of Geological Sciences, London, 26p. (Prepared for Sarhad Development Authority, Peshawar).

Key words: Mineralization, Besham, Kohistan.

L/57. Leake, R.D., 1983b. Mineralization within the Chitral District, and adjacent areas of North West Frontier Province, Pakistan. Natural Environmental Research Council, Institute of Geological Sciences, London, 30p. (Prepared for Sarhad Development Authority, Peshawar).

Key words: Mineralization, Chitral, NWFP.

L/58. Leathers, M., 1987. Balanced structural cross section of the western Salt Range and Potwar Plateau, Pakistan. Deformation near the strike-slip terminus of an overthrust belt. MS Thesis, Oregon State University, Corvallis, 297p.

Key words: Structure, Salt Range, Potwar.

L/59. Le Bas, M.J., Mian, I. & Rex, D.C., 1987. Age and nature of carbonatite emplacement in north Pakistan. Geologische Rundschau 76, 317-323.

The N Pakistan carbonatites of Loe Shilman, Silai Patti and those within the Ambela complex were formerly considered as comprising one alkaline igneous province associated with a Peshawar rift valley. New data show that these alkaline rocks occur in two distinct periods, Carboniferous and Tertiary, and are not related to any Tertiary rift faulting. K-Ar dates determined on biotites from the Loe Shilman and Silai Patti carbonatites reveal that the carbonatites were emplaced at 31 ± 2 Ma, and along thrust planes, not rift faults. Subsequent movement of the thrusts reset the argon contents in some biotites to indicate a deformation age of 24 ± 2 Ma for the carbonatites at

both localities. The Koga carbonatite in the Ambela complex occurs as a plug associated with nepheline syenites and ijolites, and Rb-Sr isotope determinations on the silicate rocks give dates of approximately 297-315 Ma. The study implies that there were thrust movements associated with the Indian – Asian plate collision more than 31 Ma ago, which is much earlier than the 20 Ma date previously advocated for the initiation of thrusting.

Key words: Carbonates, chronology.

L/60. Lefebvre, L.A. & Malinconico, L.L. Jr., 1989. Gravimetric methods for estimating the cross-sectional area of mass movement deposits in the Karakoram Range, Pakistan. Abstracts with Programs, Geological Society of America 21, p.20.

Key words: Mass movement, Karakoram.

L/61. Le Fort, P., 1975. Himalaya: the collided range. Present knowledge of the continental arc. American Journal of Science 275A, 1-44.

From a presentation of the geological and geophysical characteristics of the Himalayas, the author tries to draw the main features of mountain building. After a common Precambrian story, the Higher and Lesser Himalayas separate in two basins, the northern one on a continental thinned margin, the southern one intracratonic under shallow marine and continental influences. The beginning of this distinct evolution may be traced in both domains by a widespread spilite keratophyre episode. Caledonian and Hercynian periods are only marked by epeirogenic movements and limited volcanism. The four phases of deformation and the three intervenient phases of metamorphism (the third being a retrogression) all belong to the Tertiary orogeny.

The orogeny is composed of distinct cycles. The first ends with collision of the Indian and China plates at the beginning of the Tertiary; it leads to the formation of the Trans Himalaya range and probably develops the first phase of folding and metamorphism in the Himalayas. The second cycle (Miocene) is thoroughly intracontinental with a very large scale subduction along the Main Central Thrust; such movements provide a simple and elegant explanation of the inverted metamorphism observed all along the Himalayas, together with particular tectonic features.

The amplitude of the intracontinental subduction seems to be limited in time; it brings a high rate of erosion whose products are partly accumulated in the foredeep of the range. When movement resumes, after 10 m.y., it takes place along a weaker, more southerly line. The fossilized movements of the Himalayas are now in action along the Main Border Thrust.

Key words: Collision, continental arc, Himalaya.

L/62. Le Fort, P., 1989. The Himalayan orogenic segment. In: Sengor, A.M.C. (eds) Tectonic evolution of the Tethyan Region. Kluwer Academic Publishers, Dordrech, 286-289.

Four major plutonic belts are related to the Meso-Cenozoic orogenic evolution of the Himalaya-Trans Himalaya-Karakoram realm: the Trans Himalaya belt and its satellite Kohistan arc, the Karakoram batholith, the High Himalaya belt and the North Himalaya belt. A fifth one results from the lower Palaeozoic epirogenic events: the 'Lesser Himalaya' belt. The tectonic settings of their production and emplacement are successively reviewed. Among the first four, two results from oceanic subduction along an Andean margin locally branching into an island arc and two result from intracontinental subduction after closure of the oceanic realm. Both Andean belts are made up of very large quantities of highly diversified granitoids produced more or less continuously during 70 Ma at least, whereas the intracontinental ones are limited to a small volume of very uniform anatectic granite produced during a 10-15 Ma period. The production and emplacement in the Andean belts is partly controlled by the obliquity of the convergence between India and Eurasia. The emplacement of the intracontinental belts is even more dependent on the regional tectonic setting. These contrasting belts are case studies probing the depths and mechanisms of their production and giving adequate models for older geodynamic frames.

Key words: Orogeny, Tethys, Himalaya.

L/63. Le Fort, P., 1996. Evolution of the Himalaya. In: Yin, A. & Harrison, M. (eds.), The Tectonic Evolution of Asia. Cambridge University Press, 95-109.

The collage of the three of the Himalaya (the Sub-Himalaya, the Lesser Himalaya, and the High Himalaya) has resulted from a long evolution starting at 50 Ma with the closure of the Tethys ocean and the collision of the Indian and Tibetan continental masses. This evolution can be divided into five periods: a prelude, three main acts, and a postlude. The prelude corresponded to the Andean-type evolution of the northern margin of Tethys during the closure of the ocean; it produced the Transhimalaya and Karakoram ranges, with abundant plutonism and volcanism. The first act was the collision of the northward drifting Indian plate with the accreted continental Eurasia. It was a progressive suturing that can be dated to around 55-50 Ma, on the basis of a survey of the Indian Ocean, the paleomagnetism of the continental masses, and stratigraphic and magmatic observations. It was accompanied by the obduction of a few ophiolitic nappes and the production of very limited eclogites in the northwestern Himalaya. The Alpine period, act 2, was characterized by the development of a large system of nappes overriding the present High Himalaya, with series more than 10-km thick issuing from the suture basin. That period induced the eo-Himalayan metamorphism best represented in the northwestern part of the range. Act 3, the Himalayan period, resulted in a doubly thickened Indian crust along the Main Central Thrust (MCT). Penetrative stretching lineation and S-C-type fabric characterize the deformation of this 5-10-km-thick zone. Gravity collapse, with kilometric folds and normal faulting, with some dextral shear component, was partly contemporaneous with the MCT. Metamorphism inverted below the MCT, and leucogranite magmatism resulted from this thrusting of hot crystalline gneisses over the cooler Lesser Himalayan formations. The protracted convergence between Indian and Asia has resulted in "hyper-convergence", a southward sequence of younging thrusts, the MCT being replaced by the Main Boundary Thrust, itself replaced by the presently active Main Frontal Thrust. This tectonic evolution is also recorded in the sedimentation. The present situation of the postlude is not different from the preceding period, but benefits from actual observations and measurements of such mechanisms as seismicity, uplift, and erosion. With erosion and uplift rates mainly around a millimeter per year, the Himalaya has remained a prominent range since at least 17 Ma, dominating the evolution of most Asia.

Key words: Orogeny, Himalaya.

L/64. Le Fort, P. & Cronin, V.S., 1988. Granites in the tectonic evolution of the Himalaya, Karakoram and southern Tibet. *Philosophical Transaction, Royal Society of London* 326, 281-299.

Four major plutonic belts are related to the Meso-Cainozoic orogenic evolution of the Himalaya-Transhimalaya-Karakoram realm: the Transhimalaya belt and its satellite Kohistan arc, the Karakoram batholith, the High Himalaya belt and the North Himalaya belt. A fifth one results from the lower Palaeozoic epirogenic events: the 'Lesser Himalaya' belt. The tectonic settings of their production and emplacement are successively reviewed. Among the first four, two result from oceanic subduction along an Andean margin locally branching into an island arc and two result from intracontinental subduction after closure of the oceanic realm. Both Andean belts are made up of very large quantities of highly diversified granitoids produced more or less continuously during 70 Ma at least, whereas the intracontinental ones are limited to a small volume of very uniform anatectic granite produced during a 10-15 Ma period. The production and emplacement in the Andean belts is partly controlled by the obliquity of the convergence between India and Eurasia. The emplacement of the intracontinental belts is even more dependent on the regional tectonic setting. These contrasting belts are case studies probing the depths and mechanisms of their production and giving adequate models for older geodynamic frames.

Key words: Tectonics, granites, Himalaya, Karakoram, Tibet.

L/65. Le Fort, P., Debon, F., Pecher, A., Sonet, J. & Vidal, P., 1986. The 500 Ma magmatic event in Alpine southern Asia a thermal episode at Gondwana scale. In: Le Fort, P., Colechen, M. & Montenat, C. (Eds.), *Evolution des Domaines Orogeniques d' Asia Meridionale*. Science de la Terre, Memoir 47, 191-209.

Cordierite-bearing granitic plutons of about 500 Ma emplacement age occur in lesser Himalaya, including the Mansehra granite (consult the following account). Similar rocks of this age in Australia may be a continuity of these. The geodynamic implications of the Gondwana granitoids is discussed.

Key words: Granitic magmatism, Lesser Himalaya, Gondwana.

L/66. Le Fort, P., Debon, F. & Sonet, J., 1980. The 'Lesser Himalayan' cordierite granite belt typology and age of the pluton of Mansehra (Pakistan). Geological Bulletin, University of Peshawar 13, 51-62.

The Manserah pluton is a very typical example of the discontinuous belt of two mica-cordierite granite of the 'Lesser Himalaya'. It is aluminous, quartz rich but feldspar and sodium deficient, and igneous 'microgranular' inclusions are frequent. Severely deformed to the North, the Manserah pluton has been metamorphosed and gneissified during the Himalayan orogeny. Rb-Sr whole rock isotopic data give a well-defined seven point isochron with a Cambrian age of 516 ± 16 m. y. The high initial ratio of 0.7189 ± 6 implies derivation from a source containing a major and very old crustal contribution. The geodynamic framework for the genesis of this huge belt of similar plutons could be that of a simple thinning of a Precambrian shield or that of a late Pan African orogeny.

Key words: Granitic plutons, metamorphism, Mansehra.

L/67. Le Fort, P., Debon, F. & Sonet, J., 1983. The Lower Palaeozoic "Lesser Himalayan Granitic Belt": Emphasis on the Simchar Pluton of Central Nepal. In: Shams, F.A. (ed.) Granites of Himalayas, Karakorum and Hindu Kush. Institute of Geology, Punjab University, Lahore, 217-255.

Simchar pluton is the western-most of the six main granitic bodies emplaced in the Precambrian formations of the Kathmandu nappe South of Kathmandu. Made up of a dominant porphyritic, two mica, sometimes cordierite bearing granite, it is associated with a two mica leucocratic granite. Both form a very characteristic and typical quartz rich aluminous association. Considered by most authors as Cenozoic, it has been deformed and metamorphosed during the Himalayan orogeny by the main phase of deformation.

A Rb - Sr study on whole rock samples gives an isochron age close to the Cambro-Ordovician boundary with a rather high Sr initial ratio. The petrographical, structural, geochemical and chronological characteristics of the Simchar Pluton are quite similar to the other plutons of the Kathmandu nappe, including the Palung one, as to the fifteen or so "Lesser Himalayan" plutons that stretch for 1600 km. There is a remarkable coherence within the "Lesser Himalayan" belt. Moreover the authors have found similar rocks of similar age in the Central Mountains of Afghanistan, the Tibetan Slab of Nepal (Formation III) and Lhagoi Kangri (North Himalayan) belt of Tibet. This very large scale phenomenon seems to be independent from any true orogenesis.

Key words: Granites, Nepal, Himalaya.

L/68. Le Fort, P., Debon, F. & Stebbins, J., 1978. Mise en évidence d'une ceinture de granites a cordierite et enclaves "microgrenues" en Bas-Himalaya "Nepal, Indes, Pakistan. 6 e Reunion Annuelle Science de Terre, Orsay, Societe Geologique de France, p.243.

Consult the preceding accounts for further information.

Key words: Granites, India, Nepal, Pakistan.

L/69. Le Fort, P. & Gaetani, M., 1998a. Geological map of western central Karakorum, North Pakistan, Hindu Raj, Ghamubar, and Darkot areas at 1:250,000 scale. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 108-109.

The authors have produced a new geological map at 1:250,000 scale of the mountainous region of NW Pakistan comprising the Hindu Raj and Ghamubar ranges, and the Darkot area in between. The map includes the Karakorum central granitoid belt, in the region where it is divided into two branches, and the slightly metamorphic Darkot sedimentary group.

The region of the present map covers three main units: two crystalline masses separated by a sedimentary unit: the northern crystalline masses, the Hindu Raj' unit, is mainly made up of plutonic rocks varying from diorite to granite in composition, the granite being in the center, flanked to the north and south by the mafic plutonic rocks. In general, the Chikar meta-sedimentary formations and migmatitic gneisses occur in the northern part; intruded by the

Ishkarwaz pre-Ordovician granitoid, they represent the basement of Karakorum; the middle sedimentary unit, the Darkot unit, is composed of low-grade meta-sedimentary formations, including arenites, slates, and limestones in which Upper Paleozoic bryozoans and brachiopods have been found [1]. We have also found Triassic megalodonts, and possible Cretaceous rudists;

the southern crystalline mass, the Ghamubar unit, is composed of plutonic rocks also varying from diorite to granite in composition, and intruding into a large northern stripe of Aghost gneisses and migmatites.

To the north and north-east, the area is separated by a series of folds, thrusts, and lineaments from the East Hindu Kush, in which outcrops a large Jurassic porphyritic granite outcrops. To the south, the Nialthi meta-sedimentary formation, at least Permian in age, is overlain by the Lower Cretaceous detritic and partly volcanic formations of the Yasin group. Within the Nialthi fm have discovered a separate strip of conglomerate: the Hundur formation. One of the salient feature is the presence throughout the map of extended pinched strips of sedimentary rocks (Reshun and Hundur conglomerates, Dobargar sedimentary horizons) that underline the lenticular shape of the crystalline masses. The large-scale tectonics can be divided into three main phases: a longitudinal stretching with boudinage of the batholith, a left-lateral strike-slip that has doubled the batholith and is probably responsible for the pinched structure of sedimentary formations, and a north-south extension fast enough to produce a layer of pseudotachylite (see Le Fort & Villa, this volume) on the southern side of the 5 to 10 km wide Darkot graben.

Key words: Mapping, Karakoram.

L/70. Le Fort, P. & Gaetani, M., 1998b. Introduction to the geological map of western central Karakoram, north Pakistan Hindu Raj, Ghamubar, and Darkot areas 1:250,000 scale. *Geologica* 3, 1-67 (French version, p.69-93).

These notes introduce a new geological map at 1:250000 scale of the mountainous region of NW Pakistan comprising the Hindu Raj and Ghamubar Ranges and the Darkot area in between. The map includes the Karakoram central granitoid belt, in the region where it is divided into two branches and the slightly metamorphic Darkot group. The two crystalline massifs of the Hindu Raj and Ghamubar are mainly composed of dioritic to granitic plutons, often in tectonic contact, that seem to pertain to Cretaceous time. In addition, on the northern side of the Hindu Raj massif, outcrops of Ishkarwaz pre-Ordovician granitoid, overlain by lower Ordovician sedimentary series. All these granitoids are intrusive to metasedimentary formations of varied metamorphic grade, from epi-metamorphic to magmatic, that represent the basement of the Karakoram range.

The sedimentary series of the Darkot group: at least permo-Triassic in age, have been preserved in a 5-10 Km wide graben, filled by the sedimentary cover series of the Darkot group between the two crystalline ranges. The map also includes the Jurassic plutonic complex of Shushar, intrusive into the Wakhan slates of the Hindu Kush.

The large scaled tectonics can be divided into three main phases: a longitudinal stretching, a left-lateral strike slip that has doubled the major batholithic belt of granitoid, and north south extension enough to produce a layer of pseudotachylite on the southern side of the graben.

Key words: Geological mapping, Karakoram.

L/71. Le Fort, P., Guillot, S. & Pêcher, A., 1997a. HP metamorphic belt along the Indus suture zone of NW Himalaya: new discoveries and significance. *Comptes Rendus del' Academie des Sciences, Paris* 325, 773-778.

Key words: Metamorphism, Indus Suture, Himalaya.

L/72. Le Fort, P., Guillot, S. & Pêcher, A., 1997b. Discovery of Retrogressed Eclogites in the Indus Suture, East of Nanga Parbat-Haramosh massif (Northern Pakistan) the HP Belt of NW Himalaya. Abstract volume, 12th Himalaya-Karakoram-Tibet International Workshop, Rome, Italy, 57-58.

The eastern contact between the Nanga Parbat Haramosh Massif and the Ladakh island arc is a north-south to NNE-SSW boundary known as the Indus Suture or the Main Mantle Thrust. It is a complex ductile shear zone with right-lateral strike-slip more recently reworked by pervasive brittle faulting. Along this contact, close from the confluence between the Stak and the Indus valleys, we have found a series of metric to decametric lenticular bodies of

serpentinized peridotites accompanied by smaller boudins of garnet bearing pyroxenites and amphibolites. These lenses only form a few percents of the 2-km thick contact zone. They belong to the Arc material.

The original paragenesis of the metabasic rocks is clearly retrogressed; diopside clinopyroxene (Jd10) appears as symplectitic association with Na-plagioclase (Ab85), the globularization of the symplectites is typical of the destabilization of omphacites during decompression. Mg-rich garnet is surrounded by amphibole + plagioclase + biotite corona. Most samples remain fresh and are devoid of alteration and weathering. The occurrence of pyroxene inclusions in garnet and the reconstruction from the symplectites of the initial pyroxene gives a 30 to 40 mol.% jadeite. It allows us to evaluate the eclogitic conditions at a minimal pressure of 13 ± 1 kbar and $610 \pm 30^\circ\text{C}$, typical of low- to intermediate-temperature eclogites. The retrogressed assemblage gives a minimal pressure of 8 ± 1 kbar at $610 \pm 30^\circ\text{C}$.

We have tried to find similar occurrences along the Astor section across the eastern Himalaya-Arc contact, some 30-km south of the retrogressed eclogites, but only found high-pressure granulite facies assemblage in Himalayan gneissic material, a few hundred meters from the contact. The rocks are characterized by garnet + diopside clinopyroxene (Jd5-15) + plagioclase (Ab75) $\pm$ rutile primary paragenese. The retrogression is marked by the development of poekilitic ferroan pargasitic amphiboles. P-T conditions of the granulitic stage are evaluated at 10 ± 1 kbar and $700 \pm 50^\circ\text{C}$ whereas the retrogression is characterized by a pressure and temperature drop (6 ± 1 kbar and $570 \pm 50^\circ\text{C}$). Thus, this assemblage very much resembles the HP-granulite facies occurrence of the higher Stak Valley (Pognante et al., 1993), some 20 km north of the new eclogitic occurrence. This suggests that, on the eastern side of Nanga Parbat, the Indian continental crust has been juxtaposed to the present Arc material after an eclogitic metamorphic period, and that they experienced together only the second part of the exhumation process at relatively high-temperature.

The new occurrence of eclogites is located between those reported at the Northwestern margin of the Himalaya (Kaghan Valley, Pognante & Spencer, 1991), 120 km more to the SW, the blueschists of Ladakh (Pashkyum, Shergol, Urtsi, Puga, see Honegger et al., 1989), 130 to 300 km more to the SE, and the eclogites reported in the eastern Ladakh, 400 km more to the ESE (Tso Morari, Guillot et al., 1995). The present eclogitic metamorphism, as the blueschist metamorphism from Ladakh has imprinted oceanic material from the suture, not crustal material of the northern Himalayan margin as in the Kaghan and Tso Morari occurrences. It suggests the existence of a 600-km long HP-LT belt in the northwestern part of the Himalaya probably related to subduction process.

Key words: Structure, mineral chemistry, eclogite, ultramafics, HP metamorphism, NPHM, MMT.

L/73. Le Fort, P., Lemennicier, Y., Lambardo, B., Pecher, A., Pertusati, P., Pognante, U. & Rolfo, F., 1994. Geological Map of Himalaya-Karakoram Junction in Chogo Lungma to Turmik Area (Baltistan, Northern Pakistan). *Journal of Nepal Geological Society* 10. Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal, 81-83.

The circa 800 km² of the map mostly covers the upper Chogo Lungma glacier system flowing into the Basha river, and the Turmik valley, all on the right (northern) bank of the Indus. Previously mapped schematically by Zanettin (1964) and Desio et al. (1985), it has been surveyed by three of our expeditions (1991-1993), it concerns three major units: the High- Himalayan Nanga Parbat - Haramosh crystallines, the Ladakh terrain possibly made up of a back-arc basin, and the Karakoram. These units are thrust on each other along two major fault systems: the Main Karakorum Thrust (MKT) between Karakorum and Ladakh and the Indus Tsangpo Suture (ITS) between Ladakh and Himalaya. The ITS, described as a normal fault in lower Stak (Verplanck, 1986) with a dextral component at Stak La (Pognante et al., 1993) swirls around the Nanga Parbat - Haramosh promontory, whilst the north-dipping more brittle MKT follows a quasi planar trajectory across the entire territory. In addition a leuco-trondhjemitic pod intrudes the ITS west of Remendok.

High-Himalaya: The High Himalaya crystallines consist of kyanite grade paragneiss slightly migmatized (part of the Shengus gneiss of Macin 1986), intruded by a mass of granitic orthogneiss resembling the 500 Ma "Lesser Himalaya" granites. Mafic dykes cutting through the gneisses retain a garnet granulite paragenesis (650-700°C and 8 to 13 kbar, Pognante et al., 1993).

Ladakh: The unit comprises: (1) the Ladakh volcanic arc intruded by numerous plutons and dykes to the SW and SE, and (2) the Greenstone complex or Turmik melange to the NE. The volcanic arc (1) is limited on the map to a band of amphibolites (Askore Fm of Desio) E of Stak La and S of Chogo Lungma glacier, and a granodioritic intrusion at the Turmik-Indus confluence; it is separated at Dasu by a mass of serpentinites from (2). The Greenstone complex is a volcano-sedimentary sequence with numerous limestone horizons and a tectonic melange of meta-volcanics and -sediments. The major lms horizon (Pakora lms) has yielded post-Valanginian rudists (Le Fort et al.,

1992) and separates a southern band of tuffaceous schists from a northern bank richer in mafic material including serpentinite lenses. The complex has been strongly deformed and metamorphosed in an epidote greenschist facies. It is intruded by a granodiorite to gabbro pluton ("Tisar tonalite" of Desio, 1963) in the Shigar valley.

Karakorum: It is the most complex unit. The back bone of the mapped zone is a dome of granitic orthogneisses (Mangol Bluk dome) with an offset migmatitic core (Arandu), and an intrusive contact into the surrounding metasediments. The orthogneisses are thoroughly infolded with the Basha paragneisses bearing kyanite and sillimanite (690 C and 10 kb, Allen & Chamberlain, 1991). Isoclinal folds have been deformed by the doming. On both sides, the folded alternations of marbles, schists, quartzites and amphibolites stretch WNW-ESE, narrowing towards W. They include a few orthogneissic bands (Bolocho, Mooraine gl.) and are intruded by the Karakoram batholith (Solu granite, up Dabadas). Most of the metasediments are in the amphibolite facies with staurolite $\pm$ kyanite and andalusite. The southern limestone (Chutrung lms) follows more or less the contact with Ladakh. A unique syenitic pod (Hemasil syenite) intrudes the metasediments to the SE. In 40 km from E to W, the entire structure thins down to 1/3, as it moulds itself on the Himalayan spur.

Key words: Mapping, Baltistan, Himalaya, Haramosh, Karakoram.

L/74. Le Fort, P., Lemennicier, Y., Lombardo, B., Pecher, A., Pertusati, P., Pognante, U. & Rolfo, F., 1995. Preliminary geological map and description of the Himalaya-Karakorum junction in Chogo Lungma to Turmik area (Baltistan, Northern Pakistan). *Journal of Nepal Geological Society* 11, 17-38.

Some 800 km² of the area lying between the Haramosh Spur of the Southern Karakorum Complex, centered on the Chongo Lungma glacier system, is presented on a preliminary geological map, after three expeditions. It includes three major units from SW to NE: the High Himalayan Nanga Parbat-Haramosh Crystalline (HHC), the Ladakh Paleo Island Arc, and the Karakorum Metamorphic Complex intruded by granitoids. The three units are thrust to the south. The High-Himalayan ortho- and para-gneisses are metamorphosed to granulite facies and migmatized. The Ladakh Arc is made up of two groups of formation, the Askore Amphibolite to the SW and the Greenstone Complex to the NE, separated by a screen of serpentinitized ultramafics. It is intruded by numerous granitoids including a leuco-trondhjemite body cutting the horizons that have yielded post-Valanginian fossils. The Karakorum Metamorphic Complex includes orthogneiss domes of granitoids intruded into the surrounding metasedimentary formations. A syenitic dome of granitoid at Hemasil is apparently syntectonic. Two phases of deformation are observed in Karakorum and Ladakh and seem to correspond, but with different grades of metamorphism. The late doming structures are characteristic of the Karakorum. The Himalaya-Karakorum contact varies from south to north, from normal fault to a strike-slip shear zone, and finally a thrust fault. The original Ladakh-Karakorum contact (Shyok Suture) is folded and reactivated by late brittle thrusting, possibly the latest large-scale deformation of the region. The closure of the Ladakh-Karakorum back-arc basin followed by the collision of India is mostly overprinted by the recent structures.

Key words: Mapping, Baltistan, Haramosh, Himalaya, Karakoram.

L/75. Le Fort, P., Michard, A., Sonet, J. & Zimmermann, J.L., 1983. Petrography, geochemistry and geochronology of some samples from Karakorum axial batholith (northern Pakistan). In: Shams, F.A. (ed.), *Granites of Himalayas, Karakorum and Hindu Kush*. Punjab University, Lahore, 377-387.

Granitoid samples from the Hunza Valley have been studied and analyzed. They include dominant type of biotite - hornblende granodiorites and minor two-mica adamellites. The granodiorites are relatively rich in dark minerals, but feldspar and quartz poor; their trend is typically calc-alkaline with subordinate subalkaline affinity. The granodiorite is always gneissic and very fresh; actually it is a metagranodiorite resulting from the high grade regional metamorphism of a previously emplaced plutonic rock. Three different methods of isotopic geochemistry have been undertaken on some of the samples. The oldest age is obtained by U-Pb on zircons with a lower discordant intersection at 95 ± 8 m.y. Four K-Ar amphiboles gather around 46 m.y. and three K-Ar biotites around 26 M.Y. Younger Rb-Sr and K-Ar mica ages form two groups: around 15 m.y. and around 6 m.y.

The initial Sr ratio appears to be high. The dispersion of ages may reflect the complex history of the Karakorum, mainly: Upper Cretaceous batholithic emplacement. Eocene regional metamorphism at the time of the Indo-Eurasian

collision, Miocene rebound of the Himalaya orogeny. Similarities with the eastern Hindu Kush and the Central Mountains of Afghanistan may help to restore the Cretaceous and subsequent geodynamics.

Key words: Petrography, geochemistry, geochronology, Karakorum axial batholith.

L/76. Le Fort, P. & Pecher, A., 1995. The Scar of the Shyok Suture between Kohistan-Ladakh and Karakoram from Hunza to Baltistan (Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

There is a marked lineament, underlined by discontinuous pods of serpentinized ultramafics that can be followed from the left bank of the Shigar valley in Baltistan to the Hunza valley near Chalt along some 160 km (figure). Our fieldwork from 1991 to 1994 has enabled to follow and map this lineament linking the northern boundary of Ladakh with that of Kohistan. Typically to the north of this line, a formation of polygenic sedimentary conglomerate occurs, whereas to the south volcanic tuffs and breccias are abundant. The three formations belong to the northern suture zone of Pudsey (1986).

The serpentinite lenticular bodies have been observed at the following localities:

just E of Chalt along the Karakorum highway (KKH), an outcrop mapped by Pudsey (1986), cutting the crest on the right bank of the Pisan glacier (Askoro pass) providing boulders on the right lateral moraine of the Minapin glacier, issued from the region of the pass leading to Bualtar valley, between the Sumayar and the Diran peaks, as big boulders on the left bank of the Chogo Lungma glacier, as pebbles in the river bed of Burimis (a right bank tributary of the Chogo Lungma), as boulders in the river cone of Brag Zago (a left bank tributary of the Turmik), forming a 40 m thick lenticular band crossing the Pakore valley, north of the summer huts of Pakore, as two pods described and mapped by Hanson (1989) on the north-eastern slopes of the Shigar.

The polygenic sedimentary conglomerate contains mainly ill-rounded pebbles of recrystallised quartz-arenite and limestone, reaching up to 50 cm in diameter. It is poorly sorted and the matrix is made up of limy sandstone. Volcanic contribution seems to increase progressively towards the south, as shown on the left bank of the Minapin glacier. The outcrops include, from E to W:

outcrops of the Mayon valley (Pudsey, 1986), a thick band of massive outcrops crossing the Minapin glacier around its lower bend, a large formation forming massive peaks on both sides of the Miar glacier, cliffs on the northern side of the pass between the Chogo and Barpu basins, feeding the upper moraines of both glaciers, outcrops of the Spantik base camp, a series of outcrops on the left (northern) bank of the Turmik valley, in particular, 100 m thick north of the summer huts of Pakore, screes on the left bank up to Tisar.

The southern conglomerates, tuffs and volcanic breccias belong to the Greenstone complex of Tahirkheli & Jan (1979), Rakaposhi volcanic complex (Tahirkheli, 1982), or Turmik formation of Desio et al. (1985) (cf Le Fort et al., in press; Rolfo et al., this volume). They are made up of varied mixtures of volcano-detrital rocks, with a constant imprint of mafic volcanism, almost impossible to map in detail. At the foot of the northern crest of the Diran a formation of quartz arenites show beautiful sedimentary features of prodelta distributary channel deposit (graded bedding, climbing ripples, according to G. Allen personal communication); it forms blocks in the moraines of the Minapin glacier.

Change in thicknesses is particularly conspicuous for the northern conglomerate that varies from a few meters, and may even lack in places, to more than a kilometre on the left bank of the Miar glacier. All three formations are deformed and metamorphosed. The deformation of the conglomerates on both sides of the lineament is heterogeneous, mainly of flattening plus constriction type (cigar-like shaped). The metamorphism is of low grade greenschist facies with typical chlorite, biotite, epidote, and acicular amphibole (see also Rolfo et al., this volume).

The lineament is almost vertical and rectilinear through the entire zone, oblivious of any Nanga Parbat-Haramosh Himalayan indenter. The slight bulge to the south that it shows in the eastern portion looks like moulding around the two gneissic domes of Mangolbluk and Dassu (cf Le Fort et al., in press; Lemennicier et al., this volume).

As already emphasized by Hanson (1989), the lineament cuts across tectonic and metamorphic structures. Its age has to be fairly young, most likely contemporaneous of the end of the doming structuration known to be less than 7 Ma (Smith, 1993; Villa personal comm.). The lineament cannot represent the original suture between Karakorum and Ladakh-Kohistan arc, bracketed between 102 and 85 Ma (Pettersen & Windley, 1985), but only the trace of a recent reactivation.

Key words: Ultramafics, structure, Shyok Suture, Kohistan, Ladakh, Karakoram, Baltistan.

L/77. Le Fort, P. & Pecher, A., 1998. A new map of Hunza to Baltistan at 1:150,000 scale, northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 112-113.

The authors are finalizing a new geological map at 1: 150,000 scale of the mountainous region joining Hunza and Baltistan. The map includes the central granitoid belt and the southern metasedimentary complex of the Karakorum range, volcano-sedimentary and igneous formations of the Kohistan and Ladakh island-arc units, and the northern tip of the gneissic Himalayan spur. Some of the salient features evidenced during mapping include:

Lithology: The very continuous marble horizons of the Karakorum metamorphic complex (KMC), some of them of Permian age (see Rolland et al., this volume). The existence of long stripes of orthogneissified granitoid in Karakorum. The reconnaissance of terrigenous formations in south-western KMC. The continuity of the Kohistan to Ladakh formations, limestone horizons in particular, some of them dated as Cretaceous. The existence of ultramafic lineament that separate the island-arc in two domains.

Tectonics: The large isoclinal folding of the Karakorum metamorphic complex (KMC), underlined by very continuous marble horizons. The folding of the Karakorum granites in the isoclinal folds. The presence of a *mélange* zone along the MKT, north of it (Karakorum side) to the west, south of it (Ladakh side) to the east. Folding of the boundaries between the three units, MKT and MMT. Likelihood that some traditionally described formations may actually belong to the neighbouring unit (e.g.: amphibolites in the Himalayan unit). The pervasive doming structure in a band, east of the Raikot fault, cutting across Himalaya-Ladakh and South-Karakorum. The northern tip of the Raikot fault, presently the most active fault, corresponding to the north-western edge of the NPHM dome.

Key words: Structure, mapping, Hunza, Baltistan.

L/78. Le Fort, P., Pognante, U. & Benna, P., 1992. The Himalaya-Karakoram contact: eastern termination of the Nanga Parbat spur (Pakistan). Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.48.

The contact of the Nanga Parbat High-Himalayan crystallines (HHC) with the surrounding low-grade metamorphic rocks has been studied during a geological expedition in the Turmik valley (NW of Skardu in Pakistan). On the HHC side, para- and ortho-gneisses show rather homogeneous high-pressure amphibolite facies assemblages (see companion abstract, Pognante et al., this vol.). The metamorphic foliation, strongly underlined by the banding of the gneisses, dips some 45° east and lies parallel to the contact in the upper Stake and Turmik valleys.

The surrounding rocks belong to the Greenstone complex of Tahirkheli & Jan (1979) and Hanson (1986). It is made up of a *mélange* of greenschists, amphibolites, conglomerates and marbles, all more or less lenticular, strongly deformed and metamorphosed in an epidote greenschist facies. The size of the lenticular bodies varies from several meters to a few kilometers in thickness. In the northern tributary valley of Pakora on the way to the Gonto-La, we have found fine grained black muddy limestone containing deformed recrystallized white shells of rudists. At least three different shapes of rudists are present, the age being most likely post-Valanginian, possibly Barremian-Aptian ? (J.P. Masse pers. comm.).

The Greenstone complex comprises tuffaceous schists, banded amphibolites, volcanic breccias and conglomerates, and at least one large occurrence of a body of gabbro. In addition, several screens of serpentinized ultramafics are distributed in the Turmik *mélange*, the major one underlining its southern boundary with a plutonic member of the Ladakh batholith, at the lower end of the valley (Dasu). Going up the Turmik valley, the foliation rotates from a northern to an eastern dip. In the upper reaches of the valley, the foliation is strongly refolded by a crenulation that has accompanied, under greenschist metamorphic conditions, the differential rise of the HHC gneisses.

Key words: Structure, mapping, Hunza, Baltistan.

L/79. Le Fort, P., Pognante U. & Rolfo F., 1995. Preliminary geological map and description of the Himalaya-Karakoram junction in Chogo Lungma to Turmik area, Baltistan, Northern Pakistan. Journal of Nepal Geological Society, 11, special issue, 17-38.

Key words: Mapping, Himalaya, Karakoram.

L/80. Le Fort, P., Tongiorgi, M. & Gaetani, M., 1994. Discovery of crystalline basement and Early Ordovician marine transgression in the Karakoram mountain range. *Geology* 22, 941-944.

A granite pluton intruding low-grade quartzites and migmatites lies north of the Karakorum axial batholith of Cretaceous to Miocene age. The pluton is covered by transgressive litharenite and slate that contain a fairly rich assemblage of acritarchs of Arenigian age (Early Ordovician), belonging to the Peri-Gondwana biogeographic province. This is the first time that crystalline basement has been found in Karakorum and acritarchs in central Asia. These discoveries add new evidence that the Karakorum microplate, together with the Helmand block of central Afghanistan and the Lhasa block of Tibet, belongs to a Cimmerian domain at the northern fringe of Gondwana.

Key words: Ordovician, marine transgression, granite pluton, Karakoram.

L/81. Le Fort, P. & Villa, I., 1998. Pseudotachylites at crustal scale in Karakorum: the Thui pseudotachylite, northern Pakistan. *Geological Bulletin, University of Peshawar* 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop), 114-115.

The Karakorum mountain belt is typically divided into three main units: a northern sedimentary belt (NSB) and a southern metamorphic complex (KMC) separated by a central granitoid batholith (CGB) often referred to as the Axial batholith. In the western part of the Karakorum Mountain, two crystalline belts occur: a northern Hindu Raj belt, that includes Darkot pass and Garmush crystalline masses, and a southern Ghamubar belt, that are separated by the Darkot unit of mildly metamorphosed sedimentary series (see Le Fort & Villa, this volume).

In 1996, during the course of our regional reconnaissance and mapping of north-western Karakorum, with Maurizio Gaetani, we have discovered that the northern side of the Ghamubar belt is profusely invaded by a band of pseudotachylite. From north to south, the generally north-dipping section comprises:

the 4 to 7 km wide Darkot unit that had yielded Permian fossils and where we have retrieved Triassic megalodonts, and possible Cretaceous rudists (Gaetani, pers. comm., 1996); a tightly folded and metamorphosed contact zone, about a 100 m thick, mainly made up of black silicic schists at the top and quartzites at the base; the km-thick zone of Aghost banded gneisses, mostly granitic, but also containing very dark biotite and/or amphibole gneisses, as well as several group of layers of marble, presenting tight isoclinal folds usually north-verging. The Thui pseudotachylite fringes the northern boundary of this Aghost formation; a several km thick and massive zone mainly composed of biotite-garnet-sillimanite gneisses interlayered with granitic gneisses and partly migmatized. To the south, this zone is intruded by the Ramach granodiorite and the Ghamubar porphyritic granite (Ghamubar plutonic unit).

We have followed the Thui pseudotachylite for more than 40 km East-West, between Gazin glacier (Yarkhun valley), and summer settlement of Ghamubar (Darkot valley) at the eastern foot of the Ghamubar pass. More to the east, the pseudotachylite seems to pass to ultramylonitic bands within the Aghost gneiss. Vertically, it extends for nearly 3 km. The best set of outcrops is located in the upper Kerun Bar valley where the pseudotachylite forms most of the southern slope, and has a total thickness probably exceeding 10 m.

In the field, the rock appears as centimeter- to millimeter-thick black streaks anastomosing within the Aghost gneiss, disregarding the orientation of the metamorphic foliation. The disposition of the veinlets reminds of the hydraulic fracturation. The intruding dark veins have a glassy appearance, a conchoidal fracturation, and contain many cataclastic disrupted remains of the enclosing rock. Under the microscope, the veins have an isotropic texture. In the "basal shales" of the overlying Darkot group, the pseudotachylite develops a few meters thick "contact metamorphism" with micas and, occasionally, garnet. It is very little deformed: on a unique outcrop, we found it to be folded at 50 cm-scale. For the moment, ³⁹Ar/⁴⁰Ar dating by stepwise heating shows the predominance of inherited clasts from an older protolith. This apparently largest so far discovered pseudotachylite, is related to the fast collapse of the sedimentary cover along the top of the southern crystalline mass. One of the latest tectonic movement of the region, it has produced the Darkot graben.

Key words: Tectonics, Karakorum.

L/82. Leghari, A.L., Khan, I.H., Khan, F. & Wazir, A.K., 1986. Occurrence of sulphide mineralization in Nomal area (Toposheet 42 L/8), Gilgit District, Pakistan. *Geological Survey of Pakistan, Information Release* 268.

Massive sulphide mineralization zone have been found in volcanics and metasediment arc rocks (Greenstone Complex) of Lower Cretaceous age in Nomal area about 25 km north of Gilgit (toposheet No.42 L/8). The mineralization is exposed in an area of 7.5 sq.km approximately. This sulphide zone is recognized as highly weathered and altered product of original rocks being pale, brownish, reddish and black in colour in the upper portion of the outcrop. During geological mapping of the area, 29 samples were collected and chemically analysed.

Majority of samples show very encouraging anomalies of massive sulphide mineralization. The metallic content of analysed samples (Table 1) shows that out of 29 samples, all samples contain Fe (averaging 4.17%), 27 samples with Mn (944 ppm), 25 samples have Cu, (353 ppm), 22 samples average in Zn (108 ppm), 6 samples with Pb (550 ppm), 2 samples show content of Au (as 0.65 and 1.03 ppm), two samples have Ag (one with 69 ppm content and other with traces) and finally 9 samples show traces of Mo. Two samples collected from Naltar Gah, northwest of Nomal where volcanics are exposed contain Mn (as 848 and 986 ppm) and Cu (as 7900 and 350 ppm), (Table-1). This report is based on field investigations and chemical analyses, and will be followed by a more comprehensive account of field work and laboratory studies which may prove the area promising for further study of sulphide mineralization.

Key words: Sulphide, mineralization, Nommal, Gilgit.

L/83. Leghari, M.B., 1990-91. The geology, stratigraphy, sedimentation and micro-paleontology of Jabri area District Haripur Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 106p.

The project area is located in district Haripur (N.W.F.P). It covers about 60 sq. km. It is the part of topographic sheet No.43 G/1 published by Survey of Pakistan at the scale of 1: 50000. Geological map at the scale 1:12500 of Jabri, Akhora, Faqir Muhammad, Lassan and Dunna Naural area is presented along with complete record of Pre-Cambrian to Eocene rock units especially, Hazara Formation, Samana Suk Formation, Chichali formation, Lumshiwal Sandstone, Kawagarh Limestone, Margala Hill Limestone, Chorgali Formation, exposed in the area. On the basis of field observations and petrographic studies the depositional environments of rock units have been interpreted. The formations exhibit varying fauna and lithology and microfacies from bottom to top.

Basal unit i.e. Hazara Formation which is predominantly slates and Samana Suk Formation which is mainly oolitic Limestone and shows shallow marine environment. The Chichali Formation which is dominantly Black slates with Iron Pyrite nodules, is the result of anaerobic conditions (lagoon environments) Glauconitic and ferrogenous Sandstone of Lumshiwal Formation shows open marine shelf environment. Kawagarh Formation possess mainly, fine grained micritic Limestone, which show deep sea environment.

Hangu Formation having laterite Bauxite, limonite, quartzite, red clays, Oolitic Haematitic sandstone and Carbonaceous shales which represent facies change and shows that the area was eroded during that time of deposition and marks unconformity between Cretaceous to lower Paleocene which is the result of regression of the sea for long period. Lockhart Limestone is mainly nodular, Limestone, medium to fine grained with bituminous smell having shales and marl at various places which shows shallow marine environment.

Patala Formation having Khaki shales with fossiliferous Limestone and marl which shows that the environment is shallow marine (Circa littoral sub zone).

Margala Hill Limestone is fossiliferous, nodular Limestone, which also shows shallow marine depositional environment. Chorgali Formation consists of Limestone flaggy marly having abundance of fossils of larger sized forams. It shows shelf environment. The thin section slides from Jurassic to Eocene rock units have been studied. Petrographically Samana Suk Formation (Jurassic) Lockhart Limestone (Paleocene) and Margala Hill Limestone (Eocene) have been studied in detail.

Samana Suk Formation is normally wack to pack stone, according to Dunham's classification, fossiliferous to packed biomicrite, according to Folk's classifications, Lockhart Limestone is normal to wackstone according to Dunham's classification and biomicrite according to Folk's classification. Margala hill Limestone biomicrite, biosparite and spary biomicrite according to Folk (1962) according to Dunham (1962) it is dominantly wackstone, grain stone and pack stone. The measured stratigraphic section of the rock units from Pre-Cambrian to Eocene is presented in Lithology. No. 5 (Pocket). Tectonically the area is highly disturbed, being involved in Himalayan Orogeny. Geological sub surface structures are described with the help of cross section, Almost all the structures follow the general trend NE-SW. From the cross section line along AB shows that intensive deformation in the area. Some important folds are Dunna Naural anticline, Dotara anticline and syncline, Dubran anticline, Langrial syncline. The project area is highly faulted, the major faults are Karral Haro thrust fault, Langrial Thrust fault,

Kohala Lasan fault, Jabri fault, Dubran fault. The Economic potential of Limestone of various rock units, laterite and aggregate have been discussed.

Key words: Stratigraphy, sedimentation, paleontology, Haripur, Hazara.

L/84. Lemennicier, Y., 1996. The south Karakorum metamorphic complex in the Chogo Lungma area (Baltistan, N. Pakistan). Structural, Metamorphic, Geochemical and radiochronological study. *Geologie Alpine*. Universite de Grenoble, Memoir 26, 171p.

Key words: Structure, metamorphism, geochemistry, chronology, Karakorum, Baltistan.

L/85. Lemennicier, Y., Le Fort, P., Lambardo, B., Pecher, A. & Rolfo, F., 1995. Tectonometamorphic evolution of the central Karakoram (Baltistan-Northern Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich), Switzerland.

The tectonometamorphic history of the Karakorum has already been considered by several workers, e.g., Bertrand et al (88), Allen & Chamberlain (91), Searle & Turrill (91), but timing and interpretation of this evolution are still discussed. We present here new structural and metamorphic data from the Chogo Lungma glacier area and Basha valley, at the northeastern side of the Nanga Parbat - Haramosh spur.

A multi-stage structural evolution has been observed, including a first cryptic tectonometamorphic event (not visible at field scale but deduced from the mineral fabric and chemical zoning of minerals), followed by two main syn-metamorphic episodes plus a late folding event.

The first event (we may call it D0, the first event recognized in the field being referred to as D1), is defined by a metamorphic cleavage within garnet porphyroblasts, underlined by quartz and opaque inclusions, and only visible in the innermost part of garnet. This cleavage is oblique on the main foliation, which at turn can be overprinted by the later garnet rims.

The main tectonometamorphic event (D1) is characterized by south vergent 61 isoclinal folds (Fig.1-a) at all scales (plurimillimetric to plurihctometric), associated with a metamorphic axial-plane cleavage Si. The axial planes of those folds always strike around N110°E, with a dip of 60° to 70° northward. The plunges of the fold axis are dispersed in the average axial plane, and are usually steep (pitches from 70°NW to 60°SE). It indicates that the folds were probably formed in response to a high flattening rate of deformation, with vertical extrusion of the pinched material. The predominantly flattening regime of deformation is also emphasized by the dispersion of boudin axes in the flattening plane, the presence of circular flattened enclaves, as well as the scarcity of coherent shear criteria. A medium pressure / medium to high temperature peak metamorphism (Mi) with Grt-Bt-Mu-Ky paragenesis corresponds to D1 (620 to 730°C and 7.5 to 11 Kbar; Fig. 2).

The D2 tectonometamorphic event corresponds to the development of several conical dome structures, in which D1 isoclinal folds are refolded. The dome structures, drawn by the main metamorphic cleavage inherited from D1, have N110°E to N140°E elongations. The S₂ cleavage is scarcely individualized as it usually corresponds to a reworking of Si. For this reason, it is often difficult to interpret metamorphic fabrics. In some areas, late evolution of the D₂ doming deformation is marked by a crenulation. Petrologically, D₂ is characterized by shearing and boudinage of M1 minerals, and by development of sillimanite. Thus, M2 corresponds to a retrograde evolution in the sillimanite field, with slight changes in temperature, but with a pressure decrease (from more than 7.5 Kbar down to 4 Kbar; Fig.2).

The interpretation of the dome structures can also be debated. The diapiric model, which may be now suitable to explain Archean domes (Choukroune et al, 1994), appears to be very much dependent of the rheology of the crustal component involved. The Metamorphic Core Complex model, associated with extensional mechanisms (Brun & Van Den Driessche, 94), fits rather well with the observed regional pattern, and could apply to the Panmah dome described by Bertrand et. al. (1988) north of Korophon. However, in the Chogo Lungma area, we have no evidence of extensional ductile fabrics or of normal faulting. For Ramsay (1987), doming can be due to heterogeneous shortening. Such heterogeneous strain is easily obtained around an indenter, such as the Nanga Parbat - Haramosh spur.

The D3 event corresponds to large undulations and open folds, as, e.g., the Spantik fold, which affect the D2 crenulation. Actually, D3 seems to be the continuation of D2. The complex tectonometamorphic evolution described here has also been observed by previous workers, but different interpretations have been proposed:

-For Bertrand et al. (1988), the evolution is a two-step's evolution, with (i) the main metamorphic episode related to the D1 isoclinal folds, predating the emplacement of the Mango Gusor granite, dated at 37 ± 0.8 Ma (U-Pb datation on zircon, Parrish & Tirrul, 1989), and (ii) a distinct Miocene metamorphism and deformation, with open folds and doming;

-For Allen and Chamberlain (1991), the whole tectonometamorphic evolution predates the Mango Gusor granite emplacement. They consider that the main metamorphic imprint was acquired earlier than the main deformation, and for them, the observed metamorphic pattern is mainly due to the stacking of two nappes, separated by a thrust.

In the Basha and Chogo Lungma area, the metamorphism is clearly synchronous with the deformation: kyanite grows in the S1 foliation plane and the sillimanite development corresponds to the doming deformation. This evolution can also be seen in the garnets associated with sillimanite, in which transects indicate a retromorphosis of the rim. Considering the timing of the tectonometamorphic events, for the doming phase (D2), preliminary $^{40}\text{Ar}/^{39}\text{Ar}$ results on amphibole and biotite (I. Villa, personal communication) give very young ages (<10 Ma), in good accordance with the Miocene ages proposed by Bertrand et al. (1988) for their second metamorphic and tectonic event. We have no good constraints for the D1 age. If we consider the interpretation of the previous authors, it could predate the Mango Gusor granite, and be related to the main continental collision. However, the pattern of the metamorphic PT path (Fig.2) corresponds to rapid exhumations' rates which do not fit quite well with a long gap of time between M1 and M2. The different phases could be part of a continuum of deformation.

We have not been able to define clearly the western prolongation of the Gama Sokha Lumbu thrust described by Bertrand et al (1988). However we have mapped orthogneiss sheets intercalated in the metasedimentary formations, north of Chogo Lungma glacier. They could indicate nappe stacking, but we have not found shear criteria at their contacts. They could also be interpreted as laccolitic intrusions of granites into the sedimentary pile, previous to the main D1 isoclinal folding and metamorphism. The occurrence of retromorphosed chistolitic andalusite (relics of contact metamorphism?) could validate this second hypothesis.

Altogether, the tectonometamorphic evolution of central Karakoram remains difficult to set into a global geodynamic frame. The recent age of the D2 event implies that most of the observed tectonometamorphic evolution is fairly young. The early evolution of this portion of crust may still be blurred by this more recent activity. If this is true, central Karakoram offers the possibility of being a young collision range.

Key words: Tectonometamorphism, Karakoram.

L/86. Lemmenicier, Y., Le Fort, P., Lombardo, B., Pêcher, A. & Rolfo, F., 1996. Tectonometamorphic evolution of the central Karakoram (Baltistan, northern Pakistan). *Tectonophysics* 260, 119-143.

New structural and metamorphic data from the Chogo Lungma glacier area and Basha valley enlighten the polyphased tectonometamorphic evolution of the Metamorphic Complex of Karakorum. A pre- to early D1 event is defined by a metamorphic cleavage in the core of some zoned garnet and staurolite porphyroblasts. The main tectonometamorphic event (D1) is characterized by N110°E south-vergent isoclinal folds associated with a metamorphic axial-plane cleavage formed in a predominantly flattening regime of deformation. It corresponds to a Grt-Bt-Mu-Ky peak metamorphism (M1: 620–730°C and 7.5–11 kbar). The D2 tectonometamorphic event corresponds to the development of several conical domes elongated striking N110°E to N140°E. The S2 cleavage is seldom individualized as it usually corresponds to a reworking of S1. In some areas, late evolution of D2 doming deformation is marked by a crenulation. Petrologically, D2 is characterized by shearing and boudinage of M1 minerals and by development of sillimanite. It corresponds to a decompressional evolution (7.5 down to 4 kbar) with only slight changes in temperature. A late event corresponds to large undulations and open folds which affect the D2 crenulation. We propose here a model of vertical plus dextral extrusion of the middle crust to explain the dome structures in Karakorum. The steep pattern of the metamorphic *P-T* path implies rapid exhumation rates and suggests that the different phases could be part of a continuum of deformation. Preliminary results by $^{40}\text{Ar}/^{39}\text{Ar}$ method give young cooling ages (<10 Ma) for the D2 event (Villa et al., 1996, this issue). Thus, most of the observed tectonometamorphic evolution in central Karakorum could be fairly young.

Key words: Tectonics, metamorphism, Karakoram.

L/87. Lemennicier, Y., Le Fort, P., Pecher, A., Lapierre, H. & Rolfo, F., 1996. The Hemasil Syenitic Dome: An example of Miocene Syn-Orogenic Alkaline Magmatism, Karakoram-N

Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 85-86.

The Hemasil syenite is a small pluton intrusive in the continental formations of the Karakoram metamorphic complex near its southern contact with the Ladakh-Kohistan island arc formations. The syenite is emplaced in late Miocene times (Villa et al., in press) as a dome-shape pluton during the last tectonometamorphic event affecting the area in a compressive + transcurrent context associated with high denudation rates (Lemennicier et al. in press). It is a leucocratic rock with a fK-P1-B±Am±Sph main paragenesis and rare feldspathoids (sodalite). It is ferri-ferous and extremely potassic (7.0 to 10.6 wt% K₂O), with K₂O/Na₂O ratios from 1.15 to 5.24. La/Lu ratios are high (60.0 to 117.2). However, it shows a strong heterogeneity in trace elements composition with two main populations: population 1 enriched in MREE, Ba, Sr, V and slightly depleted in U, Th, Hf, Zr; population 2 normal in MREE, slightly enriched in HREE, enriched in U, Th, Hf, Zr, and strongly depleted in Ba. The same heterogeneity is observed in isotopic data recalculated at t=10 Ma (Fig. 2): population 1 has eSr = -2.3 and 3Nd = +4.3, whereas population 2 has positive eSr (+8.1 +/- 14.7) and slightly lower eNd (+3.0 to + 3.6). There is no isotopic correlation between the two populations. The variation cannot be explained by simple fractionation processes nor by alteration phenomena (very fresh rocks), but is more probably reflecting source heterogeneities or contamination processes. Whole rock isotopic ratios suggest a slightly depleted mantle source, mainly for population 1, but slightly enriched in strontium for population 2. However, trace elements indicate an obvious contamination, but different for each population. In addition, the trace element composition resembles that of the lower crust, except for incompatible elements. Lower crust can thus represent the (or a) contaminant. Actually, the Hemasil syenite, though it is emplaced in a continental collision chain, would result from partial melting of a mantle source contaminated, during its ascent, by a limited addition of lower crust material.

Key words: Syenitic dome, Miocene, alkaline magmatism, Karakoram.

L/88. Lemennicier, Y., Villa, I.M., Le Fort, P., Pecher, A. & Briner, A., 1997. New ⁴⁰Ar/³⁹Ar age constraint on the metamorphic evolution of Karakoram metamorphic complex in Braldu and Chogo Lungma Areas, NW Pakistan. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 171-172.

The Karakorum Metamorphic Complex (KMC), the northern margin of the Cretaceous Neotethys, is composed of amphibolite facies gneiss (ortho- and para-) domes and metasedimentary formations. Its tectono-metamorphic evolution includes a first phase of south vergent isoclinal folding of unknown age and a second phase of doming considered as Tortonian (see Le Fort et al., 1995; Lemennicier et al., 1996; Villa et al., 1996).

Ten new samples from the KMC have been analyzed by ⁴⁰Ar/³⁹Ar stepwise heating: 4 amphiboles from the Basha-Chogo Lungma area and 6 micas from the Braldu valley on the Dassu dome, east of the Basha valley.

All amphiboles have been separated from orthogneisses, viz. mafic dykes or layers. The first amphibole (Moraine gl), collected far from the dome area in the isoclinally folded metasedimentary formations, is recrystallized. It gives a little-disturbed age spectrum around 55-60 Ma. The three other amphiboles come from the Mangol Block dome sector and give well-resolved mixed-phase degassing, with the younger amphibole generation ≤20 Ma and the older one >120 Ma for two samples.

From five granitic orthogneiss samples of the Braldu valley we dated five biotites and one muscovite. The biotites yield ages between 4 and 8 Ma, although they have been collected in similar structural position within the dome. The muscovite shows a clear mixed-generation spectrum with a young generation around 7 Ma and an old generation certainly >35 Ma.

Interpretation

The amphibole from the metasedimentary formations is sufficiently far from the dome area to be not affected by their thermal effect. Its age could be interpreted as the age of the amphibolite-facies isoclinal folding, and be related to the India-Asia continental collision for the western part of the Himalayan orogenesis. However, the span of some 45 Ma between folding and doming questions the continuum of metamorphism between the two phases (as had originally been proposed by Lemennicier et al., 1996).

The young amphibole generation of the three samples from the dome is compatible with our identification of a -10 Ma doming event in that area (Villa et al., 1996), and of a partial overgrowth of the amphibole, without rejuvenation of the old cores. The old amphibole generation suggests a minimum Jurassic age for the protolith of the KMC.

The ages of the micas from the Dassu dome confirm the already published data (~5 Ma: Searle & Tirrul; 1991; Smith, 1993). They show that the Miocene evolution of the Dassu dome and Basha valley domes is similar, and emphasize the 10 Ma event. The data scatter between 4 and 8 Ma for the biotites is difficult to interpret. Numerous (up to 10 Vol %) pegmatitic dykes cutting the foliation are present in this area, and they possibly have an influence on the age of the orthogneiss biotites. The mixed-generation muscovite gives informations similar to the amphiboles from the Basha domes.

These new data seem to point to a Paleocene metamorphism linked to south vergent isoclinal folding, but this age needs to be confirmed by a larger sampling in areas not affected by the doming. The second tectonometamorphic event results in neoformation of micas and (incompletely resolved) amphibole overgrowth between 10 and 4 Ma. Thus, the development of the KMC crust is not just a simple high-grade metamorphism followed by “episodic uplift”, but a more complex geological evolution comprised of a Mio-Pliocene shearing causing recrystallization of micas and amphiboles under amphibolite grade conditions.

Key words: Chronology, metamorphism, evolution, Karakoram, Chogo Lungma, Braldu.

L/89. Li, J., Derbyshire, E. & Shuyina, X., 1984. Glacial and paraglacial sediments of the Hunza valley, North West Karakoram, Pakistan - A preliminary analysis: In: Miller, K.J. (ed.), *The International Karakoram Project 2*, 496-535. Cambridge University Press.

The tills of the upper Hunza region include both lodgement and meltout types. Particle size analysis shows them to be relatively coarse-grained and somewhat positively skewed. There is evidence of modification of the particle size distribution by melt water eluviation, especially in the case of the Ghulkin and Pasu glacier deposits by the role of bedrock lithology and glacier size is also discernible. Tills currently being deposited are predominantly of meltout type: these have diffuse fabrics, rather granular matrixes and contain evidence of eluviation and collapse. Re-deposition of the abundant coarse supraglacial debris by sliding under gravity is common. The thickest exposures of compact and sheared lodgement till, on the other hand, are of Pleistocene age, especially those of the main valley (t2), diffuence col (t3) and expanded foot (t4) stages. There is no evidence of direct deposition of till by viscous flow either during or since the Pleistocene although the abundant debris flows do contain glacial material. It appears likely that the present combination of high-activity glacial regimes and arid to semi-arid valley floor climatic conditions have prevailed since at least the beginning of the late Pleistocene. The distribution of the dense, jointed lodgement tills of Pleistocene age is consistent with their deposition in generally free-draining environment beneath thick glaciers. The genetic classification of tills based on field relationships is generally confirmed by laboratory-derived data on particle size, particle shape, stone orientation and fabric.

Key words: Sedimentology, glacial till, Hunza, Karakoram.

L/90. Lillie, R.J., 1991. Evolution of gravity anomalies across collisional mountain belts: clues to the amount of continental convergence and underthrusting. *Tectonics*, 10 (4), 672-687.

A series of density models illustrates the gross form of free air and Bouguer gravity anomalies anticipated during ocean basin closure and consequent development of collisional orogens. When compared to gravity anomalies observed across some mountain belts, the hypothetical anomalies provide a clue to the degree of under thrusting of crust associated with one lithospheric plate beneath crust of the opposing plate margin. The results of the study suggest very early stage collision in the Ouachita Mountains of Arkansas and the Sulaiman Range of Pakistan, with thin transitional or oceanic crust still intact on the lower plate. In contrast, the Himalaya of Pakistan represent a much more advanced stage of collision, where continental crust may have underthrust the mountains for 600 km.

Key words: Collision belts, orogeny, geophysics, Suleiman Range, Pakistan.

L/91. Lillie, R.J., 1996. Foreland Fold-and-Thrust Belts of the Western Himalaya: diversity due to differing stages of continental collision. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 87-88.

The active foreland fold-and-thrust belts of western India and Pakistan show a variety of deformational styles that relate to the type of crust beneath the decollement. Studies incorporation surface, drill hole and seismic reflection profiles reveal differences in thickness of strata, lithology, and overthrust wedges taper; the differences relate to varying degrees of underthrusting of the Indian continental margin.

In India and northern Pakistan, there have been several hundred km of convergence since collision, so that the full-thickness craton India constitutes the underthrusting plate in the Sub-Himalaya (Duroy et al., 1989). The pre-collisional (Mesozoic and older) strata associated with the craton are only about 1 km thick; the buoyancy of the thick craton limits the thickness of post-collisional molasse to only 5 km. In the Sulaiman Range to the southwest, convergence since collision has been minor, so that the Mesozoic passive margin of India constitutes the lower plate. Seismic reflection profiles show that the undeformed sedimentary strata in front of the Sulaiman Range are 10 km thick (Humayon et al., 1991); cross-section balancing suggests that the deformed sedimentary package in the Sulaiman interior may be considerably thicker (Jadoon et al., 1994). These thicknesses are possible because the sediments rest upon thin crust of the continent-to-oceanic transition; the thick sediments are compensated by shallow mantle of the Mesozoic passive margin.

The nature of the crust of the Indian Plate influences the thickness and composition of overlying strata, thereby affecting the critical taper angle (basement + topographic slope) necessary for overthrusting (Davis and Lillie, 1994). The thin sedimentary package that overlies the Indian craton generally deforms in a brittle regime. Beneath the Sub-Himalaya of India there is strong coupling between sediments and basement, so that a broad critical taper angle ($>5^\circ$) is observed. An exception occurs in Pakistan, where evaporites of the Salt Range Formation behave ductily; the necessary critical taper angle is narrow ($\approx 1^\circ$; Jaume and Lillie, 1988). Beneath the central Salt Range and Potwar Plateau, seismic reflection profiles (Lillie et al., 1987) reveals that the basement slope alone is sufficient to provide critical taper; not topography slope is required, so that the region is translated southward with little internal deformation. In the eastern Potwar Plateau the basement slope is less than 1° , so that distributed deformation builds the topography necessary for critical taper (Pennock et al., 1989). In the Sulaiman region, carbonates of the Mesozoic passive margin may be buried so deeply that they are ductile, producing a narrow critical taper angle.

Along virtually all the deformation front of the Sub-Himalaya, only very young molasse is exposed. The notable exception occurs where the entire sedimentary section (Eocambrian to Recent) is brought to the surface along the Salt Range Thrust. Reflection profiles reveal that ramping occurs where the salt decollement is offset by a basement normal fault (Baker et al., 1988). The normal fault, within the underthrusting craton, was apparently caused by flexure of the Indian Plate as it was loaded by weight of the Himalaya. The modern expression of the flexural bulge is the Delhi-Sargodha Ridge, revealed by Precambrian outcrop in the Kirana Hills of Pakistan.

Key words: Foreland basin, seismology, structural geology, collision, Himalaya.

L/92. Lillie, R.J., Johnson, G.D., Yousaf, M., Zamin, A.S.H. & Yeats, R.S., 1987. Structural development within the Himalayan foreland fold-and-thrust belt of Pakistan. In: Beaumont & Tankard (eds.), *Sedimentary basins and basin-forming mechanisms*: Canadian Society of Petroleum Geologists, Memoir 12, 379-392.

For further information, consult the preceding work.

Key words: Foreland basin, structural geology, Collision, Himalaya.

L/93. Lillie, R.J. & Yousaf, M., 1986. Modern analogs for some mid crustal reflection observed beneath collisional mountains belts. *Reflection Seismology Geodynamics Series* 14, 379-392.

Key words: Reflection seismology, collision belts, orogeny, Sulaiman Range, Himalaya.

L/94. Lindsay, E.H., 1987. Cricetid rodents of Lower Siwalik deposits, Potwar Plateau, Pakistan and Miocene mammal dispersal events. *Evk Magy All Foldt Intez [Budapest]* 70, 483-488.

Key words: Paleontology, rodents, siwaliks, Potwar.

L/95. Lindsay, E.H., 1988. Cricetid rodents from Siwalik deposits near Chinji Village. Part I: *Megacricetodontinae, Myocricetodontinae and Dendromurinae*. *Palaeovertebrata*, 18 (2), 95-154.

Key words: Palaeontology, rodents, Chinji Formation, siwaliks.

L/96. Lindsay, E.H., 1994. The fossil record of Asian Cricetidae with emphasis on Siwalik cricetids. In: Tomida, Y. & Setoguchi, C.K.L.T. (eds.), Rodent and lagomorph families of Asian origins and diversification. National Science Museum, Tokyo, Monographs, 8, 131-147.

Key words: Palaeontology, rodents, siwaliks.

L/97. Lindsay, E.H., 1996. A new eumyarionine cricetid from Pakistan. Acta Zoologica Cracoviensia, 39 (1), 279-288.

For further information, consult the following.

Key words: Palaeontology, rodents, siwaliks.

L/98. Lindsay, E.H., 1997. A new eumyarionine cricetid from Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 57.

Miocene deposits in four areas of Pakistan (Potwar Plateau, Trans-Indus area, Sulaiman foothills, and Balochistan) have produced a rich and diverse record of cricetid rodents that spans an interval of about 12.5 my (20 to 7.5 Ma). This interval apparently spans the “cricetid vacuums” of Europe (about 18-20 Ma) and North America (about 17-19 Ma); the Pakistan record fills a critical gap the history of Palearctic cricetid rodents and enriches our understanding of their evolution. A new species of Eumyarioninae cricetid, *Eumyarion kowalskii*, n.sp. is reported from the Sulaiman foothills of Pakistan. *E. kowalskii* probably gave rise to *Prokatzisamys* and the rest of the Rhizomyidae. In addition to Eumyarion, the Eucricetodontinae cricetids are represented in Pakistan by two species of *Primus*; the Democricetodontinae are represented by three species of *Spanocricetodon* and eight species of *Democricetodon*. The Megacricetodontinae are represented in Pakistan by four species of *Megacricetodon* and two species of *Puiyabemys*. The Myocricetodontinae are represented in Pakistan by two species of *Myocricetodon* and three species of *Dakkamyoides*. The Dendromurinae are represented by one species of *Potwarmus*, one species of *Paradakkamys* and two species of *Dakkamys*. The Miocene record of these six informal groups of cricetid rodents in Pakistan represents an important chapter in the history of muroid rodents.

Key words: Palaeontology, siwaliks.

L/99. Lindsay E.H. & Downs, W.R., 1998. Cricetid rodents from Miocene deposits of Pakistan, 35-47. In: Ghaznavi, M.I., Raza, S.M. & Hasan, M.T. (eds.), Siwaliks of South Asia. Geological Survey of Pakistan, Islamabad.

Key words: Palaeontology, Miocene, rodents, siwaliks.

L/100. Lindsay, E.H., Johnson, N.M. & Opdyke, N.D., 1980a. Correlation of Siwalik faunas. In: Jacobs, L.L. (ed.), Aspects of vertebrate history; essays in honor of Edwin Harris Colbert: 309-319. Museum of North Arizona Press, Flagstaff.

Key words: Paleontology, faunas, siwaliks.

L/101. Lindsay, E.H., Opdyke, N.D. & Johnson, N.M., 1980b. Pliocene dispersal of the horse *Equus* and late Cenozoic mammalian dispersal events. Nature, 287, 135-138.

The Cenozoic history of land mammals is marked by brief periods of intercontinental dispersal, termed dispersal events. One of these dispersal events includes the horse *Equus*, that evolved in North America, dispersed to the Old World in the Pliocene, and became a prominent member of Old World Pleistocene communities. *Equus* was derived from a species of the single-toed horse *Pliohippus*, known only from North America³. Timing for the Pliocene

dispersal of *Equus* into Europe was questioned⁴ following resolution for the appearance of *Equus* into the Siwalik sequence of Pakistan⁵. It seems that there were at least three major dispersal events of large mammals during the Pliocene (at 1.9, 2.6 and 3.7 Myr). We now report new data that limit the time of *Equus*' dispersal and into Europe to the 2.6 Myr dispersal event.

Key words: Palaeontology, Pliocene, mammalian dispersal, siwaliks.

L/102. Liu, G., 1980. The climate of the Batura Glacier and its adjacent areas. In: Shi, Y. (ed.), Professional Paper on the Batura Glacier and Karakoram Mountains, 99-110. Science Press, Beijing.

Key words: Climate, glaciology, Batura, Karakoram.

L/103. Loewe, F., 1923. Die Eiszeit in Kashmir, Baltistan and Ladakh, Zs. Gesell. Erdk, Berlin, 42-53.

Key words: Kashmir, Baltistan, Ladakh.

L/104. Loewe, F., 1961. Glaciers of Nanga Parbat. Pakistan Geographical Review 16, 19-24.

Key words: Glaciers, Nanga Parbat.

L/105. Lombardi, F., 1991. Geodatic and topographic survey of Desio's 1954 Expedition. Italian Expedition to the Karakorum (K2) and Hindu Kush (A. Desio leader). I-Geography, volume 1, 125-141, ISMEO, Milano (Scientific Reports 1-Geography).

The 1954 expedition was engaged in multi-faceted studies. Important contribution was made in geodesy and topography, especially of the high peak areas and major glacial valleys. This paper deals with the methodology and results of the survey. Contribution include four excellent topographic maps in the pocket of the volume: 1) 1: 12,500 scale of the K2 area, 2) 1:50,000 scale of the Stak valley, and 3) 1:100,000 scale of Baltoro Glacier and Stak-Turmik valleys.

Key words: Italian Expedition 1954, geodesy, topography, Karakoram.

L/106. Lombardo, B., Borghi, A., Rolfo, F. & Visona', D., 2001. Formation and exhumation of eclogites and HP granulites in the Himalaya. Journal of Asian Earth Sciences 19, p.42.

Key words: Eclogite, granulite, exhumation, Himalaya.

L/107. Lombardo, B., Le Fort P., Lemmenicier Y., Pecher A., Pertusati P., Pognante U. & Rolfo, F., 1995. The Ladakh Terrain at the Karakorum-Nanga Parbat-Haramosh junction, Baltistan, Northern Pakistan. International Ophiolite Symposium, Pavia, September 1995.

Key words: Tectonics, Ladakh terrain, NPH, Karakoram.

L/108. Lomdardo, B. & Rolfo, F., 2000. Two contrasting eclogite types in the Himalayas: implications for the Himalayan orogeny. Journal of Geodynamics 30 (1-2), 37-60.

The metamorphic evolution of granulitized eclogites recently discovered in the Eastern Himalaya compared to that of the eclogites of the Northwestern Himalaya (upper Kaghan Nappe and Tso Morari Dome) suggests the possibility of a Himalaya-wide eclogitic metamorphism of Early Tertiary age. Eclogites from the Northwestern Himalaya record peak metamorphic temperature of 580-600 °C at metamorphic pressures in excess of 23-24 kbar. They have

glaucophane as a retrograde phase and followed a nearly isothermal decompression path into the field of epidote amphibolite facies. In contrast, the Eastern Himalaya eclogites have a strong granulite-facies overprint at metamorphic temperatures of about 750 °C and pressures of 7-10 kbars, and followed a clockwise decompression path strongly convex toward high metamorphic temperatures. The main difference between the crystalline nappes of the Northwestern Himalaya and those of the East Himalaya appears to lie in the different P-T path they followed during exhumation. In particular the Northwestern Himalaya crystalline nappes lack the Miocene high temperature and low pressure overprinting which is characteristic of the Eastern Himalaya, where thermal relaxation of the thickened continental crust erased almost completely the mineralogical record of the early stage of continental collision.

Key words: Metamorphic evolution, eclogites, Kaghan valley, Himalaya.

L/109. Lombardo, B., Rolfo, F. & Compagnon, R., 1998. Glaucophane and barroisite eclogites from the High Himalayan Crystallines of the Kaghan valley, Pakistan Himalaya. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 116-118.

This report presents preliminary results of a petrographical and mineralogical study of the eclogite samples from the High Himalayan Crystallines (HHC) of the upper Kaghan valley in which Pognante discovered the presence of glaucophane.

The eclogites described here were collected by U. Pognante in 1991 just south of Babusar Pass, close to the summer settlement of Gittidas. They belong to the same suite as the garnet-omphacite-phengite-quartz-Futile eclogites dated as Eocene. The Gittidas eclogites show differences in mineralogy which reflect compositional differences in the protolith and were apparently equilibrated in different stages of the metamorphic history. In addition to omphacite, garnet and accessory rutile, most samples contain a significant amount of quartz (up to 15% vol.). The peak assemblage may also include kyanite, zoisite and ankerite or phengite. Poikiloblasts of blue-green or blue amphibole are conspicuous in thin section. In Fe-rich eclogite the amphibole is glaucophane, with high Al^{iv} (up to 0.2 atoms p.f.u.) and Ca in M4 (up to 0.4 atoms p.f.u.), whereas in more magnesian varieties it is barroisite with high Na in M4 (up to 0.7 atoms p.f.u.). Paragonite may be present either as part of the peak assemblage or as a retrogression phase after kyanite. A reddish epidote of allanite composition was found in the glaucophane eclogite.

Garnet is only slightly zoned in the glaucophane eclogite but displays strong prograde zoning in more magnesian varieties, with Fe decreasing and Mg increasing from core to rim. The iron-rich core is usually crowded with minerals of the peak assemblage, but locally inclusions of green and blue-green amphibole were also found. In foliated eclogites the garnet inclusions often define an internal foliation, commonly discordant to the main external foliation. In some garnet crystals, retrograde biotite appears to develop from the Mg-rich rim inwards, producing an atoll-like structure. Omphacite is frequently crowded with very small rutile needles, suggesting replacement of a former Ti-bearing igneous (?) pyroxene.

During retrogression garnet develops a thin corona of green amphibole, omphacite is replaced by a symplectite of albite + amphibole and phengite by a symplectite of biotite + feldspar.

The Gittidas eclogites are associated with a metasedimentary sequence of paragneiss with the high-pressure assemblage garnet-K-white mica-plagioclase-kyanite-staurolite-zoisite and accessory rutile, with retrograde margarite and biotite. Garnet is zoned, with Fe-rich cores and Mg-rich rims, its chemical composition and zoning being comparable with those found in the barroisite eclogites. This suggests that the quartzofeldspathic country rocks probably suffered the same high-pressure metamorphism as the eclogites did.

Equilibration conditions in the Gittidas barroisite eclogites have been estimated at T=600±30°C and P > 13 kbar from Fe/Mg partition in garnet-omphacite and garnet amphibole pairs, and from the jadeite content of omphacite (X_{jd} UP to 0.42). This estimate is close to temperature conditions estimated for the eclogites and high pressure metapelites of the North Himalayan Tso-Morari Dome (580±60°C and 550±50°C, respectively). However, the Tso Morari metapelites have jadeitic pyroxene, and hence this unit is believed to have equilibrated at metamorphic pressures significantly higher than the Kaghan HHC.

At the regional scale, metamorphic peak temperature recorded by both the Kaghan and Tso Morari eclogites during the Eocene high pressure event appear to be significantly different from those recorded by metabasaltic and metadoleritic garnet granulites in the HHC of the northeastern Nanga Parbat-Haramosh Massif, where geothermobarometry of the peak assemblage clinopyroxene-plagioclase-garnet-quartz-rutile suggests temperatures around 700'-800°C and pressures around 12-14 kbar for a younger (Miocene?) high pressure metamorphism affecting the High Himalayan Crystallines of the North Western Syntaxis.

Key words: Petrography, alkali amphiboles, eclogites, Kaghan valley, Himalaya.

L/110. Lombardo, B., Rolfo, F. & Compagnoni, R., 2000. Glaucophane and barroisite eclogites from the Upper Kaghan nappe: implications for the metamorphic history of the NW Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 411-430.

This paper presents the results of a petrographical and mineral chemical study of glaucophane- and barroisite-bearing eclogites from the Upper Kaghan nappe in the Higher Himalayan Crystalline of the Pakistan Himalaya, and discusses the implication of the P-T path recorded in such rocks for the tectonic and metamorphic history of the NW Himalaya. The eclogites described here come from a previously undescribed outcrop at Gittidas, but belong to the same suite as the garnet-omphacite-phengite-quartz-rutile eclogites previously described elsewhere in the Upper Kaghan nappe. The metamorphic peak assemblage is garnet-omphacite-rutile-quartz in glaucophane eclogite and garnet-omphacite-zoisite-rutile $\pm$ kyanite $\pm$ phengite $\pm$ ankerite in barroisite eclogite. Most samples contain a significant amount of amphibole, white mica and quartz. White mica may be present either as part of the peak assemblage (phengite) or as a retrogressive phase after kyanite (paragonite). Amphibole is later than the metamorphic peak assemblage and is barroisite in most samples, but in relatively Fe-rich eclogite it is glaucophane with significant Na in the A site, Ca in the M4 site and tetrahedral Al. Garnet displays strong prograde zoning in the barroisite eclogites, with Mg increasing and Fe decreasing from core to rim. The iron-rich core is crowded with mineral inclusion of the peak assemblage, but inclusion of earlier paragonite, green and blue-green amphibole was also found. Peak metamorphic conditions in the barroisite eclogites have been estimated at $T=610 \pm 30^\circ\text{C}$ and $P=24 \pm 2$ kbar from Fe/Mg partition in garnet-omphacite pairs, and from the garnet-omphacite-phengite barometer. These values are close to the equilibration conditions estimated for the eclogites of the NORTH Himalayan Tso-Moriri Dome. Strong similarities between metamorphic evolution of the Upper Kaghan nappe and metamorphic evolution of the eclogite-bearing units in the Neelum Valley just to the east of the Kaghan Valley indicate that the eclogite extent, which was subjected to high pressure metamorphism in middle Eocene times. A comparison of the metamorphic evolution recorded in the eclogites of the NW Himalaya with that of the granulitized eclogites recently discovered in the E Himalaya suggests the possibility of a Himalaya-wide eclogitic metamorphism of pre-Miocene age. Therefore, the main difference between the Higher Himalayan Crystalline nappes of the NW Himalaya and those of the E Himalaya appears to lie less in the early part of their metamorphic evolution than in the different P-T paths they followed during exhumation.

Key words: Petrology, mineralogy, eclogites, Kaghan valley, Himalaya.

L/111. Loprete, E., 1995. Studio geochimico e microtermometrico delle inclusioni fluide, in marmi e rubini del Surgun Group (Himalaya, Pakistan nord-orientale). MS Thesis, Dipartimento di mineralogia e petrografia, Facoltà di Scienze M.F.N., Torino.

Key words: Geochemistry, fluid inclusions, marbles, ruby, Himalaya.

L/112. Luff, I.W., Rex, D.C., Guise, P.G. & Windley, B.F., 1985. K-Ar and Ar-Ar dating of the Kohistan arc sequence, Northern Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The geological evolution of Kohistan is characterized by two stages of crustal accretion punctuated by a major tectono-metamorphic event. The initial island arc stage of Kohistan is represented by a sequence of dominantly meta-igneous rocks, which as a result of deformation and uplift provide a virtually complete section through the island arc. The arc sequence comprises, from north to south, the Aptian-Albian Yasin Group of upper-arc sediments, underlain by the island arc Chalt Volcanic series. The middle and lower crustal levels of the arc are represented by the mainly meta-volcanic Kamila Amphibolites, which are intruded by the Chilas Complex, an enormous mafic/ultramafic body which probably formed near the base of the arc. Metamorphic grade increases from greenschist in the north to granulite in the Chilas Complex. K-Ar dates from metamorphic mineral phases (mainly

hornblende) range from 7 to 340 Ma. Ar-Ar studies have shown that the oldest dates are due to excess Ar, with Ar-Ar patterns being generally U-shaped with minima in the range 70 to 80 Ma. The oldest reliable ages for pre-tectonic metamorphic rocks or post-tectonic intrusives are around 95 Ma, suggesting that the major deformational event took place shortly before this time.

Post-tectonic rocks in Kohistan are mainly represented by the Kohistan Batholith, a major I-type cordilleran plutonic suite forming the westwards continuation of intrusives in Ladakh and Tibet. The batholith has been dated using samples from three main areas: the northern margin gives ages in the range 32-95 Ma; the Karakoram Highway section southeast of Gilgit gives ages in the range 17-39 Ma, while at the southern margin of the batholith the 58 Ma Kalam andesitic Volcanics both overlie and are intruded by batholith rocks ranging in age from 40 to 94 Ma. In addition, an extensive post-tectonic dyke suite in the Hunza River section north of Gilgit gives Ar-Ar ages in the region 70-80 Ma. Young ages, down to 7 Ma obtained from rocks in the Indus Valley Section probably reflect recent uplift centered on the Nanga Parbat massif, as documented by Zeitler using fission track methods.

The major deformation event affecting the original island arc sequence in Kohistan must have taken place after the deposition of the Yasin Group sediments but before the oldest undeformed plutonics of the batholith at 95 Ma. This event is correlated with the formation of the Northern Suture and implies that the Kohistan Arc originally formed near the southern margin of the Asian Continent and was generated above a northwards-directed subduction zone. Continued northwards subduction following the initial collision with the Asian Continent led to the development of the Kohistan Batholith at an Andean-type margin. Major magmatism ceased around 40 Ma, close to the age of final collision with the Indian Continent, though the youngest intrusive rocks were emplaced close to 30 Ma.

Key words: Tectonics, metamorphism, chronology, Kohistan arc.

L/113. Loucks, R.R., Ashraf, M., Awan, M.A., Khan, M.S. & Miller, D.J., 1992. Subdivisions of the Kamila amphibolite belt in southern Kohistan island arc complex, Pakistan. *Kashmir Journal of Geology* 10, 147-152.

Previously known Kamila Amphibolite Belt has been studied further now in details and found to consist of three principal subdivisions. These are Dasu, Kayal and Patan complexes underplated successively. They are composite of several mafic-ultramafic cumulate intrusions that vary in degree of metamorphic hydration and deformation. The Dasu Complex Indus Valley consist of extremely deformed, polymetamorphosed, epidote-garnet amphibolite banded gneisses. These record metamorphic P-T conditions averaging 5.5-6.5 kb and 520-580°C. The Kayal Complex consists chiefly of garnet-epidote amphibolites with strong foliation but only rare gneissic segregation banding with igneous hornblende and layering. Metamorphic assemblages record P-T conditions of about 7 kb and 620°C near base. The Patan Complex is massive to modally layered and locally crossbedded gabbro-norite at base to hornblende-gabbro-norite and diorite in the upper part with magmatic-epidote tonalite adjacent to its roof. Mineral geobarometry yields a pressure of 7.5 kb near roof. The stacking thus formed by a process whereby a thick crust of continent-like thickness and composition developed by repeated episodes of igneous intrusion along Moho.

Key words: Ultramafics, metamorphisms, Kamila amphibolites, Kohistan island arc.

L/114. Loucks, R.R., Miller, D.J., Ashraf, M., Awan, M.A. & Khan, M.S., 1990. The Jijal complex: Layered mafic-ultramafic arc accumulates from the crust-mantle boundary Pakistani Himalayas. *EOS*, 71, p 664.

The mafic to ultramafic rocks of the Jijal complex are cumulates that have formed under high pressure granulite facies conditions. These rocks crystallized from magma at the crust-mantle boundary.

Key words: Ultramafic-mafic rocks, Jijal complex, Kohistan.

L/115. Loucks, R.R., Miller, D.J., Ashraf, M., Awan, M.A. & Khan, M.S., 1992-93. Principal subdivisions of the southern amphibolite belt in southern Kohistan. *Regional Postgraduate Training Course in Plate Tectonics*, Punjab University, 37-38.

We have mapped the principal lithologic units and structural features of southern Kohistan along a succession of north-south traverses in the valleys of the Panjgora River (Dir), Swat River, Indus River (Besham northward), and another north and south from Chilas. Each traverse extends from the Main Mantle thrust northward to the southern

part of the Kohistan batholith. We have found that the region previously referred to as the "Southern Amphibolite Belt" or "Kamila Amphibolites" is in fact a composite of several mafic - ultramafic cumulate intrusions that vary in degree of metamorphic hydration and deformation, and can be correlated east-west from one traverse to another to develop a consistent "stratigraphy" of layered cumulate complexes in the lower crust of the Kohistan arc. From the deepest level upward, the four principal cumulate intrusions are the Jijal Complex which is overlain by the Patan Complex that is in turn overlain by the Kayal-Chilas Complex, which is overlain by the Dasu Complex. The contact of the Jijal Complex with the Patan Complex is everywhere a thrust fault contact. The contact Of the Patan Complex with the Kayal-Chilas Complex is an igneous intrusive contact where exposed in the village of Khwazakhela in Swat and along the Karakoram Highway (KKH) 9 km north of Patan village. The roof of the Kayal-Chilas Complex intrudes the gneissic Dasu Complex in upper Swat 18 km north of Bahrain, and along the Karakoram Highway 31 km north of Patan, and in Kiner Gah 5 km north of Chilas town.

Key words: Southern amphibolite belts, Kohistan.

L/116. Loucks, R.R., Miller, D.J., Ashraf, M., Awan, M.A. & Khan, M.S., 1992-93. Platinum group element mineralization in high-pressure, layered, ultramafics-mafic cumulates of the Jijal complex, Pakistani Himalayas. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 38-39.

For more information, consult the preceding account.

Key words: Platinum group elements, ultramafic-mafic rocks, Jijal complex, Kohistan.

L/117. Lydekker, R., 1876. Notes on the geology of the Pir Panjal and neighboring district. Records of the Geological Survey of India 9, 4, 155-160.

Brief mention is given of Murree, Rawalpindi and Punch section together with brief description of Murree beds and structure in the rocks.

Key words: Mapping, Murree, Rawalpindi.

L/118. Lydekker, R., 1879. Notes on the geology of Kashmir, Kishtwar and Pangi. Geological Survey of India, Records 11, 20-63.

Key words: Geology, mapping, Kashmir.

L/119. Lydekker, R., 1879. Geology of Kashmir (3rd notice). Records of the Geological Survey of India 12, 1-15.

Treats mainly of the Mesozoic ellipse of Sonamarg and the upper Kishanganga valley, and is illustrated by a small map. A notice of the old glaciation of the Kashmir valley is appended.

Key words: Geology, mapping, Kashmir.

L/120. Lydekker, R., 1880. Geology of Ladakh and neighbouring districts, being fourth notice of geology of Kashmir and neighbouring territories. Geological Society of India, Records 13, 10-304.

Key words: Geology, mapping, Kashmir.

L/121. Lydekker, R., 1881a. Geology of part of Dardistan, Baltistan, and neighboring districts, being fifth notice of the geology of Kashmir and neighboring territories (with map). Geological Survey of India, Records 14 (1), 1-56.

Gives map and sections of the above-mentioned districts, with a general description of their geology. Gneiss belonging to two geological epochs is described, sometimes penetrated by intrusive granite. The limestone rocks of the Kashmir valley are more closely examined, and shown to be in part of Triassic age. The paper concludes with a notice of the ancient and modern glaciation of Baltistan, and of the thermal springs of the same district.

Key words: Geology, mapping, glaciation, Dardistan, Baltistan, Kashmir.

L/122. Lydekker, R., 1881b. Geology of north-west Kashmir and Khagan (being sixth note on the geology of Kashmir and neighbouring territories). Geological Survey of India, Records, 15(1), 14-24.

Key words: Geology, mapping, Kaghan, Kashmir.

L/123. Lydekker, R., 1882. Geology of North-West Kashmir and Khagan etc. Geological Survey of India, Records 15, 1.

A paper, illustrated with a map and section, describing the geology of a great part of the Kishanganga and Khagan valleys; various errors connected with the north-westerly termination of the sub-Himalayan territories are corrected.

Key words: Geology, mapping, Kashmir, Kaghan, Himalaya.

L/124. Lydekker, R., 1883. The geology of the Kashmir and Chamba territories, and the British District of Khagan. Geological Survey of India, Memoirs 22, 1-344.

This exhaustive volume gives details of physical features. The various geological formation (ranging from recent alluvium to Precambrian) and economic geology of the area. Beside, this volume contains a geological map of the area, and figures and description of paleontology. The paper also lists all the previous publications on the geology of Kashmir together with brief summaries.

TABLE OF GEOLOGICAL FORMATIONS IN THE NORTH-WEST HIMALAYA.

Kashmir Territory	European Equivalent	Spiti	Simla District
Alluvial system Low-level alluvia, etc. High-level alluvia, glacial, lacustrine, and known series.	Prehistoric Pleistocene	The Same The Same	The Same The Same
Tertiary system Siwalik series outer Inner	Pliocene	—	Siwalik series
Sirmur series Murree group Subathu group Indus tertiaries	Miocene Eocene	— —	Dugshai and Kasauli groups Subathu group

Zanskar system			
Chikkim series	Cretaceous	Chikkim series	—
Supra-Kuling series	Jura and Trias	Gieumal group Spiti group Tagling group Para group Lilang group Kuling series	Krol series Infra-Krol series
Kuling series Panjal system (not generally subdivided)	Carboniferous Silurian Cambrian?	Muth series Bhabeh series	Blaini series Infra-Blaini series
Metamorphic system Metamorphosed Panjal, etc.; Central gneiss	Paleozoic and Archean	Central	Chor gneiss

Key words: Geology, mapping, geomorphology, palaeontology, Precambrian, Kashmir.

L/125. Lyman, B.S., 1872. The topography of the Punjab oil region. American Philosophical Society Transactions, New Series 15, 1-14.

The Punjab oil region is in the corner between Cashmere and Cabul, and wholly between north latitude 32° 31', and 33° 47', and east longitude (from Greenwich) 71° 18', and 73° 5'; a nearly square space about a hundred miles long east and west by ninety miles wide, north and south.

Just inside the northeast corner of this square is Rawul Pindee, the largest town of the region, with about twenty thousand inhabitants; just inside the southwest corner is Pind Dadun Khan, a town of about twelve thousand inhabitants; and just inside the southwest corner is the ancient uninhabited ruin of a walled town, now called Kafir Kot. Just within the northwest edge of the region, and less than twenty miles from its eastern edge, stands the little village of Shah kee Dheree, on the site of the ancient capital Taxila, where the king Taxiles hospitably entertained Alexander the Great. The small town of Attok, where Alexander crossed the Indus into India, is only ten miles north of the middle of the northern edge of the square. The famous Muneekyala Tope, built by king Kanishka, about the Christian Era, to mark the spot where Booddha in compassion gave his own flesh to satisfy the hunger of a starving tiger, stands a little outside the square, fifteen miles southeast of Rawul Pindee.

The river Indus enters the square about the middle of the northern edge, and leaves it at the southwest corner. The Jhelum River (the "fabulosus Hydaspes" of the ancients), one of the five rivers that gives its name to the Punjab, flows across the southeast corner, past Pind Dadun Khan, southwesterly towards the Indus. The centre of the region is drained by the Sohan, which rises near Rawul Pindee, and flows west southwest to the Indus.

The region lies, then, mostly between the Indus and Jhelum, in what is called the Sind Sagur Doab (two rivers), and it is mainly in the mountainous or hilly part (Kohistan) of the Doab.

Key words: Topography, geology, hydrocarbons, oil, Punjab, India.

L/126. Lynam, J.O.F., 1965. Rakaposhi, the North-West Ridge. Himalayan Journal, XXVI, p.70.

Key words: Rakaposhi, Karakoram.

M/1. Macbryde, D.H., 1963. Scientific report of studies carried out on the Minapin Glacier by Members of the Cambridge Expedition to Nagir, Karakoram, 1961.

Key words: Glaciology, Minapin glacier, Hunza.

M/2. MacDonald, K.I., 1989. Impacts of glacier-related landslides on the settlement at Hopar, Karakoram Himalaya. *Annals of Glaciology* 13, 185-188.

Although the landslides have a history decades long, the land slide problem has more recently assumed heightened significance in relation to rapidly occurring economic and social change such as the introduction of wage labour and seasonal outmigration.

Key words: Landslides, glaciers, Himalaya.

M/3. Madin, I.P., 1986. Geology and neotectonics of northwestern Nanga Parbat-Haramosh massif. M.Sc. thesis, Oregon State University, Oregon, 160p.

Consult the following account for further information.

Key words: Geology, neotectonics, NPHM.

M/4. Madin, I.P., Lawrence, R.D. & Rehman, S., 1984. Neotectonics of the western Haramosh Range. *EOS* 65, p.1094.

The structure bounding the western Haramosh range has been mapped as part of the MMT, the suture between Indian and Asia. Recent mapping indicates that this structure is an active E dipping fault zone separating "Indian" metasediments of the Haramosh range from diorites and amphibolites of the Kohistan island arc. Displacement on the fault is reverse slip, with some right lateral strike slip. The bedrock trace of the fault is marked by gouge and mylonite zones, drag folds, intense hydrothermal alteration and active hot springs. The width of the fault zone and associated mylonite zones implies displacement on the order of kilometers.

Neotectonic activity is indicated by deformation of Wisconsin age till and glaciofluvial deposits and recent talus slopes. Laminated fluvial sands beneath Wisconsin age basal till are tilted 20 to 40 degrees. A scarp in Wisconsin till has a vertical displacement of 122 meters. Assuming till deposition ceased 8,000 to 12,000 years ago, this scarp represents an uplift rate of 1.0-1.5cm/yr, comparable to regional uplift rates for the area calculated by Zeitler (1982) on the basis of fission track annealing dates.

Key words: Haramosh, neotectonics, Western Himalaya.

M/5. Madin, I.P., Lawrence, R.D. & Rehman, S., 1989. The Northwestern Nanga Parbat-Haramosh massif: evidence for crustal uplift at the north-western corner of the Indian craton. In: Malinconico, L.L. & Lillie, R.J. (Eds.), *Tectonics of the Western Himalaya*. Geological Society of America Special Papers 232, 169-182.

The Nanga Parbat-Haramosh (NPHM) massif is a unique structural and topographic high in the northwestern corner of the Himalayan convergence zone. Previously, the NPHM was thought to be bounded by the Main Mantle Thrust (MMT), a fault along which the Kohistan-Ladakh island arc was obducted onto the northern margin of India. This study presents field evidence that the recently active dextral reverse Raikot fault truncates the MMT and forms the western boundary of the NPHM.

The Raikot fault separates medium-grade, Mesozoic to middle Cenozoic mafic metasedimentary and intrusive rocks of the Kohistan Island arc (Kohistan Sequence) from high-grade Proterozoic metasedimentary rocks (Nanga Parbat Group) and orthogneisses of the Indian craton. The Kohistan Sequence rocks have experienced one tight to isoclinal folding event, probably associated with obduction of the island arc, and a second folding event associated with movement on the Raikot fault. The Nanga Parbat Group rocks were transposed by an early (possibly Proterozoic) isoclinal folding event and have subsequently been folded around east-trending axes in the early Cenozoic by the obduction of Kohistan, then around north-trending axes in late Cenozoic time in association with the uplift of the

NPHM and initiation of the Raikot fault. The Raikot fault consists of both mylonite zones and numerous major and minor faults. Slickensides and mylonitic lineations both indicate dextral reverse slip. The Raikot fault and associated folds appear to have accommodated as much as 15 to 25 km of uplift during late Cenozoic time. The localization of the uplift and the involvement of the Moho suggest that the Raikot fault follows a major crustal structure, possibly a pre-collision Indian plate boundary. If this is the case, rotational underthrusting of greater India along the MMT would require dextral slip along the Raikot fault. It is proposed that the Raikot fault is a terminal tear fault on the MCT.

Key words: NPHM, tectonics,

M/6. Magsi, H.Z., 1984. Evaluation of seismic danger zones in Pakistan based on the interpretation of landsat data. Abstracts, 1st Pakistan Geological Congress, Lahore, p.46.

Key words: Seismology, Remote sensing.

M/7. Mahboob, T. & Shah, M.S., 1979. Petrography of the Shilman carbonate complex Khyber Agency. M.Sc. Thesis, University of Peshawar, 73p.

Key words: Petrography, carbonatites, Shilman, Khyber Agency, NWFP.

M/8. Maheo, G., Rolland, Y., Guillot, S. & Pecher, A., 2001. Metamorphic and magmatic evidence for slab breakoff process below NW Himalaya. *Journal of Asian Earth Sciences* 19, 43-44.

In the southern Karakorum, NW-SE metamorphic zonation coeval with nappe stacking between 90 and 37 Ma is crosscut by a recent (20-5 Ma) E-W thermal anomaly, underlined by migmatitic domes North of the MKT suture zone. These domes evolved in two stages. Mid-crustal granulitic rocks were first heated from below 600°C to above 750°C during a slight pressure drop, from 0.7 to 0.5 GPa. This heating triggered muscovite and biotite dehydration melting. The retrogressive PT path crosscut the relaxed geotherm of a tectonically thickened crust. Further, geochronological data suggest rapid cooling and rapid exhumation rate ($>5 \text{ mm y}^{-1}$) since 6 Ma, and structural analysis show that the observed retrogressed P-T-t path can be explained by rapid exhumation during fold amplifications of previously molten midcrustal levels in a N-S shortening context. The main question raised by this evolution is: how to explain the formation of HT granulites in the India-Asia convergent context? These granulites are temporally and spatially associated with granulites and lamprophyres. On the northern edge of the domes area, the 20 Ma Baltoro batholith and associated lamprophyres as well as Hunza dykes show initial ϵNd (-13 to -6) and $87\text{Sr}/86\text{Sr}$ (0.705-0.725) intermediate between crustal and mantle isotopic end members (Searle et al., 1992; Crawford and Searle, 1993). South of the Baltoro batholith, close to the Dassu Dome, the 9-10 Ma Hemasil syenite and associated lamprophyres have much higher initial ϵNd (3.0-4.4) and lower initial $87\text{Sr}/86\text{Sr}$ (0.704-0.705) (Lemennicier, 1996), suggesting increased contribution of a mantellic source. Similar geochemical characteristics have been found in Neogene (23-12 Ma) volcanic rocks of S-Tibet, close to the Indus suture zone. The selective enrichments in LREE vs. HREE and in LILE vs. HFSE and intermediate mantle-crust isotopic signatures have been explained to result from melting of a metasomatized lithospheric mantle with little crustal contamination (Turner et al., 1996; Miller et al., 1999). The increased mantellic affinity of Hemasil syenite compared to Tibetan volcanics could be interpreted as a result of the melting of metasomatized asthenosphere below Karakorum, in the mantle wedge above subducting Indian lithosphere. Such magmatism and associated metamorphism with a specific location suggest heat advection through mantellic magmas intrusions. In S-Karakorum this narrow E-W striking zone of thermal anomaly is underlined by a strong negative gravity (bouguer) anomaly, which can be due to a hot body underplate below the crust. In the India-Asia convergent context, we propose that this tectono-metamorphic and magmatic evolution is due to slab breakoff of the Indian continental lithosphere starting at circa 20-25 Ma. Moreover, magmatic evolution is consistent with melting of a deeper mantellic source (from lithosphere to asthenosphere), related to a downward propagation of the slab gap.

Key words: Metamorphism, plate tectonics, Himalaya.

M/9. Mahmood, A., 1976. Geological mapping of the Gandaf Irrigation Release Tunnel, Tarbela Dam Project with reference to the effect of structure and geohydrology on the construction of the Tunnel. M.Sc. Thesis, Punjab University, Lahore, 142p.

Key words: Engineering geology, structure, hydrology, Tarbela Dam.

M/10. Mahmood, A., 1985-87. Geology of Dunga Gali-Barian Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 105p.

This report incorporates a comprehensive geological study of nearly 25 sq. km. area between Dunga Gali and Barian on the Murree-Abbottabad road. The study includes the preparation of a geological map on the scale 1:7040. Stratigraphically the rock units range from Upper Jurassic to Eocene and represent the sequence of the Hazara Province of the Kohat-Potwar Basin. It is primarily a limestone-shale sequence reflecting a stable shelf facies. Structurally, the area shows the development of a few synclinoria and anticlinoria, within which a generally tight parallel to similar asymmetric to overturn style of folding predominates. A number of dip-slip-strike faults, both of the normal and reverse type are present. A petrographic study of all rock units, based on fairly representative field sampling, is also present.

Key words: Geology, Abbottabad, Hazara.

M/11. Mahmood, A. & Ahmad, S.A., 1986. Petrography and geology of the Jogabunj-Sadiqa banda area, Dir District, Pakistan. *Acta Mineralogica Pakistanica* 2, 93-99.

A geological map covering about 66 square miles of the Jogabunj-Sadiqa banda area on the scale of 1:0.789 miles is presented. The area is mainly composed of metasedimentary complexes; the units are amphibolite, granodiorite, pegmatite and hornblende. The amphibolite are the oldest rocks. After their formation, an acidic magma intruded the amphibolites, resulting in the formation of granodiorite: the contact between them is sharp. Dykes are present both in granodiorite and amphibolite, showing the late residual composition of the granodioritic magma; quartz-feldspathic and pegmatite veins are present in the whole area. Garnet-bearing quartzofeldspathic rocks are intrusive. Modal analyses and petrography of 32 selected samples are presented and mineralogical statistical variation diagrams are plotted. The petrogenesis of the amphibolite and granodiorite is briefly discussed.

Key words: Petrography, amphibolites, granodiorite, Dir.

M/12. Mahmood, A., Ahmad, S.A. & Dawood, H., 1985. Geology of Warai-Jogabung area, District Dir Trans Himalayan island arc, Pakistan. *Acta Mineralogica Pakistanica* 1, 83-89.

A geological map covering about 45 miles² of Warai-Jogabung area of Dir district from toposheet 43 A/4 is presented. The area contains amphibolites, diorite and granite with small patches of quartzofeldspathic veins, pegmatites and hornblendites. The amphibolites are the oldest rock units formed from calcareous quartzite. Diorite late on intruded as patches veins and dykes of granitic material. Petrology of granitic rocks is presented in detail. Modal analyses and petrography of 24 selected samples are given.

Key words: Petrology, petrography, amphibolites, Dir, Himalaya.

M/13. Mahmood, A. & Anwar, R., 2000. Microfacies and depositional environment of Shekhan Formation, Panoba Section, Kohat, N.W.F.P. M.Sc. Thesis, University of Peshawar, 46p.

Key words: Microfacies, Shekhan formation, Kohat.

M/14. Mahmood, F., 1985-87. Geotechnical studies of landslides with special emphasis on slope stability along Karakoram Highway (from Batgram to Thakot, District Mansehra). M.Sc. Thesis, Punjab University, Lahore, 95p.

The Project area is related to Hazara and Kohistan region of North West Frontier Province. Topographically the area is occupied by rugged rocks consisting of high peaks and alluvial deposits. The predominant, rock types are granite, granite gneiss, schists and various other minor bodies as dykes and sills. All the structural features coincide excellently to give NE trend that indicates NW-SE direction of tectonic forces.

The main objective of "Geotechnical Studies" is to analyse the scope of stability of rocks along roadside. For this purpose, various modes of failure, i.e. plane failure, wedge failure, toppling failure, rock fall, and circular failure etc. were observed. Theoretical models based on the actual readings (data) presented in the forthcoming chapters are intended to provide rational basis for the design of rock slope. It should however, be made clear that successful design of slope depends not only on the choice of correct theoretical model but also upon a number of other considerations which cannot be conveniently quantified.

A map has been provided which classifies the road segments as stable, unstable and potentially unstable. Stable segments are those which geometrically do not manifest any sign or chance of failure or show a high factor of safety i.e. 2.5 or 3. Unstable segments are those where small scale failures are kept on taking place with every successive rainfall. Similarly, potentially unstable segments are those which are stable in actual practice but the ratio of their resisting forces to driving forces is less than one.

Study of various roads alignment was made to emphasize on the effects of sliding. Different modes of failure were encountered, and their factors of safety were calculated. Finally, it was decided whether dangerous road or not and an attempt has been made to give remedial measures.

Key words: Landslide, KKH, Batgram, Thakot, Mansehra.

M/15. Mahmood, K., 1976. Thesis on litho-structural mapping and geology of Chalt–Hini area, Hunza valley (Gilgit Agency) with special emphasis on the Plate Tectonics. M.Sc. Thesis, Punjab University, Lahore.

Key words: Lithology, structure, Hini, Hunza, Gilgit.

M/16. Mahmood, K., 1994-96. Sedimentary petrology/sedimentology of Hangu Formation and Lockhart limestone of Early Paleocene age and lithostructural mapping of Dhamtaur area, southern Hazara, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 155p.

A comprehensive study of Geology and structure of Dhamtaur area is presented along with special constraints on the sedimentology of Hangu Formation and Lockhart limestone of Early Paleocene. Large-scale (1:10000) Geological mapping of a small segment of the Lesser Himalaya in the Dhamtaur area is presented. The lithostratigraphic unit range from upper Paleocene to Precambrian, Hazara Formation being the oldest. Structurally the area comprises NW-SE trending major anticlinorium. The folds are tight to isoclinal and opposing southeast and northwest vergence on the two sides of the lower formation. Some anticline shows plunge to the southeast direction. Almost all faults have vergence parallel to the folds developed in the core on the two sides of the main anticlinorium. Most are reverse faults although some may be of the normal type. Faulting appears to be dip-slip to oblique slip and in general involves a maximum displacement of few hundred meters.

Hangu Formation from Bagnotar and Mohar, District Abbottabad and from Chahla Bandi, Azad Kashmir has been studied for microfacies, petrographic characteristics, and environment of deposition and diagenesis in relation to sedimentary basin.

The formation shows variable lithology. The section from Bagnotar is totally residual deposit, whereas the sections from Mohar and Chahla Bandi are predominantly composed of siliceous clastics with few beds of residual deposits. The three topmost beds of Chahla Bandi section composed of coal and Bauxitic clay.

The environment of deposition varies from continental, supratidal, upper shore phase and lower shore phase. The section of Lockhart limestone near Chahla Bandi is thin to medium bedded. The Lower contact of Lockhart is disconformable with Hangu Formation and upper contact of Lockhart Limestone with Patala Formation is sharp unconformable. This section is comprises of 14 microfacies and 5 facies ranging from mudstone, wackestone and packstone, have been defined on the basis of field observation and petrographic studies. The deposition of Lockhart Limestone took place in open marine shallow shelf conditions. Neomorphism of syndepositional micrite has taken place under various conditions during different phases of tectonic activity. Mechanical and chemical compaction are present in the forms of aligned fracture and vug.

Key words: Sedimentology, lithostructural mapping, Hangu Formation, Lockhart limestone, Eocene, Hazara.

M/17. Mahmood, M.T. & Shah, S.M.H., 1998. Petrography and mechanical properties of granitic rocks from Mansehra, N.W.F.P. M.Sc. Thesis, University of Peshawar, 51p.

Key words: Petrography, granites, Mansehra.

M/18. Mahmood, N., 2000. Calcium and magnesium in calcite and dolomite using EDTA and atomic absorption spectrophotometric techniques. Abstracts, Third South Asia Geological Congress, Lahore, 174-175.

Key words: Calcite, dolomite, geochemistry.

M/19. Mahmood, Q., 1986-88. Geology and structure of Balakot-Garhi Habibullah-Batrasi area Kaghan valley District Mansehra, N.W.F.P. Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 116p.

This report comprises a complete geological study of nearly 320 sq. km; located between and around Balakot-Garhi Habibullah. In the project area micaceous quartzites, quartz mica schists, garnet mica schists, dolomite, limestone, Sandstones and slates are encountered. A stratigraphic sequence has been worked out. The rocks extend in age from Precambrian to Miocene. Structurally, the rock, are folded into a number of major structures. The area comprises of major structures like Balakot Anticline, Garhi Habibullah syncline, Muzaffarabad fault and Murree Fault. Minor structures of the project area has also been discussed in detail. Hazara Kashmir syntaxis has a great influence on the stratigraphy, structure, and tectonics of the investigated area. In the field of economic geology a number of deposits including clays, graphite, limestone, feldspar, granites and sandstone have been discussed. This report also includes a petrographic description of the rock units as well as numerous sketch section and photographs, illustrating the geology of the area.

Key words: Geology, structure, Kaghan, Mansehra.

M/20. Mahmood, S., Sattar, A. & Khan, I., 1985. The geology and structure of the central part of the Attock-Cherat Range, District Peshawar (N.W.F.P.), Pakistan. M.Sc. Thesis, department of Geology, University of Peshawar, 103p.

The area under investigation is a part of the Attock-Cherat Range which forms the southern boundary of the Peshawar Basin. The area is bound by upper Tarkhel village in the north, Khairabad-Nizampur road in the south, Inzari village in the east and Drangkhwar in the west. The relief of the area is moderate to high; the elevation range from 2500 to 3200 feet, the highest peak is 3200' feet high. The general trend of the Range is east-west which coincides with the strike of the rocks.

The area consists of three types of rocks i.e. the Precambrian Dakhner formation on the extreme north, the younger formations of tertiary sequence in the center and the rocks of Silurian-Devonian sequence forming the southern limits of the Attock-Cherat Range. An outcrop of Jurassic limestone is also observed.

Following lithological units are distinguished

1. Dakhner Formation	)	Precambrian
2. Darwazai Formation	)	
3. Hisartang Formation	)	
4. Inzari limestone	)	Silurian-Devonian
5. Jurassic limestone	)	Jurassic
6. Lockhart limestone	)	Paleocene

7. Patala Formation	)	Paleocene-Eocene
8. Murree Formation	)	Miocene
9. Quaternary Deposits	)	Recent

The area exhibits extremely complex structural features. One major thrust fault, running along the northern extremities of the area, traverse the area in the east-west direction. This thrust fault is known as the Cherat thrust. A gravity fault, which separates the Silurian-Devonian sequence from the tertiary rocks, run parallel to the Cherat thrust. Faults of smaller dimensions, which are oblique to the Cherat thrust, are also present in the area. Several Drag folds are present near the thrust which reflect the direction and sense of slip along the fault.

The Silurian-Devonian rocks are overturned in response to the thrusting from the north. Enough evidence is gathered supporting the overturning of the Attock-Cherat Range, its southern limb being eroded away by the Indus River and buried under the alluvium.

Key words: Geology, structure, Attock-Cherat, Nizampur, Peshawar.

M/21. Mahmood, S., 1975. Detailed Geology, Petrology and Economic Geology of Shangla Par Alpuri Area. Survey of Pakistan, Topographic 438/9 with special emphasis on Plate Tectonics. M.Sc. Thesis, Punjab University, Lahore.

Key words: Economic geology, petrology, plate tectonics, Shangla,

M/22. Mahmood, S.S. & Hashmir, A.K.S., 1979. The geology and the structure of the area between Kund and Khair Abad, District Peshawar (N.W.F.P.), Pakistan. M.Sc. Thesis, University of Peshawar, 92p.

Key words: Mapping, structure, Khairabad, Peshawar.

M/23. Mahmood, T., 1981-83. Geology and Petrology of Darel Valley (District Diamer). M.Sc. Thesis, Punjab University, Lahore, 54p.

This thesis presents a geological map of the 30 miles² of project area (DAREL) on scale 1 inch=1 mile. The project area (Darel) lies in Gilgit Agency district Diamer. The area is located in the centre of Kohistan. Area is disturbed tectonically, being involved in Himalayan Orogeny. The area is composed of igneous and metamorphic rocks. The main rock units in the area are Norite, Diorite, Amphibolites and Granodiorite. Mineralogical description and petrographic analysis of this rock are reported in detail. An attempt is made to interpret the petrogenesis of rock types. The thesis presents a detailed geological and petrologic investigation of the project area. Norite and amphibolites represent oceanic crust while diorite and granodiorite etc. represent plutonic equivalents of arc.

Key words: Petrology, petrography, Kohistan island arc, Himalaya.

M/24. Mahmood, T., 1986. Appraisal of two marble deposits from Northern areas, Pakistan. *Acta Mineralogica Pakistanica* 2, 161-162.

This is a short communication giving brief details of two marble deposits of northern areas. These are Khyber area, Gilgit district and Chutran area, Baltistan, to check the mineability of these marble deposits. Geochemical analyses of samples from these deposits are also given.

Key words: Marble, Northern areas, Pakistan.

M/25. Mahmood, T., 1985-87. Geology and mapping of Dulai-Kohala area with special emphasis on engineering characteristics of soils. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 91p.

Nearly 175 square km area has been mapped from Dulai to Kohala on both sides of the river Jhelum. The aim is to study the engineering characteristics of soils in detail and to classify them for the civil projects.

The engineering characteristics of soil reveal that

(A=22.6 g-36.2 g)	(B=10 g-22.2 g)
(C=7.6 g-24.9 g)	(D=14.8 g-28.4 g)
(E=5.6 g-52.5 g)	(F=1.67 g-1.83 g)
(G= 62.7 -106.7) and	(H=14.9 lb/ft ³)

is found to be suitable for construction after compaction.

A- Liquid limit.

B- Plastic limit

C- Shrinkage limit

D- Moisture content

E- Swelling test

F- Compaction test

G- Soil hardness test

H- Field density by sand replacement method

Key words: Mapping, engineering geology, soil, Azad Kashmir.

M/26. Mahmood, T., 1986-88. Geology and Structure of Azizabad-Baragali Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 166p.

Large-scale geological map at the scale 1:9434 of Azizabad-Baragali area is presented. A detailed description of the Precambrian to Eocene rock units specifically in the area of investigation has been recorded. On the basis of large number of sections measured and interpreted. A study of Kawagarh Formation indicates its deposition in deeper water above carbonate compaction depth. Subsurface structure has been described and illustrated in the form of a number of sections and stereograms. Most folds are open to tight asymmetric double plunging and trend NE-SW. A latter fainter NW-SW trending fold set is superimposed on the earlier NE-SW. The faults are dip-slip strike type some normal others reverse generally medium to high angle. Most structure verge to NW. The economic potential of various limestones, laterite and slate has been assessed and an analysis of Dor River aggregate carried out suggests that the Dor River bed gravels are unsuitable and even harmful for durable construction.

Key words: Mapping, structure, Precambrian, Eocene, Kawagarh Formation, Abbottabad.

M/27. Mahmood, T., 1990-92. Geology and structure of Changla Gali Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 143p.

Key words: Structure, Changla Gali, Abbottabad.

M/28. Mahmood, T., 1992-94. Sedimentary petrology/sedimentology of Hangu Formation and Lockhart Limestone of Early Paleocene age and Lithostructural mapping of Dhamtur Area, southern Hazara, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 200p.

A comprehensive study of Geology and structure of Dhamtaur area is presented along with special constraints on the sedimentology of Hangu Formation and Lockhart Limestone of Early Paleocene. Large scale (1:10,000) Geological mapping of a small segment of the Lesser Himalaya in the Dhamtaur area is presented. The lithostratigraphic unit range from upper Palaeocene to Pre-Cambrian, Hazara Formation being the oldest. Structurally the area comprises NW-SE trending major anticlinorium. The folds are tight to isoclinal and opposing southeast and northwest vergence on the two sides of the lower formation. Some anticlines show plunge to the southeast direction. Almost all faults have vergence parallel to the folds developed in the core on the two sides of the main anticlinorium. Most are reverse faults although some may be of the normal type. Faulting appears to be dip-slip to oblique slip and in general involves a maximum displacement of few hundred meters. Hangu Formation from Bagnotar and Mohar, District Abbottabad and from Chahla Bandi, Azad Kashmir has been studied for microfacies, petrographic characteristics, environment of deposition and diagenesis in relation to sedimentary basin.

The formation shows variable lithology. The section from Bagnotar is totally residual deposit, whereas the sections from Mohar and Chahla Bandi are predominantly composed of siliceous clastics with few beds of residual deposits. The three topmost beds of Chahla Bandi section composed of coal and Bauxitic clay. The environment of deposition varies from continental, supratidal, upper shore phase and lower shore phase.

The section of Lockhart Limestone near Chahla Bandi is thin to medium bedded. The Lower contact of Lockhart is disconformable with Hangu Formation and upper contact of Lockhart Limestone with Patala Formation is sharp unconformable. This section is comprised of 14 microfacies and 5 facies ranging from mudstone, wackestone and packstone; have been defined on the basis of field observation and petrographic studies. The deposition of Lockhart Limestone took place in open marine shallow shelf conditions. Neomorphism of syndepositional micrite has taken place under various conditions during different phases of tectonic activity.

Key words: Sedimentology, lithostructural mapping, Hangu Formation, Lockhart limestone, Eocene, Hazara.

M/29. Mahmood, Z.H. & Khan, S., 1983. Stratigraphy of the Karakoram thrust between Chalt and Budlus village along Hunza River northern Pakistan. M.Sc. Thesis, University of Peshawar, 78p.

Key words: Stratigraphy, Chalt, Hunza River, Karakoram Thrust.

M/30. Majeed, A., 1976. A report on lithostructural mapping and geology of Chalt–Hini area, Hunza Valley. M.Sc. Thesis, Punjab University, Lahore, 120p.

Key words: Structure, mapping, Chalt, Hunza.

M/31. Majid, M., 1976. Mineralogy and petrology of the Shilman carbonatite complex, Khyber Agency, North West Frontier Province. NCE Geology University of Peshawar, Information Release 8, 52p.

A number of carbonatite bodies have been reported from the northwest frontier of Pakistan. The Shilman carbonatite occurs in Khyber Agency near the Afghan border. Because of abundance of apatite and interest in REE, this body has been paid attention. This is a preliminary report on the petrography of the body that is a few hundred meters wide and a kilometer long. The body is mostly calcitic carbonatite.

Key words: Mineralogy, petrology, carbonatite, Khyber, NWFP.

M/32. Majid, M., 1978. Minerals potential. In: Causes, effects and remedies of poppy cultivation in Swabi-Gadoon area. Vol. 1, Resource Base. Board of Economic Inquiry, NWFP, University of Peshawar, 389-404.

Key words: Mineral potential, poppy cultivation, Swabi.

M/33. Majid, M., 1979. Petrology of diorites from the “Kohistan sequence”, Swat, Northern Pakistan. A genetic interpretation at plate scale. Geological Bulletin, University of Peshawar 11, 131-151.

Diorites and related rocks of calc-alkaline nature include by far the most dominant rocks of various composite plutons extensively distributed within the suture zone in the Kohistan Himalayas in northern Pakistan. The main Himalayan suture zone has been recently traced across Kohistan through the Districts of Hazara, Swat, Dir and Mohmand by Tahirkheli et al. (1979).

The development of the thick complex of various types of diorite, granodiorite, hypersthene gabbro and calc-alkaline volcanics (andesite-dacite-rhyolite) within the suture zone in Kohistan is unique because along the Tsang Po and Indus valley in the east, the suture zone is characterized by a belt of flysch and volcanics with some ophiolites

and “melanges” (Gansser, 1964, 1977) and to the west of Afghanistan it is marked by large “nappes” of typical ophiolitic rocks.

In a tectonic discussion of the Kohistan area it has been pointed out that igneous rocks within the “Kohistan Sequence” represent products of calc-alkaline activity, associated with the subduction of the floor of the former Tethyan Ocean under a marginal basin. The mineralogical and chemical constraints of the diorites and related rocks described in this paper from the Kalam area (between latitude 35°15' to 35°52' N and longitude 72°20' to 72°27'E) favor the possibility of their derivation as a result of the active consumption of the oceanic crust dragged beneath the marginal basin while the concentrations of major and trace elements within the studied suite are strictly against the process of partial melting of sialic crustal material due to the increased geothermal gradients. This point has been discussed further in this paper.

Key words: Petrology, diorites, plate tectonics, Kohistan, Swat.

M/34. Majid, M., Danishwar, S. & Hamidullah, S., 1991. Petrographic and chemical variations in the rift-related basic dykes of the Malka area (lower Swat), NWFP, Pakistan. Geological Bulletin, University of Peshawar 24, 1-23.

This paper deals with the petrography, mineral chemistry and rock chemistry of dolerite dykes of Malka (Lower Swat). These dykes intrude Late Palaeozoic Utlā granite and consist of variable amounts of plagioclase (An 53-59%), clinopyroxene (augite), ilmenite, hornblende, biotite, apatite. Altered varieties show amphibole (calcic), plagioclase (An 21-23), Fe-Ti Oxides, chlorite and epidote.

Clinopyroxene, amphibole (both primary & secondary) and plagioclase have been studied in detail. Chemical composition of these rocks exhibits transitional character between alkaline and sub-alkaline basaltic composition. Major oxides versus S. I. indicate evolved composition for these rocks. Whereas CMAS model of O' Hara (1968) show the fractionation control of plagioclase and clinopyroxene. Compositions of these dolerite dykes indicate their association with rifting of the northern margin of Indo-Pak plate.

Key words: Petrography, geochemistry, rift-related basic dykes, Buner, Swat.

M/35. Majid, M., Karim, A., Sufyan, M. & Danishwar, S., 1992. Chemical variations within rift-related basic dykes in the Peshawar plain alkaline igneous and adjoining areas, N.W.F.P., Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.26.

Key words: Chemistry, basic dykes, Peshawar plain alkaline igneous rocks.

M/36. Majid, M. & Paracha, F.A., 1980. Calc-alkaline magmatism at destructive plate margin in Kohistan, northern Pakistan. Geological Bulletin, University of Peshawar 13, 109-120.

Four episodes of calc-alkaline igneous activity have been identified in the crust of a fossil island arc, ‘the Kohistan Sequence’, in the Kalam area, Swat. The sequence which includes a thick complex of pyroxene granulite, amphibolite, various types of diorites along with metasediments and associated volcanics is 10-15 km thick and is presumed to have developed, as a result of subduction of the primary Tethyan oceanic crust beneath an arc during the suturing of Indo-Pakistan and Eurasia.

The calc-alkaline rocks within the sequence are divisible into two distinct associations. One of these, characterized by iron- and alkali-rich differentiation on variation diagrams, is volcanic, (the Utror volcanic), consisting of andesite, dacite, rhyodacite and rhyolite. The second association includes rocks varying from hornblende biotite diorite to pyroxene-biotite diorite. Analyses of these rocks, unlike the volcanics, display an iron- and alkali-poor and Mg-rich variation trend. Chemically these rocks have been distinguished into low-silica diorite, normal diorite, high-K diorite and granodiorite (Majid, 1979). The former two types contain less K₂O than the latter two.

Field evidences suggest that the volcanic phase follows plutonic activity within the province. Most of the first-order features of the studied suite are identical with the calc-alkaline rocks of the circum Pacific type. The petrochemical indices, which identify the Kohistan calc-alkaline rocks, reflect a pronounced episodicity in their evolution. The macro-episode of major significance defined in the proposed genetic scheme is synchronous with first major tectonic event, which is referred to as the subduction of the Tethyan ocean crust in the plate tectonic model of Kohistan.

Key words: Geochemistry, calc-alkaline magmatism, Swat.

M/37. Majid, M. & Shah, M.T., 1985. Mineralogy of the blueschist facies metagraywacke from the Shergarh Sar area, Allai Kohistan, N. Pakistan. Geological Bulletin, University of Peshawar 18, 41-52.

A new occurrence of the glaucophane bearing rock within the Indus suture zone is reported from the Shergarh Sar area in Allai Kohistan. Being composed mostly of quartz with small amount of white mica, glaucophane, chlorite and plagioclase etc. the rock is described as blueschist facies metagraywacke. Constituent minerals are analyzed with probe; and P-T conditions of metamorphism (about 7 kbars and 400-450°C) are calculated. Petrographic and chemical constraints of the constituent minerals oppose any retrogression or oscillatory transition in metamorphic conditions as noted in the blueschist rocks from Ladakh, and Shangla section of Swat.

Key words: Mineralogy, blueschist, Indus suture, Allai Kohistan.

M/38. Majid, M., Shah, M.T., Latif, A., Aurangzeb, & Kamal, M., 1981. Major elements abundance in the Kalam lavas. Geological Bulletin, University of Peshawar 14, 45-62.

Andesite and sialic eruptives of calc-alkaline affinity in the Kalam volcanic zone constitute the upper part of the 'Kohistan sequence' developed in the western branch of the Himalayan syntaxis between 71° E and 75° E. The sequence is interpreted as a complete cross section of a mature island arc formed by subduction during Mesozoic in the southern part of the Neotethys and obducted onto the Indian plate in Upper Cretaceous time. The Kohistan sequence includes a thick complex of amphibolites, hypersthene gabbros, pyroxene diorites, hornblende diorites, granodiorites, metasediments and volcanic rocks.

The potential usefulness of the geochemical parameters of the extrusive rocks from the Kalam area, Swat as tectonic fingerprints and genetic indicators is discussed in this paper. There is a close correspondence between the available petrochemical indices of genetic significance of the studied suite to the calc-alkaline volcanics in western and southwestern Pacific regions, which substantiates earlier workers designation of an Island arc environment in the Kohistan Himalaya during Mesozoic time.

Key words: Geochemistry, volcanics, Kalam, Swat, Kohistan.

M/39. Malik, A.R., 1987-88. Geotechnical study of slope stability problems along the Kohala-Muzaffarabad Road. M.Sc. Thesis, Punjab University, Lahore, 174p.

Two stratigraphic units i.e. Murree Formation (Miocene) and the Hazara Formation (Pre-Cambrian) exist along the Kohala-Muzaffarabad road. A major structural element (Jhelum Fault) extend full length of the area.

Kohala-Muzaffarabad road is an important link between Pakistan and Azad Kashmir. Unfortunately this strategic route is under constant threat due slope stability problems as a result of which huge landslides occur along this road from time to time. The present study is aimed at investigating and highlighting the causes of land sliding and proposing remedial measures. In order to achieve the above aims detailed geological mapping was carried out along the Kohala-Muzaffarabad road. Field measurements such as discontinuity survey, roughness profiles of joints, compressive strength and field density (Chapter VI) were determined. A large number of samples of soil and rocks were obtained and tests were carried out in laboratory (Chapter VI) for data to be used in the slope stability analysis. On the basis of prevailing conditions of lithology, structural and nature of discontinuities and materials, a broad classification of the area is made as:

Stable zones.

Potentially unstable zones

Unstable zones.

Field sketches of a number of landslides were prepared and the relevant data of each slide as far as discontinuity were collected so as to identify and analyse each slide accordingly.

An attempt has been made, in this study, to suggest economical and feasible remedies for preventing landslides.

Key words: Geotechnical, slope stability, Azad Kashmir.

M/40. Malik, I.A., 1967-68. Geological report on Kuhai-Chinar Area (Lower Swat). M.Sc. Thesis, Punjab University, Lahore, 73p.

Martin et.al. (1962) made a geological reconnaissance map of the Lower Swat-Indus Valley Region. The author worked in part of Lower Swat and did a detailed geological mapping (Fig.-I). The Ambela granitic complex of Martin et. al. includes both igneous and metamorphic rocks. The grade of metamorphism is however low.

The Field Report presents a gist of observations made during the field work as well as in the Laboratories. Field work is completed in about three months in two consecutive field sessions in 1967 and 1968. The laboratory work includes study of forty thin sections of different rock units, preparation of orientation diagrams from reading of joints and beddings, and optics of a mineral.

The object of this report is to give a comprehensive account of the geology of the area. This report includes the description of various rock units, with an emphasis on the petrogenesis. The long discussion has been summed a chronological sequence given in "Conclusions".

Key words: Geology, Kuhai, Chinar, Lower Swat, NWFP.

M/41. Malik, I.A., 1983. Graywacky in the middle Siwalik. Geological Gazette 6, 11-13.

Key words: Graywacky, siwaliks, Salt Range.

M/42. Malik, I.A. & Naseem, M., 1970. Geological Report on Rabat Area, M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, petrography, Rabat, NWFP.

M/43. Malik, I.A. & Qureshi, S.A., 1983. A note on the Tredian Formation. Geological Gazette 6, 6-10.

This note describes in detail the lithostratigraphy of the Triassic Tredian Formation of the Trans Indus Salt range.

Key words: Stratigraphy, Tredian Formation, Triassic, Trans Indus Salt Range.

M/44. Malik, M.H., 1974. A study of landslide problem along the Murree-Abbottabad Road. Geological Survey of Pakistan, Geonews 4, 59-63.

Key words: Landslide, hazard, Murree-Abbottabad, Hazara.

M/45. Malik, M.H., 1978. Some engineering geological properties of the sediments from two borrow areas at the Simly Dam-site Simly, Pakistan. Geological Bulletin, University of Punjab 15, 15-24.

The Simly dam-site on the Soan river near Rawalpindi is located at coordinates 33° 43' 45" N and 73° 20' 25" E. The various geological units present in the area belong to the Siwalik system. More than two million cubic yards of only silt and clay are required to be used in the construction of this dam. Two borrow areas namely Simly Plain and the Tamair deposits were therefore investigated for this purpose.

Undisturbed samples from both the borrow areas tested and an attempt is made to compare their engineering geological properties. The results are presented in the form of diagrams of the representative samples to make this paper brief.

Key words: Engineering geology, sediments, Simly dam, Rawalpindi.

M/46. Malik, M.H. & Farooq, S., 1991. Effect of tectonic disturbance on the stability of slopes along roads in mountainous regions. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, p.14.

Key words: Tectonics, slope stability, Mountain ranges.

M/47. Malik, M.H. & Farooq, S., 1992-93. Effect of tectonic disturbance on the stability of slopes along roads in mountainous regions. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, p.30.

Slopes in mountain regions are vulnerable to structural disturbance in general. These changes in stability of slopes are related with the already existing structural elements as fractures in different lithologies along the Murree-Muzaffarabad Road and along the Karakorum Highway, reveal interesting relations with major structural features which are the results of movement of plates in the region. The proximity of major faults seems responsible for increased fracture frequency and instability of slopes along these roads. Statistical analysis of laboratory strength test data has been used for wedge failure in rock slopes. Surface roughness of joints and wall compressive strength along-with friction angle have also been used for analysis.

Key words: Tectonics, slope stability, mountain ranges.

M/48. Malik, M.H. & Rashid, S., 1997a. Some engineering geological properties of the Murree Formations at Lower Topa (Murree) Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.41.

Consult the following account.

Key words: Engineering geology, Murree Formation, Murree.

M/49. Malik, M.H. & Rashid, S., 1997b. Correlation of some engineering geological properties of the Murree Formation at lower Topa (Murree District), Pakistan. Geological Bulletin, University of Peshawar 30, 69-81.

Uniaxial Compressive Strength, Young's Modulus, Point Load Strength Index, Schmidt Rebound Hammer Number and Matrix (calcitic as well as clayey) are correlated for 90 samples (30 from each lithology of alternating sandstones, siltstones and claystones) to determine the effect of lithological boundaries and that of the cementing material. Correlation Coefficients of different combinations of Strength, Young's Modulus and Schmidt Hammer Rebound Number were determined. Similarly various combinations of mineral assemblages and matrix with clasts and lithological position of samples were tried and compared with strength. It is observed that strength is not only variable in each lithology but also changes with position of sample with reference to the upper or lower lithological boundaries. Laboratory tests on cores seem to be imperative for supplementing the field index tests on such detritus materials.

Key words: Engineering geology, Murree Formation, Murree.

M/50. Malik, M.H., Rashid, S. & Khan, M.S., 2000. Effect of biological contamination on the water quality in Wah Cantt. area, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 140-141.

Key words: Hydrology, water quality, biology, Wah..

M/51. Malik, M.I., 1983. Scheelite prospecting in northwest Chitral, North West Frontier Province. 2nd National Seminar on Development of Mineral Resources, Peshawar 1, 3p.

Key words: Scheelite, prospecting, Chitral.

M/52. Malik, M.S., 1967. Records of groundwater levels of Peshawar valley, West Pakistan. Basic data Release No. 12, Water and Soil Investigation Department Publication No. 52, Hydrogeology Directorate, WAPDA, North West Frontier Province, Peshawar.

Key words: Groundwater, Peshawar.

M/53. Malik, M.Y. (ed.), 1983. Technical Report on groundwater resources in Lachi Valley, Kohat District, North West Frontier Province, Report 3, Hydrogeology Directorate, WAPDA, North West Frontier Province, Peshawar, 37p.

Key words: Groundwater, Kohat.

M/54. Malik, R.H., 1973-74. Geology of Nauser area, Neelum valley, Muzaffarabad Azad Kashmir. M.Sc. Thesis, University of Peshawar, 28p.

Key words: Geology, Nauser area, Azad Kashmir.

M/55. Malik, R.H., 1986. A preliminary study of the graphite-bearing rocks, at Patlepani-Mohriwali area, Muzaffarabad, A.K. Geological Bulletin, University of Peshawar 19, 101-112.

Graphite at Patlepani-Mohriwali area, District Muzaffarabad (A. K.) occurs in a skarn formed due to an intrusion of pegmatite in recrystallised limestone of Salkhala Series of Pre-Cambrian age. Skarn formed at the upper contact of pegmatite, devoid of graphite, is barren skarn, whereas, at lower contact is fully mineralised with graphite. Mineralised skarn show a well defined zonation pattern from pegmatite to amphibole-pyroxene-graphite skarn to pyroxene-amphibole-graphite skarn to plagioclase-garnet-graphite skarn.

Graphite has an average concentration of 12% and occurs in skarn as concordent lenses, disseminated flakes, bands and is formed in two phases; organic carbon present in original impure limestone was converted into amorphous to semi crystalline graphite during regional metamorphism of area. During the subsequent process of skarnification, this amorphous to semi-crystalline graphite was fully crystallized and being mobile migrated into low-pressure zones of skarn.

Key words: Graphite, skarns, pegmatite, Muzaffarabad.

M/56. Malik, R.H., 1994. Geology and resource potential of Kashmir ruby deposits, Distt. Muzaffarabad (AK), Pakistan. Azad Kashmir Mineral and Industrial Development Corporation, Muzaffarabad, 21p.

Fine crystals of gem quality ruby occur in marbles in Nangi Mali area of Azad Kashmir. The occurrence and grade of metamorphism are similar to those of the Hunza ruby. The geological aspects of the mineralization and economic potential of the deposit are described in detail in this paper.

Key words: Geology, gemstones, ruby, Azad Kashmir.

M/57. Malik, R.H., 1995. Geology and resource potential of Azad Kashmir ruby deposits. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 153-171.

Consult the preceding abstract for further details.

Key words: Geology, gemstones, ruby, Azad Kashmir.

M/58. Malik, R.H., Schoupe, M., Fontan, D., Verkaeren, J., Martinotti, G., Ahmed, K.S. & Qureshi, S., 1996. Geology of the Neelum valley, District Muzaffarabad, Azad Kashmir, Pakistan. Geological Bulletin, University of Peshawar 29, 91-111.

The central and north-western parts of Neelum valley have been mapped, proposing a new lithostratigraphic division for the region. The area comprises two main tectonic units: the Lesser Himalayan Crystalline Unit (LHC) and the Higher Himalayan Crystalline (HLC), separated from each other by the Main Central Thrust (MCT). The two units are characterized by a similar stratigraphy and share a common low-grade metamorphic assemblage. They, however, differ in the intensity of the imprints of the Himalayan metamorphism. The lithostratigraphic units comprise, from base to top, Naril Group (Precambrian basement), the Kundalshahi Group (pre-Himalayan cover) and Surgun Group (an Upper Paleozoic to Mesozoic Himalayan metasedimentary cover comprising paragneisses, mica schists, marbles, amphibolites, calc-schists and impure quartzite). This lithostratigraphic sequence is intruded by a megacrystic granite, similar to that of Mansehra (Early Cambrian) and meta-doleritic dykes, correlated with the Permo-Carboniferous Panjal Trap volcanics. Geochemistry reveals an igneous granitic calc-alkaline origin for the Naril granulitic gneiss, whereas, the sediments of Kundalshahi Group are characterized by a high SiO₂ and highly variable trace element contents except REE. In the Surgun Group two types of marbles have been distinguished on the basis of high CaO and Low MgO. The amphibolites in the Surgun Group as well as of Himalayan cover share the same igneous protolith and are basaltic in composition. Geothermobarometric studies indicate polyphase metamorphic evolution for the lithological units of the Neelum valley in the Tertiary Himalayan event. The P-T-t path suggests a prograde metamorphic evolution up to Upper Cretaceous-Eocene times, followed by a retrograde path, essentially of decompressive type. The final part of the path being accompanied by a decrease in temperature. The LHC tectonic unit and a southern portion of the HHC unit followed a different P-T trajectory, under greenschist-facies conditions. The ⁴⁰Ar/³⁹Ar determinations on muscovite and biotite from these low-grade rocks yield middle Oligocene cooling ages. Four phases of deformation have been distinguished. Isoclinal overturned to recumbent folds represent the D1 and D2 phases; contemporaneous with the regional Himalayan metamorphism, during upper Cretaceous to Miocene. The MCT developed after D2 phase of deformation generating the LHC and HHC nappes and the reversed metamorphic zonation of Neelum valley. The D3 structures comprise of open large megascopic flexural slip buckle folds trending NE-SW. The D4 deformation affects the Hazara Kashmir syntaxis.

Key words: Geology, Neelum Valley, Azad Kashmir.

M/59. Malik, T.M., 1986-88. Stratigraphic studies of area around Dhamtaur-Baghseri District, Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 96p.

The present report is a geological study of nearly 30 sq. miles Dhamtaur and Baghseri area in south eastern direction of Abbottabad. The study includes a geological map on 1:12500 (1cm-125m) and the stratigraphy of the area, from Pre-Cambrian to Upper Palaeocene (Thanetian). The geological history of the Hazara Trough and the environmental deposition of the formation is reviewed. Structurally, the area is very much complicated within which a generally complex folding and faulting predominates.

Key words: Stratigraphy, Abbottabad.

M/60. Malik, Z., Kamal, A., Malik, M. A. & Bodenhansen, J.W.A., 1988. Petroleum Potential and prospects in Pakistan. In: Raza, H.A. & Sheikh, A.M. (eds.) Petroleum for the Future. Hydrocarbon Development Institute of Pakistan, 71-100.

Key words: Hydrocarbon, Pakistan.

M/61. Malinconico, Jr. L.L., 1982. Structure of the Himalayan Suture Zone of Pakistan Interpreted from gravity and magnetic data. Unpublished Ph.D. dissertation, Dartmouth College Hanover, New Hampshire, 128p.

Two-dimensional analysis of gravity and magnetic data in northern Pakistan suggest that the Indian plate is being thrust under the Asian plate and that the major structures in this region dip towards the north.

In northern Pakistan the westward extension of the Indus Suture Zone bifurcates into two structural zones which surround a sequence of rocks interpreted as a wedge of island-arc terrain caught between the colliding Indian and Asian plates. The Main Mantle Thrust (MMT), the southern suture zone, represents the contact between the Indian plate to the south and the island-arc complex to the north. The Indian plate is composed of Paleozoic metasediments intruded by granites, while the southern portion of the island arc complex is composed primarily of mafic rocks.

These contrasting lithologies provide a strong density contrast for modeling of gravity data. The northern suture zone, the Main Karakoram Thrust (MKT), separates the island-arc from the Asian plate to the north. On the south side of the MKT are the meta-sedimentary, meta-volcanic rocks of the island-arc sequence while on the north side of the MKT are the meta-sedimentary rocks of the Asian plate. Thus there is not as strong apparent density contrast across the MKT as there is across the MMT. Close to 600 gravity and magnetic measurements were made along traverses that were approximately normal to the major structures in the area. The gravity data were reduced to terrain-corrected Bouguer values and were then analyzed using two-dimensional modeling techniques.

The results of the modeling suggest that both the MMT and the MKT dip toward the north. The MMT at angles of 35 to 45 degrees while the MKT dips at around 20 degrees. The island arc appears to be 8 to 19 km thick with its southern edge tilted upward and eroded back to expose the lower layers of the sequence. The amphibolite layer which outcrops along the southern margin of the arc must extend at depth along the entire width of the arc. Total field magnetic anomalies along the same traverses do not reflect major structural trends, but correlate instead with bodies of ultramafic rock which appear to be localized along the suture lines. An ultramafic klippe is observed 25 km south of the present outcrop of the MMT and suggests that the island-arc terrain once extended farther to the south.

The Main Boundary Thrust is the youngest structural feature studied. It is the zone of current crustal shortening along which Indian crystalline terrain is being thrust southwards over recent sediments along a plane which is modeled as dipping less than 15 degrees to the north. When the present attitudes and presumed ages of the MMT, MKT, and MBT are taken into account the generalization can be made that the older a suture zone is, the steeper its present dip. The suture margins of the island arc have been recently modified by recent uplift in the Nanga Parbat region. This has caused the suture zones in that area to steepen into near vertical attitudes. Modeling of gravity data a traverse that crosses the entire length of the suture zone in northern Pakistan suggests that the Indian plate be being thrust under the Asian plate. This thrusting is forcing sialic material to a maximum depth of 100 km.

A possible tectonic history for the area can be constructed. Approximately 40 my ago the Indian plate collided with an island arc that was growing due to the northward subduction of the Tethyan oceanic crust. The Collision caused the island-arc terrain to be obducted onto the Indian plate along a very shallow thrust (the MMT). While this was happening, the basin behind the arc began close. With the complete closing of the back-arc basin, the arc ran into the Asian plate and the Asian terrain was thrust over the arc (along the MKT). Continued northward migration of India steepened the MMT and MKT into their present attitudes, while crustal shortening was accommodated along shallow thrust (the MBT).

Key words: Structure, Himalayan suture zone, geophysics, gravity, MBT.

M/62. Malinconico, Jr. L.L., 1986. The structure of the Kohistan-Island Arc terrane in Northern Pakistan as inferred from gravity data. *Tectonophysics* 124, 297-307.

Modelling of gravity data taken across the Kohistan Island-Arc terrane in northern Pakistan can be used to constrain the shape and thickness of the Arc. Over 600 new gravity measurements were made across the Kohistan Island-Arc terrane in northern Pakistan. These data were taken along traverses normal to the structures bounding the Arc and were reduced to terrain-corrected Bouguer values. The reduced data were then modelled using standard two-dimensional modelling techniques. The southern margin of the Arc, the Main Mantle Thrust (MMT), dips to the north at approximately 45° and gradually flattens out at a depth of 7–9 km. The northern margin of the Arc, the Main Karakoram Thrust (MKT), also dips towards the north, but at a shallower initial angle (15°). From the models, the Arc terrane now appears to be around 7–9 km thick with the thicker sections occurring closer to the southern margin. The proposed model, in particular the angle of the MMT and the MKT, may have been significantly affected by the recent and rapid uplift that is occurring along the Nanga Parbat-Haramosh Massif.

Key words: Structure, gravity, Kohistan island arc, Himalaya.

M/63. Malinconico, Jr. L.L., 1989a. Crustal shortening in the west-Himalaya. *Geological Bulletin, University of Peshawar* 22, 55-64.

The main collision between the Indian and Asian lithospheric plates occurred during the late Eocene (40 million years ago) and continued closure at the rate of 5 cm/yr has resulted in approximately 2000 km of crustal shortening between the two plates (Molnar and Tapponnier, 1975; Molnar, 1984). In northern India it has been suggested that while some of the shortening is by underthrusting (Molnar and Tapponnier, 1975) much may be the result of diffuse

deformation in China (Tapponnier, 1982). However, in northern Pakistan the problem is complicated because there is no Tibetan plateau analog and no evidence of strike-slip structures that could have removed significant amounts of crustal material. In order to place tighter constraints on tectonic models for the Indian-Asian collision in the western Himalaya it is important to be able to estimate the amount of crustal shortening that has occurred. Current estimates of 500 to 700 km of convergence in northwestern Pakistan (Butler, 1986), are calculated from balanced cross section methods. This is significantly less than the 2000 km required by closure models based on paleomagnetic data (Powell, 1979; Molnar and Tapponnier, 1975; Molnar, 1984). An important step in estimating the amount of shortening that has occurred is to determine the volume of crust that remains in the orogen. The crustal models based upon observed gravity profiles presented in this paper suggest that there may be enough crustal volume to account for between 550-1100 km of shortening. This is still significantly less than the 2000 km of closure that has presumably occurred. The balance of the closure might be accounted for by erosion and/or defused deformation or it might suggest that less than 2000 km of closure has occurred in the northwestern Himalaya.

Key words: Structure, tectonics, collision, crustal shortening, Himalaya.

M/64. Malinconico, Jr. L.L., 1989b. Crustal thickness estimates of the Western Himalayas. In: Malinconico, L.L. & Lillie, R.J. (eds.), *Tectonics of the Western Himalayas*. Geological Society of America, Special Papers 232, 237-242.

The main collision between the Indian and Asian lithospheric plates occurred during late Eocene time (40 to 50 m.y. ago). Continued northward migration of the Indian plate since that time at the rate of 5 cm/yr has resulted in approximately 2,000 km of closure between the two plates. In northern India it has been suggested that, while perhaps 500 to 1,000 km of the closure can be accounted for by crustal shortening, underthrusting, and thickening, the balance (1,000 + km) may be accounted for by eastward motion along strike-slip faults in China. However, in northern Pakistan, the problem is complicated because there is no Tibetan plateau analog and no evidence of strike-slip structures that could have removed significant amounts of crustal material.

In order to place tighter constraints on tectonic models for the Indian-Asian collision in the western Himalaya, it is important to be able to estimate the amount of crustal shortening that has occurred. Current estimates of 500 to 700 km of crustal shortening in northwestern Pakistan are calculated from balanced cross-section methods.

An important step in estimating the amount of shortening that has occurred is to determine the volume of crust that remains in the orogen. The crustal model based on observed gravity profiles presented in this chapter suggest that there may be enough crustal volume in the western Himalaya to accounted for between 570 and 1,140 km of shortening. This is still significantly less than the 2,000 km of closure that has possibly occurred. The balance of the closure might be accounted for by erosion and/or diffuse deformation, or it might suggest that less than 2,000 km of closure has occurred in the northwestern Himalaya. The crustal models also suggest that the style of underthrusting in the northwestern Himalaya may be significantly different than that proposed for the Himalaya of northern India. Here the underthrusting seems to be occurring at a very steep angle when compared to the shallow underthrusting proposed for northern India.

Key words: Structure, tectonics, crustal thickness, Himalaya.

M/65. Malinconico, Jr. L.L. & Adams, K., 1986. Lithospheric underthrusting in the western Himalaya inferred from gravity data. *Geological Society of America Abstract with Programs* 18, 679.

Key words: Tectonics, lithosphere, gravity, Himalaya.

M/66. Malinconico, Jr., L.L. Johnson, N.M., Offield, O.B. & Tahirkheli, R.A.K., 1986. Gravity and magnetic constraints on the structure of the suture zone in northern Pakistan. In: Huang, J. (ed.), *Proceedings of the Symposium on Mesozoic and Cenozoic Geology*. Geological Society of China, 60th Anniversary Volume. Geological Publication House, Beijing, 357-367.

Key words: Tectonics, suture zones, gravity surveys, Island arcs, Swat.

M/67. Malinconico, Jr. L.L. & Lillie, R.J. (eds.), 1989. Tectonics of the Western Himalayas. Geological Society of America, Special Paper 232, 320p.

This edited volume contains nineteen papers on various aspects of the geology of the western Himalaya. All the papers concerning northern Pakistan are annotated in appropriate places, following alphabetic order of the authorships.

Key words: Structure, tectonics, Himalaya.

M/68. Mallick, K.A. & Valiullah, M., 1972. Mineralogical study of the non-clay fraction, in the bauxite and the associated rocks of Azad Kashmir. *Acta Mineralogica – Petrographica*, Szeged XX/2, 271-286.

Bauxite and the associated rocks from seven different localities of Muzaffarabad and Kotli areas of Azad Kashmir have been investigated for their non-clay mineral correspondence. Rocks in contact with the bauxite are the fire clay at the base and Eocene shale at the top. The fire clay overlies the Muzaffarabad Formation of Permo-Carboniferous age. The bauxite and the fire clay correspond closely with each other in their mineralogical composition. No relationship could be found between the top of Muzaffarabad Formation and the bottom of the fire clay.

The study reveals similar provenance and cycle of deposition for the fire clay and the bauxite with some breaks and changes when the pisolites of the bauxite were being formed.

Key words: Economic geology, bauxite, Azad Kashmir.

M/69. Maluski, J. & Matte, P., 1984. Ages of alpine tectonometamorphic events in the northwestern Himalaya (northern Pakistan) by ^{39}Ar - ^{40}Ar method. *Tectonics* 3, 1-18.

The main tectonometamorphic alpine events which occurred, in the western part of the western Himalayan migration at south of the main suture, in northern Pakistan, are dated by the $^{39}\text{Ar}/^{40}\text{Ar}$ method. These events are as follows: (1) the blueschist metamorphism (80 ± 5 Ma) present in tectonic/ophiolitic mélanges along the suture (this event occurred during an early subduction or obduction stage) (2) the alpine barrovian metamorphism (50-30 Ma) developed in the sedimentary cover and orthogneisses of the Indian Plate during the postcollisional northward underthrusting of this plate below Asia, leucogranites (23 Ma) resulting from the melting of the Indian crust during the climax of the alpine metamorphism.

Key words: Tectonics, chronology, metamorphism, Himalaya.

M/70. Maluski, J. & Schaeffer, O.A., 1982. ^{39}Ar - ^{40}Ar laser probe dating of terrestrial rocks. *Earth and Planetary Science Letters* 59, 21-27.

We have shown that for metamorphosed granites, as well as for metamorphosed sediments, it is possible to obtain a reliable K-Ar age from a sample as small as 0.2 µg. Samples with ages as young as 40 m.y. are easily studied. There is no reason to believe that the method could not be used for samples considerably younger. The main application of the laser will probably be for cases where the same mineral species has been formed during two distinct metamorphic events in the same rock. In this case, it is difficult, if not impossible, to make a mineral separate suitable for a ^{39}Ar - ^{40}Ar study. We have shown that in the case of an old granite the biotite in one sample distinctly shows thermal events at 1600 m.y. while its primary cooling age is 2100 m.y. The thermal release study yields a good plateau age, roughly an average age of the two thermal events. Another interest of this method is demonstrated by argon dating of two different kinds of glaucophane, only one of these showing argon in excess.

Key words: Chronology, metamorphosed granite.

M/71. Manzoor, P., 1963. Geology of the Neelum area, Hazara. M.Sc. Thesis, Punjab University, Lahore, 30p.

Key words: Geology, structure, Neelum, Kashmir.

M/72. Maraini, F., 1959. Gasherbrum IV. Baltoro Karakorum. Ed. L. da Vinci, Bari.

Key words: Gasherbrum IV, Baltoro, Karakoram.

M/73. Maraini, F., 1963. Paropamisso. Spedizione romana all'Hindu Kush ed ascensione del Pico Saraghrar (7350 m). Ed. L. da Vinci, Bari.

This is the description of the Italian expedition to the eastern Hindu Kush. The expedition conquered the Saghrar (Tirich Mir) peak.

Key words: Italian Expedition, Tirich Mir, HinduKush.

M/74. Marcoux, J. & Aymon, B., 1995. Late Permian to late Triassic evolution of the Northern Indian continental margin. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

During the late Permian, the north Indian margin is the seat of rifting processes. The rift geometry is characterized by a rim basin, a thick upper-plate volcanic extrusion on the shoulder (Panjal Trap) and a terrigenous intrarift shelf and slope. After the uppermost Permian break up the Northern part of India evolves as a passive margin.

Typical of the Permian rim basin is the Nammal Gorge section of the Salt Range. The lower part of the Wargal Formation (late Murgabian) consists of regressive shallow-water carbonate sequences. On the shoulder, the Kashmir area shows a great thickness (up to 1 km) of early, late Permian volcanic rocks: the Panjal Traps. At the Guryul Ravine-type section a marine, fossiliferous, mixed carbonate-terrigenous shelf (Zewan Formation) transgresses the Panjal Traps. On the rift side of the shoulder, in the Phuktal section, the open marine Kuling sandstones occur, transgressing on partly tilted blocks. The same lithologies characterize the whole Tethys Himalaya in India and in Tibet. Although absent in the central Himalaya, the Permian Traps, named the Abor volcanics, form large accumulations in the eastern part.

On the Zaskar traverse, the terrigenous Kuling shelf passes oceanward to the flyschoid Lutchungse basin in the Markha Valley area. The Permian exotic blocks consist of open-marine fossiliferous brecciated limestones (the Lamayuru block) or limestones with lava intercalations as in the Spongtag area. The same limestones have been found west of Raskas lake in southwest Tibet.

During the early and middle Triassic, the north Indian margin is characterized by a well-developed slope and a deep, wide, structural shelf. The distal and deeper part found in the Lamayuru and Yamdrock Tso areas consists of shaly and silty deposits with common marly intercalations, often representing turbidity currents. The deep shelf invariably characterized by nodular, condensed mudstone/wackstones of the Tamba Kurkur Formation, more shaly towards the top and cropping out in northwest Zaskar, Spiti, Kumaon, where it corresponds to the Kalapani Limestone, and Nepal. In Kashmir middle Triassic sediments, the inner-shelf, nodular limestones are richer in fine clastics, as in the Khreuh Formation. The Salt Range was mostly covered by shallow water carbonates, now dolomitized (Kingriali Formation).

In the late Triassic, the distal deeper-water sediments were found in Lamayuru, with large Dachstein-type olistoliths and in the Yamdrock Tso area with shaly and silty deposits with common, marly intercalations, often sedimented by turbidity currents. The most distal part is found in the exotics of the central Himalaya, the Kiogar Peaks, with typical shallow water Dachstein-type limestones. On the margin, the shallow shelf is characterized by fine well-sorted subarkoses and outcrops in northwest Zaskar, Spiti and Nepal. In Kumaon, the corresponding deposits are the Kuti shale. In Kashmir the inner-shelf limestones are very thick. The Salt Range area was emerged; but to the west, shallow-water limestones are present in the Samana Suk Range where the lower part of the Samana beds are middle to late Triassic in age. To the northwest the carbonate platform (Kashala Formation) is now metamorphosed to the greenschist facies.

Key words: Permian, Triassic, evolution, stratigraphy, Panjal Traps.

M/75. Marks, P. & Ahmad, A., 1962. The Giumal sandstone transgression in the Hazara mountains, West Pakistan. Geological Bulletin, Punjab University 2, 54-55.

During the field season of 1960 and 1961, parties of the Geology department, Punjab University, collected a large number of ammonites from the Giumal sandstone formation at various localities in the Hazara mountains. These faunas proved to be of different stages of the Lower to Middle Cretaceous. Previously, Spath, (1930) had already described such faunas from the same formation. The Giumal Sandstone Formation overlies in all localities the Spiti Shale Formation, which, in turn, disconformably overlies the Oolitic limestones of the Triassic (?) formation, whereas, however, the boundary between the Triassic (?) Formation and the Spiti Shale Formation is dated in all localities by an Upper Oxfordian Jurassic fauna, the faunae identified from the Giumal Sandstone Formation vary in different localities. The fauna in the eastern part of the area is Berriasian in age; that in the centre (localities 3 and 4) is Valaginian/Hauterivian; while that in the western part of the area is Middle to upper albian (Spath, 1930, 63-64). These later localities lie, generally, on the north-south line, which suggests that the change of the faunae takes place from east to west. As the thickness of the Giumal Sandstone Formation is rather small, varying from about 100 feet in the east to about 50 feet in the west, and the Formation only contains a single fauna in each locality, it follows that the Spiti Shale/Giumal Sandstone Formation boundary shows a marked time-shift from east to west.

Key words: Stratigraphy, Giumal sandstone, Hazara.

M/76. Marks, P. & Ali, C.M., 1961. The geology of the Abbottabad area, with special reference to the infra-Trias. Geological Bulletin, Punjab University 1, 47-55.

The stratigraphy and structure of the Paleozoic and Lower Mesozoic formations in the environment of Abbottabad (Hazara District) are described. The authors criticize the age given by previous authors, and suggest that part of their Triassic system is in fact Jurassic. An attempt is made to reconstruct the palaeogeography and sedimentary environment of the Infra-Triassic Group.

Key words: Stratigraphy, structure, Paleozoic, Mesozoic, Abbottabad.

M/77. Marks, P. & Ali, C.M., 1962. The Abbottabad Formation: A new name for Middlemiss' Infra-Trias. Geological Bulletin, Punjab University 2, p.56.

The Abbottabad Formation was initially named by Middlemiss as the Infra-Trias. This paper describes the formation with its new name.

Key words: Stratigraphy, nomenclature, Abbottabad Formation.

M/78. Martin, N.R., 1962. Tectonic style in the Potwar, West Pakistan. Geological Bulletin, Punjab University 2, 39-50.

A brief description is given of detailed structural observations made on number of the faulted folds of the Potwar region of West Pakistan. An attempt is made to analyze the kinematics of these structures in terms of a number of phases, and to show the general style of the tectonics. The structural analysis of the region by some of the previous workers is discussed.

Key words: Structure, tectonics, Potwar.

M/79. Martin, N.R., Siddiqui, S.F.A. & King, B.H., 1962. A geological reconnaissance of the region between the Lower Swat and Indus rivers of Pakistan. Geological Bulletin, Punjab University 2, 1-13.

The present results of a rapid reconnaissance of the Lower Swat-Indus region are given. The map is based on the interpretation of aerial photographs and selected traverses, and on some detailed mapping in the Lower Swat area. Tentative suggestions are made for the correlation of the formations encountered, and the structure of the region. Stratigraphy and structure are accompanied by description of the granitic rocks and gneisses. The southern amphibolites belt of the Kohistan magmatic arc is named as the Upper Swat Hornblendic Group. The geological map also shows the lensoid serpentinized body of the Shangla-Alpurai area.

Key words: Geology, reconnaissance, Lower Swat, Indus river.

M/80. Marussi, A., 1955a. With the Italian expedition to Karakorum, K-2. Royal Geographical Society, Series B. No. 355.

Key words: Geography, geomorphology, Karakoram.

M/81. Marussi, A., 1955b. L'Esplorazione geofisica del Karakorum. L'Universo 25, 1-12.

Key words: Geophysics, exploration, Karakoram.

M/82. Marussi, A., 1955c. Osservazioni gravimetriche e geomagnetiche effettuate dalla spedizione italiana al Karakorum 1954. Bollitin Adriatica Sc. Nat. 47, 132-137.

Key words: Geophysics, gravimetry, geomagnetism, Italian Expedition, Karakoram.

M/83. Marussi, A., 1955d. Con la spedizione italiana al Karakorum K2. Pubbl. Royal Society Geogr. 355, 21p (Madrid).

Key words: Italian Expedition, Karakoram.

M/84. Marussi, A., 1956a. Gravimetric and magnetometric surveys performed by the Italian Karakorum expedition 1954. Geodesique, London, Bull., 41.

Key words: Magnetometry, gravimetry, Karakoram.

M/85. Marussi, A., 1956b. Expedicao Italiano as Karakorum-K2. Boletin de Sociedade Geography de Lisboa, Series 74 (7-9), 252-267.

Key words: Expedition, Karakoram.

M/86. Marussi, A., 1963a. Le anomalie della gravita lungo la catena del Karakorum-Hindu Kush. Rendiconti Accademy Nazionale de Lincei, Series 8, 35, 5.

Key words: Gravimetry, Karakoram, Hindukush.

M/87. Marussi, A., 1963b. Le anomalie della gravita lungo la catena del Karakorum Hindu Kush. Atti Accad. Naz. Lincei, Rec., 35, 198-210.

Key words: Gravimetry, Karakoram, Hindukush.

M/88. Marussi, A., 1964a. Italian expeditions to the Karakorum (K2) and Hindu Kush: I-Geophysics of the Karakorum. Scientific Reports II-Geophysics. E. J. Brill., Leiden.

Key words: Karakoram, Italian Expedition..

M/89. Marussi, A., 1964. Geophysics of the Karakoram, Italian Expeditions to the Karakoram (K2) and Hindu Kush (Prof. A. Desio leader), II-Geophysics, Volume 1, 242p. Brill, Leiden.

Key words: Geophysics, expedition, Karakoram, Hindukush.

M/90. Marussi, A., 1976a. Introductory report of Geophysics. In: *Geotectonica dell zone orogeniche del Kashmir Himalaya, Karakoram-Hindukush-Pamir*. Accademie Nazionale de Lincei 21, 15-25.

Key words: Geophysics, Kashmir, Himalaya, Karakoram, Hindukush.

M/91. Marussi, A., 1976b. Gravity in the Karakorum: International Colloquium on the geotectonics of the Kashmir Himalaya-Karakorum-Hindu Kush-Pamir Orogenic Belt. *Rend. Acc. Naz. Lincei*, 131-137.

Key words: Gravity, geotectonics, Himalaya, Karakoram, Hindukush.

M/92. Marussi, A., 1978. Results of seismic sounding: gravity and crustal structure in the Kashmir Himalaya and the Karakorum – Hindu Kush region. Abstract International geodynamic conference, Kathmandu, March 26-29.

Generally speaking, geophysics fields show little correlation with geological fields in the region of the Pamir-Kun Lun-Karakoram-Himalaya-Hindu Kush syntaxis. The gravity field shows regular symmetric trends astride the Karakorum range, but west of the Chitral Line this trend is substituted by strong negative gravity anomalies. The zone of transition coincides with the area of the Hindu Kush intermediate earthquakes, is marked by the junction of the Chaman and Heart fault systems, and thus testifies deep seated phenomena. An even more striking lack of correlation is appearing if satellite gravity data are considered.

The deep seismic sounding operations performed in 1974 and 1975 between India, Italy, Pakistan and U.S.S.R. show a thickening of the crust under the Karakorum and a progressive deepening of the Moho discontinuity proceeding from the Indus platform towards North. The Nanga Parbat massif shows high velocity surface layers. A map of the lineaments of the systaxial zone has been drawn from Landsat imageries.

Key words: Seismology, crustal structure, Himalaya, Karakoram, Hindu Kush.

M/93. Marussi, A., 1980. Gravity, crustal tectonics and mantle structure in the central Asian syntaxis. *Geological Bulletin, University of Peshawar* 13, 23-27.

An attempt is made to interpret the gravity field in the zone of the Tien Shan-Hindu Kush-Kun Lun-Karakorum-Kashmir Himalaya syntaxis, considering the local features of the field generated by density anomalies in the lithosphere separated from the regional geoidal features generated by anomalous density distributions in the Mantle as obtained by satellite geodetic methods.

The local isostatic anomalies show a marked dichotomy astride of a line representing the prolongation of the Chaman Fault lineament. Remarkably, the nest of intermediate Hindu Kush earthquakes is to be found at the intersection between the same line with the Herat Fault lineament. Strong negative anomalies unrelated to either the topography or the geology prevail NW of such line, whereas SE of the line the field is characterized by stripes of alternating negative and positive anomalies all having the Himalayan trend.

Both the Himalayan and the Chaman Fault trends are to be recognized in the geoidal features of GEM 10. The Himalayan trend is here related to the upheaval of the geoid that accompanies all along the Alpine-Himalayan geosyncline, and the Chaman Fault trend to the geoidal downwarping that follows the northern continuation of the tensional zone of the Arabian Sea crossing the syntaxial zone and continuing in the Balkash-Baykal Rift Zone in Central Asia. A tentative hypothesis is made to interpret the relationship between mantle structure and the crustal tectonics by the mechanism of gravity sliding.

Key words: Gravity, crustal tectonics, mantle structure.

M/94. Marussi, A., 1980. Geoidal features and crustal structures in Central Asia. Qinghai-Xizang (Tibet) Plateau Symposium, Beijing.

Key words: Tectonics, structure, Central Asia.

M/95. Marussi, A., 1983a. Gravity anomalies and granites of the Karakoram. In: Shams, F.A. (ed.), *Granites of Himalaya, Karakorum and Hindu Kush*. Institute of Geology, Punjab University, Lahore, 389-392.

On the basis of gravity survey, it is shown that negative anomalies, over Karakorum and the Nanga Parbat – Haramosh orogens, are related to granite bodies while the positive anomalies are related to regional amphibolites, basic granulites and basalts. It is further shown that the Nanga Parbat – Haramosh tectonic event as a huge diapir is genetically related to the Karakorum axial batholith.

Key words: Gravity, granites, Karakoram.

M/96. Marussi, A., 1983b. The Pakistani-Italian Karakorum geophysical project in the frame of the Pamirs-Himalaya International Project. *Bollettino di Geofisica Teorica de Applicata (Pamir-Himalaya Volume)* 25, 137-141.

Key words: Geophysics, Pamir, Himalaya, Karakoram.

M/97. Marussi, A., 1983c. Geophysical trends and evolution of the Pamirs syntaxis and Karakorum. *Bollettino di Geofisica Teorica de Applicata (Pamir-Himalaya Volume)* 25, 443-465.

Key words: Geophysics, tectonics, Pamir, Himalaya, Karakoram.

M/98. Marwat, N.J., 1983. Geology of a part of the Shiwa-Shehbaz Garhi complex, District Mardan. M.Sc. Thesis, University of Peshawar, 56p.

Key words: Geology, granites, Shahbaz Garhi, Mardan.

M/99. Marwat, S.K., 1972. Chemical study of rocks and ore for chromium, iron and nickel and geology of Baraul valley, District Dir. M.Sc. Thesis, University of Peshawar, 20p.

Key words: Geochemistry, rre, chromium, iron, nickle, Baraul, Dir.

M/100. Marwat, W.A., 1985. A report on lithostratigraphic units of Jawaki area, Kohat. M.Sc. Thesis, University of Peshawar, 69p.

Key words: Stratigraphy, lithology, Kohat.

M/101. Mason, D., 1914. Examination of certain glacier snouts of Hunza and Nagar. *Geological Survey of India. Records* 6, 49–51.

Key words: Glaciology, Hunza, Nagar.

M/102. Mason, K., 1929a. The representation of glaciated regions on maps of the survey of India. *Geological Survey of India, Professional Paper* 25, 18p.

Key words: Glaciology, mapping, India.

M/103. Mason, K., 1929b. Indus floods and the Shyok glaciers. *Himalayan Journal*, 1, 10–29.

Key words: Indus floods, Shyok glaciers, Himalaya.

M/104. Mason, K., 1930. The glaciers of the Karakoram and neighborhood: Geological Survey of India, Records 63 (2), 214-278.

Key words: Glaciers, Karakoram.

M/105. Mason, K., 1931. Expedition notes: tours in the Gilgit Agency. *Himalayan Journal*, 3, 110-115.

These are the notes and letters sent by the political agent stationed at Gilgit during the subject years, (1928-1932) to the editor of the journal. These notes give the details of the snouts of the glaciers in the area and possible suggestions.

Key words: Expedition, Gilgit.

M/106. Mason, K., 1932. The Upper Shyok Glaciers. *Alpine Journal*, 44, 237-245.

Key words: Glaciers, Shyok..

M/107. Mason, K., 1932. The Karumbar Glacier. *The Himalayan Journal* 4, 182-183.

About 2nd March 1930 the local chief in the Karumbar valley went to see if the route in this valley was clear for a tour that Mr. Todd proposed to undertake. He found that the glacier above Bort had advanced a very long way in the past year, but that it was still about a hundred paces from the far bank. On the 22nd March, however, one of his men reported that the glacier had closed up and blocked the entire valley. The chief, doubtful of the accuracy of this report, again went up the valley to investigate and found that the glacier had actually advanced a hundred paces in three weeks. Mr. Todd visited the glacier on 20th October and found it stretching right across the main valley with its snout hard pressed against the high steep cliff of the far bank. He estimated the height of the snout to be between 120 and 150 feet, and its breadth from 250 to 300 yards. The width of the valley at the block is about 400 yards wide. Some local Wakhis had succeeded in crossing the glacier to visit their fields upstream, but it must have been a perilous passage owing to the formidable barrier of ugly pinnacles and crevasses. The main river was flowing underneath the ice close to the snout and was quite clear. The muddy waters of the glacier itself were issuing from it some 200 feet above the snout. In recent years floods have been caused by the bursting of the Karumbar ice-dam on two occasions, in July 1893 and in June 1905. Mr. Todd gives the following information concerning the latter, thereby supplementing the notes he gave in his letter published in the *Himalayan Journal*, vol. ii, p. 174. In the autumn of 1904 the Karumbar glacier made an advance similar to that of last spring, and eventually closed against the cliff on the far side in November and December 1904. It was inspected in April 1905 and reported to be about 120 feet high at the snout. A lake formed behind the barrier in the winter and spring of 1904-5, which was reported by locals to be stretching for a full day's march upstream, a statement which was probably exaggerated, unless the march is considered a laborious and difficult one. On the night of 17-18th June the imprisoned waters forced a channel underneath the glacier, and the ice-bridge above the tunnel gradually caved in. The resulting flood reached Gilgit about 8 a.m. where it carried away the one-pier bridge. It will be interesting to note whether a similar flood occurs next year. If we take the block dates as the winters of 1891-2, 1904-5 and 1929-30, the intervals between the times of maximum advance are approximately 13 and 25 years. It would be interesting to know whether there was a minor block about 1917, which would give us a fairly regular periodicity of about 13 years. We are still groping for the laws that govern glacier-movement and we hope that the future movements of this glacier will be recorded annually by the authorities at Gilgit.

Key words: Glaciers, Karumbar, Gilgit.

M/108. Mason, K., 1935. The study of the threatening glaciers. *Geographical Journal* 85, 24-41.

Key words: Glaciers, natural hazards, Gilgit.

M/109. Masood, H., 1976. An evidence of Maestrichtian rocks in Hazara. Geological Bulletin, Punjab University 13, 111-112.

In his first reference to the geology of Hazara Verchere, 1866-67, gave a rough description of the geology of Hazara without giving any reference to the occurrence of the Upper Cretaceous rocks in the area. Waagen and Wynne, 1872, in their succession of rocks mentioned a bedded limestone, without fossils apparently, possibly of Cretaceous age. Middlemiss, 1896, included the above referred thin bedded limestone as part of Tertiary rocks, as lowest bed of the Nummulitic Series. Latif, 1962, recorded the presence of microfossils of Upper Cretaceous age in the rock units referred above. Latif, 1970, identified more than 30 species of microfossils and dated the rocks as Upper Coniacian to Campanian, Upper Cretaceous. He further identified the rocks as Chanali Limestone and separated it from the overlying Tertiary formations. The microfossil studies carried by Latif, 1970, were based on a study of five samples from Changlagali section. It was found to be necessary to advance the studies by measuring various sections in Hazara and studying the relevant samples. The investigations have shown the presence of twenty seven microfossils in addition to those of Latif, 1970. These microfossils are newly recorded from Hazara.

Key words: Stratigraphy, palaeontology, Maestrichtian, Hazara.

M/110. Masood, H., 1989a. Samana Suk Formation, depositional and diagenetic history. Kashmir Journal of Geology 6 & 7, 157-162.

Samana Suk Formation exhibits an excellent example of what is called as oolite shoal in the literature. Many such examples exist in the geological record and their studies carried out. In this study we tried to interpret the depositional and diagenetic environments of the Jurassic Samana Suk Formation from Hazara, Pakistan.

Several lithofacies are differentiated on the basis of the presence of oolites, fossils and terrigenous content. They include pure micrite to a sandy facies which is classified in the sandstone category.

The diagenetic environment include cementation of the grains with coarse crystalline, bladed calcite which represent an early cement, and equigranular calcite cement representing a later phase. Dolomitization in the phratic zone has replaced all the textures including intraclasts and cements. Replacement of the oolites by the dolomite crystals is another phenomenon observed in the Samana Suk Formation which happened in the later stage of the diagenetic history.

Key words: Stratigraphy, Jurassic, Samana Suk Formation, Hazara.

M/111. Masood, H., 1989b. Hardground surfaces in Samana Suk Limestone. Kashmir Journal of Geology 6 & 7, 185-on ward.

Hardgrounds are the surfaces of the beds which show evidence of hardening or lithification on the sea floor indicating syn-sedimentary cementation. Such hardgrounds have been recognized in Samana Suk Formation in different parts of Hazara where some work is being carried out on the depositional and diagenetic processes in this formation. The study of the hardground reveal that the formation have been deposited in intertidal environments with possible transgressions of sea and slow sedimentation where the sea floor was lithified before the overlying beds were deposited.

Key words: Stratigraphy, lithification, Jurassic, Samana Suk Formation, Hazara.

M/112. Master, J.M., 1962a. Limestone resources of West Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 189-198.

Key words: Limestone, industrial rocks, Pakistan.

M/113. Master, J.M., 1962b. Gypsum deposits of West Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 363-370.

Key words: Gypsum, industrial rocks, Pakistan.

M/114. Mateen, A., Ahmed, A., Butt, K.A., Qureshi, A.A., Zaidi, H.A. & Chaudhry, M.N., 1997. Igneous phosphate (apatite) deposits associated with carbonatite of NW Pakistan: Mineralogical features and possibility of ore beneficiation. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

The apatite mineral - group is characteristic of carbonatite that commonly form apatite - carbonate ore bodies within the carbonatite complexes. Such igneous phosphate ores of commercial interest occur in the carbonatites of Sillai Patti, (Malakand) and Loe -Shilman (Khyber Agency) in N.W.E.P. Pakistan. We carried out detailed mineralogical study in order to assess the possibility and appropriate conditions for the beneficiation of the apatite - carbonate ores that can be developed as a source for the supply of raw material for phosphate fertilizer and chemical industry. Both the Sillai Patti and Shilman carbonatites are characterized by marked mineralogical and textural variations. Based on the variations genetic and mineral - petrographic features and their associated rocks, we have classified the ore-type as apatite - carbonate - silicate ore. The bulk mineral compositions of the two deposits were evaluated by several independent methods including, large number of thin-sections study, large-volume of bulk samples and chemical analysis of representative samples within the entire limits of the carbonatite. The overall apatite contents are about 5 to 8% and 4 to 6% for Sillai Patti and Shilman deposits respectively. The impurities consist of calcite and dolomite (about 80% of overall amount of carbonates - predominantly calcite), ferromagnesian silicates, iron oxide (mainly as magnetite) and other accessory heavy minerals including pyrochlore. A simple process flow - sheet is developed for the physical beneficiation which consists of crushing grinding and floating the apatite concentrates almost free from the gangue minerals. Experiments were conducted using apatite crushed ore 0.2 mm and deslimed on 0.045 mm. Relationships are discussed between quality of the apatite concentrate and the particle size and its intergrowth with coexisting minerals.

Key words: Phosphate, carbonatite, mineralogy, ore beneficiation.

M/115. Mateen, A., Ahmed, A., Chaudhry, M.N. & Ahmad, I., 2000. Geochemical and Sr-O isotope studies of Chakdara granite gneisses, North Malakand, NW Himalaya, Pakistan: Geotectonic implications. Abstracts, Third South Asia Geological Congress, Lahore, 7-8.

Key words: Geochemistry, isotopes, granite gneisses, Chakdara, Malakand.

M/116. Mateen, A., Baloch, I.H., Hussain, S.S. & Chaudhry, M.N., 1997. Mineralogical characteristics and industrial utilization of the Koga nepheline syenite deposit, Buner, Swat, Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Nepheline syenite rocks are among few industrial raw materials that can be used directly in the industry without much pre-treatment or processing. These rocks find numerous commercial applications, primarily in the manufacture of glass and ceramic wares. Because of its excellent glass and ceramic properties the Koga nepheline syenite can be considered as a suitable matrix for vitrification of high - level radioactive waste. We carried out detailed mineralogical study of the Koga nepheline syenite deposit occurring in Buner. Swat. One of us (Baloch 1994) performed electron microprobe analysis to determine the compositional variations in the different mafic and felsic mineral constituents found in these rocks. The primary aims of this study were to determine the initial mineralogy and chemistry for which the success of mineral separation can be evaluated in the industrial beneficiation of nepheline syenite and to assess the suitability for the nepheline based wasteform. The feldspathoidal rocks comprise of foyaites, sodalite - cancrinite foyaites. feldspathoidal syenite, garnet- bearing nepheline syenite, pulaskites and alkaline syenites occurring as intrusions, plugs, dykes and pegmatitic bodies within the Koga alkaline igneous complex. The important felsic modal mineralogy consist of nepheline (5 to 42 % close to ideal Na:K ratio of 3:1), K- feldspar (20 to 70% as microcline Or95 to Or100), soda - feldspar (2 to 10% as almost pure albite Ab98 to Ab100), Cancrinite and sodalite (up to 12% and 15% respectively in same sections). The iron bearing mafic mineral phases comprise of sodic clinopyroxene (2 to 3% as aegirine), Fe- rich black mica (1 to 4% as biotite - phlogopite -

Annite), iron ore (up to 3% mainly as magnetite), garnet (up to 4% in some sections as andradite - mainly Mn - bearing melanite), sphene (up to 1%) and amphibole (rare). Apatite and zircon occur as accessory minerals. Mafic minerals texturally occur as aggregates, clots and intergrowth within the felsic major phases. For industrial utilization laboratory - scale feasibility study was carried to assess the merit of the Koga nepheline syenite deposit for the glass and ceramic industry and possible use in the vitrification of radioactive waste. A process flow- sheet based on magnetic separation of iron bearing mafic mineral phases is developed for the Koga deposit to meet the commercial product specification for the industry. Results of preliminary investigations for the utilization of the Koga nepheline syenites as ceramic matrix for vitrification plant for radioactive waste disposal are presented. A glass composed of 85% nepheline syenite and 15% lime offers the best compromise in respect of high resistance to attack by water of various Eh - pH conditions.

Key words: Mineralogy, Koga, Nepheline syenite, Buner.

M/117. Mateen, A. & Chaudhry, M.N., 1997a. Geochemical and isotopic systematic in the carbonatites, Buner Swat, NW Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.44.

Key words: Geochemistry, isotopes, carbonatite, Buner, Swat.

M/118. Mateen, A. & Chaudhry, M.N., 1997b. Cogenetic association of feldspathoidal syenites, syenites and quartz syenites: Evidence for magma contamination in the Koga alkaline-carbonatite complex, Lower Swat, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.45.

Key words: Carbonatite, syenites, Koga, Buner.

M/119. Mateen, A., Chaudhry, M. N. & Tingu, C., 2000. Permo-Carboniferous Potassic-Rich Shoshonitic Alkaline Magmatism in the Koga-Bunerai area, Swat Himalaya, NW Pakistan. In: Abstract volume, 3rd South Asia Geological Congress (GEOSAS-III), Shams, F.A., Choudhry, M.N., Hassan, Mahmoodul, Kamran, M. & Rashid, S., (Eds.), Lahore (September 23-26, 2000), 5-6.

In this paper we document for the first time a distinct potassic-rich shoshonite alkaline magma series found within the Koga alkaline underand igneous complex in Buner area of Swat, NW Himalaya Pakistan. The dominant alkaline felsic plutons investigated were previously considered mostly syenitic, typically of sodic alkaline feldspathoidal syenite suites (Siddiqui et al. 1968). An entire spectrum of potassic alkaline subvolcanic rocks comprising felsic to mafic suites representing the Pangaeon Permo-Carboniferous alkaline magmatism ($^{40}\text{Ar}/^{39}\text{Ar}$ age = 290±3 Ma) been identified. The rocks of this association consist of intrusions of nepheline bearing K - rich microsyenites (well exposed near Koga village) and dykes and sills of micro-monzogabbros, monzodiorite and shoshonite lamprophyres belonging to trachybasalt-latite magma series. These are Ti shoshonitic magmatic suites, mafic to intermediate in composition slightly SiO₂- undersaturated (SiO₂ = 46.2 to 61.3Wt%) moderately alumina (Al₂O₃=12.1 to 18.5wt%) and potassium (K₂O=2.82 to 7.9) possibly representing potassic equivalents of sodic transitional rocks. elements chemistry shows enrichment in large ion lithophile elements (LILE) and light rare earth elements (LREE) relative to high field strength element (HFSE) and heavy REE with fractionated chondrite-normalized pattern (La/Yb = 9.32 to 24.4). Trace element composition and initial $^{143}\text{Nd}/^{144}\text{Nd}$ ratio (positive ~Nd: +2.3 to + 4.1) indicated metasomatized depleted lithospheric mantle source. (Mateen & Lan, unpublished work). The petrogenetic evolution of this magmatic series is interpreted in terms of late stage product of igneous activity similar possibly to Roman type potassic alkaline magmatism found away from mature volcanic arcs and/or observed along the east African Rift Valley System. The compositional variations in the magmatic series have been discussed in relation to the polybaric fractionation. Both the sodic and potassic alkaline rocks of the Koga igneous complex are discussed in relation to the spatial and temporal evolution of what is now the Himalayan orogen. This igneous activity associated with the Permo-Carboniferous, alkaline magmatism in the early stages of rifting of NE Gondwanaland.

Key words: Carbonatite, shoshonitic magmatism, Koga, Buner, Swat.

M/120. Mateen, A., Hussain, S.S., Chaudhry, M.N. & Dawood, H., 1995. Occurrence of carbonatites in higher Himalayan basement rocks of Pakistan. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 16-17.

In the northern Pakistan carbonatites and related alkaline igneous rocks occur both in the metamorphosed belt of Lesser Himalayas as well as the Higher Himalayan crystalline slab. The carbonatite occurrence just south of the Suture zone in the Higher Himalaya exposed in Malakand Agency (Sillai Patti), Bajaur agency (Turghar-bagh-Andarai) and Swat (Jambil) have distinctly unique geochemical environment and have no apparent relationship with the typical rift-related alkaline silicate-carbonatite complexes of Koga, Loe-Shilman in the Lesser Himalaya. The Silai Patti carbonatites are characterized by predominant dolomite-Anderite carbonate mineralogy with silicate-rich components of pyroxene, amphibole and biotite (>75% biotite and amphibole at places) and relatively higher REE and PO₄ (Apatite) content.

Key words: Carbonatite, Himalaya.

M/121. Mateen, A., Majid, C.A., Hussain, M.A. & Butt, K.A., 1994. Characterization of uraninite from rare metal granitic pegmatite, Bagrian, Mansehra, Pakistan. Pakistan Journal of Geology 2 & 3, 80-84.

Amorphous uraninite is described from an extremely fractionated rare earth bearing zoned complex granitic pegmatite exposed in Bagarian area, Mansehra District, NWFP Pakistan. X-Ray diffraction study suggests a complete amorphous uraninite state. X-ray diffraction pattern shows two broad bands around 317°A and 274°A, and a possible indication of very broad band around 12°A. Carefully devitrified at annealing temperature of 1350°C yielded X-ray diffraction pattern of crystalline uraninite with chemical phases in atomic proportions of UO₃ (97.15%), ThSiO₄ (1.51%) and ThO₂ (1.51%) and ThO: (1.1%).

Key words: Pegmatites, radioactive minerals, Mansehra

M/122. Mateen, A., Qureshi, A.A., Butt, A.A. & Chaudhry, M.N., 1995. Carbonatite related mineral resources with reference to carbonatite of NW Pakistan. Proceedings, Pakistan Academic of Sciences 32, 69-78.

Key words: Carbonatite, NWFP.

M/123. Mateen, A., Qureshi, A.A. & Chaudhry, M.N., 2001. Petrological and geochemical characteristics of the Tertiary lamprophyre/ ultrapotassic rock from the Loe-Shilman carbonatite complex, Khyber Agency, N.W.F.P. Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.7.

Lamprophyritic dykes and minor magmatic intrusions of ultrapotassic rocks occur within the Loe-Shilman carbonatite complex, Khyber Agency, NWFP, Pakistan. The lamprophyre dykes yielded 40Ar-39Ar biotite plateau age of 32.8 ± 0.2 Ma and isochron age of 33.4 ± 0.6 Ma. Potassic-rich alkaline rock sequence includes carbonatitic lamprophyre, alkali lamprophyre, K-micromonzonites, K-syenites and pseudoleucite syenites. Petrographic and textural features clearly show that these rocks have a magmatic rather than metasomatic origin. Lamprophyre/ultrapotassic rocks are very heterogeneous in terms of grain size, mineralogy and modal proportions. Lamprophyres are composed essentially of amphibole, biotite, sphene ± K-feldspar ± calcite. Alkali feldspar dominates in the pseudoleucite syenites. All the rocks have strong incompatible element enrichment in multi-element spidergrams which lack Nb-Ta anomaly. The rare earth element (REE) patterns are steep with fractionation ratios of (La/Yb)_m range from 27 to 87 for lamprophyres and 16 to 38 for K-syenites and pseudoleucite syenites. The enrichment of LILE, Nb-Ta, Zr-Hf, LREE and high La/Yb ratios are consistent with a phlogopite-bearing garnet peridotite residual source. Association of lamprophyres and carbonatites in the collision zone NW Himalaya of

Pakistan demand their parental magmas derived from a heterogeneous sub-continental mantle. Lamprophyres/ultrapotassic rocks are suggested to be generated by partial melting in the mantle, modified by fractional crystallization, immiscibility and magma mixing at shallow levels. Their emplacement is related to the Tertiary extensional rifling environment.

Key words: Petrology, geochemistry, carbonatite, Loe Shilman, Khyber Agency.

M/124. Mateen, A., Qureshi, A.A. & Karim, T., 1993. Chemical characterization of carbonatites from Loe Shilman. All Pakistan Sci. Conf., Aitchison College, Lahore, 26–30th Dec. 1993.

Key words: Carbonatite, geochemistry, Loe Shilman.

M/125. Mateen, K. & Haq, N., 1992. Need for understanding of hydrodynamic framework of petroleum reservoirs in exploration strategies in Bannu/Kohat Province, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 27.

Key words: Hydrocarbons, reservoir, exploration, Bannu, Kohat.

M/126. Matsumoto, Y., 1974. List of minerals from the Tirich Mir and adjacent regions, the Hindu Kush range, Pakistan. Geoscience Magazine 25, 65-76. Japanese with English summary.

Key words: Minerals, Tirich Mir, Hindu Kush.

M/127. Matsushita, S., 1956. Geology of the Karakorum. Kagaku. Science, 26(2) (in Japanese).

Key words: Geology, Karakoram.

M/128. Matsushita, S., 1965. Geological research in the Upper Swat and eastern Hindu Kush. In: Matsushita, S. & Huzita, K. (eds.), Geology of the Karakoram and Hindu Kush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindu Kush (1955) 7, 37-88.

This is an excellent geological river log, beginning at Kalam in Swat Kohistan and ending at Mastuj in Chitral. Traverse follows the course of the Ushu River up the Dadarili Pass. Then on, it follows the Ghizar River up to Gupis. This is followed by turning northwest along the course of the Yasin River to Nazbar. From then on, crossing the drainage divide, entry is made into upper reaches of the Yarkhun River for descent into Mastuj. The author used Brunton and pace method to prepare simple topographic and geological sketch maps at 1:35,000 to 1:50,000 scales for the entire route. In addition, field features were shown in a large number of neat hand sketches (totaling 75) and photographs (4). Descriptions of rocks, structures, and field relations of various rocks, especially of the granitic intrusions and their host rocks, are elaborated. A strong aspect of the paper is the description and sketches of the glaciers, moraines, glacial terraces, stream deposits, talus, etc. In the Swat-Gupis section, much of the traverse is through the granite batholith (now called the Kohistan Batholith), and the author has distinguished a succession of plutons and dykes. In the Naz Bar valley, he records the following succession of rocks:

Terrace Deposits	Pleistocene
Glacial Deposits	Pleistocene
Granite.	Tertiary
Yasin Group	Lower Cretaceous
Darkot Group	Permo-Carboniferous

The overall stratigraphic setup is given on page 84 of the paper in the following table.

Age	Eastern Hindu Kush	Upper Swāt
Pleistocene	8) Terrace deposits	8') Terrace deposits
Tertiary	7) Granite of Ghizar river	
EarlCretaceousy	6) Yasin group of Yasin 5) Green series of Ghizar valley	
	4) Granite of Shunji Gol	4') Granite in the vicinity of Kalām
Permian and Carboniferous	3) Darkot group of Darkot	? 3') Kalam group in the vicinity of Kalām
Unknown		2) Gneissose granite of Ushū Gol
Unknown		1) Gneiss of Unshū Gol

Key words: Stratigraphy, structure, lithology, glacial deposits, Swat, Hindu Kush.

M/129. Matsushita, S. & Huzita, K., 1964. Geological structure of the western Karakorum and eastern Hindu Kush. 22nd International Geological Congress, New Delhi.

Summary of the work performed during the expedition can be seen in Matsushita & Huzita 1965c below

Key words: Tectonics, structure, Karakoram, Hindukush.

M/130. Matsushita, S. & Huzita, K. (eds.), 1965a. Geology of the Karakoram and Hindu Kush. Results of the Kyoto University Scientific Expedition Karakoram and Hindu Kush (1955) 7, 160p. Kyoto University, Japan.

Summary of the work performed during the expedition can be seen in Matsushita & Huzita 1965c below. An orthoclase-muscovite-quartz pegmatite cutting biotite gneiss near dassu on the right bank of Braldu river has been dated. It gives 27 and 30 ma Rb-Sr and 4 ma K-Ar whole rock dates.

Key words: Tectonics, structure, Karakoram, Hindukush.

M/131. Matsushita, S. & Huzita, K., 1965b. Geological map of the Westernmost Karakoram and Eastern Hindu Kush. In: Matsushita, S. & Huzita, K. (Eds), 1965. Geology of the Karakoram and Hindu Kush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindukush, 1955, Vol. VII (in pocket). Nippon Printing & Publishing Co., Ltd., Japan.

This is a geologic sketch map at 1: 50,000 scale along the major stream courses traversed by the Japanese expeditions of the mid fifties. It covers northernmost Swat, northeastern Chitral, Gilgit, and parts of the adjacent areas.

Key words: Geological map, Gilgit, Yasin, NE Hindukush, Western Karakoram.

M/132. Matsushita, S. & Huzita, K., 1965c. Summary of the results of the geological researches in the Expeditions 1956 and 1957. In: Matsushita, S & Huzita, K. (Eds.), Geology of the Karakoram and Hindukush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindukush, 1955, Vol. VII, 89-92. Nippon Printing & Publishing Co., Ltd., Japan.

This is a summary of the geological studies performed by the Japanese Expeditions to the Eastern Hindukush and Western Karakoram during 1955, 1956 and 1957. The various groups of rocks have zonal arrangement and appear in some cases to be separated by faults. One of these faults runs from the south of Mastuj, through the north of Yasin, Pakhor in Ishkuman, Chalt and Chogolungma Glacier north of Haramosh. This may be the trace of the now called MKT or Shyok suture. They also describe other structures, including the extension of the NP dome and the syntaxial bend between the Hindu Kush and Karakoram.

Division of geological sequence in the Western Karakoram and the Eastern Hindu Kush

Division of the Area Age	Eastern Hindu Kush and Upper Swāt	Syntaxial area	Western Karakoram	No. of division
Unknown; probably Tertiary	Granite of Ghizar valley	Granite of Gupis and Gakuch	Pegmatite dyke near Dusso	(6)
Early Cretaceous		Yasin group of Yasin		(5)
	Green Series of Ghizar river	Green Series of Gupis and Gakuch	Green and black phyllite of Tormik and Chalt	(4)
Unknown	Granite of Shunji Gol	Granite of Karambar	Granite of Baltoro	(3)
Permian and Carboniferous	Darkot group of Mastuj	Darkot group of Darkot and Ishkuman	Calcareous rock and conglomerate of Chalt. Slate and limestone of Gasherbrum	(2)
Unknown	Gneiss of Upper Swāt	Injection gneiss of Gakuch	Injection gneiss and mica-schist of the Indus and Braldu	(1)

Key words: Stratigraphy, structures, Hindu Kush, Karakoram.

M/133. Matsushita, S. & Huzita, K., 1966. Geological researches in the western Karakoram. Geology of the Karakoram and Hindu Kush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindu Kush (1955), Additional Reports 8, 1-7.

This volume is the 7th of the series published since 1960. It comprises a Preface, Introduction, eight papers, References and a geological map of the western Karakoram and eastern Hindu Kush. Individual papers cover general geology, stratigraphy, paleontology, petrography, geochemistry, metamorphism geochronology, and are dealt with in appropriate places. The Introduction to the volume contains a brief history of geological investigations in the area.

Key words: Tectonics, structure, Karakoram, Hindukush.

M/134. Mattauer, M., 1986. Intracontinental subduction, crust mantle decollement and crustal-stacking wedge in the Himalayas and other collision belts. In: Coward, M.P. & Ries, A.C. (Eds.), Collision Tectonics. Geological Society of London, Special Publication 19, 37-50.

Key words: Tectonics, structure, collision, Himalaya.

M/135. Mattauer, M., Proust, F. & Tapponnier, P., 1977. Some new data on the India Eurasia convergence in the Pakistani Himalayas. Colloquium International. CNRS., Paris, 268, 209-220.

Key words: Plate tectonics, plate boundaries, India, Eurasia.

M/136. Matthew, W.D., 1929. Critical observations upon Siwalik mammals. American Museum of Natural History, Bulletin 56, 437-560.

During the winter of 1926-27 I spent six weeks at the Indian Museum in Calcutta and two months at the British Museum (Natural History) in London making a critical re-examination of the type collections of the Siwalik Fauna preserved in those two institutions. The object of this study was to check up in the light of modern palaeontological evidence the classic researches and descriptions of Falconer and Cautley and of Lydekker, and the admirable later work of Pilgrim, as a basis for researches and description of the collections obtained for the American Museum by Mr. Barnum Brown in 1921-1923. The expenses of making this study were defrayed from funds provided by Mrs. Henry Clay Frick, as a part of her gifts to the American Museum for Siwalik collecting, preparation and research work.

To the President and Trustees of the American Museum I desire to express my high appreciation of the opportunity and privilege of making this research, involving release from Museum duties over a period of several months. I am likewise deeply indebted to the friendly aid of Director Pascoe, Superintendent Pilgrim and others of the staff of the Geological Survey of India, to Doctor Bather and Mr. A. T. Hopwood and other good friends at the British Museum, who placed the collections wholly at my disposal for study and comparison, provided every facility for examining the specimens and referring to the published literature and the museum records, and aided and enlightened me upon various obscure points.

The accompanying series of notes and criticisms are by no means to be regarded as final conclusions. They represent principally an attempt to verify, revise and supplement the type descriptions with the aid of subsequent palaeontological knowledge, to point out doubtful or erroneous identifications or conclusions as to the affinities of certain types, and to reconsider the correlation of the Siwalik faunas with those of Europe and America. The views here expressed upon the affinities of various Siwalik mammals, and especially upon the faunal correlation, will call for a further and more careful criticism when the monographic researches upon Mr. Brown's collections have been completed. They represent the present personal viewpoint of the author, and no attempt is made at this stage to bring them into conformity with the conclusions of Professor Osborn based upon his proboscidean researches, or those of Doctor Pilgrim based upon his extensive and detailed studies of the stratigraphy and faunas of the Siwalik region.

Key words: Palaeontology, siwaliks.

M/137. Mattson, L.E. & Gardner, J.S., 1989. Energy exchanges and the ablation rates on the debris-covered Rakhiot Glacier, Pakistan. *Zeitschrift für Gletscherkunde*, 25(1): 17-32.

Consult the following account for further details.

Key words: Glaciers, ablation, Rakhiot, Nanga Parbat.

M/138. Mattson, L.E., Gardner, J.S. & Young, G.J., 1993. Ablation on debris covered glaciers: an example from the Rakhiot Glacier, Punjab, Himalaya. In: Young, G.J., (ed.), *Snow and Glacier Hydrology. International Symposium, Kathmandu, Nepal, 16-21 November 1992. Proceedings. International Association of Hydrological Sciences. IAHS/AISH Publication*, 218, 289-296.

This paper reports on ablation research carried out on the Rakhiot Glacier, Punjab, Himalaya. Specifically, detailed measurements of ablation rates on debris covered and debris free surfaces allow specification of relationships between ablation and debris cover thickness. Direct ablation measurements indicate a sharp increase in ablation with debris cover thickness increasing from 0.0 to 10 mm followed by a decrease in ablation with debris cover thickness increasing beyond 10 mm. Field observations reveal a critical thickness of 30 mm indicating that at any greater debris thickness ablation is suppressed from that expected on debris-free ice. A comparison with previous research indicates similar hyperbolic trends in the relationship between debris cover thickness and ablation, however, the intensity of these trends differ with global location.

Key words: Glaciers, ablation, Rakhiot, Nanga Parbat, Himalaya.

M/139. Matzko, J.J. & Hassan, M., 1967. Mineralogy of iron stone from Chichali and Makarwal areas, Mianwali and Kohat Districts, West Pakistan. *US Geological Survey/Geological Survey of Pakistan*, (IR) PK-26, 18p.

Key words: Mineralogy, iron ore, Chichali, Makarwal, Mianwali, Karak.

M/140. Matzko, J.J., Hussain, F. & Hassan, M., 1970. Examination of selected radioactive samples from East and West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-57, 25p.

Key words: Radioactive minerals, East & West Pakistan.

M/141. Max, G.W., 1966. Copper, Lead, Zinc, Antimony and Arsenic in West Pakistan. US Geological Survey/Geological Survey of Pakistan Project Report, IR PK-4, 39p.

Key words: Minerals, copper, lead, zinc.

M/142. Mayewski, P.A., 1976a. Geotectonics of the orogenic zone of the Kashmir Himalaya, Karakorum, Hindu Kush, Pamir: Introductory report on Geophysics. *Accad. Naz. dei Lincei*, 21, 15–25.

Key words: Geotectonics, geophysics, Kashmir, Himalaya, Hindukush.

M/143. Mayewski, P.A., 1976b. Geotectonics of the orogenic zone of the Kashmir Himalaya, Karakorum, Hindu Kush, Pamir: Gravity in the Karakorum: *Acad. Naz. die Lincei*, 21, 132–137.

Key words: Geotectonics, gravity, Kashmir, Himalaya, Hindukush.

M/144. Mayewski, P.A. & Jeschke, P.A., 1979. Himalayan and Trans-Himalayan glacier fluctuations since AD 1812. *Arctic and Alpine Res.*, 11, 267–287.

Historical records of the fluctuations of glaciers in the Himalayas and Trans-Himalayas date back to the early 19th century. Local and regional syntheses of 112 of these fluctuation records are presented in this study. The local syntheses deal with fluctuations of glaciers in Kanchenjunga-Everest, Garwhal, Lahaul-Spiti, Kolahoi, Nanga Parbat, Karakoram (north and south sides), Rakaposhi- Haramosh, Batura Mustagh, and Khunjerab- Ghujerab. Regional syntheses deal with the composite record and the differentiation of records by glacier type (longitudinal versus transverse) and regional setting (Himalayan versus Trans-Himalayan). In a gross regional sense Himalayan and Trans-Himalayan glaciers have been in a general state of retreat since AD 1850. Filtering of the fluctuation records with respect to glacier type and regional setting reveals that the period AD 1870 to 1940 was characterized by alternations in the dominancy of retreat, advance, and standstill regimes.

Key words: Glaciers, Himalaya, Karakoram.

M/145. Mayewski, P.A., Pregent, G.P., Jeschke, P.A. & Ahmad, N., 1980. Himalayan and trans-Himalayan glacier fluctuations and the South Asian monsoon record. *Arctic and Alpine Res.*, 12, 171–182.

Termini fluctuations for glaciers in the Himalayas and Trans-Himalayas are examined for the period AD 1850 to 1960. This period can be characterized as one of general retreat. Differentiation by geographic subdivision, however, reveals that Himalayan glaciers (best exemplified in Lahaul-Spiti, Kolahoi, Nanga Parbat, and Garwhal) show consistent retreat throughout the period, while Trans-Himalayan glaciers (best exemplified on the north side of the Karakoram and in Batura Mustagh and Rakaposhi-Haramosh) deviate from this pattern by displaying a major period of advance from AD 1890 to 1910. Although no apparent relationship exists between the magnitude of termini advances and glacier lengths, termini retreat records are commonly characterized by short- to medium- length glaciers (< 30 km). Termini advances are, however, related to flow direction; advancing termini most commonly face east, southeast, northwest, and west. Glaciers characterized predominantly by retreat flow commonly, but not exclusively, east and south- east. Advances of Trans-Himalayan glaciers during the period AD 1890 to 1910 are

attributed to strengthened monsoon wind currents and to secular variations in Indian rainfall. Such changes in the general atmospheric circulation, implied by climatic data, produce subsequent increases of moisture influx to the Asian land mass.

Key words: Glaciers, monsoon, Himalaya.

M/146. McDougall, J.W., 1987. Kalabagh strike-slip fault zone, western Salt Range, Pakistan. Ph.D. Thesis, Oregon State University, Corvallis, 178p.

Key words: Structure, tectonics, Kalabagh, Molasse.

M/147. McDougall, J.W., 1992. The Main Boundary Thrust and propagation of deformation into the foreland fold-thrust belt in northern Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.54.

In the western Himalaya, the Main Boundary thrust (MBT) is the floor thrust for imbricate slices incorporating Precambrian and Phanerozoic rocks in the hill ranges that are emplaced over Cenozoic strata of the northern Kohat and Potwar plateaus. In the western Kala Chitta Range, north of the MBT and south of the Attock-Cherat Range, steep thrusts (some S-dipping) do not ramp up directly from the decollement thrust at the base of the MBT allochthon. Shallow contraction is manifest as pronounced thickening and tight folding in Mesozoic strata in the upper third of the allochthon with preferred decoupling in Jurassic rocks, particularly in a belt 0-6 km north of the MBT and west of the Indus River.

The MBT is folded and exposed in a deep re-entrant of Eocene Kuldana Formation parallel to and 2-4 km north of the front fault between Mazari Tang and the Indus River. South of the MBT in the northern Kohat Plateau area of the foreland fold-thrust belt, tight folds in early to middle Tertiary rocks, including synorogenic deposits of the Murree Fm., indicate preferential decoupling at the base of the Tertiary section and in underlying Mesozoic strata. These nearly symmetrical lift-off or box folds include the Panoba anticline and related structures, which indicate out-of sequence thrusting along the MBT that deformed the northern Kohat Plateau over (against) the back limb of the M thrust sheet to the south.

Dip displacements are tens of kilometers for major thrusts on either side of the MBT, for example (from S to N), the M thrust of the northern Kohat Plateau (29-32 km), the MET (estimated >40 km), the Hissartang fault (~25 km), the Cherat fault (?>10 km), and the Khairabad fault (~25 km). South of the MET to the Surghar Range there has been about 50% shortening across the foreland fold-thrust belt on a system of blind thrusts overlying a nearly flat 8-10 km deep basement. Net horizontal shortening increases north of the MBT. The section exposed by thrusting changes markedly in the Attock-Cherat Range, 6-30 km north of the MBT, where Precambrian rocks are exposed and Mesozoic rocks are absent in thrust slices of the N-dipping Khairabad, Cherat, and Hissartang faults.

West of the Indus River, present day low-angle decollement thrusting from the top of the basement projects to the surface 40-70 km south of the MBT and is most recently active in the northern Kalabagh fault zone. Thrusting along the MBT in the Kala Chitta Range at 2.1-1.9 Ma was followed by ongoing shallow regional N-S compression and thickening of the foreland fold-thrust belt allochthon. The MBT allochthon was deformed prior to its low angle emplacement over the northern Kohat and Potwar plateaus, and folded and eroded during or after this emplacement. The MBT thrust front may participate in its own later deformation, but not as an emergent low angle thrust through the Quaternary.

Key words: Structure, MBT, deformation, Indus River.

M/148. McDougall, J.W. & Hussain, A., 1991. Fold and thrust propagation in the Western Himalaya based on a balanced cross section of the Surghar Range and Kohat Plateau, Pakistan. Bull. American Association Petroleum Geologists, 75, 463-478.

Consult the preceding information.

Key words: Structure, Foreland, Himalaya, Surghar Range, Fold and thrust propagation.

M/149. McDougall, J.W., Hussain, A. & Yeats, R.S., 1993. The Main Boundary Thrust and the propagation of deformation into the foreland fold-and-thrust belt in Northern Pakistan near the Indus River. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonic*. Geological Society, London, Special Publication 74, 581-588.

The Main Boundary Thrust in northwestern Pakistan is a floor thrust along which a thrust system incorporating Precambrian and Phanerozoic rocks of the Kala Chitta and Attock-Cherat Ranges was emplaced over Cenozoic strata of the northern Kohat and Potwar Plateaus. The MBT and successive thrusts toward the foreland are interpreted as low angle to flat decollement thrusts at 8–10 km depths that bound thrust sheets with large lateral dimensions. Admissible cross sections indicate over 60 km of shortening along the largely pre-Palaeocene Khairabad, Cherat, and Hissartang thrusts within the MBT allochthon. In the toe of the MBT allochthon, contraction is manifest at the surface as tight folds in largely Mesozoic and lower Tertiary strata, decoupled in the upper third of the allochthon. Displacement of the MBT is estimated at over 40 km and south of the MBT, shortening is interpreted along blind thrusts accompanied by shallow (0–3 km deep) backthrusting. The MBT allochthon was deformed prior to its low angle displacement over the northern Kohat and Potwar Plateaus, and folded and eroded during or after its emplacement. The MBT thrust front may participate in its own later deformation, but not as an emergent low angle thrust through the Quaternary.

Key words: MBT, deformation, Foreland, Kalachitta, Attock-Cherat, Potwar.

M/150. McDougall, J.W. & Khan, S.H., 1990. Strike-slip faulting in a foreland fold-thrust belt: the Kalabagh fault and western Salt Range, Pakistan. *Tectonics* 9, 1061-1075.

The 120-km-long Kalabagh fault zone is formed by transpressive right-lateral strike-slip along the western Salt Range-Potwar Plateau allochthon in northern Pakistan. Lateral ramping from a decollement thrust along an Eocambrian evaporite layer produced NNW- to NW-trending folds and NE- to N-dipping thrust faults in a topographically emergent zone up to 10 km wide. Piercing points along the main Kalabagh fault indicate 12–14 km of middle to late Quaternary right-lateral offset. The older right-lateral Surghar fault displaced axes of frontal folds of the eastern Surghar Range by 4–5 km. Total displacement is reduced northward in the Kalabagh fault zone where north-dipping thrust faults splay to the west. Cumulative right-slip offset in the Kalabagh fault zone is comparable to displacement along the Salt Range frontal thrust, at a minimum average displacement rate of 7–10 mm/year near the Indus River since 2 Ma. In the basement, which dips 2–3° north along the Kalabagh fault, a NNW-trending discontinuous ridge beneath the lateral ramp is interpreted from residual gravity anomalies. The eastern flank of this basement ridge probably ramped allochthonous strata upward from a depth of over 5 km in the Kalabagh fault zone. Kalabagh faulting displaced and uplifted Holocene terrace deposits and shifted the course of the Indus River eastward. A high slip rate and associated seismicity indicate that the Kalabagh fault zone should be considered active and capable of earthquakes.

Key words: Structure, strike-slip faulting, Kalabagh Fault, Salt Range.

M/151. McGibbon, K.J. (ed.), 1982. *Karakoram Expedition 1982: A scientific Expedition to the Hunza valley, northern Pakistan (74°E, 36°N)*. Newcastle University, Exploration Society. 88p.

Key words: Expedition, Hunza, Karakoram.

M/152. McGinnis, L.D., 1971. Gravity fields and tectonics in Hindu Kush. *Journal of Geophysical Research* 76(8), 1894-1904.

Gravity fields in Afghanistan are characterized by large, negative mean free-air anomalies in the eastern Hindu Kush and by essentially zero anomalies in the western Hindu Kush. Thus, the western Hindu Kush are in isostatic equilibrium, whereas the eastern Hindu Kush are associated with a large mass deficiency. A mechanism involving underthrusting of light continental crust into higher density mantle in the eastern Hindu Kush and Pamirs is consistent with regional seismicity and gravity fields. Positive free-air and Bouguer anomalies mark a belt of intrusives that occupy a region of northeast-striking fractures along the Chaman fault zone. This zone may represent the northwest border of the Indian subcontinental plate.

Key words: Gravity, geophysics, Hindukush.

M/153. McMahon, A.H., 1899. Notes on the fauna of Gilgit Agency. *Journal of the Asiatic Society of Bengal* 68, 105-109.

This, and the following two accounts, give details of the fauna of Gilgit Chitral and Swat areas. This data was collected by the author during his appointment in the area as political agent. He has given quite useful geological data as well.

Key words: Fauna, Gilgit.

M/154. McMahon, A.H., 1901a. Notes on the fauna of Chitral. *Journal of the Asiatic Society of Bengal* 70, 1-7.

Key words: Fauna, Chitral.

M/155. McMahon, A.H., 1901b. Notes on the fauna of Dir and Swat. *Journal of the Asiatic Society of Bengal* 70, 8-12.

Key words: Fauna, Dir, Swat.

M/156. McMahon, C.A., 1884. Microscopic structure of some Himalayan granites and gneissose granites. *Geological Survey of India, Records* 17, 53-73.

Key words: Structure, Himalaya, granite, gneisses.

M/157. McMahon, C.A., 1887. The Gneissose-Granite of the Himalayas. *Geological magazine (Decade III)*, 4 (5), 212-220.

The cause, or causes, which result in the foliation of igneous rocks is a subject which at present occupies the attention of many geologists, and seems likely, in the near future, to lead to some discussion. In view of this, a short account of the foliated granite of the Himalayas may be of interest. It may be as well, however, to preface my remarks by saying that I believe that foliation may be produced in several distinct ways, and the explanation which I offer of the mode in which the foliation of the Himalayan granite has been brought about is only intended to apply to the case of that granite.

In the following pages I propose to give a brief summary only of some of the more important results worked out in detail in a series of papers published in the *Records of the Geological Survey of India*; and to add thereto a brief consideration of the question whether the foliation of the gneissose-granite of the Himalayas

Key words: Structure, Himalaya, granite, Gneisses.

M/158. McMahon, C.A., 1897. Notes on the age and structure of the gneissose-granite of the Himalaya with reference to Mr. Middlemiss's memoir on the Geology of Hazara. *Geological Magazine (decade IV)*, 304-313 and 345-355.

I am indebted to Mr. C. S. Middlemiss, Superintendent of the Geological Survey of India, for a copy of his Memoir on the Geology of Hazara and the Black Mountain recently published. Mr. Middlemiss has embodied in his Memoir the results of an unfinished survey by Mr. A. B. Wynne, late of the Geological Survey of India, and by linking these with his own more recent work, has given us an interesting and valuable Memoir on the Geology of the Himalayan district of Hazara.

Key words: Chronology, structure, gneissose granites, Himalaya.

M/159. McMahon, C.A., 1900. Notes on the Geology of Gilgit. Quarterly Journal Geological Society, London, 56, 337-369.

My son, Capt. A. H. McMahon, C.S.I., C.I.E., Y.G.S., Political Agent, Malakand, when stationed at Gilgit, made field-observations and collected rock-specimens for me in the course of numerous traverses through the Gilgit area. I have not had an opportunity of visiting the region covered by this paper; but I have seen much of the neighbouring Himalaya, and I have had the advantage of correspondence not only with my son, but also with Capt. J. R. Roberts, I.M.S., regarding the geology of Gilgit. I am greatly indebted to Capt. Roberts for much valuable information, for field-observations undertaken on my behalf, for careful drawings of sections, and for numerous additional specimens supplementing those sent by my son. I cannot overrate the obligations under which I am to him.

A sketch-map (see p. 344) has been prepared to accompany this paper, compiled mainly from the map of the Pamirs (1896) by H. Sharbau and the Right Hon. G. N.—now Lord—Curzon; and from the map of Astor and Gilgit (1883) by the Surveyor-General of India. The geology of the neighbouring parts of Kashmir has been described by Mr. R. Lydekker, Y.R.S., in vol. xxii (1883) of the Memoirs of the Geological Survey of India, and in papers published in the Records of the same Survey. The map published with the above-mentioned Memoir shows the geology of Kashmir as far as Astor, at which place this paper takes up the geology.

Key words: Geology, Gilgit.

M/160. McMahon, C.A., 1902. Fossil beds and associated rocks of Chitral. Geological Magazine 9, 3-8.

Key words: Palaeontology, fossils, Chitral.

M/161. McMahon, C.A. & Huddletone, W.H., 1902. Fossils from the Hindu Khoosh. Geological Magazine 9, 49-57.

The Himalayas, with the help of that singular replica of the more mountainous region known as the Salt Range, have afforded to the paleontologist, in one place or another, a fairly good series of the several Paleozoic horizons.

1. The First Paleozoic Horizon. – The Lowest Cambrian, or Neobolus-Fauna, perhaps the lowest recognized fauna in the world, is to be found in the Salt Range in immediate succession to the Salt series. This fauna was discovered by Warth, and has been elucidated in the Paleontologia Indica at considerable length. In the volume for 1899 there is a plate of these fossils, which are described as consisting of simple forms like Neobolus, or rather complicated ones like Pseudotheca.

The Carboniferous overlap in the Salt Range, noticed by Waagen and confirmed by subsequent observers, has had the effect of shutting out the rest of the infra-Carboniferous horizons from that range, so that we there obtain nothing between the lowest Cambrian and the Carboniferous beds. On the other hand, I cannot find that the Neobolus-fauna has been recognized in the Himalayas proper.

2. The Second Paleozoic Horizon.- This must be sought in the Himalayas alone without the valuable confirmatory evidence supplied by the Salt Range in the case of the Carboniferous fauna.

A very valuable find of fossils belonging to this horizon, which in the main may be regarded as of Lower Silurian (Ordovician) age, was made by General Strachey some forty years ago in Niti. These were described and figured by Salter in a memoir printed for private circulation, to which H. F. Blanford contributed. To give an idea of the importance of this find, Salter enumerated some sixty species, as follows: - Crustacea 8 species, Annelida 2, Cephalopoda 8, Gasteropoda 11, Lamellibranchiata 3, Brachiopoda 21, Bryozoa 3, Amorphozoa 2, Zoophyta 2. Referring to the Brachiopoda only, Leptana, Strophomena, and Orthis are perhaps the best represented genera, and the fauna was regarded as most resembling Caradoc. Many of these fossils are in a fairly good state of preservation. The types are to be seen at the British (Natural History) Museum.

Shortly afterwards Stoliezka wrote a memoir on the Paleozoic formations in Spiti. Here he came across a fossiliferous horizon which he called the Bhabeh-series, but the fossils were badly preserved. In this recapitulation Steliezka described his Bhabeh-series as probably of Lower Silurian age, consisting of sandstones, slates, and quartzites, containing Orthis and other genera not specifically determinable.

Subsequently it is believed that important additions have been made to the collections from this horizon in the Himalayas, but at present these matters are in reserve. The following extract from Mr. R. D. Oldham's Manual, published in 1893, bears upon this point. It occurs as a footnote. "A large number of fossils from General Strachey's

collections were described by Messrs. Salter and Blanford in 1865, and the collections which were made by Griesbaeh, which are still in the course of description, will doubtless add to their number. Until this fauna has been worked out and its relations fully determined, there does not appear to be any benefit in printing a nominal list of the species that have been described.”

3. The Third Paleozoic Horizon. – Like the second horizon, this has no replica in the Salt Range. So far as anything is known about it, we are still indebted to Stoliezka. Referring to his experiences in Spiti, he thus speaks of the Muth-series: - “Above the true Silurian rocks there will be found a thickness of beds, of about 1,000 feet, distinguished by a different shade of a bluish colour; their age is left undecided. The fossils of this series occur in an arenaceous limestone, some of the beds being of a purer limestone of a dark colour. Specific determination is not easy owing to the bad state of preservation.”

Two species of *Cyathophyllum* were recognized, whilst the Brachiopoda were represented by *Strophomena* and two species of *Orthis*. In his summary Stoliezka regarded the Muth-series as of Upper Silurian age, and he correlated, as already stated by General McMahon, the middle or fossiliferous division of that series with the Blaina-limestone.

4. The Fourth Paleozoic Horizon.- This may be focused under the general term of the Kuling-series. The fine collection of Carboniferous fossils sent by Colonel Godwin-Austen from Kashmir engaged the attention of Davidson many years ago. A considerable number of these specimens may yet be seen in the Museum of the Geological Society. This very abundant and characteristic fauna is receiving samples attention from the writers in the *Paleontologia Indica*, supplemented as it is by the high fossiliferous Productiv limestones of the Salt Range.

Key words: Palaeontology, fossils, Hindukush.

M/162. Meciani, P., 1961. Il Karakorum, Monografia storico-geografica. In: Monzino, G., Kanjut Sar. 214-260. A. Martello, Milano.

Key words: Geography, Karakoram.

M/163. Medlicott, H.B., 1868. Note on the analysis of three specimens of coal from the "hills about Murree". Geological Survey of India. Records 64, 117-118.

Key words: Hydrocarbons, coal, Murree.

M/164. Medlicott, H.B., 1868. Report on supposed coal of Murree and Kotlee. Geological Survey of India. Records, 64, 120-126.

Key words: Hydrocarbons, coal, Murree, Kotlee.

M/165. Medlicot, H.B., 1873. Sketch of the geology of the North West Frontier Province. Geological Survey of India, Record 6(1), 9-17.

Key words: Maps, geology, NWFP.

M/166. Medlicott, H. B., 1881. The Nahan-Siwalik unconformity in the north-western Himalaya. Geological Survey of India, Records, 14 (2), 169.

Key words: Structure, siwaliks, Himalaya.

M/167. Medlicot, H.B., 1884. Sketch of the geology of the upper Punjab. Calcutta 1883-84.

Key words: Geology, maps, Punjab.

M/168. Medlicot, H.B., 1889. Sketch of the geology of the Punjab. Punjab Gazettier, 22-79.

Key words: Geology, maps, Punjab.

M/169. Medlicott, H.B. & Blanford, W.T., 1879-1887. Manual of the Geology of India. Government of India Press, Calcutta. 817p.

This is compilation of all the available data, mainly from the British Geological Survey of India. The descriptions contain references to the GSI publications. This manual was edited and revised subsequently, and annotation can be seen under Oldham, 1893.

Key words: Books, geology of India.

M/170. Mehboob, M., Pervaiz, J. & Rahman, S., 1983. Petrography of Thor and Thurlly mafic-ultramafic association in Chilas Complex, Northern Pakistan. M.Sc. Peshawar University.

The Chilas complex is principally made up of noritic rocks. In its eastern part near Chilas, there are many bodies of olivine-bearing mafic and ultramafic rocks. These range from dunite and peridotite to troctolite, gabbro and anorthosite. Such bodies in the vicinity of Thor Gah and Thurlly Gah have been mapped and petrographically described.

Key words: Petrography, ultramafics, Chilas complex, Kohistan Island Arc.

M/171. Mehdi, S.E., 1982-84. Geotechnical studies of landslides along Karakoram Highway from Shetan Pari to Ali Abad. M.Sc. Thesis, Punjab University, Lahore, 122p.

This thesis is mainly composed of the study of about land sliding along Karakoram High Way from Shetan Pari to Aliabad. A brief description of other geological features are also included in the thesis. The geological map shows the different types of rocks present in the project area. Detailed study has been made in the project area to collect the data about discontinuities as joints, which plays the dominant role in case of sliding in hard rocks. This data has been plotted on equal-area stereonet to check the stability of the slopes. In case of sliding in soft material like alluvial fan, samples were collected and tested for detailed analysis. Finally on the basis of this analysis, the road is classified into stable, potentially unstable and unstable regions.

Key words: Geotechnical, landslides, Aliabad, KKH.

M/172. Mehdi, S.S., 1979. Geology and economic aspects of the Malakand chromite deposits. Pakistan Mineral Development Corporation Report, 130p.

Key words: Geology, chromite, Malakand.

M/173. Mehdiratta, R.C., 1962. Geology of India, Pakistan and Burmah. 2nd edition. Atma Ram & Sons, Delhi.

This book provides information on Pakistan's northern part also. Much, if not all, is based on the GSI publications.

Key words: Geology, India, Pakistan, Burmah.

M/174. Mehmood, T., 1999-2000. Geological mapping, stratigraphy, petroleum geology and tectonics of Kohat sub-basin, N.W.F.P., Pakistan with special emphasis on structure and sedimentology of Shadi Khel-Gumbat area District Kohat N.W.F.P., Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 95p.

The study area lies in the Kohat sub-basin of upper Indus Basin which constitutes the western part of the Himalayan fold-and-thrust belt and is bounded by Surghar Range in the south. Regionally Kohat plateau is underlain by sedimentary rocks ranging in age from Pre-Cambrian to Pliocene. Oldest rocks are exposed in the north while most of the middle and southern portions are covered by rocks of Rawalpindi and Siwalik groups. Deposition of the

sediments was interrupted several times, however, the major one with in the exposed sequence is between the Eocene and Miocene. The rocks, exposed in the area, are locally highly folded and faulted due to orogenic movements related to Himalayan uplift.

The objective of the project was to study the structural style, stratigraphy, petrography of different rock units and to evaluate the hydrocarbon potential of the area. Within the exposed rock units, shales of the Chichali and Patala Formations are the potential source rocks. Limestone of the Samana suk, Lockhart and Shekhan Formations are the potential reservoir rocks. Potential cap rocks of the Kohat plateau are shale/clay of Datta, Patala, Kuldana and Kohat Formations. Bahadurkhel salt and Jatta Gypsum may prove very effective cap rocks, especially in the southern portion of the study area. Structural analysis of different rock units shows that there are two deformational events i.e. D1 and D2 which are related to F1 and F2 folding. F1 folds related to D1 are north vergent folds with NE-SW extension. F2 folds and structures are formed by northeast and southwest compression. D2 deformation phase change the fold axis and plunge of F1 fold. The F2 cross folds are mainly anticlines and synclines.

Key words: Mapping, stratigraphy, tectonics, structure, sedimentology, Kohat.

M/175. Meier, A., 1992. The geology of the Higher Himalaya in upper Kaghan valley, NE Pakistan (Buruwai-Jalkhad section—Aspects of Tectonics). Master Thesis, ETH Zurich.

Consult the following for further information.

Key words: Structure, tectonics, Kaghan valley, Himalaya.

M/176. Meier, A. & Wahrenberger, C., 1991. The stratigraphy of the Higher Himalaya at upper Kaghan Valley, NE-Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 59.

As a part of the Himalayan research programme of the ETH we has the opportunity to do the fieldwork for our diploma thesis in summer 1990 in Pakistan. During the fieldwork a stratigraphic profile of a total measured length of about 1400-m was taken. The effect of deformation on the original bed thickness has not yet been considered.

Three major lithological groups can be defined: a group of metagranitoid rocks overlain by metapelites form a “basement” overlain by a series of metamorphic calcpelites, which have been interpreted as cover to this basement (Greco et al., 1989).

The stratigraphically lowermost group is represented by a leucocratic-mesocratic garnetiferous two mica-gneiss. A banding with dark mica dominated schist layers takes place at 10-cm scale.

The transitional contact with a stratigraphically overlying group of micaschists takes place within about 2 m. No angular discordance was observed. These rocks are garnet-two micas gneisses characterized by porphyroblastic feldspar and an abundance of biotite. The aluminium rich nature of these rocks and the preservation of sedimentary structures show that the original material was pelitic to semipelitic sediment. The group also comprises occasional quartzitic layers and rare marbles. The contact to the uppermost group is also transitional over a distance of about 15 to 20 m. this group consists mostly of metamorphic calcpelites which vary from pure marbles to garnet-micaschists together with more psammitic layers. At the top of the profile stromatolitic layers are associated with structures indicating syndimentary extension. Amphibolites are present in all groups. These being interpreted associated with the Panjal Trap Basalts (Papritz and Rey, 1989). They are probably of both extrusive and intrusive origin.

Key words: Stratigraphy, Kaghan Valley, Himalaya.

M/177. Meier, A. & Wahrenberger, C., 1992. Metamorphism and tectonics in the higher Himalaya crystalline of upper Kaghan valley, NE Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 55.

Based on the field data from summer 1990 we summarize our observations and interpretations on the geology of Burawai-Jalkad Section in Upper Kaghan Valley as follows:

The rocks can be separated in three major stratigraphically successive groups: The lowermost group of metagranitoid rocks form a basement to a first cover of metapelites. These are overlain by a series of metamorphic calcpelites (second cover). The stratigraphic profile taken in the field confirms this succession, but must include at

smaller scale several duplications produced by the F1 folds. The geological map shows regional unconformities between all lithological groups.

Different metamorphic histories can be derived for basement and cover rocks. Second cover metapelites suggest two phases of metamorphism. A first phase (M1) being of staurolite-kyanite grade syn- to postkinematic to f1 and a second phase (M2) postkinematic to f2. Kyanite of the first phase is broken during f2 and re-crystallizes during M2. Peak metamorphic conditions are reached during M2 and are estimated to 600-650 °C and pressures between 6 and 9 kbars by petrographic grid. First cover rocks suggest a two-fold re-equilibration of an earlier metamorphic event. Euhedral clinopyroxene, which is later consumed by amphiboles, encloses symplectitic structures of diopsidic pyroxene with plagioclase. These symplectites as well as rutiles enclosed in titanite are preliminary regarded as indicators for a former eclogite facies event. Eclogites which formed under 650±50 °C and 13-18 kbars are reported further to the north by Pognante and Spencer (1991). These observations, as well as the presence of migmatized rocks, suggest a decompressional path with rising temperatures. The dissolution of white mica indicates the beginning of high temperature metamorphic overprint in the basement.

The structural data analysis leads to a ductile deformation of rocks documented by a polyphase folding history. Three different folding phases can be distinguished: A first phase (f1) produces tight to isoclinal folds with axial planes strongly deformed as a result of later folding phases. The well-developed penetrative schistosity, made up by oriented platy and acicular minerals, is the most dominant microstructural feature. Bedding and schistosity planes are subparallel and are folded together with schistosity-bedding intersection lineations (interpreted as first phase fold axes) by the second deformation event (f2). The second phase folds show an open fold type. The axial planes strike NE-SW and the fold axes are gently plunging to the southwest. A third folding phase (f3) deflects the older structures. The superpositions of the folding phases result in interference patterns. The crenulation of penetrative schistosity with constantly oriented fold axes plunging to southwest could document a further deformation event.

Key words: Metamorphism, tectonics, Himalaya, Kaghan valley.

M/178. Meier, W., Heintz, M., Kretzschmar, D., Niedtfeld, B., Wagner, E., Wagner, R., Dr. Gerhard Weiß, Beheng, K., Dr. Anno Diemer, Holtmann, G., Jaeger, W., Michaelis, W., Obrocki, U. & Wasel, P., 1976. Eine expedition ins Hohe Lungma-Gletscherbecken. Kolner Karakorum-Expedition 1976. Prufer, Kasendorf.

On August 8, the Cologne started with two jeeps and two tractors through the Shigar-Valley by the end of the jeep track to Jouna. At the mouth of the river in the Braldu Basha River at Youno or Jouna they rented carriers and marched along the Braldu in northern direction until Dassu had to the base camp withdraw. Only on August 24, a new trial could be started, because of fresh snow but managed only to Camp 1. Now turns at the mouth of the Hoh River Lungma the Braldu River to the east. But the Germans followed the Hoh Lungma-River and camped in Tapsa (3700 m). Here she first had with the inhabitants negotiate for the permission for entering the Hoh Lungma-area. After the agreement it went to Hoh Lungma Glacier where on the "Bärenwiese" in 4150 m Height on August 11, the base camp was. About the lower plateau of the glacier Tsilbu (4500 m) we went up to the upper plateau, where in 4700 m camp 1 has been built. On August 15, a barrage increased from three climbers on the top Tsilbu-Glaciers to South Hikmul pass on and established in 5390 m camp 2. After there was once a weather burglary and Cologne the weather was consistently bad and so they decided to retreat. Hillside, the Germans had split into two groups working completely separately. The second group was on August 12 by Tapsa the orographic right side the lower Sosbun glacier until about 4200 m height. The following day erected it their base camp on the upper Sosbun Glacier in 4440 height. After a rest day it continued on August 15 and was at the foot of Sosbun Brakk-west ridge stock 1 built in 4820 m height. In the following days, the climbers started the Climbing at West Ridge. In about 5000 m, they crossed a glacier, and laid on Gratfuß to a first material depot. Another depot was with rope Insurance (IV Degrees) created in 5250 m. Following were equipment and food up stock 1 made from base camp. On August 23, it was in complicated Ridge climbing above the second depot on. There had to a large intersection and an ice slope (V degree) to be overcome in 5350 m. Following was the explored route insured. Behind the intersection it went on 25 August. Next, the Cologne reached the actual rock body in 5400 m height. Smoothness Plates and mixed terrain (V-VI grade) were a real challenge. Of the highest point, which was achieved, was in about 5500 m altitude. Because of slumping Night rose the roped off a piece, but then had in 5300 m altitude a bivouac set up. Prolonged snowfall demoralisierte Cologne so much that they decided dismount.

TRANSLATED

Key words: Lungma Glacier, Karakoram.

M/179. Meiners, S., 1998. Preliminary results concerning historic to Post-Glacial glacier stages in the NW-Karakorum (Hispar Muztagh, Batura Muztagh, Rakaposhi Range). In: Stellrecht, I., Karakorum-Hindukush-Himalaya: Dynamics of Change (Culture Area Karakorum, Scientific Studies 4). Rudiger Koppe, Koln.

Key words: Glaciers, Batura, Hispar, Mustagh, Rakaposhi, Karakoram.

M/180. Meissner, C.R., 1966. Phosphatic rock in the Nizampur area of the Kala-Chitta Hill. MROP, USAID/Geological Survey of Pakistan 3, 5p.

Key words: Phosphatic rocks, Nizampur, Nowshera.

M/181. Meissner, C.R., Hussain, M., Rashid, M.A. & Sethi, U.B., 1964-65. Reconnaissance geologic map and cross sections of the Parachinar quadrangle, Pakistan. US Geological Survey, Geological Map Series PP 716F Plate 1. Scale 1:250,000.

Key word: Reconnaissance geology, structure, Parachinar.

M/182. Meissner, C.R., Hussain, M., Rashid, M.A. & Sethi, U.B., 1969. Geology of the Parachinar quadrangle, Pakistan. Geological Survey Pakistan and U.S. Geological Survey, Professional Paper 716-G, 20p.

The Parachinar quadrangle occupies approximately 3500 square miles along the western border of West Pakistan. The area consists mainly of sedimentary rocks that range in age from Jurassic to Pliocene. A total of 23 stratigraphic groups and formations, most of them having formally accepted names, have an aggregate stratigraphic thickness of more than 23,000 feet; more than 13000 feet is Late Tertiary in age. Sixteen stratigraphic sections provide much detailed information on the lithology and stratigraphic relations of the rock units. The work was correlated with that done in the Kohat quadrangle to the east and the Bannu quadrangle to the south. Of major stratigraphic importance is the juxtaposition of two distinct facies of Cretaceous rocks in the quadrangle, a shale facies on the west and a limestone facies on the east.

Key words: Stratigraphy, structure, Parachinar.

M/183. Meissner, C.R., Hussain, M., Rashid, M.A. & Sethi, U.B., 1975. Geology of the Parachinar quadrangle, Pakistan. US Geological Survey Professional Paper, 716F, 1-24. Reconnaissance geological map 1:250,000.

Key words: Stratigraphy, structure, Parachinar.

M/184. Meissner, C.R., Master, J.M., Rashid, M.A. & Hussain, M., 1968. Stratigraphy of the Kohat quadrangle, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-20, 86p.

The Kohat quadrangle (Survey of Pakistan topographic sheet 38-O) consists of approximately 4,000 square miles. Sedimentary rocks in the area have a total stratigraphic thickness of more than 25,500 feet. The oldest rocks crop out in the northeastern and northwestern parts of the quadrangle, and are slate, slaty shale, and sandstone of Precambrian or early Paleozoic age. Jurassic, Cretaceous, Paleocene, Eocene, Miocene, and Pliocene sedimentary formations are found in the Kohat quadrangle. Pleistocene sedimentary rocks also may be present, but were not recognized.

The rock sequence of 21 formations, six of which are formally defined for the first time.

The Jurassic System consists mostly of limestone: two subdivisions have been recognized. The Lower half of the Cretaceous System is mostly marine sandstone, and the upper half is mostly marine limestone. The Paleocene Series, which includes three formations, consists mostly of carbonate rocks but also contains some sandstone and shale. Of the Eocene Series, only rocks of early Eocene age are present in the Kohat quadrangle, and they contain extensive deposits of gypsum, rock salt, marine limestone and shale. A relatively thin section of the Murree Formation of Miocene age unconformably overlies lower Eocene rocks. It, in turn, is overlain by more than 10,000 feet of strata.

Key words: Stratigraphy, mapping, Kohat.

M/185. Meissner, C.R., Master, J.M., Rashid, M.A. & Hussain, M., 1974. Stratigraphy of the Kohat quadrangle, Pakistan. US Geological Survey Professional Paper 716-D, 30p. Geological map 1:250,000.

Key words: Stratigraphy, structure, Kohat.

M/186. Meissner, C.R. & Rehman, H., 1973. Distribution, thickness and lithology of Paleocene rocks in Pakistan. US Geological Survey, Professional Paper 716-E, 6p.

Key words: Stratigraphy, lithology, Paleocene.

M/187. Meixner, H. & Paar, W., 1976. Ein vorkommen von vayrynenit-kristallen aus 'Pakistan'. Z. Kristallen 143, 309-318.

Key words: Gems.

M/188. Meltzer, A., Sarker, G., Seeber, L. & Armbruster, J., 1998. Snap, crackle, pop! Seismicity and crustal structure at Nanga Parbat Pakistan Himalaya. Eos Transition American Geophysical Union 79 Supplements F909.

For details, consult the following two accounts.

Key words: Seismicity, structure, Nanga Parbat, Himalaya.

M/189. Meltzer, A., Seeber, L. & Armbruster, J., 1998. Seismicity and crustal structure at Nanga Parbat, Pakistan Himalaya. Geological Bulletin, University of Peshawar 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop), 128-129.

Nanga Parbat lies on the western end of the Himalayan Mountain chain in NE Pakistan. This >8 km high peak, sculpted from Indian crust, is the site of rapid uplift, denudation, and young (<1 Ma) igneous and metamorphic activity. Substantial reworking of the crust occurs today, although the initial collision between India and Asia occurred ~55 my ago. While the Indian basement gneisses that make up the Nanga Parbat massif were clearly involved in a major collisional event, they exhibit virtually no evidence for early Himalayan metamorphism. As part of a multidisciplinary study to understand the active tectonic processes at Nanga Parbat we deployed a dense seismic array to characterize active seismicity at the massif (fault geometry and kinematics) and determine crustal structure beneath the mountain. Extremely rapid exhumation, the presence of hot springs, young intrusive rocks, and young metamorphism all suggest an anomalous thermal structure lies beneath Nanga Parbat.

Our 60 station array consists of 10 broadband and 50 short period three component stations deployed in a 60 x 60 km area surrounding the massif. Station spacing varies from 1 to 6 km, and station elevations range from 1.0 to 4.3 km. The array recorded local and regional seismicity for a 4 month period (May-September, 1996). Primary source regions are the Hindu Kush, the Karakoram, the Himalayan and Hazara arcs, and local seismicity beneath the massif itself. The Hindu Kush events which originate 200-300 km northwest of Nanga Parbat, and at 200-300 km depth serve as a beam source to illuminate the structure beneath the massif.

In a four month time window we recorded over 1500 associated events, a combination of teleseismic, regional, and local earthquakes. Our initial focus has been on locating events and analyzing waveforms. Ultimately, we'll use the Hindu Kush events and additional regional events from a range of azimuths combined with local events to produce a tomographic image of velocity and attenuation structure beneath the massif.

Our array recorded a high level of microseismicity at Nanga Parbat, between 3 and 8 small magnitude events per day. Seismicity is somewhat distributed along strike beneath the massif but exhibits a sharp drop off in intensity both west and east of the main summit. The sharp cut off in seismicity to the west corresponds to the mapped trace of the Raikot fault. This young active structure juxtaposes Indian Pre-Cambrian gneisses against mafic rocks of the Kohistan Island arc captured during the collision of Indian and Asia and provides a mechanism to expose Indian plate rocks from beneath Asia. The adjacent Kohistan terrane is virtually aseismic. The sharp cut off in seismicity to the east is bound by the region of highest topography. In fact, the highest intensity of distributed seismicity is associated with the region of highest topography. Local seismicity beneath Nanga Parbat is restricted to very shallow depths (< 8 km bsl) providing constraints on the transition from brittle to ductile deformation. Hypocenters projected to a NW-SE cross section outline a prominent bow or antiformal shape. The cutoff of seismicity with depth is shallowest beneath the summit (5-km bsl) and deepens to 8 km to the NW and SE. This observation is consistent with petrologic and thermochronologic data indicating very high geothermal gradients (~60-100o/km) at Nanga Parbat. At these rates, rocks pass through the 450o isotherm by ~7 km depth which approaches the ductile regime for quartzofeldspathic rocks, especially in the presence of fluids and high strain rates.

Most of the local events have clean impulsive signals allowing high quality focal mechanisms to be determined. While we recorded some thrust and some right-lateral strike-slip focal mechanisms, much of the observed seismicity is from a set of shallow normal faults striking roughly parallel to the main massif and dipping south to southeast, back toward the summit.

While many of the igneous, metamorphic, and petrologic observations at Nanga Parbat could be explained by a young intrusive body at depth, complicated but prominent S wave arrivals at stations throughout the array rule out the possibility of a substantial magma body beneath Nanga Parbat. This observation holds for both Hindu Kush events with a relatively vertical ray path beneath the massif sampling the entire crust and local events, which travel through the shallow crust. However, we do see local travel time delays and anomalous waveforms suggesting small scale heterogeneity possibly related to small partial melt zones. We also see a large variation in waveform coda associated with propagation path (not site affects). While we see many clean impulsive arrivals, others appear more harmonic, not unlike signatures associated with geothermal systems and volcanoes, suggestive of magmatic or fluid injection at shallow depths. These events are intriguing given the evidence for recent igneous activity focused at the core of the massif and evidence from fluid inclusions indicating a dry steam phase associated with a hydrothermal system below 3 km depth. Finally, on many of the local events we see evidence of shear wave splitting presumably due to anisotropy associated with the metamorphic or strain fabric of the rocks.

Key words: Seismicity, structure, Nanga Parbat, Himalaya.

M/190. Meltzer, A., Seeber, L., Sarker, G. & Armbruster, J., 1999. Seismic characterization of active metamorphism, Nanga Parbat, Pakistan Himalaya. *Terra Nostra* 99 Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 98-99.

Earthquakes recorded by a dense array of seismometers deployed around the Nanga Parbat massif in the Himalaya of Pakistan provide new insight into synorogenic metamorphism and deformational processes. Microseismicity distributed along strike beneath the massif exhibits a sharp drop-off to the east bound by the main summit massif. An abrupt cessation of seismicity with depth defines a shallow brittle-ductile transition at 5-8 km bsl. Low P and S wave velocity anomalies observed at the core of the massif extend to depth through the entire crust. At Nanga Parbat local seismicity and low seismic velocities are associated with the highest topography, youngest metamorphic and igneous ages, high geothermal gradients, and active crustal fluid flow suggesting a genetic link between these phenomena.

Most of the local events have clean impulsive signals allowing high-quality focal mechanisms to be determined. While we have recorded some thrust and some right-lateral strike-slip focal mechanisms, much of the observed seismicity is from a set of shallow normal faults striking roughly parallel to the main massif and dipping south to southeast, back toward the summit. These extensional focal mechanisms are not associated with low-angle crustal-scale faults typically associated with tectonic denudation in orogenic belts. Instead, they fall along planes that are relatively high angle, limited in lateral extent, and restricted to the shallow portions of the crust (upper 5-8 km). These normal faults are consistent with extension above the doubly vergent thrust system which bounds the massif.

Some extensional events may also record hydrofracturing associated with the release of overpressured fluids at depth. We see a cluster of events associated with the Tato hot springs. These events, when relocated using a cross-correlation technique, locate within $\pm 50\text{m}$ of each other defining a tightly constrained fault plane that may serve as a pathway for circulation of meteoric water to and from the surface. A 3-D joint inversion for hypocenter location, V_p , and V_s shows that the velocity structure beneath the Nanga Parbat massif is anomalously low, up to 10%, over lateral distances of 20-40 km (11). In the shallow crust ($<10\text{-km}$ depth) V_p ranges from 5.6-5.8 km/s and V_s from 3.3-3.5 km/s within the massif compared to velocities of $V_p=6.0\text{-}6.4\text{ km/s}$ and $V_s=3.5\text{-}3.6\text{ km/s}$ in adjacent regions. Analyzing arrivals at the stations deployed in valleys as subsets of small linear arrays yields similar velocity values confirming the robustness of these results. At greater depths (10-50 km) V_p ranges from 5.8-5.9 km/s and V_s from 3.5-3.6 km/s within the massif compared to velocities of $V_p=6.2\text{-}6.5\text{ km/s}$ and $V_s=3.6\text{-}3.8\text{ km/s}$ in the surrounding area. Both the P and S wave velocity anomalies are observed at the core of the massif and extend to depth through the entire crust. Low velocities imply hot rocks at depth in this region as the composition of the massif is monotonously homogeneous with respect to seismic wavelengths. The distribution of low velocities found at Nanga Parbat is consistent with the prediction of numerical models examining the evolution of the conductive geotherm during rapid advection of crustal rocks, which indicate that Nanga Parbat should resemble a “pillar of heat”. This result also suggests that the primary flow path of material into the massif is from depth rather than along a shallow detachment. Finally, our initial inversions yield slightly low V_p/V_s ratios at several areas within the massif, which may reflect the presence of super-critical fluids in small regions of limited extent. While many of the igneous, metamorphic, and structural observations at Nanga Parbat could be explained by a young intrusive body at depth, prominent but complicated S wave arrivals at stations throughout the array rule out the possibility of a substantial magma body beneath Nanga Parbat. This observation holds for both Hindu Kush events with a relatively vertical ray path beneath the massif sampling the entire crust and local events, which travel more obliquely through the shallow crust.

The seismic data recorded at Nanga Parbat supports a model of strain induced metamorphism. Focal mechanisms, travel time and waveform anomalies, low V_p and V_s , and low V_p/V_s ratios are consistent with the model in which rapid and dramatic exhumation leads to pervasive reworking of continental crust. Dehydrated Indian gneisses are transported from depth toward the surface. As this material is brought to the surface advection of isotherms results in low P and S wave velocities throughout the crust and elevates the position of the brittle-ductile transition causing it to bow, convex upward beneath the massif. As dry gneisses then pass into the lower strain zone beneath the summit, they are brought into communication with surface waters. Fluids may be released due to shear failure at elevated fluid pressure or due to local hydrofracturing providing the source of some of the microseismicity recorded at Nanga Parbat.

Key words: Seismicity, metamorphism, Nanga Parbat, Himalaya.

M/191. Memon, A.R., 1966. Sedimentary petrography of Siwalik sediments exposed in Khaur, Dhok Pattan, and Soan syncline areas. M.Sc. Thesis, Sind University, Jamshoro.

Key words: Sedimentary petrography, siwaliks, Khaur, Dhok Pattan, Soan syncline.

M/192. Memon, M.A. & Tietze, Klaus-W., 1997. Depositional environments and diagenetic history of the Lumshiwal Formation, Miranwal Nala section, Surghar Range. Pakistan Journal of Hydrocarbon Research, 9, 3–14.

Key words: Depositional environments, Lumshiwal Formation, Surghar Range.

M/193. Menke, W. & Jacob, K.H., 1976. Seismicity patterns in Pakistan and northwestern India associated with continental collision. Seismological Society of America, Bulletin 66, 1695-1711.

Key words: Seismicity, continental collision, India, Pakistan.

M/194. Mensink, H., Mertmann, D. & Ahmad, S., 1986. Stratigraphical dates on the Triassic rocks of Landu Nala, Surghar Range. Geological Bulletin, Punjab University 21, 104-119.

The stratigraphy and microfacies of some of the Triassic rocks of Landu Nala are described. Within the pisolitic horizon on top of the Mianwali formation a few species of conodonts namely *Gondolella timorensis*, *Neospathodus homeri* and *Ozardina tortilis* are recorded. Within the Kingriali succession some brachiopod species of *Spiriferinoides* and some pelecypods have also been identified. An Anisian and Carnian age is proposed on the basis of fossil contents.

Key words: Stratigraphy, Triassic, Surghar Range, Mianwali.

M/195. Mensink, H., Mertmann, D., Ahmad, S. & Shams, F.A., 1984. Facies of Jurassic rocks in the Surghar Range, Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, 63-64.

The Jurassic sediments of the Surghar and Salt Range show a variety of microfacies-types. It is possible to distinguish 12 different rock facies. Furthermore, the sections contain many discontinuities. Both are interpreted. The sedimentary history can be divided into 5 subsequent phases between the Upper-Trias and Neocom.

Key words: Microfacies, Jurassic, Surghar, Trans-Indus Salt Range.

M/196. Mensink, H., Mertmann, D., Ahmad, S. & Shams, F.A., 1985. A microfacies reconnaissance of the Kingriali Formation of the Nammal Gorge and Gulakhel areas. Geological Bulletin Punjab University, 20, 1-10.

Microfacies-analysis of 60 thin sections based on 80 rock samples from two sections namely Nammal Gorge and Gulakhel belonging to the Kingriali-Formation is presented. Eleven types of microfacies have been differentiated and are described. Most of these are of dolosparitic nature, others are dolomicritic. Furthermore, calcitic onco-, oo- and bio-sparites are also encountered during the present investigation. Based on facies-analysis the rock sequence is subdivided into different facies units. Paleoenvironments are interpreted as shallow marine to intertidal.

Key words: Microfacies, reconnaissance, Nammal Gorge, Salt Range.

M/197. Mensink, H., Mertmann, D., Ahmad, S. & Shams, F.A., 1991. Facies of Jurassic rocks in the Surghar Range, Pakistan. Acta Mineralogica Pakistanica, 5, 109-120.

Key words: Microfacies, Jurassic, Surghar Range, Trans Indus Salt Range.

M/198. Mercer, J.H., 1963. Glacier Variations in the Karakoram. Glaciological Notes 14, 19-33.

Key words: Glaciers, Karakoram.

M/199. Mercer, J.H., 1965. Glaciers of Karakoram. In: Field, W. (ed.), Mountain Glaciers of the Northern Hemisphere, 371-409. US Army Cold Regions Research & Engineering Lab., Hanover, NH.

Key words: Glaciers, Karakoram.

M/200. Mercer, J.H., 1975. Glaciers of the Karakoram. In: Inventory of World Glaciers. Field, W., (ed.), 377-407.

Key words: World Glaciers, Karakoram glaciers.

M/201. Merla, G., 1931. Fossili Antrocolitici del Caracorum. In: Relazioni Scientifiche della Spedizione Italiana de Filippi Nel'Himalaia, Caracorum e Turchestan Cinese (1913-1914), 2(5), 101-319. Zanichelli, Bologna.

Key words: Fossils, Karakoram, Chinese Turkestan.

M/202. Merla, G., 1934. Fossili triassici del Dapsang. In: Relazioni Scientifiche della Spedizione Italiana de Filippi Nel'Himalaia, Caracorum e Turchestan Cinese (1913-1914), 2(9), 51-124. Zanichelli, Bologna.

Key words: Triassic fossils, Karakoram, Himalaya, Chinese Turkestan

M/203. Merla, G., 1936. Prime osservazioni su alcuni fossili permici raccolti della spedizione. Appendix to: La Spedizione Geografica Italiana al Karakorum (1929). Arti Grafiche Bertarelli, Milano, 29-48.

Key words: Fossils, Italian Geographic Expedition, Karakoram.

M/204. Mertmann, D. & Ahmed, S., 1997a. Sedimentary sequence of the marine Permian rocks, Salt Range, Surghar Range, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.46.

Key words: Sedimentary sequence, Permian, Surghar Range, Salt Range.

M/205. Mertmann, D. & Ahmed, S., 1997b. The drowning of the Jurassic carbonate platform in Pakistan in the context of a peri-Gondwanian event. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.47.

Key words: Jurassic, carbonate, Gondwana.

M/206. Mertmann, D. & Ahmed, S., 2000. Foraminiferal assemblages in Permian carbonates of the Salt Range and Trans Indus Ranges, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 21-22.

The marine Permian sediments (Amb-, Wargal- and Chhidru Formations) of the Salt Range and the Trans Indus Ranges yield an abundant fauna of foraminifera. Main groups include Fusulinina, Miliolina and Rotaliina. The fauna occur as benthic organisms setting under open marine to lagoonal conditions in a warm Tethyan sea (P.J.R.G., 1985). The foraminifera show strong palaeobiogeographic relations to other Tethyan carbonate platforms situated in today's Iran, Afghanistan, China and Asia (Jenny-Deshusses 1983, Lys 1988).

Fusulinaceans (*Parafusulina* (*Monodiexodina*) *kattaensis* (Schwager) and *Codonofusiella laxa* Douglass) are rare in the Amb Formation due to strong clastic input and an agitated coastal water. In the lower Wargal Formation and association comprises *Neoschwagerina margaritae* DEPRAT, *Sphaerulina* sp., *Schubertella* sp., *Chusenella* sp. and *Reichelina* sp. Therefore, a Murghabian age is evident. The occurrence of the *Neoschwagerina*-association is related to a major marine transgression together with a warm surface current along the northern margin of Gondwana. In the upper part of the Wargal Formation and in the Chhidru Formation, *Nanlingella simplex* Sheng & Chang, *Reichelina* sp., *Nankinella* sp. and *Staffella* sp. indicate a Djulfian age. Small foraminifera include a variety of long ranging species from *Parathuramminidae*, *Earlandiidae*, *Nodosinellidae*, *Endothyridae*, *Lasiodiscidae*, *Hemigordipsidae* and *Fischeridae*. Others are more interesting *Globivalvulina vonderschmitti* REICHEL and *Dagmarita chanakchiensis* RIETLINGER indicate a Murghabian to Djulfian age. Both are present in the Wargal- and Chhidru Formation. *Globivalvulina mira* REITLINGER (Midian - Djulfian) occurs from the Upper Wargal onward. *Colaniella* ex grupo *lepidi* WANG and *Colaniella* ex grupo *minima* WANG are restricted to the Upper Wargal and the Chhidru Formation. Stratigraphically confined to the Midian to Dorashamian, older forms are described only from the Pamir and Caucasus. In the southern Peri-gondwanian areas they represent a Djulfian age, whereas the youngest forms are

known from China (Jenny-Deshusses et al., 1989). Within the Wargal Formation they are often distributed in a coral reef facies.

Key words: Carbonate, Permian, Trans Indus Range, Salt Range.

M/207. Mertmann, D. & Ahmed, S., 2000. Evolution of Tethyan carbonate platform during the Upper Permian (Salt Range, Surghar Rang), Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 22-23.

During the Permian, a large carbonate platform developed on Gondwana continental crust in front of the Indian Shield. The platform was influenced both by sea-level fluctuations and by repeated intervals of hinterland uplift associated with an increase in clastic terrigenous input. Sedimentary environments were mainly of the following types; deltaic and siliciclastic shelf and carbonate platform with a variety of reef mounds, bioclastic shoals and tidal flats. The sequence can be divided into depositional sequences and the system tract philosophy can be applied. Third-order cycles are represented by at least 6 depositional sequences with internal shallowing- upward parasequences. Moreover, a superimposed cycle spans the whole Zaluch Group.

Key words: Carbonate, Permian, Tethyan, Salt Range.

M/208. Mertmann, D., Dragastan, O. & Ahmed, S., 1992. Depositional environments of Jurassic carbonate rock of the Salt Range, Surghar Range and Kala Chitta areas, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.28.

Key words: Depositional environments, Jurassic, carbonates, Salt Range, Surghar Range, Kala Chitta areas.

M/209. Mian, I., 1970a. The chromium-bearing minerals of the North West Frontier Province. Geological Bulletin, University of Peshawar 5, 131-134.

During the past few years, many interesting minerals have been reported from the N.W.F.P. Of these, the chromium-bearing minerals – emerald, mica, spinal and tourmaline – merit special attention because of the economic and / or academic importance. Gem quality emerald from Swat and Mohmand Agency is sold at high price and has attracted a lot of people during the past few years. All of the chromium-bearing minerals are closely associated with ultramafic rocks from which chromium was derived by various mechanisms. In this paper, the writer has tried to gather all the published data available on these occurrences, and has added some new information.

Key words: Minerals, gems, ultramafics, N.W.F.P.

M/210. Mian, I., 1970b. Building and decorate material of North West Frontier Province. National Seminar on Mineral Development, Lahore.

Key words: Building stones, decorative stone, NWFP.

M/211. Mian, I., 1987. The mineralogy and geochemistry of the carbonatite, syenites and fenites of North West Frontier Province, Pakistan. Ph.D. thesis, Leicester University.

Key words: Mineralogy, geochemistry, carbonatite, syenites, fenites, NWFP.

M/212. Mian, I., 1994. Sulphide occurrences in Shinkai area of North Waziristan Agency, FATA. Abstracts, Second SEGMIITE International Conference on the Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 33-34.

Waziristan area representing a typical ophiolite environment with a diagnostic sequence of ocean floor ultramafics, sheeted dykes and pillow lava with subordinate deep marine sediments. The ophiolite sequence is intruded by plutonic rock (Diorite and granodiorite).

Copper occurrences in brecciated pillow lavas of the ophiolite have been recorded in a North-west trending belt. Various gossans have been identified along 100-kms, as linear belt and confined to the west central part of Waziristan area. Major occurrences are confined in Shinkai and Degan-Paikhel area, North Waziristan Agency and Spinkamar area of South Waziristan Agency, total of 15 prospects of various area extent have been studied for sub-surface behaviour of copper and related sulphide in Shinkai and Degan Paikhel area.

Primary sulphide mainly (pyrite, chalcopyrite and bornite) are confined to the chloritized pillow breccia as stock work in the form of fractures, cavity fillings and fine disseminations. These sulphides are mostly associated with quartz, epidote, calcite and chlorite. The stock work zone is capped by a thin layer of secondary oxides including malachite, azurite, Limonite, iron limonite, jarosite, goethite and hematite. Geochemical studies of 92 bore hole samples of about 12,462 meters strata at 1 meter interval are conducted for copper and related sulphides.

Multidisciplinary geophysical survey has been conducted in the Degan Paikhel through Geological survey of Pakistan in 1988. Induced polarization survey has been initiated at Shinkai area. Total of 1411' profiles at 50 meters and 100 meters electrode spacing have been conducted. Based on bore hole geochemical studies, petrography, induced polarization (IP) studies and subsurface alteration, it is suggested that the sulphide mineralization is of volcano genic massive sulphide type (VMS); formed at or near the submarine spreading center and later on subjected to uplift and exposure during collision of Indian mass with the Eurasian continental block.

Key words: Sulphide mineralization, ophiolites, ultramafics, North Waziristan.

M/213. Mian, I. & Afridi, M.I., 1996. Sulphide occurrences in Shinkai area of North Waziristan Agency, FATA. Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, p.77.

Key words: Sulphides, ophiolites, ultramafics, North Waziristan.

M/214. Mian, I. & Jabeen, N., 1990. Sodic pyroxenes and amphiboles from Koga syenites of Ambela Granitic complex, NWFP, Pakistan. Geological Bulletin, University of Peshawar 23, 67-85.

The Koga syenites are intruded and fenitized by at least two carbonatite intrusions having different Na/K ratios. The carbonatite with high Na/K ratio formed Na-fenites, while the low Na/K ratio produced K-fenites. Amongst the fenitic pyroxenes, Na-pyroxene shows a trend from actinolitic to diopsidic and/or hedenburgitic component in contrast to magmatic trend. The fenitic Na-amphibole occurs only in Na-fenitized rocks and shows a trend from magnesio-arfvedsonite to richterite, which is opposite to the magmatic subsolidus trend. The amphibole composition shows an increase in MgO ratio with increasing intensity of fenitization and suggests the crystallization of fenite amphibole under strong oxidation conditions.

Key words: Mineralogy, pyroxene, amphibole, Koga, Buner.

M/215. Mian, I. & Le Bas, M.J., 1986. Sodic amphibole in fenites from the Loe Shilman carbonatite complex, NW Pakistan. Mineralogical Magazine 50, 187-197.

The carbonatites at Loe Shilman, near Khyber in NW Pakistan, fenitize their country rocks to form a metasomatic zone c.100 m wide of alternate dark blue (mafic) and pale grey (felsic) banded fenites which grade into unfenitized bedded slates and phyllites. The Na-amphiboles in the banded fenites form a complete solid solution series between magnesio-arfvedsonite and magnesio-riebeckite which coexist with varying proportions of aegirine, albite, and K-feldspar, with or without phlogopite or biotite. The amphiboles show a gradual decrease in Na₂O, K₂O, Mg ratio [100Mg/(Mg + Fe^T + Mn)] and iron oxidation ratio, and an increase in total iron away from the carbonatite contact. The pleochroism correlates with the chemistry and distance from the carbonatite contact.

The Mg ratio decreases from 74 to 35 away from the carbonatite contact. The iron oxidation ratio [100Fe³⁺/(Fe³⁺ + Fe²⁺)] decreases in the magnesio-arfvedsonite for the first 30 metres from the carbonatite contact, and then increases in the magnesio-riebeckite from 40 to 60 metres from the carbonatite contact. K relative to Na decreases away from

the contact in the amphibole, and the decrease in K causes an increase in vacancy in the A site. The main variation in the chemistry in this solid solution series is due to $(K, Na)_A + (Mg, Fe^{2+})_c \rightleftharpoons \square + (Fe^{3+})_c$ substitution.

Key words: Mineralogy, amphibole, Loe Shilman.

M/216. Mian, I. & Le Bas, M.J., 1987. The biotite-phlogopite series in fenites from Loe Shilman carbonatite complex, NW Pakistan. *Mineralogical Magazine* 51, 397-408.

The Loe Shilman carbonatite sheet complex comprises an extensive amphibole sovite which is intruded by minor biotite sovite and amphibole ankeritic carbonatite. The carbonatites have fenitized the country rocks to form a metasomatic zone c. 100 m wide of alternating mafic and felsic mica-bearing banded fenites which grade into slates and phyllites. Phlogopite-rich micas occur nearest to the carbonatite contact. The biotites occur in K-feldspar + albite $\pm$ Na-amphibole $\pm$ aegirine and $\pm$ phengite fenites produced by the intrusion of the early amphibole sovite. Aegirine buffered the iron distribution and the biotites became more magnesian. Veins cross-cutting the fenites consist of biotite and/or Ba-bearing K-feldspar, and are interpreted to result from solutions emanating from the biotite sovite. The ankeritic carbonatite is responsible for the formation of phlogopite in the fenites in a c. 3 m wide zone adjacent to the carbonatite, and evidently are the result of fenitizing fluids rich in Mg. Chemical equations calculated to balance the reactions interpreted to have taken place in the fenites suggest that about 10% of the Al and Si in the protolith was mobilized and moved towards the carbonatites during fenitization, and that the fenitizing solutions were strongly alkaline and oxidizing.

Key words: Mineralogy, biotite, fenite, Loe Shilman, NWFP.

M/217. Mian, I. & Le Bas, M.J., 1988. Feldspar solid solution series in fenites from Loe Shilman carbonatite complex, NW Pakistan. *Geological Bulletin, University of Peshawar* 21, 71-83.

The carbonatite sheets at Loe Shilman in Khyber Agency, NW Pakistan, fenitize their country rocks to form a metasomatic zone, c. 100 metres wide, of alternate dark blue (mafic) and pale grey (felsic) banded fenites which grade into unfenitized slates and phyllites. The carbonatite sheets comprise a more extensive amphibole sovite which is intruded by biotite sovite in different parts of the complex. These sovites are in turn intruded by ankeritic carbonatite mainly along the southern contact with the country rocks.

Among the new minerals, formed as a result of three fenitizations (two sodic and one potassic), K-feldspar are formed as a result of contact thermal effect by the early amphibole sovite at the expense of phengite and argillaceous material. The more disordered K-feldspar, which were formed at high temperature ($\sim 7000^\circ\text{C}$), in the inner zones 3, 4 and 5 are now readjusted to maximum-microcline to intermediate-microcline. While in zone 2 the more disordered relict K-feldspar escaped readjustment, and therefore, produces reverse zonation in contrast to the temperature gradient. The effect of biotite sovite is restricted to the thin veins composed of K-feldspar (Ba=1.4 wt %) and biotite. The samples SM93 and SM84, amongst the banded fenites, have been also metasomatized by the biotite sovite.

Albite, which coexists with other metasomatic minerals, formed first by the early amphibole sovite, was presumably more disordered towards the carbonatite contact. It is now readjusted to its present lowest structural state by the ankeritic carbonatite. The presence of relict disordered intermediate low-albite now shows reverse zonation in contrast to the temperature gradient. Both the solid solution series are well correlated with distance from the carbonatite igneous contact.

Key words: Mineralogy, feldspar, fenite, Loe Shilman, Khyber Agency.

M/218. Mian, I. & Le Bas, M.J., 1990. The geochemistry of the zoned fenites at the Loe Shilman carbonatite complex, NW Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 26-27.

The carbonatite at Loe Shilman in Khyber Agency, NW Pakistan, fenitize the country rocks to form a metasomatic zone c. 100m wide of alternate dark blue (mafic) and pale grey (felsic) banded fenite which grade into unfenitized thin bedded laminites (slates and phyllites).

The banded fenites are syenitic in composition which show gradual increase in Na from 2 to 13.7 (calculated into a standard cell of 100 anions) while Si and Al decreases from 37 to 33.7 and 11.7 to 0.8 respectively from the outer zone 1 to the inner zone 5. K, Mg and FeT remain approximately constant in the outer four zones and range between

3.5-4.3, 1.9-3.0 and 2.5-3.5 respectively while K decreases sharply from 6.0 to 1.5 and Mg and FeT increase sharply from 5 or less to 9 and 11 respectively in the innermost zone in contact with the carbonatite. The decreases and increases correlate well with the distance from the carbonatite contact.

Trace elements La, Nb, Zr and Zn are approximately constant in the outer four zones but increase sharply in the inner zone. However, Rb, Ba, Cr, Ni, Ga, and Y decrease gradually from the least fenitized laminites towards the carbonatites and decrease sharply in the inner zone. Similarly, the total REE increases towards the carbonatites and the LREE to HREE ratio remains constant in the outer zones and increases in the innermost zone in contact with the ankeritic dolomite carbonatites. A negative Eu anomaly is present in the least fenitized rock and is gradually diluted in the inner zones (1-4) and almost disappears in the inner zone 5. These gradual increases and decrease in major, trace and RE elements are due to the metasomatism as result of Na-fenitization fluids (from the early amphibole sovite) soaking through the low permeability slates and phyllites. The latter biotite sovite has superimposed K-metasomatism over the Na-metasomatism. However, an even later ankeritic dolomite carbonatite is responsible for the sharp increase and decrease of major, trace and RE elements in the inner zone as a result of a second Na-fenitization, this time by fluids rich in Mg and Fe.

Key words: Geochemistry, fenites, Loe Shilman, Khyber Agency.

M/219. McGibbon, K.J. (ed.), 1982. Karakoram Expedition 1982. A Scientific Expedition to the Hunza Valley, northern Pakistan (74°E, 36°N). Newcastle University Exploration Society, 88p.

This is a generalized account of the Hunza valley in central Karakoram. It deals with various aspects of the geography of the area.

Key words: Exploration, expedition, Hunza, Karakoram.

M/220. Middlemiss, C.S., 1890. Preliminary note on the coal seam of the Dore ravine, Hazara. Geological Survey of India, Records 23(2), 267-269.

As this account does not have an abstract, the first few pages of the account are presented here as an introduction.

It is usual in the Memoirs of the Geological Survey to begin the description of a country with some remarks on the surface features, physical geography, etc. if I seem to be departing from a good old rule here, it is for the reason that all particulars, such as cannot be gathered from an inspection of the map, will more consistently find a place in the following chapters, when I come to describe in detail the geology of each of the zones, or strike areas, into which I shall find it expedient to divide up the country. This seems the more desirable inasmuch as the very varied aspects of the country are so indissolubly connected with the geological components of the zones that the former would be bare and meaningless if presented without their structural raisons centre.

I may remark, however, that Hazara is a strip of generally mountainous country, bounded on the south by the Rawalpindi plateau, on the north by the little-known mountainous country belonging to a number of warlike, independent hill clans, on the west by the Indus river, and on the east by Kashmir, with the Jhelum river below Domel as the line of demarcation.

Structurally, and therefore geologically, it connects the Rawalpindi and Jhelum districts (which embrace the Salt-Range) with the territory of Kashmir; all of which have been geologically described in considerable detail by former members of the Geological Survey of India (see list of authors and works in the Introduction).

The table which follows shows the stratigraphical elements or formations which take part in the Geological Record of Hazara, arranged chronologically:—

Table of formations in Hazara {in descending order}.

Historical Rocks.

VIII.—Murreebeds. . . Miocene .

VII.—Kuldana beds (passage). * ' I Tertiary ' .

VI.— Nummulitic series . Eocene

V.— Middle Cretaceous = Chalk Marl and U

Greensand = Cenomanian > Mesozoic
IV, — Jurassic•

III.— Triassic

II.— Inira-Triassic=Carboniferous or. Carbo. Paleozoic and pro-Permian(P) probably older.

I.— Slate series . Age unknown . . .)

Crystalline and Metamorphic Rocks.
b.^Tanol . . . Infra-Triassic in the main \

a. Crystalline schists. . Equivalentents of I and II f

v Palaeozoic or above in the main, or older.

x. Intrusive gneissose-granite. . . . A

y. Intrusive dyke rocks /

From the above table the youngest Tertiary, or Siwalik formation, Pliocene, is absent, as it does not occur in Hazara, although it is well developed towards the south in the Rawalpindi plateau. From the Murree beds to the Jurassics the Geological Record in Hazara is fairly complete, save that Upper Cretaceous rocks (if represented) are not marked by any fossil zone; and that the Jurassics, if lithological identity with other parts of India is disallowed as evidence, cannot be subdivided more closely into life-zones. With the Trias comes a small, though consistent, stratigraphical break. The evidence for any trustworthy subdivision of the Trias is wanting, or very doubtful. At the base of the Trias there is another stratigraphical break, and it seems certain that all representatives of the great Carboniferous, or Carbo-Permian epoch, so well developed in Kashmir and the Salt-Range, are either completely absent in Hazara or are represented by the unfossiliferous Infra-Trias limestone (but see p. 29).

With the so-called Infra-Trias we enter on unfossiliferous rocks of unknown age; but a comparative study of other Indian regions gives us a possible clue to the age of its lowest member (see p. 19 et seq.). Below the Infra-Trias is a great stratigraphical break with total unconformability upon the great azoic Slate series beneath. The crystalline and metamorphic rocks exhibit a Himalayan facies as regards the crystalline schists and intrusive sills of gneissose-granite and the basic dyke rocks; but the great thickness of subaerial volcanic rocks of Palaeozoic age, exposed in Kashmir, are not known in Hazara.

Key words: Hydrocarbons, coal, Hazara.

M/221. Middlemiss, C.S., 1896. The Geology of Hazara and the Black Mountain. Geological Survey of India, Memoirs 26, 1-302.

This detailed and well illustrated publication presents the geology of the Hazara area together with notes on economic geology. The rocks have been divided as following:

VIII.-Murree beds	Miocene	TERTIARY
VII.-Kuldana beds (passage)		
VI.-Nummulitic series	Eocene	
v.-Middle Cretaceous=Chalk Marl and U Greensand=Cenomanian		MESOZOIC
IV.-Jurassic		
III.-Triassic		
II.-Infra-Triassic=Carboniferous or Carbo-Permian (p)		PALEOZOIC AND PROBABLY OLDER.
I.-Slate series Age unknown		

CRYSTALLINE AND METAMORPHIC ROCKS.

b. "Tanol"	Infra-Triassic in the main	PALEOZOIC OLDER	OR
a. Crystalline schists	Equivalent of I and II above in the main,		
x. Intrusive gneissose-granite			
y. Intrusive dyke rocks			

Key words: Geology, Hazara.

M/222. Middlemiss, C.S., 1910. A revision of the Silurian-Trias sequence in Kashmir. Geological Survey of India, Records 40(3), 206-209.

Key words: Stratigraphy, Silurian, Triassic, Kashmir.

M/223. Middleton, D., 1984. Karakoram history, early exploration. In: Miller, K.J. (eds.), The International Karakoram Project, Volume 2. Cambridge University Press.

The Karakoram is the most heavily glaciated area outside the Polar Regions and contains some of the world's highest peaks. It is also the most formidable of the parallel mountain ranges dividing the Indian subcontinent from Central Asia. Early exploration was directed to finding a way beyond the Karakoram to trading centers in Eastern Turkestan (now Sinkiang). Attention focused first on the route from Leh to Yarkand by the Karakoram Pass, later on the Gilgit road into Hunza (William Moorcroft 1765-1825). G.T. Vigne (1830-1878) was the first official among the pioneer who opened up the Karakoram, and the first official maps were made by the Survey of India operating in Kashmir between 1857 and 1864. T.G. Montgomerie (1830-1878) was the first to see K2 and H.H. Godwin-Austin (1834-1923) the first actually to put it on the map with its surrounding peaks. The explorations of George Hayward (d. 1870) and the Intelligence work of Francis Younghusband (1863-1942) helped to build up a general picture of the region, and so paved the way for private enterprise and the scientific exploration of the twentieth century. Lord Conway, T.G. Longstaff, the Duke of the Abruzzi, Filippo De Filippi, the Duke of Spoleto, Giotto Danielli, Ardito Desio, Dr and Mrs Visser, Kenneth Mason and Eric Shipton were active in the Karakoram between 1908 and the outbreak of the Second World War.

Key words: Glaciation, geology, Karakoram.

M/224. Miehe, G., 1992. Recent climatic changes in the subhumid to arid regions of High Asia (Karakorum, Kunlun, Himalaya, Tibet) as indicated by vegetation features. In: Zheng, D., Zhang, Q. & Pan, Y. (eds.), Proceedings of International Symposium on the Karakorum and Kunlun Mountains, Kashi, June 1992., pp. 333-346. China Meteorological Press, Beijing.

In the context of environments changes in High Asia, indications of dessication are described. They refer to different periods and are caused by different climate changes. In southern Tibet, the plant relics of one of the younger Holocene phases of higher humidity (Kobresia pygmaea age) have been widely destroyed by Himalaya-front, giving way to semiarid alpin steppe on stone pavements. A decrease of plant vigor at climatically sensitive vegetation borders (upper treeline, drought limit of forests, transition zone between alpine Cyperaceae mats and the free gelifluction belt, transition zone between humid alpine mats and alpine steppe) gives evidence of diminishing winter precipitation during the last 30 to 40 years in the Karakorum.

Key words: Vegetation history, climate change, Asia, Karakorum, Kunlun, Himalaya, Tibet.

M/225. Mikoshiba, M., Takahashi, Y., Takahashi, Y., Kausar, A.B., Khan, T. & Kubo, K., 1996a. Rb-Sr dating of the Chilas Igneous complex, Kohistan, northern Pakistan. Abstract volume 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, U.S.A., p.102.

Key words: Rb-Sr dating, Chilas complex, Kohistan.

M/226. Mikoshiba, M., Takahashi, Y., Takahashi, Y., Kausar, A.B., Khan, T. & Kubo, K., 1996b. Rb–Sr dating of the Chilas Igneous complex, Kohistan, northern Pakistan: A short note. Geological Survey Pakistan. Proceedings Geoscience Colloquium, 14, 69–70.

The Chilas complex gives a Rb-Sr age of 112 ± 24 ma. with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.70403 ± 0.00006 . the whole rock isochrones age of this main facies is concordant with the Ar-Ar and K-Ar age of hornblende around 80 ma which may date cooling through 500°C (Treloar et al., 1989)

Key words: Rb-Sr dating, Chilas complex, Kohistan.

M/227. Mikoshiba, M., Takahashi, Y., Takahashi, Y., Kausar, A.B., Khan, T. & Kubo, K., 1996c. Rb–Sr whole–rock age of Chilas gabbroic complex, Kohistan, northern Pakistan. Abstract volume Annual Meeting Geological Society of Japan, p.279.

For details, consult Mikoshiba et al. below.

Key words: Rb-Sr dating, Chilas complex, Kohistan.

M/228. Mikoshiba, M.U., Kausar, A.B., Khan, T., Takahashi, Y., Takahashi, Y., Kubo, K. & Shirahase, T., 1996. Petrochemical study on the gabbro norite, diorite and quartz diorite of the Chilas igneous complex, northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc*. Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 15, 137-155.

Many chemical analyses have been presented for various rocks of the Chilas complex. It is considered to have formed in an island arc setting during the Late Cretaceous. These analyses, and many more were included in a later publication by Takahashi et al, 2006, *Asian Journal of Earth Sciences*. For details, consult Mikoshiba et al. in the following.

Key words: Petrochemistry, gabbro norite, Chilas complex, Kohistan island arc.

M/229. Mikoshiba, M.U., Takahashi, Y., Kausar, A.B., Khan, T., Kubo, K. & Shirahase, T., 1999. Rb-Sr isotopic study of the Chilas igneous complex, Kohistan, northern Pakistan. In: Macfarlane, A., Sorkhabi, R.B. & Quade, J. (eds.), *Himalaya and Tibet: Mountain root to mountain tops*. Geological Society of America, Special Papers 328, 47-57.

The Chilas Igneous Complex is one of the major geologic units in the Kohistan terrane of the Himalaya of northern Pakistan. The Kohistan terrane is regarded as a tilted island-arc sequence. The Chilas Complex is a 300-km-wide-long, 40-km-wide plutonic body that intrudes the Kamila Amphibolite. The Main facies rocks of the Chilas Complex consist of gabbro norite, diorite, and quartz diorite. Small bodies of ultramafic-mafic association composed mainly of peridotitic-gabbroic cumulates, and a layered gabbro norite body, are also present, probably as xenoliths. A few samples are considered to have been contaminated as a result of assimilation of xenolithic materials and country rocks: Excluding them, 14 whole-rock samples of the Main facies have an Rb-Sr age of 111 ± 24 Ma and an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.70403 ± 0.00006 . Gabbroic rocks from the ultramafic-mafic association, from the layered gabbro norite body, and from mafic dikes, have $^{87}\text{Sr}/^{86}\text{Sr}$ ratios between 0.7039 and 0.7044, interpreted to be close to the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios at the time of their generation. The whole-rock isochron age for the Main facies is regarded as the age of intrusion. The initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio for the Main facies is within the range of typical arc magmas, suggesting that the igneous activity occurred within an island arc or orogenic belt close to a continental margin. The age of intrusion of the Chilas Complex is similar to that of the earliest magmatism in the Kohistan batholith and to the Cretaceous plutonism in Ladakh and Karakoram, indicating large-scale generation of subduction-related magmas in the western Himalayan region and Karakoram during the mid-Cretaceous.

Key words: Rb-Sr dating, isotopes, Chilas complex, Kohistan.

M/230. Mikoshiba, M.U., Takahashi, Y., Kubo, K., Kausar, A.B., Khan, T., Takahashi, Y. & Shirahase, T., 1998. Petrochemical characteristics of the eastern part of the Chilas Igneous Complex, Kohistan, northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 129-131.

The Kohistan terrane of the western Himalaya, northern Pakistan, is regarded as an island-arc sequence sandwiched between the Asian and Indian continental crusts. Deep crustal members are now widely exposed in Kohistan, which makes it an ideal area to study the genesis and evolution of subduction-related crustal structures and rocks.

The Chilas Igneous Complex is one of the major geological unit in the Kohistan terrane, and it is exposed in a large area of 300 km long and 40 km wide. Most of the complex consists of generally homogeneous gabbro-norite, pyroxene diorite and pyroxene quartz diorite. They can be called as the Main Facies, which was termed the gabbro-norite association by Khan et al. (1989). Rocks with layered structure are also found within the Chilas Complex, which often occur in km-scale masses. One gabbro-norite mass is characterized by well-developed rhythmic layering. Some of the masses are abundant in peridotites associated with layered gabbroic rocks (UMA, ultramafic-mafic association), which are deduced to be crystal accumulates. These layered rocks are considered to be intruded by the Main Facies rocks.

The rocks of the Chilas Complex (the Main Facies) have a calc-alkaline nature. The UMA rocks have chemical compositions reflecting their cumulate characteristics. Here we present detailed geochemical data of the constituent rocks in the eastern part of the complex, to discuss the evolution and crystallization processes in the Chilas Complex.

The Main Facies rocks have continuous variation of chemical compositions. Their SiO₂ content ranges from 49 to 60wt% in almost all samples. The concentrations of K₂O, Y, Zr, Th and rare earth elements (REE) are positively correlative with the SiO₂ content, while the concentrations of Ga, Sr, Cr and Ni do not vary with SiO₂ content. The chondrite-normalized REE patterns of many of the rocks with SiO₂ content less than 52 wt.% have a positive Eu anomaly, while those of some rocks with SiO₂ content more than 56 wt.% have a negative Eu anomaly. The light REE are enriched relative to the heavy REE, and the enrichment is clearer in the rocks with higher SiO₂ content.

Samples from the layered gabbro-norite mass have chemical compositions resembling with the Main Facies, although their compositions are scattered reflecting their modal variation. In the case of the UMA, major chemical compositions of ultramafic rocks support the petrographic observation implying that they consist mainly of olivine-clinopyroxene cumulates. Some of layered gabbroic rocks in a UMA indicate accumulation of plagioclase, having low REE contents with a clear positive Eu anomaly. Ultramafic rocks and layered gabbroic rocks from the UMA have low incompatible element concentrations.

The chemical composition of the Main Facies rocks support the idea that they solidified from a single evolving magma or from magmas having similar origin. Chemical compositions of a large part of the Main Facies may be similar to those of the magma(s), rather than the crystal cumulates, and they have characteristics of magmas relating to a subduction zone. A part of the Main Facies rocks with low SiO₂ content, may have lost the residual liquid at the late stage of solidification, or may have been enriched in the early-formed crystals. Therefore, it is possible to explain the chemical variation in the Main Facies by a weak segregation of melt and early-formed crystals composed of plagioclase, orthopyroxene and clinopyroxene. The relatively low concentrations of Cr and Ni in the mafic rocks suggest the magma had more evolved characteristics than the primary magmas from mantle.

The rocks of the layered gabbro-norite mass have petrographical and chemical characteristics which resemble those of the Main Facies, suggesting a common origin. In the case of the UMA, chemical composition of the layered gabbroic rocks and ultramafic rocks clearly have characteristics of cumulates, implying the separation of the melt and crystals were effective. Their chemical and petrographical characteristics suggest that they were crystallized from more primitive magma, probably at the earlier stage than the crystallization of the Main Facies rocks.

Key words: Petrochemistry, gabbro norite, Chilas complex, Kohistan island arc.

M/231. Mikoshiba, M.U., Takahashi, Y., Takahashi, Y., Kausar, A.B., Khan, T. & Kubo, K., 1996. Rb-Sr dating of the Chilas igneous complex, Kohistan, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram- Tibet Workshop, Flagstaff, Arizona (USA), 102.

The Chilas igneous complex is one of the major geological unit in the Kohistan terrane of the western Himalaya, northern Pakistan. The Kohistan terrane is regarded as a tilted island arc sequence, sandwiched between Asian and Indian continental crust (Coward et al., 1982).

The Chilas complex is a 300km long and 40km wide plutonic body (Khan et al., 1989). The rocks of the Chilas complex intrude into the Kamila amphibolite which is mainly located in the southern side. In the north, quartz diorite to tonalite of the Kohistan batholith intrude into the Chilas complex.

Most of the complex consist of generally massive gabbonorite, diorite and quartz diorite. They can be called as the main facies. There are also small masses of ultramafic-mafic association (UMA, Jan et al., 1984) in the complex. The rocks of the UMA are mainly composed of peridotite and gabbonorite, often showing layered structure. The rocks of the main facies intrudes into the UMA in several outcrops.

Rb-Sr isotopic study is applied to the Chilas complex. The analyzed samples are mostly collected from the eastern part. Gabbonorite and quartz diorite or the main facies are analyzed. In these samples, main constituent minerals are plagioclase, orthopyroxene and clinopyroxene, but small amounts of hornblende, biotite, quartz or K-feldspar are often associated with them, especially in quartz diorite. Gabbonorite of the UMA are also analyzed, in which hornblende, olivine or spinel are often associated

Ten whole-rock samples of the main facies give a Rb-Sr age of 8914 Ma with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.704004 ± 0.00005 . Their $^{87}\text{Rb}/^{86}\text{Sr}$ ratios are less than 0.65. Six whole-rock samples of the UMA have $^{87}\text{Sr}/^{86}\text{Sr}$ ratios with the range of 0.7039-0.7044. Their $^{87}\text{Rb}/^{86}\text{Sr}$ ratios are less than 0.1

The whole-rock isochron age for the main facies is concordant with the Ar-Ar and K-Ar age of hornblende from the Chilas complex around 80 Ma which may date cooling through 500°C (Treloar et al., 1989). This Rb-Sr age can be regarded as the intrusive age. The results of the Rb-Sr analysis indicates that a large amount of magma intruded in the Cretaceous time, which produced the thick mafic crust in the Kohistan. The initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio for the main facies is higher than the range in MORB, and it is within the typical range in the arc magma. The initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios in the rocks of the UMA are also deuced to be higher than the range in MORB.

Key words: Rb-Sr dating, isotopes, Chilas complex, Kohistan.

M/232. Milisenda, C.C., Bank, H. & Henni, A., 1995. Peridot aus Pakistan. *Gemmologie* 44(2-3), 33-42.

In the watershed between Kohistan and Kaghan to the north of Naran, ultramafic rocks host high quality peridot crystals. This paper gives an account of the gemological characteristics of the gemstone, including physical properties.

Key words: Gemology, peridot, Pakistan.

M/233. Miller, D.J. & Christensen, N.L., 1994. Seismic signature and geochemistry of an island arc: A multidisciplinary study of the Kohistan accreted terrane, northern Pakistan. *Journal of Geophysical Research* 99, 11623-11642.

Systematic sampling and mapping in the Kohistan accreted arc terrane of northern Pakistan has provided a sample suite representing the lithologic diversity of the section from its base along the Main Mantle Thrust upward through several stacked intrusions and their metamorphosed equivalents into the Kohistan batholith. A new lithologic column for the terrane has been developed during the course of this study using geothermobarometry based on elemental exchange reactions calculated from electron microprobe analyses of mineral assemblages. The pressures calculated from the chemical analyses of various mineral assemblages are constrained by recently published activity-composition models and an internally consistent thermodynamic data base. Compressional and shear wave velocities and densities have been measured on samples that represent the diverse lithologies in this section and have been correlated with the new lithologic column. This data set has been augmented with published compositions and values for the uppermost part of the arc, not sampled in this study. Compressional wave velocities range from 4.3 km s⁻¹ in supracrustal volcanogenic sediments to 7.5 km s⁻¹ in lower crustal mafic cumulates. Underlying ultramafic rocks with velocities of 8.0 to 8.4 km s⁻¹ define a sharp seismic Moho. The strong inflection in the velocity profile to greater than 8.0 km s⁻¹ is due to the transition from plagioclase-bearing to plagioclase-free cumulate rocks in a continuous ultramafic-mafic intrusion. The base of the crust lies at least four kilometers below this transition. Correlation of these laboratory-measured values and the new lithologic column has allowed development of a velocity profile comparable to profiles developed through more conventional field seismic methods. Geochemical indices of fractionation exhibit a reasonable correlation with Compressional and shear wave velocities. An estimate of mean crustal V_p is remarkably similar to models for other cordilleran terranes at 6.7 plus or minus 0.05 km s⁻¹. An estimate of the bulk chemical composition of the Kohistan terrane does not compare favorably with most

published assessments of bulk continental crustal chemical composition, but is significantly more mafic than the latter. The striking resemblance of our reconstructed velocity profile to models generated from field seismic studies not only addresses the veracity of these models, but suggests that the Kohistan arc is a superbly well-preserved analog for other arc terranes.

Key words: Seismology, geochemistry, oceanic crust, Kohistan island arc, Himalaya.

M/234. Miller, D.J., Loucks, R.R. & Ashraf, M., 1991. Platinum-group elements mineralization in the Jijal layered ultramafic-mafic Complex, Pakistan Himalaya. *Economic Geology* 86, 1093-1102.

Notable enrichments of gold and platinum-group elements (PGE) have been found during the course of our petrochemical enrichment within the Jijal Complex, Northwest Frontier Province, Pakistan. To our knowledge, the only prior documented report of PGE minerals in Pakistan is by Ahmed and Bevan (1981), who described Ir-Ru-Os-Ni-Fe alloy in one sample of serpentinized chromitite from the Sakhakot Qila ophiolite (also called the Dargai complex), ca. 50 km northeast of Peshawar. The chromite deposits were described by Ahmed (1984). Page et al. (1979) reported whole-rock assays of Pt, Pd, and Rh totaling 5 to 25 ppb in six samples of dunite, harzburgite, and chromitite from the Dargai Complex. They also assayed 30 samples from the Zhob valley ophiolite near Quetta, reporting up to 375 ppb Pt + Pd + Rh in a gabbro sample and <3 to 81 ppb in the other 29 samples, which are mostly chromitites.

Key words: PGE, chromite, Jijal complex, Kohistan island arc.

M/235. Miller, K., 1982. *Continents in Collision*. International Karakoram Project. George Phillip & Son Ltd. London, 212p.

Key words: Continents, collision, MMT, MKT, Karakoram.

M/236. Miller, K.J., (ed.), 1984. *International Karakoram Project*. Cambridge University, Press. Cambridge, U.K., vol. 1, 406p., & vol. 2, 642p.

This is a compilation of papers resulting from the Royal Geographic Society International Karakoram Project, 1981. Individual papers are presented in this volume of ours.

Key words: Geography, geophysics, geology, Karakoram.

M/237. Mirza, A.R., 1981-83. *Geology of Paras-Bela-Jared Area central Kaghan Valley*. M.Sc. Thesis, Punjab University, Lahore, 148p.

This report covers a comprehensive study of a part of central Kaghan Valley. The principal emphasis has been on detailed lithostructural mapping of the area of the scale 1:8333. The rocks range in age from Pre-Cambrian Salkhallas to Miocene Murrees. Stratigraphically, the geology is in many ways different from that in the Abbottabad-Murree-Tarbela-Attock area further south. Part of the Mesozoic and part of the Tertiary sequence is missing in the project area. Furthermore, the equivalents of Panjal Trap and associated limestone are not found in the above mentioned area southwards. Structurally except for some folding in the blocks and nearly all contacts are faulted. The succession in the area is overturned. A fairly detailed account of the stratigraphy is being given and the report also includes a detailed account of the petrography of all the units based on extensive sampling. Tectonically the area is very interesting and the Panjal Traps appear to represent Ophiolites while the agglomerate slates appear to indicate volcano-sedimentary material with island arc affinities. There is, thus some evidence of a Paleozoic subduction zone in this area. Numerous photographs and sketches have also been included to illustrate the geology of the area.

Key words: Geology, structure, Kaghan valley.

M/238. Mirza, K., 1994-96. Geology of Dubran Area, District Haripur with special reference to palynology, micropalaeontology and biostratigraphy of some Paleocene-Eocene rocks. M.Sc. Thesis, Punjab University, Lahore, 219p.

Geological mapping of some 64 sq. Km area around Dubran in District Haripur has been carried out at the scale 1: 12500. The geomorphology, stratigraphy, structure, palynology and micropaleontology have been described. Stratigraphically a Mesozoic Tertiary sedimentary cover is overlying a Precambrian to Eo-cambrian basement of Hazara group now metamorphosed in the lower green schist facies. Numerous faults, high angle, reverse and normal have now disrupted the sequence. High angle north dipping Nathia Gali Thrust is the main fault that passes through the area and has thrust the Precambrian Hazara Slates over the younger sedimentary sequence. Dubran syncline lying on top of a major anticlinorium makes an interesting structure.

Key words: Palynology, micropalaeontology, biostratigraphy, Paleocene, Eocene, Haripur, Hazara.

M/239. Mirza, M.A., 1971a. Magnetic survey over the magnetite deposit of Dammer Nisar area, Chitral. Geological Survey of Pakistan, Information Release 42(1).

Key words: Magnetite, magnetic survey, Dammer Nisar, Chitral.

M/240. Mirza, M.A., 1971b. Magnetic survey near Ghazanosar, Swat State, West Pakistan. Geological Survey of Pakistan, Information Release 42(2).

Key words: Magnetic survey, Swat.

M/241. Mirza, M.A., 1980. A preliminary report on the interpretation of seismograms observed at Tarbela-Network of seismic stations. Geological Survey of Pakistan, Information Release 120, 12p.

A deep seismic sounding profile was observed in northern Pakistan in August 1975 under a programme of joint Pak-Italian Karakorum Geophysical Project. Two charges of 1600 kg and 2000 kg were detonated at Astore and Lawrencepur on August 15 at 0300 and 0400 GMT. On August 20 detonation of two more charges of 2400 kg and 2000 kg was repeated at Astore and Lawrencepur. The Russian seismologists followed a similar programme of explosion seismology and blasted charges of 10 tons at Karakul on August 15 and 20, and of 20 tons on the same dates at a site 30 km northeast of Zorkul. The observation timings of these blasts were 0100 and 0200 GMT respectively (Table I).

The detonation at Astore, Lawrencepur, Karakul and northeast of Zorkul for deep seismic studies along a profile joining Astore - Ishkuman and Astore- Lawrencepur was also recorded by seismic stations at Terbela (Fig. I) which were preinformed and alerted to receive the signals. The present report describes the results of seismograms observed at these stations, on 15th and 20th August 1975.

Key words: Seismicity, Tarbela.

M/242. Mirza, M.A., 1983. Seismic risk evaluation in Pakistan. Geological Survey of Pakistan, Records 56, 6p.

Key words: Seismic risk evaluation.

M/243. Mirza, M.A., 1984. Gravity survey in pyrite bearing area near Reshian. Geological Survey Pakistan. Pakistan. Information Release 221.

Key words: Gravity survey, pyrite, Reshian, Azad Kashmir.

M/244. Mirza, M.A., 1988. Seismic risk map of northern Pakistan. Geological Survey Pakistan. Seismic Risk Series Sheet No. 2.

Key words: Seismic risk, mapping.

M/245. Mirza, M.A. 1995. Magnetic polarity stratigraphy of Soan Formation (Plio- Pleistocene), Mujahid village, Rawalpindi district, Punjab, Pakistan. Abstract volume, International seminar and field work on quaternary stratigraphy of the North – Eastern part of the Indian subcontinent Dhaka. 9-12 December, 1995. (IGCP – 347, Quaternary stratigraphic correlation of the Ganges – Brahmaputra sediments and of the Indian subcontinent. P.11.)

The Mujahid section is the type locality of Soan Formation (Plio-Pleistocene) of the Siwalik Group in Pakistan. The section is located on the road from Galijagir to Sihal, about half a kilometer short of Mujahid village, Rawalpindi District, Punjab Pakistan. It lies to the north of Soan River. The section is comprised of an alternation of pale-pinkish, orange-brown, grey silt shale and sand. The sand is greenish grey, fine, medium grained, having 1.5 to 3 meter thick beds of conglomerate. The conglomerate is dark grey, coarse, densely packed, containing rounded pebbles and boulders of grey limestone with the size of 5-25 cm. The formation possesses a thickness of 300 to 400 metres. Horizontally stratified magnetic zones have been studied for establishing the magnetic stratigraphy of the formation. Within 400 metres of the stratigraphic section, eleven magnetic polarity zones are identified. These zones represent the time from the upper Gauss Epoch (2.3 my.) through the Olduvai Event in Matuyama Epoch (1.6.m.y.) as determined from sedimentation rate of about 0.5 m/1000 years. The Gauss-Matuyama correspond to the Pliocene-Pleistocene chronology of the Soan Formation in general as indicated by the lithological and faunal correlation.

Key words: Magnetic polarity, stratigraphy, Soan River, Rawalpindi.

M/246. Mirza, M.A., 1997. An overview of mineral resources of Pakistan. Geological Survey of Pakistan, Information Release 644.

In 1947, when Pakistan came into existence only 6 mineral commodities were being mined on small scale and potential of finding minerals in the area which constituted Pakistan was not known. The Geological Survey of Pakistan (GSP) , through its endeavours, has proved that Pakistan is geologically a unique country . Its landmass consists of rocks which were formed at oceanic centers, continental and oceanic island arcs, deep oceanic to shallow marine and even continental sediments . These rocks, as elsewhere in the world, have been proved by the GSP to contain a large variety of mineral deposits.

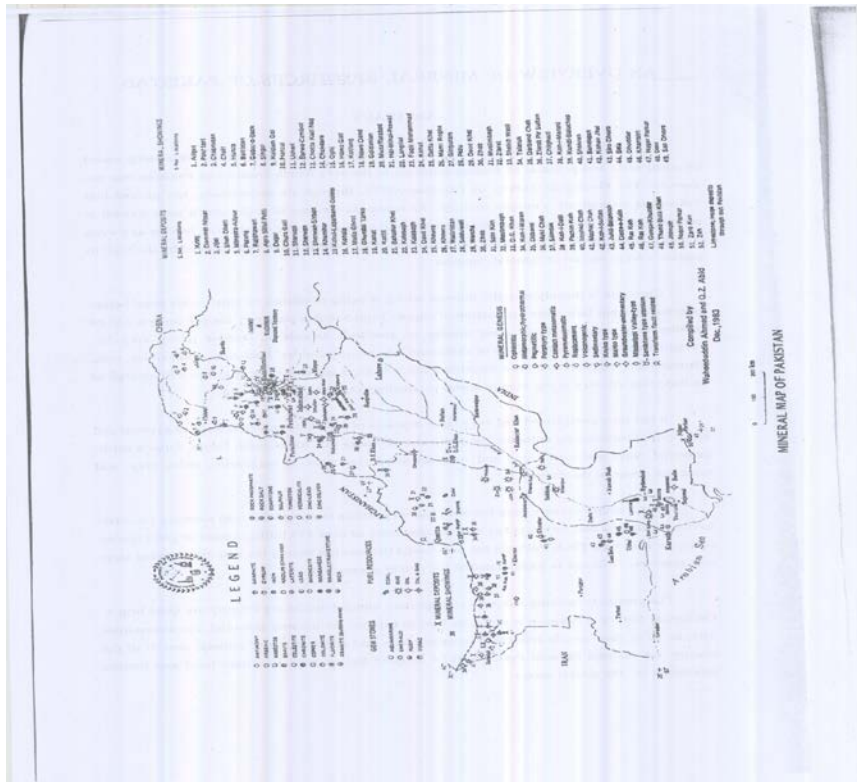
Chromite is the only metallic mineral which is being produced on small scale since before independence but large scale production of copper from Saindak porphyry copper deposit will be starting very soon and large scale mining of zinc/lead deposit of Duddar is not very far.

Favourable areas of mineralization of aluminum, chromium, copper, lead-zinc, gold, silver, iron, platinum and tungsten have been identified and it is expected that soon Pakistan will emerge as an important country on the map of metal producing countries of the world.

It has now been proved that very large deposits of industrial minerals such as gypsum and anhydrite, limestone and dolomite, building stones, rocks salt, silica sand, barite, fuller's earth, industrial clays and soap stone and medium sized resources of magnesite, china clay, and bentonite occur in the country.

Only a couple of years back Pakistan had no position on the global map showing countries having substantial coal resources but with the discovery of over 175 billion tonnes of good quality lignite in Thar Coal Field, Pakistan has achieved 11th position among the countries having large coal reserves. The coal is found suitable for power generation. The prospect of making Pakistan an important mineral producing country are quite bright.

Geological Survey of Pakistan is doing its best to explore the mineral potential and disseminate data, so as to make people interested in exploration and exploitation of mineral wealth of the country. A National Mineral Policy will be adopted during 1995 to attract local and foreign investment in the mineral sector.



Key words: Mineral resources.

M/247. Mirza, M.A., Babar, M.Z., Farah, A. & Ali, K.S.A., 1988. Seismic risk map of Northern Pakistan. Geological Survey of Pakistan, Geological Map Series, Scale 1:1,000,000.

Key words: Mapping, seismic map.

M/248. Mirza, M.A. & Farah, A., 1984. Recent crustal deformation and seismicity in Pakistan. Abstracts, 1st Pakistan Geological Congress, Lahore, p.63.

Key words: Crustal deformation, seismicity.

M/249. Mirza, M.A., Jamiluddin, S. & Ahmad, M., 1983. Accomplishment report of the Geological Survey of Pakistan (1978-1983). Geological Survey of Pakistan, Record 62, 42p.

Key words: Geological Survey of Pakistan.

M/250. Mirza, M.A., Jamiluddin, S., Ahmad, M., Javed, N. & Haq, I., 1984. Status of geological mapping in Pakistan. Geological Survey of Pakistan, Information Release 220, 51p.

Key words: Mapping, geology, Pakistan.

M/251. Misch, P., 1935a. Arbeit und vorläufige Ergebnisse des Geologen. In: Finsterwolder, Forschung am Nanga Parbat. Sonderveroff Geog. Gesellschaft, Hannover, 91-130.

Key words: Nanga Parbat.

M/252. Misch, P., 1935b. Nanga Parbat. *Geologische Rundschau* 26, 156-158.

Key words: Nanga Parbat.

M/253. Misch, P., 1936a. Ein junger gefalteter sandstein im nordwest-Himalaya und sein gefuge. *Festschrift zum 60. Geburtstag von Hans Stille, Enke, Stuttgart*, 259-276.

Key words: Structure, sandstone, Himalaya.

M/254. Misch, P., 1936b. Einiges zur metamorphose des Nanga Parbat. *Geologische Rundschau* 27, 79-81.

Key words: Metamorphism, Nanga Parbat, Himalaya.

M/255. Misch, P., 1949. Metasomatic granitization of batholithic dimensions. Part 1: Synkinematic granitization in Nanga Parbat area, Northwest Himalayas. *American Journal of Science* 247, 209-245.

In the Nanga Parbat area (Northwest Himalayas) a thick group of presumably pre-Cambrian argillites with thin calcareous and basic bands is overlaid by Cretaceous-Eocene volcanics, and both are bordered by extensive Eocene norite masses. These rocks have undergone regional metamorphism during Early Tertiary orogeny. Synkinematic metamorphism of the argillites progresses from slates and phyllites through mica schists, biotite-paragneisses, kyanite-schists and –paragneisses to sillimanite-paragneisses. The metamorphic zones in the argillites are matched by those in the calcareous bands.

Synkinematic granitization of the potash-predominant variety begins within the kyanite zone with microperthite-porphyroblast-schists passing to potash-rich augen gneisses of granitic appearance which contain relict kyanite in their groundmass. Lit-par-lit replacement—as against mechanical injection—along active foliation planes makes banded gneisses. In the interior of the Nanga Parbat massif, granitization becomes more complete, and coarse-grained granitic gneiss forms. Here only small quantities of argillite altered to sillimanite-schist have escaped transformation into granitic rock. The calcareous bands are not granitized, and are preserved as conformable intercalations in the gneissose granite which has replaced the argillites. Metamorphism and granitization progress both along and across the strike of the altered sediments. There is complete structural continuity from the weakly metamorphosed sedimentary areas to the intensely granitized region. Also the type of tectonic deformation is the same throughout these areas, and is that characteristic of the deformation of solid rocks during orogenic metamorphism. The granitized body as mapped measures 25 by 60 miles.

The chemical nature of the granitizing agent is discussed. The metamorphic isograds (approximately vertical in this region) are shown to be independent of depth, and a function of differential introduction of heat from below. It is stressed that degree of metamorphism and granitization are systematically linked and convection of heat by the granitizing solutions is held responsible for high grade regional metamorphisms in the upper part of the crust.

Key words: Himalaya, Nanga Parbat, granitization, metasomatism.

M/256. Misch, P., 1950. Late Cenozoic diastrophism in Himalayan system. *Geological Society of America Bulletin*, Abstract 61, p.1487.

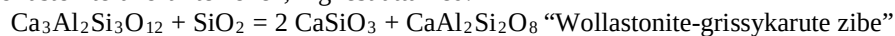
Key words: Diastrophism, Cenozoic, Himalaya.

M/257. Misch, P., 1964. Stable association wollastonite-anorthite, and other calc-silicate assemblages in amphibolite-facies crystalline schists of Nanga Parbat, Northwest Himalayas. *Beitrage zur Mineralogie und Petrographie* 10, 315-356.

Progressive regional metamorphism and granitization of a dominantly pelitic sequence was essentially isobaric and proceeded on a level of rather high P within the field of amphibolite facies. The transition from kyanite to sillimanite zone does not coincide with the boundary between medium and high-grade rocks but is displaced toward higher T. Many of the Al-Si-rich high-grade rocks carry stable muscovite. Staurolite, andalusite, and cordierite are characteristically absent. Green hornblende occurs throughout the high-grade zone in rocks of appropriate composition.

Calcareous intercalations permit recognition of three distinct zones of high-grade metamorphism. They, and the reaction defining their boundaries, are:

a) "Wollastonite-anorthite zone"; highest attained.



b) $\text{CaCO}_3 + \text{SiO}_2 = \text{CaSiO}_3 + \text{CO}_2 \uparrow$ "Calcite-quartz-grossularite (bytownite) zone"

(lower limit defined by lower limit of bytownite).

Reaction (b) is sensitive to PCO_4 . It is suggested that most of the rocks, especially those with excess silica, were open systems for CO_2 , so that $\text{PCO}_4 \ll P_{\text{total}}$. Locally, as in some tight marbles, CO_2 was retained, and the wollastonite reaction was arrested or altogether prevented, in zone (2) and even in zone (1). Reaction (a), involving no gas phase, is dependent only on P, T. Under the prevailing high pressures, the temperatures required to make reaction (a) proceed to the right, must have been rather high.

Quartz-excess and calcite-excess, diopside-bearing assemblages of the three zones are described. Associate K-feldspar is orthoclase with very small — 2V. Metamorphism of argillaceous dolomitic limestones illustrates the principle of preferential decarbonation of Mg. Assemblages include (omitting dominant calcite): forsterite-spinel-phlogopite, found only in zone (1); phlogopite-diopside-(tremolite); diopside-(tremolite)-orthoclase; diopside-(tremolite)-anorthite-(orthoclase); diopside-wollastonite-grossularite (zone 2); diopside-grossularite-quartz (zone 3). Relations of mineral assemblages found in the three calc-silicate zones to bulk compositions are discussed. Boundary layers between diopsidic calc-silicate rocks and associated pelitic schists are described. As a rule, a thin band of para- amphibolite is developed at the contact, characterized by the garnet-free assemblages, green hornblende-anorthite (bytownite)-quartz. In adjacent, partly almandine-bearing biotite-quartz-plagioclase schists, plagioclase ranges from sodic andesine to bytownite. Widespread reverse zoning of this plagioclase is attributed to slow, short-range (a few centimeters) diffusion of anorthite-building substance from the adjacent Ca-richer rock into the schist. Locally, the amphibolite band is lacking, and diopside and biotite mingle in the boundary layer. Although this local association recalls pyroxene hornfels facies, nearby rocks have amphibolite facies mineralogy.

Part of the diopsidic calc-silicate rocks of zone (1) show incipient retrogression under conditions of zone (2) or (3), the pair, wollastonite-anorthite (bytownite), being "parasitically" replaced by grossularite. Retrogression below the limits of zone (3) locally displays the assemblage, zoisite-labradorite-grossularite. Calcic scapolite found in some of the high-grade calc-silicate rocks is retrogressive, replacing anorthite (bytownite).

Calc-silicate mica schists of higher-medium grade carry mutually stable calcic scapolite, andesine and zoisite, associated with calcite, quartz, local epidote, biotite, muscovite, and garnet. Much of their plagioclase is zoned. Reverse followed by normal zoning is interpreted as a record of the thermal history of metamorphism. Associated non-calcareous mica schists, commonly with almandine and kyanite, carry more sodic plagioclase which is unzoned. Garnet amphibolites of this zone have andesine plus zoisite or epidote, and some contain diopside.

Physical conditions of the metamorphism of the high-grade calc-silicate rocks are discussed further, in the light of available experimental data.

Key words: Nanga Parbat, Himalaya, Metamorphism.

M/258. Miyata, T., 1988. An Introduction to gem mines of Pakistan. (Japanese with English abstract). Journal of the Gemmological Society of Japan 13, 31-42.

Pakistan has 4 main mining areas in its territory. In Hunza valley, specimen- and gem-quality crystals of corundum occur in bed of marble. This area is not in operating at present. However, small, intensely coloured emerald crystals occur in dolomitic talc schist in the Swat valley. So many kinds of gemstones, aquamarine, topaz (F-type), tourmaline, zircon, quartz, are found from the pegmatite in Shingus-Dusso areas. Katlang area is the only place in the world to produce natural pink topaz.

Key words: Gems, Hunza.

M/259. Mohiuddin, M., 1972. Report on mineral in North Waziristan, Dera Ismail Khan Division, North West Frontier Province. Pakistan Chrome Mines Limited, Report, 7p.

Key words: Minerals, DI Khan, North Waziristan, NWFP.

M/260. Mohmand, A., 1971. Geology and mineralogy of Swat Hornblendic Complex in Charbagh-Khawaza Khela area, Swat. M.Sc. Thesis. Punjab University, Lahore, 78p.

Key words: Mapping, hornblendic complex, Swat.

M/261. Mohmand, A.K. & Tariq, M., 1982-83. Petrographic comparison of Khunjerab-Wakhan-Tirichmir, Karakoram and Kohistan-Ladakh granitic belts in Northern Pakistan. M.Sc. Thesis, University of Peshawar, 128p.

Key words: Petrography, granitic belt, Khunjerab-Wakhan-Tirichmir, Kohistan-Ladakh.

M/262. Mohmand, A.R.K., 1976. A field report on the geology and mineralogy of Hamoi valley area, Matta, Swat. M.Sc. Thesis. Punjab University, Lahore, 78p.

Key words: Petrology, petrography, Swat.

M/263. Mohsin, S.I., Hasan, S. & Latif, F., 1991. Export potential of Pakistani granites. Proceedings, First SEGMIITE Symposium, Peshawar, 1-7.

The paper gives a brief account of the occurrence of granitic rocks in Pakistan, including those of the Himalayan region. Comparatively greater information is given on the Nagar parkar granites.

Key words: Granite, Nagar Parkar, Himalaya.

M/264. Mohsin, S.I., Qadri, M.U. & Ansari, I.A., 1979. Geology and evaluation of marble and travertine deposits of Pakistan. *The Geologist*, 4, 1-8.

Key words: Marble deposits, travertine, Pakistan

M/265. Mohsin, S.I., Qadri, M.U. & Hissamuddin, S., 1983. Technological characteristics of the Peshawar marbles, Pakistan. *Acta Universitatis Carolinae Geologica* 4, 311-322.

White and gray coloured crystalline limestone and pink fossiliferous dense limestone are extensively quarried in Peshawar Division for dimension stone. The deposits belong to a reef belt which developed at the northern margin of Indo – Pakistan landmass during Silurian-Devonian. They are metamorphosed and dolomitized to varying degrees. White crystalline limestones are calcite marble of high purity comparable to world class marbles. Dolomite marbles are of inferior quality however they constitute only a small part of the deposits. A number of physical tests prove the soundness of the Peshawar marbles in confirmation to the ASTM standards.

Key words: Marble deposits, Peshawar, Nowshera, Swabi, Mulagori.

M/266. Moin-ud-Din, 1998-99. Geological mapping of Muzaffarabad-Chattar Kalas area with special emphasis on slope instability analysis and Hazards evaluation of Dulai area Muzaffarabad (A.K.). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 95p.

Key words: Hazards, slope stability, mapping, Muzaffarabad, Hazara.

M/267. Molloy, P.D., 1979. Conodont faunas from northwest Pakistan. M.Sc. dissertation, Macquarie University, Sydney, Australia, 283p

Key words: Palaeontology, conodonts, NW Pakistan.

M/268. Molloy, P.D., Khan, F., Khan, A.A., Simpson, A., Mawson, R. & Talent, J.A., 1999. Conodont correlations between Pakistan and eastern Australia for the latest Silurian to earliest Devonian interval. IGCP 421 Meeting, North Gondwana Biogeography, Bioevent Patterns in relation to Crustal Dynamics, Peshawar, Pakistan, 19–20.

Key words: Palaeontology, conodonts, Silurian, Devonian, Pakistan, Australia.

M/269. Molloy, P.D., Talent, J.A. & Mawson, R., 1997. Late Devonian-Tournaisian conodonts from the eastern Khyber region, north-west Pakistan. *Rivista Italiana di paleontologia e stratigrafia* 103, 123-148.

Conodonts (62 species and subspecies) from acid-leaching of 226 samples from four sections through the Ali Masjid Formation west of Misri Khel in the former South Khyber Agency, north-west Pakistan, are documented by illustrations and distributional data. These indicate that most of this unit, at least in that area, spans the interval Middle *crepida* Zone (low in the Famennian) to at least Early *crenulata* Zone (mid-Tournaisian), though a fauna from low in one of the sections produced conodonts indicative of the Late *falsiovalis* Zone (early Frasnian). Two major hiatuses are inferred: between the Late *falsiovalis* and Middle *crepida* zones, and between the Late *expansa* and Early *duplicata* zones. Coherence of the conodont biostratigraphy accords with lithologic alignments between the sections.

Key words: Palaeontology, conodonts, Devonian, Khyber Agency, NWFP.

M/270. Molnar, P., 1988. A review of geophysical constraints on the deep structure of the Tibetan plateau, the Himalaya and the Karakoram and their tectonic implications. *Philosophical Transaction, Royal Society London, Special Publication A-326*, 33–88.

The Tibetan Plateau, the Himalaya and the Karakoram are the most spectacular consequences of the collision of the Indian subcontinent with the rest of Eurasia in Cainozoic time. Accordingly, the deep structures beneath them provide constraints on both the tectonic history of the region and on the dynamic processes that have created these structures. The dispersion of seismic surface waves requires that the crust beneath Tibet be thick: nowhere less than 50 km, at least 65 km, in most areas, but less than 80 km in all areas that have been studied. Wide-angle reflections of P-waves from explosive sources in southern Tibet corroborate the existence of a thick crust but also imply the existence of marked lateral variations in that thickness, or in the velocity structure of the crust. Thus isostatic compensation occurs largely by an Airy-type mechanism, unlike that, for instance, of the Basin and Range Province of western North America where a hot upper mantle buoys up a thin crust.

The P-wave and S-wave velocities in the uppermost mantle of most of Tibet are relatively high and typical of those of Precambrian shields and stable platforms: $V_p = 8.1 \text{ km s}^{-1}$ or higher, and $V_s \approx 4.7 \text{ km s}^{-1}$. Travel times and waveforms of S-waves passing through the uppermost mantle of much of Tibet, however, require a much lower average velocity in the uppermost mantle than that of the Indian, or other, shields. They indicate a thick low-velocity zone in the upper mantle beneath Tibet, reminiscent of tectonically active regions. These data rule out a shield structure beneath northern Tibet and suggest that if such a structure does underlie part of the plateau, it does so only beneath the southern part. Lateral variations in the upper-mantle structure of Tibet are apparent from differences in travel times of S-waves from earthquakes in different parts of Tibet, in the attenuation of short-period phases, P_n and S_n that propagate through the uppermost mantle of Tibet and in surface-wave dispersion for different paths. The notably lower velocities and the greater attenuation in the mantle of north-central Tibet than elsewhere imply higher temperatures there and are consistent with the occurrence of active and young volcanism in roughly the same area.

Surface-wave dispersion across north-central Tibet also requires a thinner crust in that area than in most of the plateau. Consequently the relatively uniform height of the plateau implies that isostatic compensation in the north-central part of Tibet occurs partly because the density of the relatively hot material in the upper mantle is lower than that elsewhere beneath Tibet, the mechanism envisioned by Pratt. Several seismological studies provide evidence consistent with a continuity of the Indian Shield, and its cold thick lithosphere, beneath the Himalaya. Fault-plane solutions and focal depths of the majority of moderate earthquakes in the Himalaya are consistent with their occurring on the top surface of the gently flexed, intact Indian plate that has underthrust the Lesser Himalaya roughly 80-100 km or more.

P-waves from explosions in southern Tibet and recorded in Nepal can be interpreted as wide-angle reflections from this fault zone. P-wave delays across the Tarbela network in Pakistan from distant earthquakes indicate a gentle dip of the Moho beneath the array without pronounced later variations in upper-mantle structure. High Pn and Sn velocities beneath the Himalaya and normal to early S-wave arrival times from Himalayan earthquakes recorded at teleseismic distances are consistent with Himalaya being underlain by the same structure that underlies India.

Results from explosion seismology indicate an increase in crustal thickness from the Indo-Gangetic Plain across the Himalaya to southern Tibet, but Hirn, Ltpine, Sapin and their co-workers inferred that the depth of the Moho does not increase smoothly northward, as it would if the Indian Shield had been underthrust coherently beneath the Himalaya. They interpreted wide-angle reflections as evidence for steps in the Moho displaced from one another on southward-dipping faults. Although I cannot disprove this interpretation, I think that one can recognize a sequence of signals on their wide-angle reflection profiles that could be wide-angle reflections from a northward-dipping Moho.

Gravity anomalies across the Himalaya show that both the Indo-Gangetic Plain and the Himalaya are not in local isostatic equilibrium. A mass deficit beneath the plain is apparently caused by the flexure of the Indian Shield and by the low density of the sedimentary rock in the basin formed by the flexure. The mass excess in the Himalaya seems to be partly supported by the strength of the Indian plate, for which the flexural rigidity is particularly large. An increase in the Bouguer gravity gradient from about 1 mGal km⁻¹ (1 mGal = cm sCZ) over the Indo-Gangetic Plain to 2 mGal km⁻¹ over the Himalaya implies a marked steepening of the Moho, and therefore a greater flexure of the Indian plate, beneath the Himalaya. This implies a northward decrease in the flexural rigidity of the part of the Indian plate underlying the range. Nevertheless, calculations of deflections of elastic plates with different flexural rigidities and flexed by the weight of the Himalaya show larger deflections and yield more negative gravity anomalies than are observed. Thus, some other force, besides the flexural strength of the plate, must contribute to the support of the range. A bending moment applied to the end of the Indian plate could flex the plate up beneath the range and provide the needed support. The source of this moment might be gravity acting on the mantle portion of the subducting Indian continental lithosphere with much or all of the crust detached from it.

Seismological studies of the Karakoram are consistent with its being underlain by particularly cold material in the upper mantle. Intermediate-depth earthquakes occur between depths of 70 and 100 km but apparently do not define a zone of subducted oceanic lithosphere. Rayleigh-wave phase velocities are particularly high for paths across this area and imply high shear wave velocities in the upper mantle. Isostatic gravity anomalies indicate a marked low of 70 mGal over the Karakoram, which could result from a slightly thickened crust pulled down by the sinking of cold material beneath it. Geophysical constraints on the structure of Tibet, the Himalaya and the Karakoram are consistent with a dynamic uppermost mantle that includes first, the plunging of cold material into the asthenosphere beneath southern Tibet and the Karakoram, as the Indian plate slides beneath the Himalaya, and second, an upwelling of hot material beneath north-central Tibet. The structure is too poorly resolved to require such dynamic flow, but the existence for both a hot uppermost mantle beneath north-central Tibet and a relatively cold uppermost mantle beneath southern Tibet and the Karakoram seem to be required.

Key words: Tectonics, geophysics, Tibetan Plateau, Karakoram.

M/271. Monir, M., 1973. Geological mapping of Chalt area, Gilgit Agency with special emphasis on engineering geological problems of reservoir of Chalt dam site. M.Sc. Thesis, Punjab University, Lahore, 99p.

Key words: Mapping, structure, engineering geology, reservoir, damsite, Gilgit.

M/272. Monachese, G.L., 1993. Indagini mineralogico petrografiche sui materiali di rivestimento degli stupa della velle dello Swat (Pakistan), relazione ai litotipi impiegati. Thesis, University of Bari, 98p.

This is the mineralogic and petrographic investigations of the coatings used in the stupas in Swat valley. A relationship of the results with the rock types used is also given.

Key words: Mineralogy, petrography, stupa, Swat.

M/273. MonaLisa, & Khawaja, A.A. 2001. Seismic zonation based upon peak ground acceleration (PGA) values of a part of Northern Pakistan. Ten years of paleoseismicity in the ILP: progress and prospects, 17-21 December, 2001, Kaikowa, New Zealand.

A part of Northern Pakistan bounded by Lat: 32° - 35° $30'$ N and Long: 69° $45'$ - $75'$ - $15'$ E has been divided into 360 grids of 0.15° X 0.15° size for carrying out seismic zonation. Instrumental data of $M_b > 4.5$ have been used. It comprises of 3197 events that occurred during the period April 1905 to April 1998. Peak ground accelerations (PGA) have been determined for the mid points of each grid applying the attenuation equation of the Public Works Research Institute of Japan (1990) for the return period of 100 years. These PGA values have been calculated using ERISA-P software. Contour map has been prepared for this return period and is discussed taking into consideration the geology of the region.

A number of distinct zones are observable in the PGA map of 100 years return period. In our area of interest (excluding Afghanistan), the highest PGA values correspond to the tectonically active hinterland zone of NW Himalayan fold and thrust belt. Besides containing localities like Dasu, Chilas and Mansehra, the important strategic link between Pakistan and China - the Karakorum highway also passes through this zone.

Another zone having high PGA values corresponds with the South Waziristan region and the Kurram Fault passes through the area. The other closure corresponding to the areas of Islamabad, Rawalpindi, Wah, Taxila, Tarbela have comparatively lower PGA values. According to our map the safest areas (with low PGA values) are in the Salt Range, Bannu and Peshawar Basins.

Key words: Seismology, PGA, North Pakistan.

M/274. MonaLisa, Khawaja, A.A., Ghazi, G.R. & Jadoon, I.A.K., 1997. Nature of faults and focal mechanism solutions of part of Northern Pakistan. Geological Bulletin, University of Peshawar 30, 143-151.

The area extending southwards from the MMT to Kohat/Potwar plateau in Northern Pakistan is considered to be one of the most seismically active region in the world. 13 earthquake events recorded during 1984-1995 from this area have been investigated for focal mechanism solution. Solution shows strike-slip faulting with a majority (eight) indicating a left lateral sense of motion. They mostly confirm the trend and behavior of the exposed faults with exception of one, which might be related with a blind fault.

Three right lateral strike-slip focal mechanism solution, one associated with the Thakot fault and other with the Kalabagh fault, support the active character of these faults or represent their buried offshoots. Two E-W trending right lateral focal mechanism solutions are considered to represent left lateral sheer at the western boundary of Indo-Pakistan Plate.

The P and T-axis orientation indicate NE-SW direction of compression for area located north of MBT, whereas in Kohat and Potwar area mixed trend of both NE-SW and NW-SE compressive directions are obtained suggesting more complexity. In this active zone of convergence i.e., thrusting dominated region, a kinematic change due to oblique collision is inferred.

Key words: Structure, faults, focal mechanism, Kohat-Potwar plateau, Kalabagh fault.

M/275. MonaLisa, Khawaja, A.A., Ghazi, G.R., Qureshi, S.N. & Boustani, M., 2000. Seismic risk analysis of Islamabad and its adjoining areas. Abstracts, Third South Asia Geological Congress, Lahore, p.51.

Earthquakes of $M_b > 4.5$ that occurred during the period from 1905 to April 1998 have been used to determine Peak Ground Acceleration (PGA) of an area of 200 Km radius around Islamabad. Midpoint of 1248 grids (0.065×0.065) established for this purpose were considered as sites and the PWRI attenuation equation used for the calculation at these midpoints. Raster maps for return periods of 50, 100 and 200 years have been prepared and seismic risk evaluation of the whole area undertake.

Key words: Seismicity, seismic risk, PGA, Peshawar.

M/276. MonaLisa, Khawaja, A.A. & Qureshi, S.N., 2001. Seismic zonation and peak ground acceleration of Peshawar and adjoining areas. Abstracts, 4th Pakistan Geological Congress, Islamabad, 70-71.

An area of 200 km radius around Peshawar has been divided into 360 grids of 0.150×0.150 size for carrying out seismic zonation of the area. Instrumental data of $M_b > 4.5$ have been used. It comprises of 3197 events that occurred during the period April 1905 to April 1998. Peak ground accelerations (PGA) have been determined for the mid points of each grid applying the attenuation equation of the Public Works Research Institute of Japan (1990) for the return periods of 50, 100 and 200 years. ERISA-P software has been used for calculating the PGA values. Contour maps have been prepared for these different return periods and are discussed taking into consideration the geology of the region. A number of distinct zones are observable in the PGA map of 50 years return period. The high PGA value zones in the northwestern quadrant of the map cover the area of Afghanistan. In our area of interest (excluding Afghanistan), the highest PGA values correspond to the tectonically active area i.e., hinterland zone of NW Himalayan Fold- and- Thrust Belt. Besides containing localities like Drosh, Chilas and Mansehra, which are highly populated areas, the important strategic link i.e. the Karakoram Highway also passes through this zone. Another zone having PGA values ranging from 70 gals ($0.07g$) to 290 gals ($2.9g$) corresponds with the Kalabagh fault thereby indicating the active nature of this fault. As such it is recommended that construction in this area should take into consideration the active nature of the faults. The other closures corresponding to the areas of Islamabad, Rawalpindi, Wah, Taxila, Tarbela have PGA values ranging upto a maximum of $0.08 g$ and may still be considered as hazardous area. According to our map the safest areas (with low PGA values ranging from $0.02g$ to $0.06g$) are Peshawar, Swat, Bannu, Thal and Mardan.

Key words: Seismicity, seismic zonation, PGA, Peshawar.

M/277. Mononobe, S., Hirayama, J. & Karim, T., 1992. A preliminary report on the reserves of Kumhar magnesite mine, Hazara area. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 3, 11-22.

Deals with economic geology of the deposit including reserve estimates (6.2 m tons) and chemical analyses ($MgO > 45 \text{ wt\%}$).

Key words: Magnesite, Hazara.

M/278. Mononobe, S., Karim, T. & Khan, I.H., 1992. A preliminary report on a short visit to mineral deposits around Abbottabad, Hazara area. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 3, 5-10.

Gives basic information on the mineral deposits of the area. The small-sized deposits include barite, soapstone, kaolin, scheelite and sericite, and the relatively large-sized deposits include phosphorite, gypsum and hematite.

Key words: Mineral deposits, Hazara.

M/279. Montgomerie, T.G., 1857. Memorandum on the Nanga Parbat and other snowy mountains of the Himalayan Range adjacent to Kashmir. Journal of the Asiatic Society of Bengal 26, 266-174.

Key words: Snow, Nanga Parbat, Himalaya.

M/280. Montgomerie, T.G., 1860. Memorandum on the Great Flood of the River Indus which reached Attock on the 10th August. Journal of the Asiatic Society of Bengal 29, 128-135.

"At 5 A. M. on the 10th August, 1858, the Indus at Attok was very low. At 7 A. m. it had risen 10 feet. By 0.30 p. M. it had risen 50 feet, and it continued to rise till it stood 90 feet higher than it did in the morning. The Cabul River continued to flow upwards for ten hours." — Extract from the proceedings of the Asiatic Society for September 1858, Journal Vol. XXVII. p. 366.

The flood destroyed a large amount of property in British territory both above and below Attok; and the back water (on the Cabul river) destroyed the greater part of the private property in the cantonment of Naoshera.

After the subsidence of the water, numerous reports were current near Attok, viz.: that the river was still blocked up and that another similar flood might soon be expected. These reports were generally given out on the authority of the inhabitants far up the river, who had sent down word to say that the water was still dammed up. Such a sudden flood or cataclysm on such a gigantic scale, at all times an important and interesting subject of enquiry, was rendered still more so to me by the above mentioned circumstances. Being at the time of the flood in the territories of the Maharajah Rumbhir Singh. I was in a favorable position for making enquiries in the Upper Valley of the Indus as far as the Maharajah's territories and influence extended, and I consequently made all the enquiries that I could.

On applying to the Wazeer Punnoo, the governor of Kashmir, he told me that had any damage been done in the Maharajah's territories by a flood on the Indus, he would certainly have heard of it, but up to that time he had received no report on the subject. However I begged him to write to all the Maharajah's officials (on the Indus and on its tributaries)* to enquire whether any extraordinary flood had been noticed. The answers were all in the negative except that from Boonjee, (the Maharajah's most northerly fort and cantonment on the Gilgit frontier) the report was as follows, viz. :—

"That a great flood (bura sailab) was noticed by the sepoys at Boonjee on the 27th day of "Sawan Mahina," "derh pahar din gaiya" when it first arrived. Shortly afterwards the sepoys saw a mass of timbers floating down the stream, which they recognised as belonging to the gateway of the Numbul fort." The Nfimbul fort is said to have been on the Gilgit river below the point where the Naggar River joins the Gilgit river.

I understand "the 27th day of Sawan Mahina, derh pahar din gaiya" to mean the 11th day of August about 9 or 10 in the morning. Although this is the day after the flood was noticed at Attok, it is in my opinion sufficiently near the date to make it highly probable that it was the same flood that was noticed at Attok.

At a frontier outpost of the Maharajah's (where no one goes that has sense enough to make interest to keep away), a mistake of two or three days in the date would be no wonderful thing considering the general indifference of natives on the subject of dates and the numerous doubts as to when their months begin.

I am therefore of opinion that the flood (sailab) noticed at Boonjee was the same that passed Attok on the 10th of August, and for reasons given hereafter I am of opinion that the sepoys' date at Boonjee should have been the 25th of Sawan or the 9th of August about 9 or 10 a. ft. The Trigonometrical height of Skardo the capital of Little Thibet situated on the river Indus has been ascertained to be about 7700 feet above the sea and that of the G. T. Station eighteen miles above Attok has been found to be about 1050 feet above the sea, thus shewing a difference of height between the two places of about 6650 feet. The distance between Skardo and the above G. T. Station by the course of the river Indus is approximately about three hundred and ten miles, and consequently there is an average fall in the bed of the Indus between those places of about 21 feet per mile.

Similarly the height of Baramoola where the Jhelum river leaves the Kashmir valley is about 4930* feet, that of the river two miles below Jhelum is about 750 feet above the sea, shewing a difference in height between the two places of about 4180 feet. The distance by the course of the river Jhelum between those two places is about one hundred and ninety-four miles giving an average fall in the bed of the Jhelum of a little over 21 to 5 feet per mile. Consequently we may assume that the Indus and Jhelum rivers flow at (very nearly) the same average rate between the respective places mentioned. With the assistance of Lieut. Melville I measured the rate of the Jhelum river at Naoshera, one march below Baramoola, in as slow a part of the stream, as there is between Baramoola and Jhelum, and I found the rate to be nearly 690 feet per minute, or about seven miles per hour. And Lieut. Melville quite agreed with me that we had taken a place where the rate was far below the average. The river Jhelum between the points mentioned has in general such rugged and precipitous banks that it was with difficulty that even the above measurement was made.

The distance from Boonjee to Attok may be taken approximately as about two hundred and twenty miles, and if the flood in question was the one noticed at Boonjee it traversed the distance between those two places between 10 o'clock in the morning of some day before the 10th of August and say 6 A. M. of the 10th August, that is the flood

must have taken either twenty-one hours or forty - five or sixty-nine &c. to traverse two hundred and twenty miles, that is, it must have passed Boonjee on 9th, 8th or 7th of August. Had the flood passed Boonjee on the 5th August, it would have taken forty- five hours and would have travelled at the rate of hardly five miles an hour, but it has been shewn above that the average rate of the Indus must be above seven miles an hour in ordinary times, and of course much greater during a flood, so it may, I think, be fairly concluded that the flood would take only about twenty-one hours in traversing the two hundred and twenty miles, and that it passed Boonjee on the 9th August, 1855, about 10 a. m. If so it travelled at the rate of ten and half miles per hour, by no means an improbable rate* as the Ganges when it issues from the hills opposite Hurdwar is stated by the Canal officers to flow in ordinary times at nine miles an hour, and its pace looks slow compared with that of the Jhelum below Baramoola.

As soon as I got the report from Boonjee I sent for further information but could only make out that the flood was understood to come from Naggar, an independent district which the Maharajah's people called a part of Yaghistan! quite inaccessible to ordinary messengers. Nothing would induce a man to go there; and the Wazeer said that when a present was offered, the man took the money, but only went a short distance and returned after a time with a made-up-story. Though repeated enquiries were made, nothing further was elicited.

Indeed beyond the fact that the flood had come from the Gilgit river, as reported by natives and as shewn by its carrying away the well known gateway of the Numbul Fort, nothing positive was known as to the cause of the flood or of the exact site of the place dammed up, though the Boonjee sepoy believed that it came from the Naggar valley which is drained by an Eastern tributary of the Gilgit river.

"Whether the flood in question came from Naggar or not, I feel quite certain that it did not come from above Skardo. At the time of the flood two of my assistants were working round Skardo, and another was working on the Shayok River within a month afterwards. I asked them to make particular enquiries, but they heard nothing of a large flood from any of the inhabitants of those parts. A table taken from the Philosophical transactions gives 450 feet in one minute or nearly five and a half miles an hour as the velocity of absolute torrents with an inclination of only 3 feet 1.27 inches per mile. The table gives no greater inclinations. Had the flood been generated on any of the tributaries of the Shayok I must have heard of it, as the damage done by the water on first escaping from the barrier or dam would have been very great in the Shayok valley itself.

No report was prevalent at Boonjee or elsewhere in the Maharajah's territories as to any river being still dammed up or as to the prospect of another flood. Should the river Indus or any of its tributaries be hereafter dammed up in any part of the Maharajah's territories, there would not be much difficulty in getting information from the Maharajah's officials, if proper measures were taken for collecting the same. If timely warning were given, I think that the water might be eased off, if the place was accessible and labour was available for the necessary blasting, mining and other operations. If, however, an obstruction should arise on the Gilgit River or any of its tributaries, there is, in the present political state of those valleys, no chance of getting timely warning or any accurate information, and if such was forthcoming, nothing could be done as to easing off the water unless the Engineer was accompanied by troops.

Key words: Floods, Indus River, Attock.

M/281. Montgomery, D.R., 1994. Valley incision and the uplift of mountain peaks. *Journal of Geophysical Research* 99, 913-921.

Simple end-member models describe the effect of isostatically compensated valley incision on the elevation of mountain peaks. These models allow calculation of the maximum portion of mountain peak elevations attributable to the development of observed relief and predict general downstream patterns of ridgetop uplift in response to erosion by fluvial processes. Analyses of topographic profiles across major drainages of the central Sierra Nevada and the Tibetan Plateau indicate that isostatically compensated valley incision could account for at most 5–10% of the present elevation of mountain peaks. In contrast, analyses of topographic profiles across the Himalaya show that as much as 20–30% of the present elevation of Himalayan peaks could be explained by isostatically compensated valley incision. The degree to which valley incision is compensated locally, however, depends on the flexural rigidity of the lithosphere, the size of the range, and its tectonic boundary conditions. These results show that while a tectonic control is required for late Cenozoic surface uplift of the Sierra Nevada, a significant portion of the elevation of Himalayan peaks may reflect late Cenozoic valley incision on the margin of the Tibetan Plateau.

Key words: Mountain peaks, Himalaya.

M/282. Moonen, J.J.M., Sondaar, P.Y. & Hussain, S.T., 1978. A comparison of larger fossil mammals in the stratotypes of the Chinji, Nagri and Dhok Pathan formations (Punjab, Pakistan). Koninklijke Nederlandse Akademie van Wetenschappen, Proceedings, Series B, 81, 425-436.

Key words: Mammals, fossils, Chinji, Nagri, Dhok Pathan, Punjab.

M/283. Moorcroft, W. & Trebeck, G., 1841. Travels in the Himalayan Provinces of Hindustan and the Punjab; in Ladakh and Kashmir; in Peshawar, Kabul, Kunduz and Bokhara; from 1819 to 1825, 2 vols, 495 + 508 p. Oxford University Press, Oxford.

William Moorcroft was a veterinary surgeon in charge of the stables of the British East India Company and on the pretext of finding better breeds of horses made a pioneering journey from the heart of India up to the icy plateau of Central Asia. The other side of Moorcroft's efforts was that of a spy who looked to survey the probable friends and foes of India in the face of a Russian invasion. He started this journey from Kullu in the foothills of the Himalayan and it ended with his murder outside Kabul deep into Central Asia. During the course of his travels he stayed for 2 years in Ladakh and his account of this place is unmatched by later travelers. Moorcroft also wanted to open up the Central Asian markets to British good, and in his enthusiasm signed treaties in the name of the crown with local chiefs of the lawless tracts of Central Asia. In this book one finds details of almost everything that he saw, experienced and heard. The lands, the people, the customs, the royalty, commercial potential, the flora and fauna, the river systems, the local religions. Moorcroft's account is not wanting in playing the role of being the eyes and ears in a foreign land. The journey took Moorcroft from the Punjab through to Bokhara via Ladakh, Kashmir, Peshawar, Kabul and Kunduz.

Key words: Travel, Ladakh, Kashmir, Bokhara, Himalaya.

M/284. Moosvi, A.T., Haque, S.M. & Mulsim, M., 1974. Geology of China clay deposits Shah Dheri (Swat), NWFP, Pakistan. Geological Survey of Pakistan, Record 26, 28p.

This report gives a detail geology of the china clay deposit at Shah Dheri, Swat. Reserves are estimated at 2980654 short tons. Mineralogical study shows that the commercial grade China clay is about 467217 short tons. This report contains a map and 10 figures.

Key words: China clay, mineralogy, Swat.

M/285. Morgan, M.E., 1992. Stable carbon isotope analysis of Miocene herbivores from the Siwaliks of northern Pakistan. American Journal of Physical Anthropology (Supplement 14), 127.

Key words: Palaeontology, herbivores, Miocene, isotopes, siwaliks.

M/286. Morris, C.J., 1928. Some valleys and glaciers in Hunza. The Geographical Journal 71, 513-531.

Key words: Glaciers, Hunza, Karakoram.

M/287. Morris, T.O., 1938. The Bain Boulder bed; a glacial episode in the Siwalik series of the Marwat Kundi Range and Sheikh Budin, NWFP, India. Quarterly Journal of the Geological Society of London 94, 385-421.

In October 1934, at the western end of the trans-Indus continuation of the Salt Range of North-West India, extensive outcrops of a deposit possessing all the characteristics of a typical boulder-clay were discovered in the middle of the strongly folded and faulted Siwalik series of the Marwat Kundi hills and on the northern slopes of Sheikh Budin. The

boulder-clay was named the Bain Boulder-bed, after the frontier village nearest to its most conveniently accessible outcrop alongside the frontier road from Bannu to Tank, through the Bain pass.

The occurrence of a glacial deposit in this area and at such an horizon was totally unexpected. Successive studies of Siwalik faunas, made since Falconer's pioneer work, have raised progressively the age of the Siwalik series in terms of the European and American time-scales, but no dating later than Middle Pliocene had been suggested for the thick sandy formation in which the Bain Boulder-bed occurs; neither is there any record of evidence of glacial conditions during the deposition of the Siwalik series (Colbert 1935, p. 11). Prior to the discovery of the Bain Boulder-bed, the age of the formation enclosing it had been regarded as Upper Miocene, following Pilgrim (1913), or Middle Pliocene, following Matthew (1929). The nearest place to Shekh Budin at which fossils had been collected from the formation was the type locality of Pilgrim's Nagri fauna (1913, pp. 267, 318). That fauna lies in the lower portion of the Nagri outcrop cis-Indus, about 100 miles from Shekh Budin.

Key words: Glaciers, Bain pass, siwaliks, NWFP, India.

M/288. Mostler, H., 1980. Zur mikro fauna der unterkambriums in der Hazara Formation, Hazara, Pakistan. *Annals Naturhistorisches Museum Wien* 83, 245-247.

The acetic acid residue showed a microfauna proving that the Hazira-formation (Hazara, Pakistan), which lies transgressively on the paleo-relief of the Sirban-formation, belongs to the lowest part of the Cambrian (Tommotian). Therefore the Sirban-formation is of pre-Cambrian age and so all further stratigraphic speculations concerning the classification of this formation are without support. The microfauna corresponds with the fauna-association known from the trilobitelacking stage of China. Its point of effort lies in the *Lapworthella tortuosa*-subzone respectively *Sachites-Zhijiinites-Turcutheca*-assemblage-zone. In this study eight new species of the genus *Sachites* (Cambroscleritida) are described.

Key words: Palaeontology, Hazara Formation, Cambrian, Precambrian. Hazara.

M/289. Mott, P.G., 1950. Karakoram survey: A new map. *The Geographical Journal* No. CXVI, 1-3, 89-95.

Key words: Expedition, Karakoram.

M/290. Moudden, A., 1991. Petrology-Geochemistry des mafiques et ultramafiques grenues de l'arc volcanique obducte du Kohistan (NW Pakistan). Thesis, University of Montpellier, France.

Key words: Petrology, geochemistry, mafic-ultramafics, volcanics, Kohistan, Himalaya.

M/291. Mughal, M.A., 1981-83. Geology and petrology of Tangir valley (District Diamer) with special emphasis on the mineralogy/petrology of the intrusives. M.Sc. Thesis, Punjab University, Lahore, 147p.

Tangir covers 351 square kilometers area located between Kohistan in the South and Yasin in the North. According to plate tectonic concept it lies in between Indo-Pakistan and Eurasian plates comprising a part of Kohistan Island arc. The particular project area is mapped on a scale of 1:62500. In the thesis, an attempt is made to introduce the detailed Geology of the area. Bulk geological sequence of the area is consisted of Norite, Diorite, Amphibolite, Granodiorite and granite which is obducted on to the Paleozoic rocks of Indo-Pakistan plate in the South and subducted under the Eurasian plate towards the North. The Northern part of the area is in contact with Yasin Group which is volcanic. So Tangir area constitutes the lower sequence of Kohistan Complex.

Key words: Petrology, Tangir, Kohistan island arc.

M/292. Mughal, M.A., Sarhan, A.G., Gilmour, E.H. & Rahman, O., 1981. Carbonate petrography and microfacies of a portion of the Samana Suk Formation, Kohat range, Pakistan. *Geological Bulletin, University of Peshawar* 14, 73-84.

Five carbonate microfacies occur in a portion of the Jurassic Samana Suk Formation of the Kohat range, Pakistan. These microfacies are widespread over the area in the sections measured and indicate carbonate deposition in shoal environment in agitated water, restricted marine shoals and restricted marine shelf lagoons. The detailed petrographic study uncovered a duplication of section which had been caused by faulting and was previously unrecognized.

Key words: Carbonates, petrography, microfacies, Kohat range.

M/293. Mughal, M.Y., Baig, M.A.S. & Syed, S.A., 1997. Siwalik Group: A potential host for uranium. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, p38.

Siwalik Group of rocks, Middle Miocene in age are exposed in part of AJK, Potwar, Bannu Basin and Sulaiman Range all along the foothills of NW and Western Himalayas. The Group basically comprises sand-shale interlayering with occasional development of conglomerates as channel lags or terrace deposits. The sand-shale ratio, their colour and horizontal distribution varies greatly within its four subdivisions i.e. Chinji, Nagri, Dhok Pathan and Soan formations. Uranium occurrences have been discovered over a major part of its exposures within Nagri and Dhok Pathan formations yet U-deposits could only be found in Bannu Basin and Sulaiman Range.

To develop a U-deposit three pre-requisites are essential i.e. U-source, U-mobilization, and U-precipitation and its stabilisation. Due to widespread syn-deposition of volcanic ejects and feldspar the U-source is available indiginously. The movement of meteoric water, through the preamble strata, during diagenesis and upheaval mobilized the Uranium by leaching it from the volcanics as well as feldspars. The Siwalik rocks contain grey facies which is indicative of deposition in reduced environments. As a result reductants such as organic trash and pyrite were also deposited at more humid sites favourable for precipitation of U-from the solution.

The Himalayan Orogeny being still active imparted a very unstable character to the area with Siwalik rocks. Large scale thrusts and fold belts caused upheaval of strata due to which fluctuations of water table caused unstability for U-accumulation due to which the newly formed deposits in the uplifted blocks got mobilized. Areas still exist where upheaval movements were minimal as such chances of getting good quality U-deposits exist therein.

Key words: Radioactive minerals, Potwar, siwaliks.

M/294. Muhammad, J., 1990-93. Geology of Kumbar magnesite deposit near Sherwan, Abbottabad (N.W.F.P.). M.Sc. Thesis, University of Peshawar, 25p.

Key words: Magnesite, Abbottabad.

M/295. Muhammad, S., Kakakhel, M.A.G. & Nawaz, M., 1980. Swat China Clay. M.Sc. Thesis, University of Peshawar, 83p.

Key words: China clay, Swat.

M/296. Muir-Wood, H.M., 1930. The fossil fauna of Samana Range and some neighbouring areas; Part 3, The Brachiopoda. Geological Survey of India, Memoir 15(3), Palaeontologica Indica (New Series), 25-37.

Key words: Fossils, Samana Range, Hangu.

M/297. Muir-Wood, H.M., 1934. On the internal structure of some Mesozoic brachiopoda. Philosophical Transaction, Royal Society of London, B223, 511-567.

This is a discussion of modern methods of investigating the internal structure of fossil Brachiopod shells. The present paper show how a method of research hitherto but tentatively used by a few workers on the internal characters of Brachiopod shells has been elaborated and applied to certain Mesozoic genera of different families, and has resulted in establishing the relationship of the forms examined more satisfactorily than by methods and

classification of such numerous species of the Brachiopod families Rhynchonellidae, Terebratulidae, and Terebratulidae, as are found in Jurassic and Cretaceous rocks. At the present time less than half of the Mesozoic Brachiopods are specifically determinable.

Key words: Brachiopods, Mesozoic.

M/298. Muir-Wood, H.M., 1937. The Mesozoic Brachiopoda of the Attock district. Geological Survey of India, Memoirs 20(6), *Palaeontologica Indica* (New Series), 1-34.

Key words: Brachiopods, Mesozoic, Attock.

M/299. Muir-Wood, R., 1980. Science goes to the Karakorum. *New Scientist* 88, 374-377.

This account is a fore-runner of the Royal Geographic Society international and multidisciplinary expedition to the Karakoram mountain range.

Key words: Karakoram.

M/300. Muir-Wood, R., 1981a. Islands at the top of mountains. *New Scientist*, 89, 274-277.

This is a simplified version of the geology of Kohistan, based on published data. It's a popular article, but gives a tectonic model for the development of Kohistan island arc in consequence of plates interaction since the late Cretaceous.

Key words: Island arcs.

M/301. Muir-Wood, R., 1981b. The moving mountains. *New Scientist* 89, 540-543.

This is a popular scientific article on geology and tectonics of the western Himalaya, Kohistan and central Karakoram mountain ranges. It describes their tectonic evolution, continental collision and geomorphology of the area.

Key words: Tectonics, Himalaya, Karakoram, Kohistan.

M/302. Muir-Wood, R., 1981c. Decay in the Karakorum. *New Scientist*, 89(1246), 414-417.

Key words: Karakoram.

M/303. Muir-Wood, R., 1981d. Highway to the top of the world. *New Scientist*, 91(1270), 656-658.

In the late seventies, the government of Pakistan with support from China opened up the Karakoram Highway. It traverses across some of the most fantastic scenery and highly rugged mountain terrain comprising from south to north, western Himalaya, Kohistan and Karakoram mountain ranges. The transect from Gilgit to Khunjerab provides access to a highly glaciated terrain with extreme relief at places.

Key words: Karakoram Highway, Himalaya, Karakoram.

M/304. Muir-Wood, R., 1984. A science of mountains. In: Miller, J.A. *International Karakoram Project, Volume 2*, Cambridge University Press.

This article considers the beginning of the science of mountains and the role of the International Karakoram Project (IKP) in the integration of several disciplines concerned with that science. The hope is expressed that the IKP may help stimulate more projects to further that integration towards a more unified approach to the study of earth sciences.

Key words: Mountain science, Karakoram.

M/305. Mujahid, W.K., 1982-84. Structural studies of Chinarkot-Galigada Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 87p.

The landforms bear a specific relationship with geological structure and climate which can be worked out by qualitative as well as quantitative analysis of the topographic map. The most predominant lithologies of the project area are garnet mica schists and Susalgali granite gneiss. The rocks of the project area have been classified into eight lithologic units for the sake of mapping purpose at a scale of 7 cm to a kilometer.

Mesoscopic deformational structures are well exhibited in the project area including both planar and linear structures. The rocks have been folded isoclinally and later being refolded into open folds. The area is traversed by a shear zone, the Chalundri fault and is divisible into two structural domains.

The area lies in the core zone of the regional synformal structure of the Mansehra Complex, which has experienced metamorphism in Barrovian style. The project area has been metamorphosed upto garnet grade with local contact metamorphic effects along the contacts of granites.

Key words: Structure, granite gneiss, schists, Mansehra.

M/306. Mujtaba, G., 1970-71. Geological mapping of Lawari Pass Area with special reference to engineering geological aspects. Institute of Geology, Punjab University, Lahore, (M.Sc. Thesis), 84p.

The aim of the project was to map the Lawari Pass area and to investigate about its engineering geological aspects. The area has never been geologically mapped before and no considerable work has been done there. The field work was carried out in the months of October and November, 1971. Field partner was Mohammad Ilyas. The area was again visited in September, 1972. Only the adits were examined during this. The thesis is divided into two parts. First part comprises of the introduction, physiography. Petrographic and structural studies. The second part relates to the engineering properties of rocks, tunnel and the location of a best route.

An area of about 40 square miles has been mapped. The area includes the following rock units:-

1. The granodiorite,
2. The granite,
3. The gneiss,
4. The quartz-amphibole schist,
5. The chlorite schist.

Their megascopic as well as microscopic features have been studied. A little description about their petrogenesis is also included. Regional geology has been summed up separately in Chapter-III.

Dikes and Vein are described in Chapter VII. A different chapter about the structural studies is written. Stereographic projections of the foliation and the joint planes for the major rock zones are produced.

The results of the engineering tests performed on almost all rock types have been discussed in Chapter VIII. The data is included in the appendix. Chapter IX is a summary of the data from subsurface explorations through drilling and aditing. Separate writing of Chapter X about tunnel and tunneling was considered necessary to get familiar about its theoretical aspects only related to the project. Prospecting for the construction of the proposed Lawuri pass tunnel has been discussed in detail in Chapter XI A few sketches have been drawn here.

Chapter XII discusses the location of best possible route. In addition, some measures have been suggested to keep the road clear of snow, throughout the year. The proposed location of the route is shown on Map 1.

Photographs show different features from the field area as well as the laboratory work. Conclusions have been drawn in the last chapter and also recommendations have been made.

The author has found a great shortage of the literature relating to the tunnels and the highway problems in the mountainous regions.

Key words: Engineering geology, Lowari Pass, Dir, Chitral.

M/307. Mujtaba, M., 1968. Field report of eastern Buner and Northern Chamla (Lower Swat Area). Institute of Geology, Punjab University, Lahore, (M.Sc. Thesis), 76p.

A detailed geologic and petrologic study of the eastern Buner and a part of northern Chamla was done with a special stress on granite complex. Granite rocks of the area are very complex mineralogically, compositionally as well as in field occurrence. The rock is composed of both granodiorite and granite but no sharp contact was found in the field to separate them. A third type of granite, known as Dumbukia Granite was noticed near the village Dumbakia, which is in the form of an oval body with a distinct weathering and gradational contact with the host granite. Due to this complexity of the granite, fifteen thin sections of the rocks were studied but the problem is still unsolved. Therefore, to solve the problem of the granite a very careful study and detail mapping must be carried out.

Metamorphic rocks of the area are also very complex. This complexity is due to thermal retrogressive and metasomatic metamorphisms which are superimposed on a previously regionally metamorphosed rocks. The highest grade of metamorphism in the area is found to be of staurolite and sillimanite grade of Amphibolite facies.

Basic dykes are very common in the area. There are younger than metamorphics but older than granite. These dykes are also metamorphosed along with the country rocks.

Dolerite dykes in granite have partly granitized. Three outcrops of iron-ore were noticed in the area. These ores, in the form of siderite and field evidences indicate that the ores are of magmatic in origin. A detail mapping must be done of these ores, in and outside the area so that it can be found whether these are economically useful or not.

Key words: Petrology, Buner, Swat.

M/308. Mujtaba, M. & Abbas, G., 2001. Diagenetic control on porosity development in Early Eocene carbonate reservoirs of Potwar Sub-Basin, Pakistan. *Pakistan Journal of Hydrocarbon Development Research* 12, 64-72.

Key words: Diagenesis, porosity, Eocene, carbonate reservoir, Potwar.

M/309. Muniam, A., 1983. Geology and petrography of sedimentary rocks from Jamal Khel, Dara Adam Khel, Kohat. M.Sc. Thesis, University of Peshawar, 70p.

Key words: Petrography, sedimentary rocks, Kohat.

M/310. Munir, A. & Khan, N., 1995. Structure and stratigraphy of a part of northern Kohat Plateau, south of Kohat City, N.W.F.P. M.Sc. Thesis, University of Peshawar, 54p.

Key words: Structure, stratigraphy, Kohat Plateau, Kohat.

M/311. Munir, M., 1973. Geological mapping of Chalt Area (Gilgit Agency). M.Sc. thesis. Institute of Geology, Punjab University, Lahore.

Key words: Mapping, geology, Chalt, Gilgit.

M/312. Munir, M.H., Baig, M.S. & Qureshi, M.A., 1997. Lower Tertiary litho-biostratigraphy of the Bagla-Kohala Bala area, Haripur Hazara (NWFP), Pakistan. *Geological Bulletin, Punjab University* 31 & 32, 153-160.

The Lower Tertiary shallow water marine sequence of Bagla-Kohala-Bala area overlies unconformably on the Late Cretaceous deep water marine Kawagarh Formation. The Lower Tertiary shaly, marly and limestone sequence of Lockhart Limestone, Patala Formation, Margala Hill Limestone, Chorgali Formation and Kuldana Formation yields rich foraminiferal assemblages. The study of four stratigraphic sections yield 19 age diagnostic benthonic larger foraminiferal species. These foraminiferal species include Lockhartia tipperi, Lockhartia conditi, Assilina granulosa, Assilina subspinosa, Assilina laminosa, Daviesina khatiyahi, Miscellaneous miscella, Miscellaneous stampi, Nummulites atacus, Nummulites boninensis, Nummulites globulus, Nummulites sp., Operculina canalifera, Operculina complanta, Operculina salsa, Operculina subsalsa, Daviesina lunghami, Ranikothalia nuttalli and Bigenerina sp. The

analysis of these benthic foraminifers suggests that the deposition of the Lower Tertiary sequence occurred in an open sea upper slope to outer shelf shallow marine environment.

Key words: Litho-biostratigraphy, foraminifera, Tertiary, Haripur, Hazara.

M/313. Munthe, J., 1981. Lithostratigraphy of the fluvial deposits of Late Pliocene and Pleistocene age in the Bhattani and Marwat Ranges, northwestern Pakistan. Proceedings, Neogene-Quaternary Boundary Field Conference, India, 1979, 101-105.

Key words: Lithostratigraphy, fluvial deposits, Pliocene, Pleistocene, Bhattani, Marwat Ranges.

M/314. Munthe, J., Hussain, S.T., Lukaes, J.R., West, R.M. & Shah, S.M.I., 1979. Neogene stratigraphy of the Daud Khel area, Mianwali District, Pakistan. Contributions in Biology and Geology 23, Milwaukee Public Museum Press, 1-18.

Key words: Stratigraphy, Mianwali.

M/315. Munther, H. & Khan, Z.A., 1979-80. Stratigraphy and structure of the reef complex in Nowshera, N.W.F.P. M.Sc. Thesis, University of Peshawar, 72p.

Key words: Stratigraphy, structure, reef complex, Siluro-Devonian, Nowshera.

M/316. Mustafa, Y.M., Khan, M.H. & Muhammad, N., 1985. Geology of Jatta Ismail Khel and Takht area, Karak, N.W.F.P. M.Sc. Thesis, University of Peshawar, 86p.

Key words: Geology, Karak, NWFP.

M/317. Muzaffar, H., Rashid, M.A., Sethi, U.B., & Meissner, C.R., 1967. Geology of the Parachinar quadrangle, West Pakistan. Geological Survey Pakistan and U.S. Geological Survey Project Report, PK (IR)-28, 75 p.

Key words: Geology, Parachinar.

M/318. Mytton, J.W., 1969. Appraisal of phosphate in Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-53, 36p.

Key words: Phosphate.

N/1. Nabi, S.M., 1968. Preliminary investigation of muscovite-pegmatite of Khadang Banda near Talash, Dir state, West Pakistan. Geological Bulletin, University of Peshawar 3, 12-14.

The pegmatite of Khadang Banda near Talash, Dir State, was mined by the locals for extracting muscovite. According to the information, about 15 to 20 maunds of white mica had been extracted from the pegmatite veins, which were sold at Lahore and Karachi, during the last five years. A partly M. Sc. students under the supervision of the author conducted geological investigation of this area to study the mineralization in these veins and to assess their potential for large scale economical exploitation muscovite.

Key words: Pegmatite, Talash, Dir.

N/2. Nadeem, M., Chaudhry, M.N. & Baig, M.G., 2000. Sedimentological studies of Lumshiwal Formation at Kalas, Attock Hazara fold and thrust belt, Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 64-65.

A preliminary study of facies, microfacies, diagenesis, provenance and environment of deposition of Lumshiwal Formation of Early Cretaceous age from Kalas, Attock Hazara Fold and Thrust Belt, was carried out for the first time. The objective was to study the formation in the northwestern part of the oil and gas producing Indus Basin. The formation is producing gas from Punjab Platform.

The Kalas section (Lat: 33° 02' 45" N; Long: 73° 25' 30" E) of Lumshiwal Formation near Barian is 33.55 meter thick. The formation at Kalas comprises mainly of fine to medium grained sandstone which is medium grey, light brown, medium to dark grey, light grey and greenish to medium grey on fresh surface. At places fresh surface shows greenish tinge which becomes darker green on wetting. The sandstone weathers to rusty brown, dirty grey, yellowish brown, light to medium rusty brown, dark brown and greenish grey.

The Kalas section of Lumshiwal Formation comprises of six facies and sixteen microfacies. Compositionally all the sandstone horizons are mature. Texturally four microfacies are immature and rest of the microfacies are mature to submature. The sandstone is predominantly medium grained and only four microfacies are fine grained. Quartz, carbonate and glauconite are the common cements while iron oxides and clay occur as subordinate cements. Accessory to rare amounts of tourmaline, epidote and sphene which may occur either as discrete grains or as inclusions within quartz grains suggest an ultimate derivation from sialic metamorphic-igneous basement with minor contribution from basic sources. The source granitoids were mainly S-type. However restricted suite of heavy minerals, compositional maturity and rounded to subrounded shape of tourmaline grains strongly suggest significant recycling. Diagenetic history indicates that glauconite formed from clay during early diagenesis. The formation of glauconite suggests slow rate of sedimentation and mildly reducing conditions. Suturing of quartz grains occurred during deep burial. Fracturing of quartz grains occurred during tectonic deformation in a brittle regime. Calcite cement appears to have formed during shallow burial. Silica cement in the Lumshiwal Formation owes its origin mainly to pressure solutioning and secondarily to water rising from the underlying Chichali Formation which is composed predominantly of shale. Iron oxide is believed to have formed during halmyrolysis as well as during uplift. The section of Lumshiwal Formation at Kalas is different in terms of environment of deposition compared with Lumshiwal Formation at other parts of Hazara where it shows low energy, subtidal zone. At Kalas, presence of oolites in Lumshiwal Formation indicates shallowing and shoaling of basin and high energy environment while glauconite indicates reducing subtidal environment. Lower part of the Lumshiwal Formation was deposited in reducing subtidal environment, but afterward it was followed by two periods of regression during which oolites were formed. Towards the upper part of the Lumshiwal Formation there is evidence of progressive deepening. This is shown by the absence of oolites and presence of glauconite.

Key words: Sedimentology, structure, Lumshiwal Formation.

N/3. Naeem, A., 1988. Report on Geology and Structure of Balakot-Kummi Area. M.Sc. Thesis, Punjab University, Lahore, 78p.

The present work constitutes a comprehensive report on the geology of Balakot-Kummi area and is submitted in partial fulfillment of the requirements for the degree of M.Sc. at the University of the Punjab. The report includes a detailed geological map at 1:6,000 of about 65 Km² area along with a number of geologic sections and sketches. The various chapters include geomorphology, stratigraphy, structure and tectonics. Stratigraphically, the Balakot-

Kummi area includes a number of diverse sedimentary and metamorphic elements ranging in age from Precambrian to Miocene with a fairly large gap in the Mesozoic period. Structurally, the area incorporates part of the core and western limb of the Hazara-Kashmir syntaxis and through it pass the major Murree and Panjal Faults. The Balakot-Muzaffarabad anticline is the major fold overturned and overthrusts to the southwest. No major economic mineral deposit was found within the project area, although a lot of material is available as rock crush, aggregate components and building stones.

Key words: Geology, structure, metamorphism, Hazara-Kashmir Syntaxis, Balakot, Mansehra.

N/4. Naeem, M., 1961. Geology of Bagnotar (Abbottabad) area, Hazara. M.Sc. Thesis. Punjab University, Lahore, 28p.

Key words: Structure, Bagnotar, Abbottabad.

N/5. Naeem, M.M. & Bajwa, M.S., 1983. Geology of Kach-Tavisar area, topographic sheet No. 38 O/12, Attock, Kohat and Mianwali Districts. Geological Survey of Pakistan, Information Release 190.

Key words: Geology, stratigraphy, Attock, Kohat, Mianwali.

N/6. Naeem, M.M. & Bajwa, M.S., 1987. Geological map of Chauntra (43 C/15), Rawalpindi District, Sheet No. 16, scale 1:50,000. Geological Survey of Pakistan. Map Series.

Key words: Geology, mapping, Rawalpindi.

N/7. Naeem, M.M., Mian, M. & Bhatti, A., 1985. Geological map of Islamabad (43 G/2); Islamabad District, Sheet No. 9, scale 1:50,000. Geological Survey of Pakistan. Map Series.

Key words: Geology, mapping, Islamabad.

N/8. Nagappa, Y., 1951. The stratigraphical value of *Miscellenea* and *Pellatispira* in India, Pakistan and Burma. Proceedings, Indian Academy of Sciences, Section B, Volume 33(1), 41-48.

Key words: Paleontology, stratigraphy, *Miscellenea*, *Pellatispira*, India, Pakistan Burma.

N/9. Nagappa, Y., 1957. Further occurrences of *Botryococcus* in Western Pakistan. American Museum of Natural History, Micropaleontology 3(1), p.83.

Records occurrences of the alga *Botryococcus* in Cambrian (or Precambrian) bituminous shales of Makrach and Eocene shale of Kohat, western Pakistan.

Key words: Paleontology, stratigraphy, Salt Range, Kohat.

N/10. Nagappa, Y., 1959. Foraminiferal biostratigraphy of the Cretaceous-Eocene succession in the India- Pakistan- Burma region. American Museum of Natural History, Micropaleontology 5(2), 145-177.

A synthesis of the available stratigraphic and foraminiferal evidence from the upper Cretaceous-Eocene sequence of various parts of the India-Pakistan-Burma region "shows that there were four main cycles of deposition. Each cycle is shown to have started with a transgression and ended with a regression. Evidence of minor local regression is present in some places. The earliest of these cycles ended with the Maestrichtian, and this is taken to indicate the

end of the Cretaceous period. The next cycle started with the Danian, which is now placed in the lowermost Tertiary (basal Paleocene), and continued into the Ranikot stage (Paleocene). The third and fourth cycles began with the Laki and the Khirthar stages, respectively, the two cycles together representing the whole of the Eocene."

Key words: Paleontology, stratigraphy, India, Pakistan Burma.

N/11. Nagappa, Y., 1960. The Cretaceous-Tertiary boundary in the India, Pakistan Subcontinent. 21st International Geological Congress, Copenhagen, Part 5, 41-49.

Key words: Cretaceous-Tertiary boundary, Pakistan, India.

N/12. Najman, Y., Garzanti, E., Khan, I.A., White, N. & Stix, J., 2001. Determining the rates and timing of exhumation in the Himalayan orogen: Constraints from Ar-Ar dating of detrital micas from the foreland basin sedimentary record, Pakistan. GSA-GSL Earth Sys. Proceedings Global Meeting. Edinburgh.

Key words: Geochronology, Ar-Ar dating, Siwaliks.

N/13. Najman, Y., Pringle, M., Garzanti, E., Stix, J., White, N. & Khan, I.A., 2000. Constraints on Himalayan tectonic and exhumation history determined from its foreland basins sedimentary record. Abstracts, European Union of Geologists Meeting, London, 131-132.

Key words: Tectonics, exhumation, sedimentology, foreland basin, siwaliks.

N/14. Najman, Y., Pringle, M., Garzanti, E., Stix, J., Khan, I. & White, N., 2001. The timing of movement on the Main Mantle Thrust; Constraints from the Kamliyal Formation foreland basin sediment record, Pakistan. Journal of Asian Earth Sciences 19, 46.

Key words: Tectonics, Kamliyal Formation, foreland basin, Siwaliks.

N/15. Naka, T., Hirayama, J. & Karim, T., 1995. Phosphorite-bearing Cambrian formations in the Himalayan fold and thrust belt, Hazara Division, northern Pakistan. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 11, 148-179.

The Abbottabad area is underlain by Precambrian to Cretaceous partially metamorphosed sedimentary rocks deposited on shelves surrounding Gondwana. The Cambrian formations are thrust southeastward over the Precambrian metamorphic rocks (Hazara/Tanawal Formation) along the Panjal Thrust and are unconformably overlain by Jurassic to Cretaceous formations.

The Cambrian rocks in the study area are divided into two: the Abbottabad and Hazira Formations. The phosphorite deposits occur mainly in the uppermost part of the Abbottabad Formation and also in the Hazira Formation in a minor amount. The upper part of the Abbottabad formation, Sirban Dolomite Member, is subdivided into three units: the Lower Middle, and Upper. The Lower Unit consists of micritic dolomite and the Middle Unit of dolomite and quartzite. The Upper Unit is characterized by numerous chert intercalations in the dolomite. The economically important phosphorite deposits are recognized at least three levels in the upper part of the unit. The phosphorite deposits show generally nodular or ooid-like structure and are intercalated in dolomite. The phosphorite horizons are variable in thickness, reaching 5 m thick in maximum.

The Hazira Formation is 125 m thick and overlies the Abbottabad Formation with a minor sedimentary gap. It is subdivided into two facies: Hazira and Galdanian Facies. The Hazira facies consist of glauconite-bearing calcareous mudstone in the lower part, and sandstone in the upper part. The Galdanian Facies is composed of hematitic red mudstone, siltstone and then breccia Thin phosphorite beds occur in the lower part of the formation. Many of the thrust faults developed in the area generally parallel to the Panjal Thrust and bedding planes. The faults strike NNE-SSW, and their inclinations are moderate to steep with westward or eastward direction. Folds are divided into two

type: symmetrical open folds and asymmetrical light folds. and their half wavelengths are about 150 m and 100 m, respectively.

Key words: Tectonics, Cambrian, phosphorite, Himalayan Fold and Thrust belt, Abbottabad.

N/16. Nakagawa, M., Yajima, J., Khan, S.R., Akram, H. & Yoshida, M., 1996. Potential applicability of the magnetic survey for prospecting of PGE in Jijal layered complex, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 124-127.

Key words: Geophysics, magnetic survey, Jijal Complex, Kohistan.

N/17. Nakata, T. & Tsutsumi, H., 1989. Photogrametric study on active faults of Pakistan. In: Okimura, Y. & Fatmi, M.N. (Eds.), Tectonics and sedimentation of the Indo- Eurasian colliding plate boundary region and its influence on the mineral developments in Pakistan. Hiroshima University, 69-82.

Key words: Structure, tectonics, active faults.

N/18. Nakazawa, K. & Dickins, J.M. (Eds.), 1985. The Tethys; Her Paleogeography and Paleobiogeography from Palaeozoic to Mesozoic. Tokai University Press, Japan, 312p.

The volume consists of three parts. Part I contains five papers concerning the regional aspects of the European, Himalayan, and Chinese Tethys and the general aspects of Gondwanaland and Tethys. Part II includes six papers treating the paleobiogeography and/or paleobiofacies of respective taxa, namely smaller foraminifers, fusulinids, conodonts, bryozoans, brachiopods, and land plants. Part III is a detailed report of the Permian-Lower Triassic stratigraphy, biostratigraphy, and sediments environment of the Salt Range region in Pakistan by the Pakistani-Japanese joint research group.

Key words: Palaeontology, Paleozoic, Mesozoic, Tethys.

N/19. Nanda, A.C., 2000. Some observations on the linkage, migration and extinction of the Siwalik fauna. Abstracts, Third South Asia Geological Congress, Lahore, 72-73.

The known mammalian fauna from the Ladakh Molasse Group and Murree Group indicate that during the Upper Oligocene - Lower Miocene Himalaya was never a barrier for the to- and from- migration of the fauna. The fauna shows linkage with Europe and Central Asia and with the Bugti fauna of Pakistan. Siwalik Group (18.3 Ma to 0.22 Ma) overlies the Murree Group and is known for very rich occurrence of vertebrate remains. Fauna from the Lower Siwalik of Ramnagar, Jammu or even from Potwar plateau show a poor linkage with China or Central Asia, but good linkages with Europe and Africa. However, in the Middle Siwalik, fauna do not show linkage with Central Asia, and Himalaya was a barrier for the migration. Thus river valleys which might have formed convenient routes for migration in Oligo-Miocene became inaccessible to the fauna, either due to the high altitude of the Himalaya or energy in the river system was much more to permit migration of the fauna.

In the Upper Siwalik, rich mammalian collections have been made from Chandigarh and Jammu regions and sequence yielded both Tatrot and Pinjor Faunas. The collection made in the last 35 years near Chandigarh includes 31 marker taxa for the Pinjor Formation. In addition there are 14 taxa which although are characteristic of the Pinjor Fauna but occur in the transitional zone between the sequences which yielded Tatrot and Pinjor Fauna. The process of migration or extinction of the Pinjor Fauna ranges from 1.72 Ma to 0.6 Ma. The unfossiliferous Boulder Conglomerate Formation which overlies conformably on the Pinjor Formation is having thick sequence mainly of boulder and cobble conglomerates. The river system at that time became very furious with the abrupt rise of the Himalaya, and the energy of the rivers was enormous which forced the animal life either to migrate or to become extinct.

Thus evidence indicate that faunal migration across the Himalaya took place in Oligo-Miocene when the Himalayan rivers probably formed the favorable routes of migration. With the formation of the Siwalik Foredeep, the Himalaya started gaining rapid heights and became a barrier, and migration of the fauna along its valleys stopped. Routes of migration shifted along the southern foothills. With the extinction or migration of the Pinjor Fauna, the rivers became very furious and were having enormous energy. This inhospitable environment had caused extinction of the Siwalik fauna.

Key words: Fauna, siwaliks.

N/20. Naqvi, M.M.H., 1979-79. Mineralogy of Hini-Karam Butt Area (Hunza Valley). M.Sc. Thesis, Punjab University, Lahore, 104.

Key words: Mineralogy, Hunza.

N/21. Naqvi, S.A., Ahmed, H.M., Muneer, A. & Qayyum, A., 1983. Mineralogy, petrology and economic geology of Lahor Pazang area, Swat, Kohistan. Kashmir Journal of Geology 1, 121.

Detailed geological mapping was carried out in the Besham and allied areas on the toposheet 43 B/13 of the survey of Pakistan. The mapping has revealed the following rock units in the project area; granites, pegmatites, metamorphics of the Thakot and Salkhala groups, and a number of amphibolite dikes.

The granites and metamorphics of the area depict the varying types of conditions which affected the rocks of the area probably in Precambrian time. The granites of the area have both granular and microphyritic textures. The two kinds have been assigned different origins.

Greater emphasis has been paid to the study of the skarn bodies. These contain significant amounts of magnetite, sphalerite, galena and molybdenite. The skarn bodies have developed by the interaction of granite with the surrounding metamorphics. Some mineralization has also resulted through a hydrothermal action. The hydrothermal mineral veins are of hydrothermal to mesothermal type. Disseminated sulphide are also occurs within the altered granite.

Key words: Mineralogy, petrology, sulphide mineralization, Lahore-Pazang, Kohistan.

N/22. Naqvi, S.A.H., 1974. Groundwater investigation in North West Frontier Province. Hydrogeology Directorate, WAPDA, North West Frontier Province, Peshawar, 12p.

Key words: Groundwater, hydrogeology, WAPDA, NWFP.

N/23. Narayana Rao, S.R., 1941. An algal flora from the Lockhart Limestone (Ranikot Series) of the Samana Range. Journal of the Mysore University, Section B— science, including medicine and engineering, 2 (2), 41-53.

Lockhart Limestone is the name given by Lt.-Col. L. M. Davies' to a compact, massive, grey limestone of some 200 feet in thickness, occurring in the region of Fort Lockhart on the Samana Range between Kohat and Thal. The Samana series as worked out by him consists of 12 beds; beds 8-12 (uppermost members of the sequence) are of Ranikot age, while the base of the series.(bed 1) extends down to the Jurassic (or even the Triassic). The Lockhart limestone (bed 10) represents the uppermost portion of the Lower Ranikot and the lower portion of the Upper Ranikot.

Key words: Stratigraphy, Lockhart limestone, Ranikot, Samana Range, Hangu.

N/24. Nasar, R.A.H. & Khan, S.A., 1983. Geology of Dara Adam Khel, Kohat, N.W.F.P., M.Sc. Thesis, University of Peshawar, 54p.

Key words: Geology, Darra Adam Khel, Kohat.

N/25. Naseem, A. & Mahmood, T., 1982. Field report on lithostructural mapping and geology of Balakot–Batrasi area, Mansehra with special emphasis on structure of the area. M.Sc. Thesis. Geology Department, Punjab University Lahore.

Key words: Mapping, structure, Balakot–Batrasi, Mansehra.

N/26. Naseem, M., 1996. Analysis of gold in Loess-paleosol deposit of Haro river area, Attock district, Punjab, Islamabad. Proceedings of geoscience colloquium, 14, 125-127.

Gold was analysed in 25 samples. Its concentration is less than 40 PPB except in two layers with 62 and 230 PPB values. The gold may be derived from the Indus placers.

Key words: Geochemistry, gold, loess-paleosol, Haro, Attock, Punjab.

N/27. Naseem, M., Iqbal, A., Kato, K. & Itoh, S., 1994. Determination of arsenic and antimony in geochemical samples using hydride formation system by Atomic Absorption spectrometry. Proceedings of geoscience colloquium, 9, 59-72.

This paper describes the hydride formation system analytical technique. It is intended to determine the optimization of a suitable procedure for the determination of As and Sb. Field survey was conducted in the Swat area for collection of geochemical samples from kaolinite deposits. The area went through a hydrothermal activity and the sampling of B horizon of the Shahdheri China clay deposit was done for the path finders As and Sb for Au. The samples from Swat showed good agreement with recommended value.

Key words: Geochemistry, Swat.

N/28. Naseem, M., Kato, K. & Aziz, A., 1996. Estimation of arsenic and antimony in clay sample using hydride formation system by atomic absorption spectrometry. *Geologica* 2, 157-163.

Key words: Clay, heavy metals detection, geochemistry.

N/29. Naseem, M., Khan, I.H. & Yoshida, M., 2000. Adsorption of multiple heavy metal ions on clays in Pakistan: an example of kaolinite from Salt Range and bentonite from Azad Kashmir, Pakistan. *Geologica* 5, 21-31.

Key words: Clay, heavy minerals, Salt range, Azad Kashmir.

N/30. Naser, R.I. & Hassan, M., 1969. Geology of the part of Hazara District between Haripur and Khanpur. M.Sc. Thesis, Peshawar University.

Key words: Clay, heavy minerals, Salt range, Azad Kashmir.

N/31. Nasir, A., Mohsin, M. & Tariq, M., 1989. Geology and beneficiation studies of Kakul phosphate, Hazara. M.Sc. Thesis, University of Peshawar, 60p.

Key words: Phosphate beneficiation, Kakul, Abbottabad.

N/32. Nasir, M., 1985-87. Electrical resistivity survey for groundwater potentials in Masal Talao, Amir Khan Talao, Khachar Talao and Haji Talao, District Peshawar. M.Sc. Thesis, Punjab University, Lahore, 90p.

Electrical resistivity survey in Masal Talao, Amir Khan Talao, Khachar Talao and Haji Talao (District Peshawar) was carried out in collaboration with Hydrogeology Directorate WAPDA Peshawar. The main purpose of the survey was to determine hydrogeological features such as depth to the bed rock, nature and thickness of aquifers, the quality of groundwater, and to select suitable sites for tubewell installation in the project area.

According to resistivity survey and drilling data the entire area is underlain by low resistive clay with occasional gravels. The overlying alluvium is composed of alternating layers of gravels and clays.

Ground water appears to be quite fresh in the entire project area. Water table depth varies from 13m to 40m in the area under investigation. In the project area, twenty seven probes were carried out. After interpreting the data, the V.E.S. No. 95, 93, 51, 40, 15 and 17 have been selected for the test drilling, however other probe sites also indicate the presence of aquifers in the area but of varying thickness. The entire area appears to be favourable for tubewell installation, however the yield of water depends upon the nature of aquifers, may range from half cusec to one and half cusec project area.

Key words: Geophysics, groundwater, resistivity, Peshawar.

N/33. Nasir, M.A., 1985-87. Geotechnical studies of land slides with special emphasis on slope stability along Karakoram Highway (From Batgram to Thakot, District Mansehra). M.Sc. Thesis, Punjab University, Lahore, 96p.

The project area is related to Hazara and Kohistan region of North West Frontier Province. Topographically the area is occupied by rugged rocks consisting of high peaks and alluvial deposits. The predominant rock types are granite, granite gneiss, schists and various other minor bodies as dykes and sills. All the structure features consider excellently to give NE trend that indicates NW-SE direction of tectonic forces.

The main objective of "Geotechnical Studies" is to analysis the scope of stability of rocks along roadside. For this purpose, various modes of failure, i.e., plane failure, wedge failure, toppling failure, rock fall, and circular failure etc., were observed. Theoretical models based on the actual readings (data) presented in the forthcoming chapters are intended to provide rational bases for the design of rock slope. It should however, be made clear that successful design of slope depends not only on the choice of correct theoretical model but also upon a number of other considerations which cannot be conveniently quantified.

A map has been provided which classifies the road segments as stable, unstable and potentially unstable. Stable segments are those which geometrically do not manifest any sign or chance of failure or show a high factor of safety i.e., 2.5 or 3. Unstable segments are those where small-scale failures are kept on taking place with every successive rainfall. Similarly potentially unstable segments are those which are stable in actual practice but ratio of their resisting forces to driving forces is less than one.

Study of various roads alignment was made to emphasize on the effects of sliding. Different modes of failure were encountered, and their factors of safety were calculated. Finally, it was decided whether dangerous road or not and an attempt have been made to give remedial measures.

Key words: Geotechnical, landslides, KKH, Batgram, Thakot, Mansehra.

N/34. Nasir, M.J., 1997. Pothole development along River Indus near Khairabad. Abstracts, 9th All Pakistan Geographic Conference, Islamabad, 6-7.

Key words: Pothole, Indus River, Khairabad.

N/35. Nasir, S. & Ahmad, I., 1988. A short note on the geology of the Bagarian Pegmatite, Mansehra district, NWFP., Pakistan. Geological Survey of Pakistan. Information Release 350.

Key words: Pegmatite, Mansehra, Hazara.

N/36. Naveed, M.A., 1982-84. Economic geology and petrology of graphite and other minerals in Naran-Paludaran area, middle northern Kaghan valley, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 120p.

Key words: Petrology, economic geology, Naran, Kaghan valley.

N/37. Nawaz, H., 1980-82. Geology of Balakot Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 125p.

This report incorporates results of geological mapping and investigations of about 15-miles² area surrounding Balakot. Structurally, most significant character in an overturned anticlinal structures. The overturning is towards southwest. The overturned limb of major anticline is broken by numerous faults.

At the right side of the river Kunhar the crystalline rocks are exposed generally, while at the left side of the river, sedimentary rocks are exposed except Panjal Trap, which are meta-volcanic rocks.

Key words: Mapping, structure, Balakot, Hazara.

N/38. Nawaz, K.R., 1989. Feldspar deposits of NWFP. Geological Survey of Pakistan. Information Release 283.

Key words: Economic geology, feldspar, NWFP.

N/39. Nawaz, S., 1989-91. Geological study for petrography and geology of Fatehpur Miandum (District Swat). M.Sc. Thesis, Punjab University, Lahore, 60p.

Miandum area (Lower Swat) are part of metamorphic hornblende complex. The area lies within the Southern portion of Lower Swat. These rocks are probably the extensions of rocks of Dir in the form of a belt running approximately in East-West direction. The area given field work comprises 30 miles in the North- West of Saido-Sharing. The area mainly comprises the main rock units are amphibolite, Norite, Diorite, quartz-o-feldspar and pegmatite veins amphibolites have been metamorphosed basic rocks probably Norite gabbro. As the field evidences, and the Laboratory study shows that the amphibolites were formed from basic magma, which has undergone regional metamorphism under the intense orogenic conditions. Quartz-o-feldspathic and pegmatite veins are extensively distributed all over the area, indicating the evidence of diorite magma. Major minerals are plagioclase, Hornblende, epidote and quartz with accessories as sphene and magnetite. These are products of regionally metamorphosed igneous rocks.

Key words: Petrology, petrography, Fatehpur, Swat.

N/40. Naz, M.A., Naqvi, A.A. & Safdar, M., 1964. Evaluation of some West Pakistan clays. Pakistan Journal of Scientific and Industrial Research 7, 174-181.

Twenty-seven clay samples from different regions of West Pakistan have been studied. The tests include chemical analysis, infrared absorption analysis, plasticity, water of plasticity, drying and firing behavior including shrinkage, water absorption and colour. The majority of these clays have been found suitable for different uses in the ceramic industry.

Key words: Clay deposits, West Pakistan.

N/41. Nazir, R., Hussain, M. & Rehman, H., 1995. Evaluation of Eocene shale associated with Jatta gypsum as a potential hydrocarbon source in Shakardara area, Kohat, N.W.F.P. M.Sc. Thesis, University of Peshawar, 57p.

Key words: Hydrocarbons, shale, gypsum, Eocene, Shakardara, Kohat.

N/42. Nazirullah, R., Alam, K. & Hussain, M., 1988. Geologic investigation for graphite prospects in Ghore Maidan, Mohriwali area, Neelum valley, Azad Jammu and Kashmir. Geological Survey of Pakistan, Information Release 337.

Key words: Geology, structure, graphite, Neelum valley, Azad Kashmir.

N/43. Negrotto Cambiaso, F., 1911. Rilievo fotogrammetrico alla scala di 1: 100,000 nella regione del Karakorum (Imalia Occidentale) comprendente gran parte della estrema superiore del Ghiacciaio Baltoro ed i Ghiacciai Godwin Austin e Savoia. In: De Filippi, La spezione nel Karakoram. Relazioni Scientifiche, 1-19. Zanichelli, Bologna.

This is a photogrammetric study of the Godwin Austin and Baltoro glaciers area at a scale of 1: 100,000.

Key words: Photogrammetry, Baltoro, K2, Karakoram.

N/44. Neve, A., 1907. Rapid glacial advance in the Hindu Kush. *Alpine Journal*, 23, London.

Key Words: Glaciation, Hindukush.

N/45. Ni, J.F., Ibenbrahim, A. & Roecker, S.W., 1991. Three-dimensional velocity structure and hypocenters of earthquakes beneath the Hazara Arc, Pakistan: Geometry of the underthrusting Indian Plate. *Journal of Geophysical Research* 96, 19865-19877.

The three-dimensional P and S wave velocity structures and hypocenters of 420 events beneath the western Hazara Arc are obtained simultaneously by inverting travel time data observed at fifteen Tarbela seismic stations. In general, the P and S wave velocity distribution of the top layer (0–6 km depth) correlates well with surface geology. Within this layer we find a low-velocity region beneath the Hazara Thrust Zone (HTZ) corresponding to the underthrust Murree Formation, and there are high-velocity regions south of the Main Mantle Thrust (MMT) which are associated with the exposed Cambrian, late Paleozoic, and Tertiary granites. A low-velocity zone immediately to the west of the Hazara-Kashmir Syntaxis (HKS) indicates the existence of a Miocene foreland basin which is covered by late stage southeasterly directed thrusts along the Hazara Arc and is consistent with the idea that the HKS is detached from the lower crust. From the Salt Range to the HTZ, the Indian plate dips at a shallow angle, about 2°–3° to the northeast. North of the HTZ the underthrusting Indian plate dips gently to the northeast with an increased slope of 5° to 8° until it reaches the Indus-Kohistan Seismic Zone (IKSZ). Along the NW trending IKSZ the Indian plate bends more steeply to the northeast beneath a seismically active mid crustal wedge directed to the southwest. The larger events in the IKSZ are interpreted as occurring on a major thrust zone that can be followed to a depth of 24 km. The IKSZ appears to consist of an upper seismic zone (from the surface to about 8 km) and a lower seismic zone (12 km to 24 km) separated by an aseismic region about 4 km thick. The lower IKSZ may represent the leading edge of a southwestward directed slab which has not yet ruptured the surface. Hypocenters of relocated earthquakes indicate that the HTZ is about 30 km wide with most of the larger microearthquakes occurring at 12–14 km. Seismicity along the HTZ suggests that the Panjal, and Murree thrusts are active.

Key Words: Seismology, earthquakes, structure, Indian Plate, Hazara Arc.

N/46. Nicora, A., Angiolini, L. & Gaetani, M., 1992. The Permian/Triassic boundary in Hunza valley (N. Karakoram). Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 61.

The Permo-Triassic sedimentary succession of the north Karakoram microplate is a typical succession of a passive continental margin and records the opening of Neotethys. The continental margin starts to be built up during Sakmarian-Artinskian with the deposition of a deltaic to subtidal terrigenous succession (Gircha Formation) and of a

thick carbonate platform (Panjshah Formation). During Murgabian the extensional tectonic related to the rifting of Neotethys results in the downwarping of the platform and in the deposition of pelagic limestones with white chert (Kundil Fm.), Late Permian in age.

In 1991 the Italian expedition to the Chapursan Valley (upper Hunza Valley) discovered new pelagic many formation overlying the Upper Permian cherty limestones and passing upward to the anoxic limestone with black chert of the Borom Formation (Early to Middle Triassic in age). This new stratigraphic unit has been named Wirokhun Formation (Wirokhun Pass,) 4300 metres a.s.l., on the right idiographic side of the Kundil Valley) and corresponds to the unnamed unit in Gaetani et al., 1990. Its lithology chiefly consists of thin bedded marly limestones alternating with black shales and marls. The Wirokhun Formation contains the Permo/Triassic boundary in its uppermost portion based on conodont associations. At present the basal Dorashamian and the Early Dienerian have been detected.

Key words: Sedimentation, Permo/Triassic boundary, Karakoram Hunza valley.

N/47. Nida, Y., Terai, Y., Khan, S.R. & Kausar, A.B., 1998. Origin of chromitites from the Jijal complex, Kohistan arc, North Pakistan. Geological Bulletin, University of Peshawar 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop), 140-141.

The Jijal complex is a tectonic wedge of layered ultramafic cumulates and garnet granulites exposed at the base of the Cretaceous Kohistan arc [1-2]. The lower half of the complex is composed of layered peridotitic and pyroxenitic rocks, which are strongly mylonitized and amphibolitized, especially along the Main Mantle Thrust. Towards the central part of the complex the rocks are fresh and the primary minerals, magmatic textures and structures are well preserved.

On the basis of chemical composition of constituent minerals, the ultramafic rocks are classified into two series. The orthopyroxene-free dunite-chromitite series is composed of dunite, wehrlite and chromitite having high-Mg#, high-Cr# and low-Ti. The second series is pyroxenite series, comprising dominantly of clinopyroxenite, websterite and small amounts of dunite, wehrlite, chromitite, with relatively low-Mg#, low-Cr# and high-Ti. Rocks of both the series occur irregularly and are mixed, suggesting magmatic interaction of crystal mushes during the process of crystallization. At places a number of clinopyroxenite dykes and veins cross-cut the dunite-chromitite series rocks.

The chromitite occurs as disseminated and massive bodies in close association with dunite and clinopyroxenite of both the series. Clinopyroxene-chromitites are rarely observed in the pyroxenite series. The mode of occurrence of the Jijal chromitites is similar to the stratiform-type chromitites and sometimes similar to podiform-type chromitites in ophiolitic sequences. Rhythmic layering, modal gradation of chromite and cross-bedded structure in disseminated chromitites, suggest gravitational control during the deposition of chromitite.

Olivine ranges from Fo(95.4-90.8) in chromitites to Fo(91.5-89.4) in dunites for the dunite-chromitite series, and from Fo(93.0-87.4) in dunite, Fo(90.6-89.2) in wehrlite, Fo(89.286.1) in clinopyroxenite, to Fo(84.1-80.6) in websterite for the pyroxenite series. The variation in NiO wt.% of olivine with decreasing Fo content in the dunite-chromitite series shows a fractionation trend clearly distinctive from that in the pyroxenite series. The systematic Mg# change of spinel and clinopyroxene cores with the lithological change from chromitite through dunite to pyroxenite also suggests a fractional crystallization in separate magmatic processes. The range of Cr# of spinel cores from the dunite-chromitite series (Cr#=86.1-66.3) is higher than that of the pyroxenite series spinel cores (Cr# = 73.5-42.6). The Cr# and Mg# variations also display separate fractionation trends from chromitite, through dunite and wehrlite, to pyroxenites. The TiO₂ contents in spinel cores are 0.62-0.10 wt.% for the dunite-chromitite series, and 2.08-0.20 wt.% for the pyroxenite series. Clinopyroxene mineralogy also supports the above explanation.

The chemistry of the constituent minerals suggests that the magmas for the formation of Jijal ultramafic cumulates can be explained as boninitic for the dunite-chromitite series and island-arc basaltic for the pyroxenite series. The very high Cr# range of the dunite-chromitite series spinels is consistent with that of spinels in boninites [21], whereas the pyroxenite series spinels also have high Cr# range which is consistent with that of island-arc basalt magma derived from highly depleted mantle peridotites [31]. Extremely high Fo content in the dunite-chromitite series olivines and a moderately high Fo content in the pyroxenite series are suitable to the parentage described above. The extremely low content of TiO₂ in spinels (< 0.5 wt.%) and in clinopyroxenes (< 0.03 wt.%) from the dunite-chromitite series rocks characterizes the magma type as boninitic one. It can be assumed that an interaction process between two different magma types "boninitic and island-arc basalt" has taken place within a single, large-scale magma chamber.

Key words: Tectonics, ultramafics, chromitites, Jijal, Kohistan.

N/48. Niida, K., Kausar, A.B. & Khan, S.R., 1996. Ultramafic crystal mush intrusion into crystallization magma chamber: Field evidence from the Chilas complex, northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc*. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 15, 157-171.

Modes of occurrence of the dunite-wehrlite intrusions and the field relationships between the intrusion and the gabbroic host rocks were reported from the Chilas complex of the Kohistan island arc, northern Pakistan.

A model of ultramafic crystal mush intrusion into crystallizing gabbroic magmas was discussed to examine the heterogeneous lithology of ultramafic-mafic associations in the main gabbroic rocks of the complex. The well-developed layering of gabbroic to anorthositic rocks, dyking of wehrlite in gabbroic hosts, incorporation of wehrlitic xenoblocks and xenocrysts into gabbros, and other heterogeneous lithology are closely associated with the dunite-wehrlite intrusions. This suggests that the ultramafic crystal mush intrusions generated during crystallization of the gabbroic host magmas.

Key words: Ultramafic crystal mush, crystallization, magma chamber, Chilas complex, Kohistan.

N/49. Ninglian, W., Tandong, Y., Zongtang, F. & Zhiqiang, 2000. Chemical weathering in the Batura glacier basin, Karakoram Mountains. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, 440.

Glacially driven chemical weathering could make concentration of CO₂ in the atmosphere decrease, and the process might play a significant role in climate change and the carbon cycle. So the study of chemical components and their contents of glacial meltwater in an alpine glacier-covered catchment has important geochemical and climatological significance.

Batura Glacier is large glacier located in the Karakoram Mountains. Its length is about 59.2 km. The glacier basin is 687 km², in which 332 km², nearly a half of the basin, is occupied by glacier. The lowest limit of the glacier is 2540 m.a.s.l., where mean annual temperature is about 10°C, and annual precipitation is about 97 mm. According to the hydrological measurement in 1974-1975, the runoff of Batura River was about 9.3X10⁸m³ at the terminus of the glacier.

In 1994, the Batura Glacier was investigated again for its variations. Meanwhile, the discharge of the Batura River was measured, and ice and meltwater samples were collected during that field season. In this paper, we report the analytical results of major ions in the ice and meltwater of the Glacier. And based on these data, it is found that chemical weathering in the catchment of this glacier is intense (Table 1), and the cation denudation rate, reaching the level of the tropical very humid regions, is much larger than that in the arid regions.

Key words: Weathering, glaciers, Batura, Karakoram.

N/50. Nio, S.D. & Hussain, S.T., 1981. Sedimentary study of Neogene Quaternary fluvial deposits in the Bhattani Range, Pakistan. Proceedings, Neogene-Quaternary Boundary Field Conference, India, 1979, 177-183.

Key Words: Sedimentary petrology, fluvial deposits, Neogene-Quaternary boundary, Bhattani Range.

N/51. Nio, S.D. & Hussain, S.T., 1984. Sedimentological framework of Late Pliocene and Pleistocene alluvial deposits in the Bhattani Range, Pakistan. *Geologie in Mijnbouw* 16, 55-70.

Key Words: Sedimentology, Pliocene-Pleistocene, alluvial deposits, Bhattani Range.

N/52. Nisar, A.K. & Kella, S.C., 1968. Iron-manganese deposits of Churgali (Hazara). Report West Pakistan Industrial Development Corporation, 20p.

Key words: Mineral deposits, iron, manganese, Churgali, Hazara.

N/53. Nizam-din, 1998. Paleoclimatic reconstruction of the Late Pleistocene loess-paleosol deposits in the Attock Basin, North Western Himalayan Foothills, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 50-51.

Late Pleistocene (approx. 18-130ka) loess-paleosol deposits exposed along the Haro river, Attock basin Pakistan, north western Himalayan Foothills has been studied for stratigraphy, particle-size distribution, geochemistry and paleoclimatic investigation. The deposits cover approximately 30-km² area and are up to 20 meters in thickness. The deposits are mostly composed of less-weathered loess while at least seven highly-weathered paleosol beds, PS-1-7 in descending order, are intercalated. Loess beds are generally light brown to brown in color, poorly-stratified, porous, and calcareous. Paleosols are generally dark reddish brown in color and have vertical partings and solution cavities

Particle-size distribution analysis of the loess-paleosol deposits shows that loess beds have generally unimodal, well-sorted, leptokurtic, and negatively-skewed particle-size population whereas the paleosols have bimodal and poorly-sorted population. Loess deposits are generally composed of high percentage of silt-size particles while paleosols are rich in sand-size particles. On the basis of median particle-size (M_d in ϕ scale), silt content (in weight %), and modal analysis, the loess-paleosol sequence can be divided into two part: The lower part, below the PS-4 paleosol bed show relatively coarser population with smaller M_d ϕ values and larger sand-content (wt%) attribute to an increase of local input of coarser materials and/or aggregating fine particles caused by relatively active pedogenesis during the accumulation of loess deposits. On the other hand the upper part, above the PS-4, gives relatively finer population with larger M_d ϕ values and larger silt-content (wt%) representing lower pedogenic activity during the deposition. (Nizam-Din & Yoshida, 1997)

Geochemical analysis of the loess paleosol deposits shows that the loess has high weight percent Of SiO₂ and CaO with respect to the paleosol enriched in Al₂O₃ and Fe₂O₃. Stratigraphic variation of chemical composition and molecular weathering ratios (Retallack, 1990) in the loess-paleosol sequence also reveals a two fold division. The lower part shows high concentration of Al, Fe & Mn and a dominant effect of hydrolysis, hydration and Ca dissolution representing a humid and warm climate. Conversely the upper part shows relatively high concentration of Na, Ca, & LOI and is more oxidized, salinized, dehydrated which is probably caused by and cool climatic condition during the accumulation of upper part.

Similarly the magnetic susceptibility of the loess-paleosol deposits (Akram & Yoshida, 1997) also show a systematic variation. In the upper part show low values marking and climate and very high values in the lower part representing a comparatively warmer conditions.

These drastic change in particle-size distribution, geochemical characteristic and magnetic susceptibility between the upper and lower parts of the loess-paleosol sequence possibly provides a terrestrial record of continental paleoclimate in the area during late Pleistocene: i.e. it can be interpreted in terms of relative strength of paleo-monsoon winds by the model in Chinese loess plateau (Heller et al, 1991). That is, the lower part is marked by intense summer monsoon winds whereas the upper part is dominated by stronger winter monsoon winds. This climatic deterioration in the section may correspond to the climatic change from the Last Interglacial to the Last Glacial epoch of Himalayan glaciation.

Key words: Pleistocene, loess deposits, Attock Basin, Himalaya.

N/54. Nizam-din, Ahmad, M.N., Akram, H. & Yoshida, M., 1996. Particle size distribution analysis of Late Quaternary Loess-paleosol deposits in Haro river area, Attock district, Punjab. Geoscience colloquium 14, 77-97.

Key words: Quaternary, loess deposits, Attock, Punjab.

N/55. Nizam-din, Yoshida, M., Akram, H. & Ahmad, M.N., 1996. Particle size distribution analysis by sieving and centrifugal analyser: An example from Quaternary loess-paleosol deposits. *Geologica* 2, 143-155.

An eleven meter thick section of the Quaternary loess deposit exposed along the Haro river was measured. The loess section comprises of twenty- less-weathered loess beds and four highly weathered beds called "paleosols" showing a change in climate and depositional environment of these deposits. Grain size distribution of the loess deposits shows that loess beds have generally unimodal, well-sorted leptocratic and fine skewed population whereas paleosols are bimodal and poorly-sorted. Loess deposits have high percentage of silt size particles while paleosols are rich in sand size particles.

Key words: Quaternary, loess deposits, sedimentology.

N/56. Nizami, A.R. & Rehman, F., 1992. Importance of nepheline syenite rocks of Koga, Distt. Swat, NWFP, Pakistan. *Mountnews* 5, 78-82.

Large deposits of nepheline syenite occur in or near Koga in Buner. This note describes the potential industrial use of the deposit on commercial scale, especially in ceramic industry.

Key words: Economic geology, nepheline syenite, Koga, Buner.

N/57. Nizami, A.R., Rehman, F. & Khan, I.H., 1992. A Note on the use of nepheline syenite from NWFP Pakistan. *Acta Mineralogica Pakistanica* 6, 161-163.

Large deposits of nepheline syenite occur in or near Koga in Buner. This note describes the potential industrial use of the deposit on commercial scale, especially in ceramic industry.

Key words: Economic geology, nepheline syenite, Koga, Buner.

N/58. Nizami, M.S. & Farooq, M.K., 1990. Geology and evaluation of recently exposed lower Jurassic glass sand deposits of Datta Formation in the Salt Range and Surghar Range, Pakistan. *Geological Bulletin, Punjab University* 25, 62-69.

A number of comparatively new glass sand deposits in the Salt Range and Surghar Range were studied geologically to know the nature of country rocks and feasibility of mining. Five representative specimens from the same deposits were analysed physio-chemically and evaluated regarding glass manufacture. Two of these were found suitable for producing general colorless such as container glass and sheet glass and third one for coloured glasses. The remaining two might find utilization in ceramic industry, as one was more fine-grained while the other contained less SiO₂ than required for glass melting.

Key words: Economic geology, silica sand, Datta Formation, Salt Range, Surghar Range.

N/59. Nizamuddin, M., 1992. Structural traps in the Potwar basin, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, 30-31.

Key words: Hydrocarbons, structural traps, Potwar.

N/60. Noetling, F., 1897. Fauna of Baluchistan and N-W Frontier of India. The fauna of the Neocomian belemnite beds. *Geological Survey of India, Memoirs, Palaeontologica Indica, Series* 16, 1(2), 5p, 2pls.

First paragraph of the book: The oldest formation seen in the sections of the Mari hills of Baluchistan is represented, according to Messrs. Griesbach and Oldham, by a massive limestone which is generally devoid of fossils, or at most contains some ill-preserved fossils here and there; commonest are Brachiopods belonging to the genera *Rhynchonella* and *Terebratulina*. It is clear that these two genera would not have been sufficient to determine the age of the " massive limestone " with certainty, but fortunately Lala Kishen Sing of the Geological Survey

discovered a rich fauna of ammonites in these deposits near Mazar Drik. It is, however, to be regretted that almost every specimen has suffered more or less from deformation by pressure, and that the finer structure of the sutural line has been completely destroyed in every case. Under these circumstances the specific determination would have been exceedingly difficult had I not been able to compare this collection with the type specimens from the Jurassic beds of Kutch, which have been so diligently worked out by Professor Waagen. The only fault which I have to find with this fine publication consists in the fact, that the figures of the specimens described do not always represent the original in its actual state, but that they are in many cases considerably, and not always happily, restored. The determination from the figures only, as given in Professor Waagen's publication, is therefore extremely difficult, and it may be noticed that my figures differ considerably from those of the species of the same name as shown by Professor Waagen. I have, however, convicted myself by actual comparison with the Kutch originals that the specimens here described under specific determinations attributed by Professor Waagen to forms from Kutch, are really identical with these species, notwithstanding the apparent difference of the figures. In two cases, however, I felt under an obligation to reproduce two of Professor Waagen's originals, in order to prove to the reader the identity of the Baluchistan forms with those from Kutch, as the published figure of the Kutch species differs considerably from the type specimen. The Jurassic limestone of Mazar Drik has up to the present yielded 22 species, of which 17 have been determined specifically, while of 5 only the genus could be determined. Out of the 17 species specifically determined, 16 could be identified with species already described, while one form, *Perisphinctes baluchistanensis*, could be recognized as new. The 22 species mentioned represent the following classes *Braehiopoia* 2 species (two especially deteruined), *Pelecffiioda*, 3, *Gastropoda* 1 (none), *Cephalopoda* 16, (15).

Key words: Paleontology, fauna, belemnite beds, Baluchistan, NWFP.

N/61. Noor, I., 1978. Geology and structure of the part of the area, north of Babri Banda, Kohat District, North West Frontier province, Pakistan. M.Sc. Thesis, University of Peshawar, 78p.

Key words: Geology, structure, Kohat.

N/62. Norin, E., 1925. Preliminary notes on the late Quaternary glaciation of the northwestern Himalaya. *Geog. Annaler* 7, 165-194.

Key words: Glaciation, Himalaya.

N/63. Norine, E., 1946. Reports from Scientific Expedition from NW province of China under leadership of Swen Hedin. Publication 29, III geology 7, geological expeditions in western Tibet, Stockholm.

This is a report of the geological studies in, perhaps, eastern Karakoram and the bordering regions. The granitic rocks are considered to be of three principal types; a. biotite granite, post Paleozoic and perhaps post Triassic, but pre Sinonian, b. plagioclase granite, referable to the late Cretaceous or lower Tertiary, C. biotite-hornblend granite of Tertiary age.

Key words: Granites, Karakoram.

N/64. Norine, E., 1976. The "Black Slates" formations in the Pamir, Karakorum and western Tibet. In: *International Colloquium on the Geotectonics of the Kashmir Himalaya–Karakorum–HinduKush–Pamir Orogenic Belt*. Rome, 1974, *Atti dei Convegna Lincei*, 21, 245–264.

Key words: Slate, Pamir, Karakoram, Tibet.

N/65. Nosenko, G.A., 1993. Distribution and regime of Karakorum glaciers from space imagery. *Mapping Sciences and Remote Sensing* 13, 85-95.

Key words: Remote sensing, glaciation, Himalaya.

N/66. Novarese, V., 1911a. Appunti geologiche intorno alla Spedizione di S.A.R. il Duca degli Abruzzi nel Karakoram. In: De Filippi, La spezione nel Karakoram. Relazioni Scientifiche, 65-85, Zanichelli, Balogna.

Key words: Geology, Italian Expedition, Karakoram.

N/67. Novarese, V., 1911b. I risultati scientifici della Spedizine di S.A.R. il Principe Luigi Amedeo di Savoia nel Karakoram. Bollitin Soc. Geogr. Ital., ser.V, I, 355-365.

Key words: Italian Expedition, Karakoram.

N/68. Nowroozi, A., 1972. Focal mechanism of earthquakes in Persia, Turkey, West Pakistan and Afghanistan and plate tectonics of the Middle East. Bulletin of the Seismological Society of America 62, 823-850.

Focal mechanism solutions are determined for 23 earthquakes that occurred from 1965 to 1970 in Persia, Turkey, Pakistan, and Afghanistan. These mechanisms were obtained from the long-period first-motion P waves recorded by the World-Wide Standardized Seismograph Network stations. Mechanism solutions for the earthquakes in the folded foothills of the Zagros are predominantly thrust faulting, but depending on the assumed crustal velocity, many have strike-slip components. Cross sections of the seismic zone of the folded foothills of the Zagros show that the earthquakes are confined to a possible lithospheric slab nearly 60 km thick dipping 10° to 20° toward the north. For the earthquakes with focal depth of about 200 km, in the Hindu Kush in Afghanistan, mechanism solutions are characterized by a nearly horizontal compressional axis and a steeper extensional axis. The seismic zone appears as a contorted slab-like structure 20 to 30 km in width. This lithospheric slab may be a remnant of the Tethys Sea floor. Consistent right-lateral strike-slip mechanism solutions are found for earthquakes on the Anatolian fault in Turkey. For earthquakes on the Ferdows fault in eastern Persia, mechanism solutions vary from pure left-lateral strike-slip faulting to pure thrust faulting. Mechanism solutions for earthquakes on the Kirthar-Sulaiman shear zone in West Pakistan show consistent left-lateral strike-slip motion on a fault plane that strikes north-south. This is in agreement with the northward movement of India with respect to Afghanistan. On the basis of seismic and geological evidence, the entire Middle East is divided into eight plates which are moving northward, at different rates, with respect to Eurasia. The differential motion between various plates can explain the sense of offset and other geological features.

Key words: Tectonics, seismology, earthquakes, Persia, Turkey, Pakistan, Afghanistan.

O/1. O'Brien, P.J., Zotov, N., Law, R., Khan, M.A. & Jan, M.Q., 1999. Coesite in eclogite from the upper Kaghan valley, Pakistan: a first record and implications. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet workshop, Kloster Ettal, Terra Nostra 99, 109-111.

Coesite, recognized petrographically and confirmed by in situ Raman microprobe spectroscopy, is reported from an eclogite from the Upper Kaghan Valley, Pakistan and represents the first record of Ultra-High Pressure (UHP) metamorphism in the Himalaya. The formation conditions >25 kbar, implied by the presence of coesite, are also supported by garnet-pyroxene-phengite barometry. The mafic bodies of the Upper Kaghan Valley have been interpreted as the metamorphic equivalents of mafic lavas, dykes and sills of Permian age (Panjal Trap volcanics). The important implication is, therefore, not only that the leading edge of the Indian plate, i.e. continental crust, was subducted to extreme depths (<90-km) during the Himalayan collision phase but that part of it was also quickly exhumed. The coesite-bearing eclogite was discovered in the Loihalol Nala, north of Gittidas, opposite the settlement Faqir Shah di Baihk. This location lies only a few kilometers from the Indus Suture. The macroscopically fresh eclogite exhibits a massive, fine grained (mostly less than 1mm), red garnet and dark green omphacite matrix, sprinkled with mm-sized white mica grains and overgrown by randomly oriented, black amphibole crystal up to 1cm in length. The body is also cut by quartz-white mica veins. Microscopically, anhedral garnet, mostly under 0.5 mm and with conspicuous darker cores, sits with a weakly-defined foliation defined by elongate omphacite (mostly 0.5-1.5mm and commonly dusted with tiny rutile inclusions), phengitic white mica (0.5-1mm), aggregates of quartz, and chains of rutile (rimmed by titanite). The large amphiboles grow across the fabric and enclose garnet, phengite and rutile but only scarce omphacite. Regression is extremely minor. The coesite (largest grain is 60 microns) occurs as inclusions in omphacite and shows the characteristic breakdown to radiating (palisade-texture) quartz as well as the typical radiating network of fractures in the host pyroxene. Inclusion with just palisade quartz are also present as are omphacites with more than one coesite inclusion preserved. Optically, coesite shows a higher relief than its surrounding quartz as well as a lower birefringence. Microprobe analysis showed a pure SiO₂ composition for both phases of the inclusions and by use of raman spectroscopy, including a two-dimensional mapping technique, it was very easy to distinguish between clinopyroxene, quartz and coesite spectra. The distinct color zoning of garnet is reflected in compositional zoning. Element distribution maps allow distinction of a relatively Ca-rich core (Alm₅₀ Prp₁₈ Grs₂₉ Sps₃), surrounded by zone with lower Ca (Alm₅₀ Prp₂₁ Grs₂₁ Sps₁) and followed by a narrow- but distinct- overgrowth where Ca is again higher than Mg. The jadeite content of omphacite ranges between 25 and 33 mol% (aegirine content 4-13 mol% from charge balance) but individual grains appear to be unzoned. Phengite shows a maximum Si per formula unit of 7.2 (Mg/Mg+Fe=0.74) in grain interiors with both values falling towards the margins of grains. The large amphiboles are Mg-hornblende, zoned to barroisite close to garnet, whereas younger amphibole formed as a breakdown product of garnet plots in the field of sub-silicic ferroan paragonite. The geothermobarometric methods that would most commonly be applied to an eclogite of this kind are the garnet-clinopyroxene and garnet-phengite Fe-Mg exchange geothermometers and geobarometer based on the reaction albite + aegirine + quartz. Unfortunately, the jadeite geobarometer, in the absence of plagioclase (as is the case in eclogites), can only yield a minimum pressure. From these 'traditional' methods alone, equilibrium conditions of around 650°C and 14 kbar were estimated: values perfectly in line with what previous workers in the area have deduced. An additional, and very useful geobarometer, is that based on the reaction between garnet, omphacite and phengite described by: Pyrope (in garnet)+Grossular (in garnet) = Diopside (in omphacite)+inverse Tschemaks (=Al₂Mg₂Si₋₁) (in phengite). The inverse Tschemaks activity is derived as Muscovite/Celadonite. This water-absent geobarometer reaction, calibrated initially by waters and Martin (1993), has been successfully tested in the Dabie Mountains, China by Carswell et al. (1977), to distinguish phengite-bearing eclogites that formed in the quartz stability field. It was results from the application of this geobarometer to data from Kaghan Valley eclogites (taken from Spencer 1993). i.e. pressures well above 20 kbar, that prompted the new field work in this area. Interestingly, some of the eclogite samples described from the Tso Moriri area of Ladakh by de Sigoyer et al., (1977) also yield pressures in the coesite field. For the coesite-bearing sample described here, the estimated equilibrations fall on the coesite-quartz curve at around 27 kbar, 680°C. This first discovery of coesite, combined with the new pressure estimates obtained from garnet-clinopyroxene-phengite geobarometry, are strong evidence that at least this corner of the Indian Plate has been subducted to considerable depth (27 kbar is equivalent to 90-100 km i.e.

almost three times the normal thickness of the continental crust). More important for the tectonic interpretation, however, is that rocks from this depth have managed to reach the surface again without being completely overprinted. Exhumation rates and exhumation model for the various metamorphic rocks in this area had been estimated, before, the discovery of eclogites, based on the maximum pressure conditions deduced for garnet-kyanite-staurolite-bearing assemblages in metapelites-parameters not significantly modified if the conservative minima estimated for the eclogites (Spencer, 1993) were taken into consideration. Model parameters must now be corrected as the pressure (or depth) deduced from this study is greater by at least a factor of 2. As the age constraints on the timing of collision, metamorphism, exhumation and cooling are entirely unaffected by these results, the only possible conclusion is that exhumation of rocks from coesite-forming depths, and more importantly the metastable preservation of coesite in such rocks, may well be entirely due to the buoyancy of the relatively low density (compared to the mantle) subducted continental crust slice hosting the eclogites. Tectonic models promoting this aspect, such as that proposed by Chemenda et al. (1995), may therefore be directly applicable to the early part of the Himalayan collision event. The first definite eclogites in the Himalayan were reported only in the early 1990's and there are still only very few areas where eclogites (or their retrograded or overprinted equivalents) have been identified. In comparison to European continental collision belts such as the Alps, Variscides, or Caledonides, eclogites are extraordinarily scarce in the Himalayas and other characteristic high-pressure rocks, such as garnet peridotite, are completely unknown. Is this just a product of the lack of investigation or is the lack of high-pressure rocks a function of the pervasive amphibolite facies event? One thing is certain: the eclogites were encased in continental crust at these mantle depths and it is only a question of time before a high-pressure evolution is confirmed in these rocks as well. It should not be forgotten that easily accessible rocks preserving relics of ultra high-pressure metamorphism in the Dora Maira Massif, Western Alps, had been completely overlooked by generations of geologists before their true worth was discovered.

Key words: Eclogite, UHP metamorphism, tectonics, Kaghan, Kohistan.

O/2. O'Brien, P.J., Zotov, N., Law, R., Khan, M.A. & Jan, M.Q., 2001. Coesite in Himalayan eclogite and implications for models of India-Asia collision. *Geology* 29, 435-438.

Coesite, recognized petrographically and confirmed by in situ Raman microprobe spectroscopy, is reported from an eclogite from the Kaghan valley, Pakistan, and represents the first record of ultrahigh-pressure metamorphism in the Himalaya. The formation conditions of >27 kbar implied by the presence of coesite are supported by garnet-pyroxene-phengite barometry (27-29 kbar, 690-750 °C). If, as seems likely from previous field and geochronologic studies, the eclogites represent metamorphosed dikes, sills, and lava flows of Permian age within the granitic gneiss-metapelite-marble sequence of the Higher Himalayan crystalline nappes, then continental crust-the leading edge of the Indian plateaus also have been subducted to coesite-forming depths (90-100 km). This more than doubles previous depth estimates and, on the basis of available geochronological data for this area, requires average exhumation rates at least twice as fast (~10 mm/yr) as previously imagined. A further implication, based on interpretations of deep seismic data, is that the present-day shallow angle of subduction of Indian plate lithosphere beneath Tibet represents a significant change from an initially much steeper angle.

Key words: Eclogite, Coesite, collision, Kaghan.

O/3. Odell, N.E., 1983. On the occurrence of granite in the Himalayan mountains. In: Shams, F.A. (ed.), *Granites of Himalayas, Karakorum, and Hindu Kush*. Institute of geology, Punjab University, 1-10.

The varying occurrences of granite in the principal regions of Himalaya proper and the Karakorum – Hindu Kush are considered and contrasted. Professor A. Desio's important work in the Karakorum in particular is cited. The older concept of there being on an 'axial granite core' in the Great Himalaya range is shown to be erroneous. Instead, later exploration and mountaineering in the main ranges have revealed that a large proportion of the high peaks are composed of sedimentary rocks, with intrusive granite appearing only very locally, while most, if not all, occurrences of granite, whether of the older granite gneiss or the newer

intrusives, are considered to be magmatic in origin, the special case of Nanga Parbat, claimed by Mish to be metasomatic and a major example of granitization is briefly discussed. The recent extensive geological survey of Nepal by Magen is touched upon and details given of important work in the area of Mount Everest and Makalu; with emphases made upon the earlier and significant studies of Wager in the injected granite sheets of Everest and vicinity, their role and their radiometric ages. Gansser's current work in Bhutan is also cited, apart from references to his outstanding and comprehensive studies of the better-known portions of the main Himalaya.

Key words: Granite, Nanga Parbat, Karakorum, Hindu Kush, Himalaya.

O/4. Oestreich, K., 1912. Der tschochogletcher in Baltistan. Zeitschrift für Gletscherkunde 6, 1-30.

Key words: Baltistan.

O/5. Offield, T.W., 1964. Preliminary bibliography and index of the geology of Pakistan. Geological Survey of Pakistan, Records, 12(1), 54p.

This is a compilation of contributions to the geology of both East Pakistan (now Bangla Desh) and West Pakistan (the present day Pakistan). A useful index accompanies the document for ready access to the contributions. The bibliography has been incorporated in subsequent bibliographies, such as that compiled by I. A. Khan et al., 2002.

Key words: Bibliography.

O/6. Offield, T.W. & Abdullah, S.K.M., 1968a. Reconnaissance geology of the Balakot and Mahandri quadrangles, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-34, 41p.

Key words: Reconnaissance, Balakot, Mansehra.

O/7. Offield, T.W. & Abdullah, S.K.M., 1968b. Reconnaissance geology of the Darband quadrangle, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-35, 24p.

Key words: Reconnaissance, Darband, Hazara.

O/8. Offield, T.W., Abdullah, S.K.M. & Khan, M.S.Z., 1966. Reconnaissance geology of the Mansehra quadrangle, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-10, 31p.

Key words: Reconnaissance, Mansehra, Hazara.

O/9. Offield, T.W., Calkins, J.A. & Ali, S.T., 1964. Reconnaissance geologic map and cross section of Tarbela area, Pakistan. US Geological Survey, Geologic Map Series 1109, PP716C, Plate 3, 94, (43 B/2).

Key words: Reconnaissance, mapping, structure, Tarbela.

O/10. Offield, T.W., Calkins, J.A. & Ali, S.T., 1968. Reconnaissance geology of the Tarbela quadrangle, Hazara District, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-37, 37p.

Key words: Reconnaissance geology, Tarbela.

O/11. Ogasawara, M., 1998a. Interpretation of JERS-1 remote sensing data on Karakoram, northern Pakistan. Geological Bulletin, University of Peshawar 31 (Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop. Abstract Volume, Geological Bulletin, University of Peshawar 31, 143-144.

Remote sensing data obtained by JERS-1 (Japanese Earth Resources Satellite) have been evaluated for lithological and structural interpretations in areas from the Karakoram, northern Pakistan. A comparison has also been made with similar images from Landsat TM. JERS-1 carries an optical sensor (OPS) which records seven spectral bands. Three bands around 2.2 micron wavelength have been designed to provide valuable information for lithological discrimination. The spatial resolution of JERS-1 (18m) is better than that of the Landsat TM (30m), and provide very detailed topographical and geological information [11. One scene of JERS - 1 covers an area of about 75 * 75 km, and for the purposes of this study, twenty scenes of JERS-1 data were examined. Excellent data have been obtained along two strips of JERS-1, i.e. paths 183 and 188 (Fig. 1).

Among the factors limiting the use of remote sensing data in the high mountain terranes are the snow cover and the cloudy weather. For instance, the Karakoram Ranges is largely covered by snow in the winter, but the highest mountains are also covered in the summer. An image of northern Karakoram, north of Gilgit, taken in middle of November, shows that more than 90 % of the area is covered by snow. The images of the similar area in the northern Karakoram taken at the end of June still indicates that it is covered by snow. Thus, in order to have a minimum snow cover, it is necessary to select appropriate remote sensing data, for instance, these obtained at the end of summer (e.g., from the end of August to early September). In addition to problem by the snow cover, cloud cover also provides limitation on the image selection. Despite the problem of the snow covers, the Karakoram range is an ideal area for interpreting the remote sensing data, since it is characterized by a scarcity of vegetation mainly due to the relatively dry weather conditions. The different rock types are easily distinguished using JERS- 1 data.

Four scenes of JERS-1 Path 183, covering the area from Nanga Parbat to Khunjerab pass, were collected at the end of September, and they contain excellent geological information. The Karakoram Highway runs in the middle of the images. These show very detailed topographic features and fine geological structures. The high spatial resolution of JERS-1 data is very useful especially in areas where there are no good topographic maps or air-photos. The JERS-1 images can be enlarged into 1/100,000 scale without the loss of image quality.

Distribution of carbonate rocks and acidic granitic rocks [2] in the area is clearly shown in the images. The carbonate horizons which are several tens of meters thick, can be easily detected. These horizons are important key beds for the structural interpretation of the area. The black slate formations, e.g., Misgar slate, can also easily traced because they are appeared with a distinct black tone on the false color image.

In conclusion, the satellite images with the high spatial and spectral resolutions are useful for making geological survey in the area with difficult access. Geological information of several limited traverse can be correlated on a regional scale by using remote sensing data. Although Landsat TM data provide useful geological information, remote sensing data with even higher spatial resolution, JERS-1 or possibly SPOT, can be utilized in the area like the Karakoram.

This study was supported by joint research program between Geological Survey of Japan and Earth Resources Satellite Data Analysis Center.

Key words: Remote sensing, tectonics, structure, Karakoram.

O/12. Ogasawara, M., 1998b. New muscovite Rb-Sr ages of mylonite from the Misgar Shear Zone, in northern Karakoram: implications for late Cretaceous tectonism in the

Eurasian plate. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 144-145.

The mylonite was found near Misgar in the northern Karakoram which consists largely of Permian to Jurassic sediments. The mylonite is well exposed on the road cut of the Karakoram Highway at a distance of about 5-km upstream of the Khunjerab River from the Khunjerab-Kilik Rivers junction with a width of 900m. It continues 7km northwest to north of Misgar with a N70°W trend. The mylonite separates the Misgar Slate to the north from the Kilik Formation to the south. The occurrence of such wide zone of the mylonite could indicate the presence of a major shear zone, Ogasawara et al. proposed to use the term Misgar Shear Zone (MSZ) to describe it. The MSZ consists of mylonitic rocks, gneiss and schist originated from granodiorite, granite, limestone, sandstone and mudstone. Cataclasites after the mylonite are also present. Pseudotachyite veins are found in the cataclastic rocks. Mylonite of plutonic origin is dominant in the northern portion of the MSZ, and augen texture is commonly observed in it. Calcareous and pelitic schists are present in the southern portion. A narrow calcareous mylonite with a width of 15m bounds the southern margin of the MSZ. The mylonitic foliation mostly dips 70-80° to the south. Horizontal to southeast shallow plunging lineation is commonly observed on the foliation plane. Several types of asymmetric microstructures, e.g. asymmetric pressure shadows, are observable in the mylonite and pelitic schist in the MSZ. All the asymmetric microstructures demonstrate a dextral strike-slip shear.

K-Ar ages of the muscovite and biotite of the mylonite are 66.5 ± 5.3 and 63.4 ± 3.4 Ma, respectively. New muscovite Rb-Sr ages of mylonite are 69.9 ± 1.7 and 66.6 ± 1.5 Ma. Though, these are slightly older than the K-Ar ages, all the ages obtained are clearly indicating that the mylonite was formed by a late Cretaceous tectonic event in the Eurasian plate.

The Kohistan-Ladakh arc collided with the Eurasian plate before the collision of India to Eurasia, and the northern suture is thought to have closed during late Cretaceous time between 95 and 75 Ma. Therefore, the late Cretaceous age of the MSZ suggests that the dextral strike-slip displacement of MSZ in the Karakoram terrane may be related to final movement of the collision of the Kohistan-Ladakh arc to the Eurasia. On the other hand, Klootwijk et al. suggested an early India-Asia contact before 55N1 (as early as 70Ma) from paleomagnetic constraints. Such early India-Asia contact may have led to deformation of the Eurasian continent even in the late Cretaceous. Late Cretaceous radiometric ages of the mylonite from MSZ could support this model.

The presence of cataclastic and pseudotachylite with dextral strike-slip sense of shear indicates that the dextral strike-slip displacement continued after several kilometers uplift of Karakoram terrane from the depth of mylonite formation. The dextral strike-slip Misgar fault which occurs at a distance of about 5 km south of the MSZ at Khunjerab River and merges into MSZ near Misgar, also records the same strike-slip displacement. Therefore, the continued convergence of the Indian and Eurasian plates led to the strike-slip displacement of the crust within the Eurasian plate and it started from the late Cretaceous.

Key words: geochronology, Rb-Sr dating, K-Ar dating, mylonite, Misgar shear zone, Hunza, Karakoram.

O/13. Ogasawara, M., Watanabe, Y., Khan, F., Khan, T., Khan, M.S.Z. & Khan, K.S.A., 1992. Late Cretaceous igneous activity and tectonism of the Karakoram block, Northern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.31.

Consult the following account for further details.

Key words: Tectonics, granites, Geochronology, K-Ar dating, Cretaceous, Tirich Mir, Khunjerab, Karakoram.

O/14. Ogasawara, M., Watanabe, Y., Khan, F., Khan, T., Khan, M.S.Z. & Khan, K.S.A., 1994. Late Cretaceous igneous activity and tectonism of the Karakoram block in the Khunjerab valley, Northern Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 203-207.

In the Karakoram block of the Eurasian plate to the north of the Northern Suture in Pakistan, the Karakoram Batholith is a major body of granitic rocks. However, several smaller granitic bodies are present to the north of the Karakoram Batholith, which comprise the Khunjerab-Trich Mir granite belt. Some of the granitoids of this belt which occur in the Khunjerab Valley have been investigated. The Khunjerab pluton consists of hornblende-biotite granodiorite and granite. Its K-Ar hornblende and biotite ages are 107 ± 5 Ma and 96.9 ± 4.8 Ma, respectively. The K-Ar hornblende and biotite ages of 105 ± 5 Ma, and 95.0 ± 4.7 Ma respectively, for the Girag syenite are not different from the ages of the Khunjerab pluton. Slightly younger K-Ar biotite ages of 84.2 ± 4.2 Ma and 85.9 ± 4.3 Ma have been obtained for the North Sost pluton. These data and the age of the Tirich Mir pluton from the reference indicate that plutonism of the Khunjerab-Trich Mir granite belt took place during 120-85 Ma. The age is similar to the ages of the older plutonism found in the Karakoram Batholith. That plutonism could be generated by the northward subduction of the oceanic crust, which was present between the Kohistan Island Arc and the Karakoram Block.

Key words: Tectonics, Cretaceous granites, geochronology, K-Ar dating, Tirich Mir, Khunjerab, Karakoram.

O/15. Ogasawara, M., Watanabe, Y., Khan, F., Khan, T., Khan, M.S.Z., & Khan, K.S.A., 1997a. Late Cretaceous igneous activity and tectonism of the Karakoram block in the Khunjerab valley, northern Pakistan. In: Research on Geology and Mineral Resources of the Collision Zone in Pakistan International Research and Development Coop. ITIT Project, Japan, Rep 87(1-2), 42-62.

Consult the preceding account.

Key words: Tectonics, Cretaceous granites, geochronology, K-Ar dating, Tirich Mir, Khunjerab, Karakoram.

O/16. Ogasawara, M., Watanabe, Y., Khan, F., Khan, T., Khan, M.S.Z. & Khan, K.S.A., 1997b. Mylonite of Misgar Shear Zone, in northern Karakoram: Evidence for late Cretaceous dextral strike-slip displacement in Eurasian plate. In: Research on Geology and Mineral Resources of the Collision Zone in Pakistan International Res and Development Cooperation, ITIT Project No. 87-1-2, Japan, Rep., 63-79.

Consult Ogasawara et al., 1994 for further details.

Key words: Shear zone, Karakoram, Cretaceous, Eurasian Plate.

O/17. Oil and Gas Development Corporation of Pakistan 1987. Natural oil and gas resources of mountainous regions of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resources Potential of Mountainous Regions of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 45-54.

Key words: Hydrocarbon potential, Himalaya.

O/18. Okimura, Y. & Fatmi, A.N. (eds.), 1988. Tectonics and sedimentation of the Indo-Eurasian colliding plate boundary region and its influence on the mineral developments in Pakistan. Hiroshima University, 1-31.

Key words: Tectonics, sedimentation, mineral potential, collision, plate boundaries.

O/19. Okrusch, M., Bunch, T.E. & Bank, H., 1976. Paragenesis and petrogenesis of a corundum-bearing marble at Hunza (Kashmir). *Mineralium Deposita* 11, 278-297.

A calcite-marble containing gem-quality ruby is exposed in the Hunza Valley, northwestern part of the Karakoram Mountains, Pakistan zone of Kashmir. The marble forms concordant intercalations within sillimanite- and garnet-bearing biotite-plagioclase gneisses and mica schists. The metamorphic sequence is cut by discordant aplite and pegmatite dikes. The following mineral assemblages are recognized in the marble:

- 1) Calcite+corundum+phlogopite±margarite±sheridanite±Al-rich pargasite±anorthite (An 96.7),
- 2) calcite+spinel±corundum+phlogopite+sheridanite.

Microprobe analyses are given for the essential minerals including corundum (ruby) and three different colour varieties of spinel. On the basis of recent experimental data, especially in the system $\text{CaO} - \text{Al}_2\text{O}_3 - \text{SiO}_2 - \text{H}_2\text{O} - \text{CO}_2$ (and related subsystems), we assume that, during the regional metamorphism, temperatures of about 600 – 620°C and a water vapour pressure of about 6 kb were realized in part of the Hunza area. The gas phase must have contained roughly 20 mole-% of CO_2 . Thus the total fluid pressure may have reached about 7 kb. Presumably, temperatures increased in northwest direction, perhaps up to about 700°C. The estimated P-T conditions are consistent with a geothermal gradient of about 25°C/km.

Key words: Paragenesis, geothermobarometry, petrogenesis, corundum, marble, Hunza.

O/20. Oldham, R.D., 1884. On the re-discovery of certain localities for fossils in the Siwalik beds. Geological Survey of India, Records 17, Part 2.

Key words: Paleontology, fossils, Siwaliks.

O/21. Oldham, R.D., 1887. Notes on some points in Himalayan geology. Geological Survey of India, Records 20 (4), 155-161.

Key words: Himalayan geology.

O/22. Oldham, R.D., 1888. Some notes on the geology of the North West Himalayas. Geological Survey of India, Record 21(4), 149-159.

Key words: Himalayan geology.

O/23. Oldham, R.D., 1891. Preliminary report on the oil locality near Moghal Kot in the Shirani country, Sulaiman Hills. Geological Survey of India, Records 24(2), 83-84.

Key words: Hydrocarbons, Shirani area, Sulaiman Hills.

O/24. Oldham, R.D., 1893. Encyclopedia of Indian geology. 2nd edition, Government of India Press, Calcutta, 543p.

This is an edited and revised version of the manual of Indian geology by H.B. Medlicott and W.T. Blanford (1879-1887). It is based on all the data (essentially generated by the Geological Survey of India) up to 1892. The two volumes comprise 19 chapters containing many tables, 19 illustrations and 27 figures. The various chapters are titled as: I. Physical geography, II. Metamorphic and crystalline rocks, III. Transition systems, IV. Older Paleozoic (Cuddapah and Vindhyan) systems of the peninsular, V. older Paleozoic systems of the extra peninsular area, VI. Carboniferous and Triassic rocks of extra peninsular India, VII. The Gondwana system, VIII. Homotaxis of the Gondwanic system, IX. Marine Jurassic rocks, X. Marine Cretaceous of the Indian Peninsula, XI. Deccan trap, XII. Cretaceous rocks of the extra peninsular India, XIII. Tertiary deposits, XIV. Tertiary of the Himalayas, XV. Laterite, XVI. Pleistocene and recent deposits, XVII. The Indo-Gangetic plane, XVIII. The age and origin of the Himalaya, XIX. Geological History of the Indian Peninsula. These are followed by 14 pages of subject index. References to source literature are given in foot notes. Available information of the geology of the area of our compilation has been included. This manual is a valuable compilation and easy reference to the earlier publications of the GSI.

Key words: Books, geology, India.

O/25. Oldham, T., 1868. Memorandum on the results of cursory examination of the Salt Range and parts of the Districts of Bannu and Kohat, with a special view to the mineral resources of those districts. Selection from the Records of the Government of India, 64, 126-156.

Key words: Mineral resources, Salt Range, Bannu, Kohat.

O/26. Oldham, T., 1882. Thermal springs of India. Geological Survey of India, Memoirs 19(2), 63p.

No abstract could be obtained by the authors about this account. But other authors (e.g. THERMAL SPRINGS OF DAKSHINA KANNADA - K.R. Chandrashekar, K.R. Sridhar, M. Rajashekar and K.M. Kaveriappa, Indian Institute of Science 2000) have referred to Oldham, T. as follows.

T. Oldham, a veteran geologist, catalogued the thermal springs of India as early as 1882. He located a thermal spring in a remote and inaccessible part of Puttur taluk in South Kanara district (cf. Radhakrishna, 1971). This spring, referred to as "Bendre Thirtha" by the locals, is located on the south bank of the Badantadka river, which emerges after the confluence of two tributaries, Balakku and Ermati (12° 43' N, 75° 13' S) (Fig. 1). The spring is located on a private areca garden. There are very few trees surrounding the spring viz., *Ficus benghalensis* L., *Mangifera indica* L., *Artocarpus heterophyllus* Lam., *Cocos nucifera* L., and *Areca catechu* L. Waring (1965) referred to the existence of this spring in U.S.G.S. Publication "Thermal springs of the United States and other countries of the world". Radhakrishna (1971) was impressed by a beautiful description of this spring in the Kannada novel "Karulina Kare" written by the noted Kannada writer Dr. Shivarama Karanth who had woven a beautiful story around this thermal spring. He carried out preliminary investigations on the geology of this thermal spring. Later, Chandrashekar et al. (1991) did some investigations on the aquatic hyphomycetes occurring in this spring.

Key words: Thermal Springs, India

O/27. Olson, T.M., 1982. Sedimentary tectonics of the Jalipur sequence, northwest Himalaya, Pakistan. M.A. Thesis, Dartmouth College, Hanover, New Hampshire, 152p.

This is a study of the young molasse sediments along the Indus River on the western flank of the Nanga Parbat massif. These rocks are dominantly immature sandstones with fragments of metamorphic rocks and feldspar derived from the massif and mafic rocks of the Kohistan arc. The observed tectonic deformation is interpreted as gravity collapse structures induced by uplift of the adjacent massif. Extensive soft sediment deformation, sandstone dikes, and deposits representing catastrophic events suggest deposition of the units of the sequence in an active tectonic environment. The presence of the once-buried Jalipur sequence and the overlying undeformed sediments on the flanks of the rapidly uplifting Nanga Parbat massif suggests that uplift is sporadic rather than continuous uplift would inhibit accumulation of a significant amount of sediment.

The Jalipur sequence consists of a series of alluvial fan, lacustrine, and braided stream deposits in the middle Indus Valley in the northwest Himalaya. Units in the sequence are similar in character to recent sedimentary deposits but have undergone extensive deformation. Stratigraphic relationships indicate a very young age for the sequence a conclusion which was suggested previously by fission-track dating of detrital zircons from a sandstone unit in the sequence.

The intermontane setting of the deformed sedimentary sequence and the proximity of the sequence to a branch of the Himalayan suture zone provided the initial framework for the study of these late-orogenic sedimentary rocks. Recent work on regional thermal history has indicated that the dominant structural element of the region, the Nanga Parbat- Haramosh Massif, is undergoing very rapid uplift.

A geologic map of the region was produced through a combination of field mapping and computer classification of digital Landsat spectral data. The dual approach to mapping proved effective in this area,

where ground access is difficult and air photographs and accurate topographic maps are not readily available.

No coherent structural style, such as might be expected in a thrust-dominated suture zone setting, is apparent in the deformation of the young Jalipur sequence. The observed tectonic deformation is interpreted as gravity collapse structures induced by uplift of the adjacent massif. Extensive soft sediment deformation, sandstone dikes, and deposits representing catastrophic events suggest deposition of the units of the sequence in an active tectonic environment.

Sandstones in the sequence are immature and contain large amounts of metamorphic rock fragments and feldspar grains. The petrology and heavy mineral compositions of these sandstones indicate that the detrital components were locally derived; sandstone composition was strongly influenced by the granitic rocks and metasediments of Nanga Parbat and by pyroxene granulite, the other major local bedrock type. The degree of lithification and the microstructures are evidence for some degree of burial of the sequence.

The presence of the once-buried Jalipur sequence and the overlying undeformed sediments on the flanks of the rapidly uplifting Nanga Parbat massif suggests that uplift is sporadic rather than continuous uplift would inhibit accumulation of a significant amount of sediment.

Key words: Sedimentation, tectonics, Quaternary, Jalipur, Chilas, NW Himalaya.

O/28. Omodei, D., 1911. Relazione sulle osservazioni meteorologiche fatte dalla spedizione S.A.R. il Duca degli Abruzzi nel Karakoram ed Imalia Occidentale e calcoli altimetrici. In: F. De Filippi. La Spedizione di S.A.R. il Principe Luigi Amedeo e calcoli altimetrici.

Key words: Meteorology, altimetry, Italian expedition, Karakoram.

O/29. Opdyke, N.D. (ed.), 1982. The geochronology and biochronology of the Siwalik Group, Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 37, 1-130.

Key words: Geochronology, paleomagnetism, Siwaliks.

O/30. Opdyke, N.D., et al., 1977a. The magnetic polarity stratigraphy of the Upper Siwalik sediments of northeast Pakistan and the age of the transition between Pinjore and Tatrot land mammal faunas. *Geological Society of America Abstract with Program*, 9, 1120-1121.

Key words: Paleomagnetism, Upper Siwaliks, Potwar, Kashmir.

O/31. Opdyke, N.D., Johnson, N.M., Johnson, G.D., Lindsay, E.H. & Tahirkheli, R.A.K., 1977b. Paleomagnetism of the Upper Siwalik sediments of Pakistan. *Transactions American Geophysical Union*, 58, p.379.

Key words: Paleomagnetism, Upper Siwaliks, Pakistan.

O/32. Opdyke, N.D., Johnson, N.M., Lindsay, E.H. & Johnson, G.D. & Tahirkheli, R.A.K., 1982. Paleomagnetism of the middle Siwalik formations of northern Pakistan and rotation of the Salt Range decollement. *Palaeogeography, Palaeoclimatology, Palaeoecology* 37, 1-15.

Sampling for paleomagnetic study has been carried out at seven localities in the Potwar Plateau region of Pakistan in the vicinity of the Salt Range. In all, 253 sites, consisting of three samples per site, were studied. The sites were taken from the Chinji, Nagri, Dhok Pathan and Upper Siwalik formations which span the last 14 m.y. of Earth history. The formations have been deformed in the ongoing Himalayan orogeny and are exposed today in sections which dip at angles of from 10° to 90° in different directions.

A characteristic direction of magnetization was isolated at all sections by thermal demagnetization at temperatures of from 550° to 650°C. The sediments have been folded within the last 2 m.y. and because of a positive fold test it can be shown that the characteristic magnetization of these sediments was acquired before folding. Four of the sections have directions of magnetization which have been rotated in a counter-clockwise fashion up to 40°; however, sections taken along the Indus River, the north flank of the Soan syncline and the south flank of the Salt Range show small counter-clockwise rotations of under 10°. These observations are in agreement with previous suggestions that strata in the Salt Range have been moved to the south and rotated in a counter-clockwise fashion. The observations reported here indicate that the paleomagnetic poles derived from Cambrian and Permian formations within the Salt Range have probably also suffered rotation and should be removed from consideration in Gondwanaland reconstruction of the Paleozoic.

Key words: Paleomagnetism, structure, Siwaliks, Northern Pakistan.

O/33. Opdyke, N.D., Lindsay, E.H., Johnson, G.D., Johnson, N.M., Tahirkheli, R.A.K. & Mirza, M.A., 1979. Magnetic polarity stratigraphy and vertebrate paleontology of the Upper Siwalik Sub Group of northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 27, 1-34.

Two hundred and fifty three sites consisting of three samples per site were taken from eight separate stratigraphic sections from sediments of the Upper Siwalik subgroup of northern Pakistan. All samples have been partially demagnetized in alternating fields of from 150 to 300 °c. The sediments are dipping at angles of up to 75° in a variety of directions, and the locality mean directions improve significantly after correcting for bedding attitude, providing a statistically significant fold test at the 95% level.

The magnetic stratigraphy was obtained based on the statistically significant well-grouped partially demagnetized data. Two prominent bentonitized tuffs occur in several sections above and below a prominent reversal of the earth's magnetic field. Radiometric dates of 2.3 ± 0.4 m.y.B.P. and 2.5 ± 0.4 m.y.B.P. have been obtained by fission track on zircons from these tuffs. This allows the magnetic stratigraphy to be correlated to the standard reversal chronology of the Pliocene and Pleistocene. The longest stratigraphic section (1.87 km in thickness) can be shown to span the time between 0.6 m.y.B.P. and 5.5 m.y.B.P.

The individual stratigraphic sections can be correlated on the basis of magnetic stratigraphy. All sections contain important vertebrate fossil localities which can be placed relative to each other in the time stratigraphic framework provided by the magnetic stratigraphy.

The change from the Pinjor fauna to the Tatrot fauna occurs at about 2.47 m.y.B.P. (the Gauss/Matuyama boundary) based on the simultaneous occurrence of *Equus*-*Elephas*, *Bos* and cervids with antlers. *Hipparion*, the three-toed horse, persists to the lowermost Pleistocene just after the termination of the Olduvai event. The ranges of other important vertebrate faunas are also discussed.

The folding of the eastern Salt Range has been very recent, beginning within the Brunhes normal magnetic epoch, since sediments of lower Brunhes age are folded on the flanks of the Pabbi and Rohtas anticlines and on the flanks of Chambal Ridge. The rate of uplift of these structures above the present base level is estimated to have a minimum rate of four meters per thousand years for the Rohtas anticline and three meters per thousand years for the Pabbi Hills. The rates of subsidence (i.e., rates of sedimentation) of the various sections are estimated to range from 0.35 m/103 yr to 0.50 m/103 yr. The first occurrence of conglomerate-containing clasts derived from the Himalayan uplift occurs just prior to the Olduvai event at the base of the Pleistocene.

Key words: Vertebrate paleontology, stratigraphy, Siwaliks.

O/34. Orlando, M. & Laffi, F., 1985. K2 La montagna degli italiani. Ed. Yak, 240p. Fiesse d'Artico.

Key words: K2, Karakoram.

O/35. Osmaston, H.A., 1986. The Siachen and Terong Glaciers, East Karakoram. *Himalayan Journal* 42, 87-96.

Key words: Glaciers, Siachen, Terong, Karakoram.

O/36. Oswald, G.K.A., 1984. Ice-depth echo-sounding techniques employed on the Hispar and Ghulkin glaciers. In: Miller, K.J. (ed.), *The International Karakoram Project*, Volume 2, 86-99. Cambridge University Press.

The impulse radar technique used originally to sound the temperate Vatnajökull, Iceland ice cap and successfully employed on the Hispar and Ghulkin glaciers during the Karakoram Project is reviewed. Possible improvements to the system are discussed, with particular reference to the transmitting and receiving systems and to their implementation in the 'Subscan' impulse radar system. Attention is given to techniques for integrating successive output signals in order to reduce the effective noise level, and the statistical theory of a fast and simple digital integration technique is given. A brief description of the Subscan digital signal discrimination and recording systems concludes the paper.

Key words: Glaciers, Hispar, Gulkin, Karakoram.

O/37. Ottiger, R., 1985. Rocks of the Murree Formation: indicators of a descending foreland basin of lower to middle Eocene age. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The red clastic sand and shale deposits of the Murree Formation have been regarded as continental deposits of Miocene age. A new and more detailed sedimentological and micropaleontological survey on a profile of fifteen-kilometer length, in the apex region of the Hazara-Kashmir Syntaxis in Northern Pakistan, has shown that these rocks were deposited in a very shallow marine (sub-supratidal) environment, on a 5tidal flat. This hypothesis is based on a reinterpretation of the cyclic sedimentation seen in these rocks. One can interpret a single cycle as the product of meandering tidal channels in a continuously descending foreland basin. Each cycle starts with typical channel fill deposits (microconglomerates, crossbedded sandstone) and passes upwards into tidal flat deposits (laminated and strongly bioturbated sand and siltstones). The uppermost part of a cycle is composed of red clayey silt with local horizons containing calcareous concretions and which are interpreted as a type of fossil Caliche. Evidence is presented that the formation of single cycle, of an average thickness of ten meters, lasted about 8-10000 years. It would take about 13.5 million years for the deposition of the complete fifteen-kilometer thick sequence. This deduction fits very well with age determination based on syndeositional Nummulites and Assilines. These fossils indicate an age of upper Illerdien (lowermost Eocene) at the base of the Murree Formation (Balakot region) and upper middle Lutetien at Kawal, at a position some two thirds from the base of the profile. In the North, the Murree Formation is therefore much older than it is in the South (Kohat, Potwar) where data suggest a lower Miocene age.

Key words: Foreland basin, Eocene, Murree formation.

O/38. Ottiger, R., 1986. Einige Aspekte der Geologie der Hazara-Kashmir Syntaxis (Pakistan). Dissertation ETH Nr. 8083, Zurich.

Key words: Hazara Kashmir syntaxis, geology.

O/39. Owen, L.A., 1988a. Terraces, uplift and climate, the Karakoram Mountains, Northern Pakistan: Ph.D. thesis, Univ. Leicester, 399p.

For some information readily available, see Owen, 1989.

Key words: Terraces, climate, uplift, sedimentation, geomorphology, Karakoram.

O/40. Owen, L.A., 1988b. Wet-sediment deformation in Quaternary and recent sediments in the Skardu Basin, Karakoram Mountains, Pakistan. In: Croot, D. (ed.), *Glaciotectonics*. Balkema, Rotterdam, 123-147.

Key Words: Sedimentation, deformation, Quaternary, Skardu basin, Karakoram.

O/41. Owen, L.A., 1989a. Neotectonics and glacial deformation in the Karakoram Mountains and Nanga Parbat Himalaya. *Tectonophysics* 163, 227-265.

The Karakoram Mountains and the Nanga Parbat Himalaya are one of the most rapidly rising mountain areas in the world with uplift rates in the order of 2 mm/yr. Large-scale regional warping is the most likely form of uplift with the greatest rates around the Nanga Parbat-Haramosh Massif. Only two active faults have been recognised in the Pakistan Karakoram, the Rakhiot and the Misgar valley fault. The Rakhiot fault zone is a neotectonic expression of the rapid uplift centred around the Nanga Parbat syntaxis. Deformation structures in Quaternary and Recent sediments in the Rakhiot area are not produced solely by neotectonic processes but also by processes in the glacial depositional environment and slope related processes. Structures present vary from neotectonic shear zones, folds, thrusts and high-angled faults; glacially produced folds, thrusts, shears and joints; and debris slides bounded by discrete shear zones. The distinction between these structures is vital in making valid neotectonic models for high active mountain belts.

Key Words: Neotectonics, glaciation, deformation, Karakoram.

O/42. Owen, L.A., 1989b. Terraces, uplift and climate in the Karakoram Mountains, Northern Pakistan: Karakoram intermontane basin evolution. In: Derbyshire, E. & Owen, L.A. (eds.), *Quaternary of the Karakoram and Himalaya*. *Zeitschrift fur Geomorphologie* 176, 117-146.

Key Words: Tectonics, uplift, geomorphology, Karakoram, Himalaya.

O/43. Owen, L.A. 1991. Mass movement deposits in the Karakoram Mountains and western Himalayas. *Zeitschrift fur geomorphologie* 35, 401-424.

Mass movement is a major process in the valleys of the Karakoram Mountains. Here very long and steep slopes, resulting from tectonically induced fluvial and glacial incision, and intense weathering help induce slope failure. These include rockfalls, avalanche, debris slides and rockslides, creep, rotational slips, debris flows and flowslides. Processes vary in scale from isolated small failures to extensive areas of complex movements. The most common and important processes are debris flows and flowslides. Sediments deposited by these processes are highly variable, consisting dominantly of coarse diamictos. These form a major component of the valley fills which frequently exceed several hundreds of metres in thickness. Distinctions between the different debris deposits and landforms are difficult to make in the Karakoram Mountains because of the polygenetic origin of many of these mass movement sediments.

However, distinctions can be made using their sedimentary characteristics including: sedimentary structures, microstructures, grain size characteristics, clay mineralogy, degree of compaction and petrology. Correct identification of sediments is particularly important in reconstructing accurate Quaternary histories and palaeoenvironments. Many of these deposits have originated from the resedimentation of glacial and non-glacial diamictos by debris flow and flowslide processes. A major phase of resedimentation occurred soon after the last major glaciation in the Karakoram Mountains (c. 50,000 years B.P.) resulting in thick deposits and creating many of the present valley landforms, such as fans and terraces. These processes are important in reconstructing the evolution of the Karakoram landscape.

Key Words: Mass movement, Karakoram.

O/44. Owen, L.A. 1993. Glacial and non-glacial diamictos in the Karakoram Mountains. In: D. Crofts & W Warren (eds.), The deposition and deformation of tills. Balkema, Rotterdam, 9-29.

Key Words: Diamicton, deformation, Karakoram.

O/45. Owen, L.A. 1996a. High roads, high risks. The Geographical Magazine. 118. 12-15.

Key Words: Geomorphology, geohazards.

O/46. Owen, L.A. 1996b. Quaternary lacustrine deposits in a high energy semi-arid mountain environment, Karakoram Mountains, northern Pakistan. Journal of Quaternary Science, 11, 461-483.

Impressive Quaternary lacustrine deposits are present as terrace remnants throughout the Karakoram Mountains, northern Pakistan. They are mainly the result of damming of drainage systems during glacial advances or by catastrophic mass movement deposits. The longevity of most lakes is relatively short, in the order of years to tens of years, but sedimentation rates are extremely high as a consequence of the high sediment loads within the rivers. This results in deposits that frequently exceed 10 m in thickness. The sediments comprise dominantly planar bedded, massive and, less commonly, planar laminated, silts, comprising detrital quartz, feldspar, mica, calcite, chlorite and illite. A facies model for lacustrine sedimentation in a high energy semi-arid high mountain region is presented, using case studies from a glacially dammed palaeolake (Glacial Lake Gilgit) and a debris-flow dammed palaeolake (Lake Serat). The rapid deposition and absence of organic material restricts the usefulness of these lacustrine Sediments as proxies for palaeoenvironmental reconstruction, but they are helpful in reconstructing the former extent of glaciers and illustrating the importance of high-magnitude-low-frequency events, such as landsliding, as formative processes contributing to the evolution of the Karakoram landscape.

Key Words: Sedimentology, glaciation, landslide, dammed lakes, Karakoram.

O/47. Owen, L.A. & Derbyshire, E., 1988. Glacially deformed diamictos in the Karakoram Mountains, northern Pakistan. In: Crofts, D.G. (ed.), Glaciotectonics. Balkema, Rotterdam, 149-176.

Key Words: Glaciation, deformation, diamictites. Karakoram.

O/48. Owen, L.A. & Derbyshire, E., 1989. The Karakoram glacial deposition system. In: Derbyshire, E. & Owen, L.A. (Eds.), Quaternary of the Karakoram and Himalaya. Zeitschrift fuer Geomorphologie 76, 33-73.

The Karakoram glaciers are among the largest outside the polar regions. They are glaciologically complex with thick and steep glaciers of high activity Alpine type. Large quantities of debris are supplied to the surface of the ice by avalanching, with the result that the supraglacial debris path is dominant. Glacial deposits are thus deposited mainly by melt out with an important input from supraglacial sliding. The basal debris zone is relatively thin, and observed lodgement tills rarely exceed a few metres in thickness. Two main types of glaciers can be differentiated based on the landforms in their lower reaches:

1. Ghulkin type, dominated by ice-contact fan landforms;
2. Pasu type, dominated by hummocky moraines and glaciofluvial outwash plains.

Ancient examples of the glacial sediments and landforms and the sedimentary characteristics of these deposits are described. The sedimentary characteristics are used to compare the different types of tills and to compare sediments deposited during the Pleistocene with those of the Holocene.

Key Words: Glaciation, sedimentary deposits, geomorphology, Karakoram.

O/49. Owen, L.A. & Derbyshire, E. 1993. Quaternary and Holocene intermontane basin sedimentation in the Karakoram Mountains. In: Schroder, J.F. (ed.), *Himalayas to the Sea: Geology, Geomorphology and the Quaternary*, Routledge, London, 108-131.

Key Words: Sedimentation, intermontane basin, quaternary, Karakoram.

O/50. Owen, L.A., Derbyshire, E., White, B.J. & Rendell, H., 1992. Loessic silt deposits in the western Himalayas: their sedimentology, genesis and age. *Catena*, 19: 493-509

Loess is abundant in the foreland basins of the Himalayas. However, it is poorly developed within the intermontane basins of the western Himalayas and Karakoram. Selected sections were studied from the Swat Himalaya and the Karakoram Mountains. Fieldwork and sedimentological analysis including grain size, mineralogy and microfabric showed that the loessic sediments have been reworked and some have undergone weak pedogeneses. These silts are not true loess, rather a "loessic colluvium". Thermoluminescence (TL) dates from the loessic sediments in sections from the Swat valley provided younger ages than earlier workers had suggested. This is consistent with reworking of the loess in these areas. It is concluded that care must be taken when using loessic silts for TL in similar mountainous terranes.

Key Words: Loessic silt, sedimentology, thermoluminescence dating, intermontane basins, Swat.

O/51. Owen, L.A., Finkel, R.C., Caffee, M.W. & Gualtieri, L., 2001. Timing of multiple late Quaternary glaciations in the Hunza Valley, Karakoram Mountains, northern Pakistan: Defined by cosmogenic radionuclide dating of moraines. *Geological Society of America Bulletin* 114(5), 593-604.

Moraines and associated landforms in the upper Hunza Valley, Karakoram Mountains, northern Pakistan, provide an excellent record of multiple glaciations. During the late Quaternary, glaciers advanced at least eight times. By using ^{10}Be and ^{26}Al surface-exposure dating on moraine boulders and scoured bedrock, we determined the timing of glaciation for four of these glacial advances: ca. 54.7–43.2 ka (Borit Jheel glacial stage), ca. 25.7–21.8 ka (Ghulkin I glacial stage), ca. 18.4–15.3 ka (Ghulkin II glacial stage), and ca. 10.8–9.0 ka (Batura glacial stage). For two of the older advances, the Yunz and Shanoz glacial stages, our data set a limit of >60 ka. Although, at present, the uncertainties in dating make it impossible to describe unequivocally the climate processes controlling glaciations in the Hunza Valley, the results suggest that precipitation changes related to oscillations in the southwest Asian monsoonal system combine with cooling that is broadly associated with Heinrich events to cause glacial advances in this region.

Key Words: Glaciation, Late Quaternary, Hunza, Karakoram.

P/1. Paar, W. & Ruschka, S., 1977. Ein vorkommen von alumohydrocalcit von Chitral, West Pakistan, und neue beobachtungen an chrome haltigem alumohydrocalcit von Nowej Rudy, Polen (= Neurode, Schleisen). *Der Aufschluss* 28, 269-272.

Mineralogical information about alumohydrocalcite mineral from Chitral is provided. The mineral is compared with newly discovered chrome-containing alumohydrocalcite of Poland.

Key word: Hydrocalcites, mineralogy, Chitral, Poland.

P/2. Paffen, K.H., Pillewizer, W. & Schneider, H.J., 1956. Forschungen im Hunza-Karakorum. *Erdkunde* 10(1), 1-33.

Key word: Hunza, Karakoram.

P/3. Paganini, P., 1912. Relievi fotogrmetrici nella regione del Karakoram, eseguiti dalla spedizione di S.A.R. il Duca degli Abruzzi. *Boll. Soc. Geogr. Ital., Ser. V, I, (8)*, 819-840, (9) 947-965.

Key words: Photogrammetry, Karakoram.

P/4. Page, N.J., Haffty, J. & Ahmad, Z., 1979. Platinum, palladium and rhodium concentrations in mafic and ultramafic rocks from the Zhob Valley and Dargai Complexes, Pakistan. *U.S. Geological Survey Professional Paper 1124F*, 1-6.

This is an earlier study of mafic-ultramafic rocks from Zhob and Dargai, two of the largest ophiolite occurrences of Pakistan. Analytical data are presented for Pt, Pd and Rh in the rocks.

Key word: Ultramafics, platinum, palladium, Zhob, Malakand.

P/5. Pakistan Council of Scientific and Industrial Research 1963. Properties of some Pakistani bentonites. *Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore*, 161-165.

Key word: Industrial rocks, Bentonite.

P/6. Pakistan-Japanese Working Group 1981. Stratigraphy and correlation of the Marine Lower Triassic in the Surghar Range and Salt Range, Pakistan. *Memoir Faculty of Science, Kyoto University, Series Geology and Mineralogy*, 25p.

Key word: Stratigraphy, Surghar Range, Salt Range, Triassic.

P/7. Pakistani-Japanese Research Group 1985. Permian and Triassic systems in the Salt Range and Surghar Range, Pakistan. In: Nakazawa, K. & Dickins, J.M. (Eds.), *The Tethys - Her paleogeography and paleobiogeography from Paleozoic to Mesozoic*. Tokai University Press, Japan, 221-312.

Key word: Stratigraphy, Surghar Range, Salt Range, Permian, Triassic.

P/8. Palmer-Rosenberg, P.S., 1985. Himalayan deformation and metamorphism of rocks south of Main Mantle Thrust zone, Karakar Pass area, southern Swat, Pakistan. *M.S. Thesis, Oregon State University, Corvallis*, 67p.

The Swat and northern Buner area to the south of the Main mantle thrust is occupied by Precambrian metasedimentary rocks with intrusions of granitoids. These rocks have passed through episodes of deformation and metamorphism. This thesis describes Himalayan orogeny related metamorphism and deformation in the rocks.

Key word: Deformation, metamorphism, MMT, Karakoram pass, Swat, Buner.

P/9. Pan, Y., Zheng, D. & Zhang, Q., 1992. Introduction to integrated scientific investigations on Karakorum and Kunlun mountains. China Meteorological Press, Beijing.

This is a summarized account of the geology and geography of the Kunlun Mountain, and the northern flank of the Karakorum Range in China. The Khunjerab area is shown to be occupied by Late Mesozoic rocks. The Yanshanian granitoid at Khunjerab is reported to have a U-Pb age of 104 Ma. Bodies of similar granitoids are shown to occur up to 250 km to the north.

Key words: Geology, geography, Kunlun, Karakoram

P/10. Pande, K., Sarin, M.M., Trivedi, J.R., Krishnaswami, S. & Sharma, K.K., 1994. The Indus Rivers system (India-Pakistan): Major-ion chemistry, uranium and strontium isotopes. *Chemical Geology* 116, 245-259.

The Indus River is one of the large river systems draining the Himalaya. We report in this paper the major-ion chemistry, Sr and U isotope systematics of the Indus system, particularly its headwaters. The results show that: (1) on an average about a third of the cations in the waters can be from silicate weathering; however, most of the (Ca + Mg) is likely to be from the weathering of carbonates and evaporites; (2) the $^{87}\text{Sr}/^{86}\text{Sr}$ of the waters ranges between 0.7085 and 0.7595, the higher values (> 0.72) are typical of the tributaries draining the Precambrian granite/gneissic terrains. The $^{87}\text{Sr}/^{86}\text{Sr}$ of the Indus main channel, throughout its entire stretch, shows only minor variations, 0.7104–0.7116. The Indus transports $\sim 8.8 \cdot 10^6$ mol Sr to the Arabian Sea annually with a $^{87}\text{Sr}/^{86}\text{Sr}$ of 0.7111 if our results of Sr concentration and $^{87}\text{Sr}/^{86}\text{Sr}$ measured at Thatta can be considered typical of the Indus throughout the year; and (3) the U concentration in the Indus and its tributaries is generally high, 0.37–10.3 $\mu\text{g l}^{-1}$. The source for the high uranium can be the weathering of granites, zones of uranium mineralisation and black shales.

The Indus results when compared with our earlier data on the Ganga-Brahmaputra show that in all these three river systems carbonate weathering is the dominant source of (Ca + Mg) and HCO_3^- and that U concentrations are high. In the case of $^{87}\text{Sr}/^{86}\text{Sr}$, the Indus waters are less radiogenic; however, its tributaries draining the Precambrian granites/gneisses have $^{87}\text{Sr}/^{86}\text{Sr}$ in excess of 0.72, similar to that in the rivers of the Ganga system. The low $^{87}\text{Sr}/^{86}\text{Sr}$ of the Indus, 0.7111, suggests that its contribution to the Sr isotope evolution of oceans since the Cenozoic is less significant than that of the Ganga-Brahmaputra.

Key word: Hydrochemistry, U and Sr isotopes, Indus River.

P/11. Papritz, K., 1989. The Geology of the Kaghan Valley (NE-Pakistan): Aspects of Tectonics, Metamorphism and Geochemistry. Master's Thesis, ETH, Zurich, 143p.

Key word: Tectonics, metamorphism, geochemistry, Kaghan valley, Himalaya.

P/12. Papritz, K. & Rey, R., 1989. Evidence for the occurrence of Permian Panjal trap basalts in the lesser- and higher-Himalayas of the Western Syntaxis area, NE Pakistan. *Eclogae Geologicae Helveticae* 82, 603-627.

The Panjal volcanics of Permian age constitute a prominent belt in western Kashmir. This work provides evidence for their occurrence in the Hazara-Kashmir syntaxial area and surroundings.

Key word: Panjal volcanics, Permian, Hazara-Kashmir syntaxis, Himalaya.

P/13. Paracha, M.H., Unwar, K. & Fazle, R., 1976. Groundwater conditions in Yar Hussain unit of Mardan District. M.Sc. Thesis, Peshawar University.

Key word: Hydrology, groundwater, Mardan.

P/14. Paracha, W., Kemal, A. & Abbasi, F., 2000. Kohat duplex in northern Potwar Deformed Zone, Pakistan. *Geologica* 5, 99-107.

Key word: Deformation, structure, Potwar, Kohat.

P/15. Park, S.K. & Mackie, R.L., 1997. Crustal structure at Nanga Parbat, northern Pakistan, from magnetotelluric soundings. *Geophysical Research Letters* 24(19), 2415-2418.

A magnetotelluric survey in northern Pakistan contains effects from both 2D and 3D structure. Identification of the effects of the sediments along the Indus River valley using 3D modeling permitted the selection of modes that could be accurately inverted with 2D inversions. The resulting 2D model reveals generally resistive ($> 500 \text{ km}$) upper crust (0–8 km), a more conductive (30–50 km) middle to lower crust (8–40 km), and a resistive ($> 300 \text{ km}$) upper mantle. Shallow crustal ($< 10 \text{ km}$) conductors correlate with a hydrothermally altered fault zone and/or carbonaceous metamorphic rocks near the Raikot fault. A prominent midcrustal conductor located beneath Nanga Parbat is required to fit the data, but its depth, dimensions, and conductivity are poorly constrained by existing data.

Key word: Sediments, magnetotelluric study, structure, Nanga Parbat, Himalaya.

P/16. Park, S.K. & Mackie, R.L., 1998. Lack of crustal fluids beneath Nanga Parbat, northern Pakistan: Results from magnetotelluric soundings. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 146.

The Nanga Parbat-Haramosh Massif (NPHM) in the Himalaya of northern Pakistan is a finger of Indian crust extending northward into the Kohistan-Ladakh island arc. Collision between Kohistan and the Indian plate about 55 Ma along the Main Mantle Thrust (MMT) placed plutonic and high-grade metamorphic rocks of Kohistan above the Indian plate. In the past 10 M.y., differential erosion of NPHM has exposed the underlying Indian crust. Recent and rapid denudation has provided a unique glimpse into modern reworking of old continental lithosphere by metamorphic processes and partial melting. As part of a multidisciplinary study of NPHM, a magnetotelluric (MT) study was conducted to determine the distribution of fluids and partial melt in the crust. Mafic partial melts, water-saturated silicic melts, brines and metamorphic or igneous waters, metallic solid phases, and graphite are all capable of increasing the conductivity of the crust and upper mantle.

This MT study was interpreted with both 2-D and 3-D models to account for the complex geology and physiography. North of Nanga Parbat in Kohistan, the upper crust (0-8 km) is generally resistive ($> 500 \text{ ohm-m}$), the middle to lower crust (8-40 km) is generally conductive (30-50 ohm-m), and the upper mantle is again resistive ($> 300 \text{ ohm-m}$). This structure is reminiscent of the typical continental crust in which the generally conductive middle layer reflects fluids trapped in the ductile region of the crust and is similar to the structure seen on the INDEPTH profile of Tibet. Immediately north of Nanga Parbat, the Raikot fault is imaged to depths of 8-10 km as a vertical, tabular conductive body. The high conductivity of the fault is attributed to fluids migrating along the fault zone and to hydrothermal alteration. South of Nanga Parbat, the MT data show a moderately conductive region at midcrustal levels which appears to match a shear zone mapped by geologists. The shear zone is likely conductive because it offers a more porous conduit for fluid migration; hydrothermal alteration is seen in the zone in the eastern end of Rupal Valley.

There is no evidence of conductive bodies beneath the Nanga Parbat peak between Fairy Meadows and Rupal Valley to depths of at least 50 km. The data are matched instead by very high resistivities ($> 5000 \text{ ohm-m}$) indicative of igneous and/or high-grade metamorphic rocks. If magma is present beneath Nanga Parbat, then it must be the result of water-unsaturated partial melting of continental crust (which would result in high resistivities). The simpler interpretation is that magma is not present, however.

Key word: Magnetotelluric studies, structure, MMT, Nanga Parbat, Himalaya.

P/17. Park, S.K. & Mackie, R.L., 2000. Resistive (dry?) lower crust in an active orogen, Nanga Parbat, northern Pakistan. *Tectonophysics* 316, 359-380.

Conductivity models beneath the Nanga Parbat Haramosh Massif (NPHM) derived from magnetotelluric soundings reveal that there is no widespread, interconnected, conductive aqueous fluid to minimum depths of 40 km below sea level. Given the continuing tectonic denudation, young granitic and migmatic bodies indicating partial melt at shallow crustal depths, and active seismicity, this result is surprising in light of similar studies in active tectonic regimes elsewhere. Away from the NPHM, models reveal the usual conductive lower crust. We propose that deep magmatic and metamorphic fluids are produced beneath NPHM in isolated zones but that the active deformation permits their escape through the brittle-ductile transition. A magnetotelluric survey in an area as complicated as Nanga Parbat required the development of methodologies for utilizing standard two-dimensional inversions in a three-dimensional environment. We show here how to identify which parts of the magnetotelluric responses are adequately represented with two-dimensional approximations. Unlike previous efforts, we do not attempt to create a set of generic rules that may be applicable to all geologic environments. Instead, a procedure is outlined that can be tailored to each interpretation. One important result of this work is that magnetotelluric data along a profile can be used to constrain structure off the ends of the profile.

Key word: Geophysics, tectonics, granites, Nanga Parbat, Himalaya.

P/18. Parker, N.A., 1968. Lightweight aggregate as a potential industry for Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-48, 11p.

A common characteristic of growing economics throughout the world is the ever increasing demand for all kinds of construction materials, at which sand, gravel, and crushed stone play a most important part. Increasing sophistication in building, and structural designs, in turn demands more exacting specifications in aggregate (sand, gravel, and crushed stone mixtures) requirements for concrete; furthermore in the construction of large buildings, reduction in weight, through the use of light-weight but strong aggregate, becomes important.

In East Pakistan the topography and geology is such that rock suitable for concrete aggregates is in limited supply. In such areas where the natural material or aggregate are lacking but where clay, shale, and slate are present the development of a light weight (synthetic) aggregate industry offers a mean of supplying much of the demand.

In 1971, a chemist by the name of Hayde found that by heating certain clays, shales and slates to incipient fusion he was able to produce an extremely light weight material of high strength and excellent insulation properties. By reason of patent held by Mr. Hayed, only seven plants were licensed under the "Haydite" patent, and the industry did not develop extensively until the expiration of basic license.

Key word: Light weight aggregate, clay, sand.

P/19. Parona, C.F., 1917. Faune Cretaciche del Caracorum e degli altipiani Tibetane. *Rendiconti della Reale Accademia Nazionale dei Lincei*, Series 2(26), 53-57.

Key word: Fauna, Cretaceous, Karakoram.

P/20. Parona, C.F., 1928. Faune Cretaciche del Caracorum e degli altipiani Tibetane. In: *Realizioni Scientifiche della Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan Cinese (1913-1914)*, Series 2(6), 3-39. Zanichelli, Bologna.

Key word: Fauna, Cretaceous, Karakoram, Tibet.

P/21. Parona, C.F., 1932. Appunti su fossili raccolti sul Caracorum durante le esplorazioni F.de Filippi (1913-14) e Giotto Dainelli (1930). *Atti della Reale Accademia delle Scienze dei Torino* 3, 179-193.

Key word: Fossils, Cretaceous, Karakoram.

P/22. Parona, C.F., 1933. Alcuni fossili raccolti al Caracorum da G. Dainelli. In: Realizzazioni Scientifiche della Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turchestan Cinese (1913-1914), Series 2(11), 127-140. Zainchelli, Bologna.

Key word: Fossils, Cretaceous, Karakoram.

P/23. Parrish, R.R. & Tirrul, R., 1989. U-Pb age of the Baltoro granite, northwest Himalaya, and implications for monazite U-Pb systematics. *Geology* 17(12), 1076-1079.

The Baltoro granite is a major late- to post-tectonic plutonic phase of the Karakoram batholith of the northwest Himalaya in northern Pakistan. U-Pb zircon analyses indicate both emplacement at 21.0 ± 0.5 Ma and significant Precambrian zircon inheritance. Dates on monazite are 17-19 Ma and are interpreted to have remained near their closure temperature of about 700 °C for several million years after emplacement, resulting in Pb loss by diffusion. We suggest that the granite was emplaced into rocks which were at high temperature and that they remained so until late Miocene northeast-tilting, rapid uplift and/or tectonic denudation, and cooling.

Key word: Geochronology, U-Pb dating, granite, Baltoro, Himalaya.

P/24. Parrish, R.R., Tirrul, R., Rex, D.C., Rex, A.J. & Searle, M.P., 1988. U-Pb and ^{40}Ar - ^{39}Ar geochronology and evolution of the Karakoram batholith, Northern Pakistan. Abstracts, 4th Himalaya-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.13.

Key word: Geochronology, U-Pb dating, Ar-Ar dating, Karakoram batholith.

P/25. Parsons, E., 1926. The structure and stratigraphy of the north-west Indian oilfields. *Journal of the Institute of Petroleum Technology* 12, 439-505.

This account includes the structure and stratigraphy of the old oil fields of NW India. These include those to the north of the Salt Range in the present day Pakistan.

Key word: Structure, stratigraphy, oilfields, Punjab, India.

P/26. Pascoe, E.H., 1919. The early history of the Indus. Brahmaputra and Ganga. *Quarterly Journal of the Geological Society of London* 75, 138-157.

The ideas expressed in this paper are the outcome of a study of the Punjab oil-belt. The principal hypothesis proposed has been advanced simultaneously by Dr. H. G. E. Pilgrim. F.G.S., in a paper still in manuscript, to explain the formation of the Siwalik boulder-conglomerates. That paper will, I hope, soon be published, but I have taken the liberty of following up an interesting point to which Dr. Pilgrim has drawn attention: namely, the frequent V-shaped course of the north-bank tributaries of the Ganges where they leave the belt of Siwalik deposits.

Briefly, the hypotheses that I desire to bring forward may be summarized as follows:—

(i) That in Eocene times a gulf extended from Sind northwards as far as Afghanistan, and thence curved eastwards and south-eastwards through Kohat and the Punjab to the neighbourhood of Naini Tal.

(ii) That this gulf gave place to a great river, the head-waters of which consisted of the portion of the Brahmaputra flowing through Assam. This river flowed westwards and north-westwards along the foot of the Himalaya as far as the North-West Punjab, where it turned southwards along a line not very different from that of the modern Indus, and emptied itself into the Arabian Sea. In other words, the Assam Brahmaputra was once the head- waters of the Indus.

(iii) That two separate rivers or two branches of the same river, debouching into the Bay of Bengal, cut back and beheaded this old Indus, the

Key word: Indus, Brahmaputra, Ganga, India.

P/27. Pascoe, E.H., 1920. Petroleum in the Punjab and North-West Frontier Province. Geological Survey of India, Memoirs 40(3), 331-393.

Key word: Hydrocarbons, Punjab, NWFP.

P/28. Pascoe, E.H., 1923. General report for the year 1922. Geological Survey of India, Records 55.

Key words: Geology, India.

P/29. Pascoe, E.H., 1924. General report of the Geological Survey of India for the year 1923. India Geological Survey Records 55(1).

Key words: Geology, India.

P/30. Pascoe, E.H., 1950. A manual of the Geology of India and Burma. Volume 1, 1-483. Government of India Press, Calcutta.

For details, consult information under volume 3 of the Manual.

Key words: Geology, India, Burma

P/31. Pascoe, E. H., 1959. A manual of the geology of India and Burma. 2, 485-1338. Government of India Press, Calcutta.

For details, consult information under volume 3 of the Manual.

Key words: Geology, India, Burma

P/32. Pascoe, E.H., 1964. A manual of the Geology of India and Burma. Volume 3, 1345-2130. Government of India Press, Calcutta.

Pascoe presented in three comprehensive volumes all the information available on the geology, stratigraphy, structure, mineral deposits and other geological aspects of sub-continental India and Burma. This is the most comprehensive compilation of the geological account of the region and a very important contribution to our knowledge. The book is a must for all libraries interested in the geology of the sub-continent. vol. 1 deals with the Pre-Cambrian rocks, vol. ii with the Palaeozoic and Mesozoic, vol. iii with the Deccan Traps, the Tertiary, the Pleistocene, and Recent deposits, and vol. iv will contain geographical and general indexes. The preface to the first volume is given in the following, and sets up the format and contents of the three volumes published. The fourth was not published.

This is the first volume of an important work which, when completed, will take first place as a standard book of reference on the geology of India and Burma. The complete *Manual* will consist of four volumes : vol. 1 deals with the Pre-Cambrian rocks, vol. ii with the Palaeozoic and Mesozoic, vol. iii with the Deccan Traps, the Tertiary, the Pleistocene, and Recent deposits, and vol. iv will contain geographical and general indexes. The second edition, revised by R. D. Oldham, was published in 1893, and when the late Sir Edwin Pascoe began the work of preparing a new edition in 1933, he was faced with a formidable task. The first three volumes were ready for the printers in 1939, and more than half the book had been set up in type when Japan entered the war. Owing to the extreme shortage of paper in India at that time, it was impossible to print off even the first volume, and the type, weighing 2 tons, was broken up and melted for munitions. Thus faced with a long delay in publication, the author once more revised the text of volumes i and ii, and was still engaged on volume iii when he was taken seriously ill in 1949. The first two chapters give an admirable summary of the physical geography and geological history of India and Burma, which every student of regional geology could read with profit. Throughout this account the reader cannot fail to be impressed by the contrast between the rapidity of recent geological changes in the mountains and the almost ageless

permanence of the main features in the peninsula. Thus we read of violent movements in the front ranges of the Himalaya during Pleistocene times, and of the probability that important river captures have taken place during historical times. In contrast with this we are told that the Aravalli range (folded and uplifted before the end of the Pre-Cambrian) is in fact a remnant of one of the most important watersheds of Peninsular India; it may well have been from this watershed, for instance, that some of the rivers flowed in which the rich coal deposits accumulated. The remaining eleven chapters are devoted to the Pre-Cambrian rocks, which are divided into two major groups, separated by a profound unconformity. The author wisely makes no attempt to extend smaller divisions to the whole of India, but describes in full detail the sequences found locally in the various parts of his territory, and then gives his opinions on their correlation. It would be futile to attempt to review the wealth of information contained in these chapters, whose value can only be appreciated when they are appealed to for reference. Nevertheless, a few subjects of outstanding interest deserve special mention. There is an excellent description of the remarkable manganiferous schists of the Dharwar System, with their valuable ore-bodies in the Central Provinces, and the discussion of the banded iron ores also contains much of general interest, particularly in the comparison with similar rocks in the Pre-Cambrian of other continents. The author has taken great pains to present a logical and well-argued account of the post-Dharwar intrusions, and to give a strictly impartial and balanced discussion of the charnockites and their associated problems. The attempt to sort out the complicated relationships of the various masses of gneiss, both to each other and to the adjacent schists, clears away a good deal of confusion and misconception about the chronology of the pre-Purana rocks of Peninsular India.

In the absence of Cambrian fossils, it is not easy to determine the age of some of the unaltered but unfossiliferous sediments in relation to the beginning of the Palaeozoic era. There is reason for regarding the bulk of the Purana group, which includes the Cuddapah and Delhi systems, as being Pre-Palaeozoic in age, and this conclusion is supported by such evidence as is available from radioactive minerals. The Vindhyan System, on the other hand, contains rocks unlike any known before the Cambrian either in India or elsewhere, and the author removes the Vindhyan from the Purana and refers it, with some doubt, to the earliest Palaeozoic. In his preface the author points out that the *Manual* is to be regarded as a work of reference rather than as a students' textbook, and the treatment of the Pre-Cambrian rocks in this volume is fully in keeping with this purpose. The information is so detailed, indeed, that the book may well prove to be of considerable service to local geologists in India, as the author intended. It is pleasantly written, and notwithstanding the wealth of local detail, is far from being heavy reading; but without its index it is by no means easy to use, and we must hope that the appearance of volume iv will not be unduly delayed. The price is extremely reasonable when compared with that of books of a similar calibre which have been published recently. It is perhaps a pity that a work of such scholarship and distinction, destined to face many years of constant use, could not have been given a more attractive format and a more robust binding; most of the copies seen by the reviewer had already suffered damage before reaching their destination in this country. But these are trifling matters: it is a cause of great satisfaction that Sir Edwin Pascoe's edition of the *Manual* is at last being published. For many years to come it will remain as a fitting memorial not only to the author himself, but also to the whole staff of the Geological Survey of India, with their long record of devoted service and distinguished achievement during the period which has now come to an end.

The second edition of this well-known and useful book has been considerably revised and improved. While the author keeps, for the most part, to the well-tried methods given in the previous edition, he is careful to point out improvements or alternative methods which have been devised during the past twelve years. In the chapter on Normal Methods for Silicate Rocks more attention is given to methods of determining ferrous iron, lithium, chromium, and vanadium, while new sections on phosphate rocks and on the determination of free and combined silica appear in the Notes on Technological Applications. The chapter on Special Methods has much enlarged sections on determination of ferrous iron in refractory silicates, and of manganese, with new sections on the direct determination of sodium or potassium, the determination of minute quantities of nickel, and on micro- and semi-micro- methods of analysis. It is a pity that no mention is made of the polarograph or of the flame photometer as these are likely to be increasingly used in silicate analysis in the future. The chapter on Errors is enlarged and made more valuable, and the final chapters on Occurrence of the Various Elements and on Computations as a Check on the Accuracy of Chemical Analyses have been virtually rewritten. Incidentally, the statement on page 258 that Al occurs surrounded by four oxygens in the structures of minerals is very misleading. In calculating the structural formulae of minerals, the author advocates the use of molecular weights to two places of decimals and five-figure logarithms, so that the results are accurate to three places of decimals. It is doubtful if the average chemical analysis of a mineral is of a high enough degree of accuracy to give a structural formula accurate to more than two places of decimals. Errors occur in the valency checks given in Tables X (p. 314) and XI (p. 316). In Table X, Si^{+4} should be 7.868, Al^{+3} should be 0.240, Li is shown with two positive charges. In Table XI, Al^{+3} should be 8.292, Ti^{+4} should be 0.356, Mg^{+2} should be 6.216, and Mn^{+2} should be 0.030. The author points out that the kind of valency

check used by him is no check on the accuracy of the chemical analysis of a mineral. But valency checks balancing excess negative charges caused by substitution of metal ions of lower valency than that proper to a group, with excess positive

Key words: Geology, India, Burma

P/33. Pathan, M.T., 1973. An outline of the Geology of Pakistan. Geological Survey of Pakistan, Geonews 3(1), 9-11.

A generalized account on the geology of Pakistan, and briefly covers the area of this document.

Key words: Geology, Stratigraphy, Pakistan

P/34. Patriat, P. & Attache, J., 1984. India-Eurasia collision chronology and its implications for crustal shortening and driving mechanism of plates. *Nature* 311, 615-621.

The motion of the Indian plate is determined in an absolute frame of reference and compared with the position of the southern margin of Eurasia deduced from palaeomagnetic data in Tibet. The 2,600±900 km of continental crust shortening observed is shown to have occurred in three different episodes: subduction of continental crust, intracontinental thrusting and internal deformation, and lateral extrusion. The detailed chronology of the collision and plate reorganizations in the Indian and Pacific oceans supports the hypothesis that slab-pull is a dominant driving mechanism of plate tectonics.

Key words: Chronology, collision, Plate movement, India-Eurasia.

P/35. Pêcher, A., Giuliani, G., Kausar, A.B., Malik, R.M. & Muntaz, H.R., 2001. Geology of Nanga-Parbat Himalaya in Nangimali ruby deposit area (Azad Kashmir, Pakistan). *Journal of Asian Earth Sciences* 19, p.50.

The Nangimali ruby deposit in the southern part of the Nanga Parbat Himalaya has been investigated through field work, geochemistry, stable and radiogenic isotopes. It outcrops in the Shontar valley in a large north-vergent syncline consisting of high-grade metamorphic gneisses capped by a metasedimentary series dominated by marbles and amphibolites. The ore-body is stratiform. Ruby is found within 0.1 - 2 cm thick shear-veinlets and gash veins cutting dolomitic marbles and carbonate-bearing bands.

The marbles of the Nangimali Formation display restricted ranges in $\delta^{18}\text{O}$ (from 23.6 to 27.6 ‰ relative to SMOW) and in $\delta^{13}\text{C}$ (from - 1.9 to 2.6 ‰ relative to PDB). Fluid infiltration along the shear-zone in the marble has no effect on the isotopic signatures of the carbonates. Fluids are metamorphic and CO_2 is derived from the decarbonation of marbles.

Mass-balance and geochemical analyses suggest that the mobilisation by the fluids of aluminium and chromium in the marbles is sufficient to enable the formation of ruby in the shear-zone. Rubies have been indirectly dated using a stepwise ^{40}Ar - ^{39}Ar laser heating technique on syngenetic phlogopites. The Miocene age records a Neogene cooling in the South of the Nanga Parbat massif and a minimum formation age for ruby of 16 Ma.

Key words: Geology, Ruby, corundum, Nanga Parbat, Azad Kashmir, Himalaya.

P/36. Pêcher, A. & Le Fort, P., 1996. Is Nanga Parbat an active indenter or a passive dome? Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 113-114.

1 – Tectonic interpretation around the Himalaya-Karakoram boundary has consider the present structure, clearly revealed by the geological map (Figure):

Nanga Parbat has the shape of an indenter in the heart of the Himalayan western syntaxis, bending out the “Indus-Tsangpo suture”, i.e. the accepted limit between the Himalaya and the Ladakh-Kohistan island arc; the rectilinear pattern of the southern Karakoram and “Shyok suture”, the traditional limit between the Karakoram and the Ladakh to Kohistan island arc, forms a strong contrast with the Indus-Tsangpo suture; between the two, the green belt of the island arc, made up of the Greenstone complex to the north and the Askore amphibolite to the south, continues without interruption from Ladakh to Kohistan; the two, “sutures” are clearly recent tectonic boundaries that crosscut all previous deformation.

2 – In both the Karakoram and the Himalaya the ductile syn-metamorphic deformation displays recumbent isoclinal folding in amphibolite grade metamorphism as the major structural event.

In the Karakoram, this deformation involves granitoid bodies and marble levels in plurikilometric folds; In the Himalaya, similar structures can be observed although they may be less conspicuous due to the abundance of basement gneissic material. In places, marble horizons draw large scale (kilometric) isoclinal folds; In the Karakoram-Ladakh contact zone, this same style of deformation persists, but the lithological contrast is less obvious. Polygenic conglomerates, with pebbles originating in both units, are highly affected by the syn-metamorphic deformation in greenschist metamorphic grade. The major difference between the Karakoram, north, and Ladakh-Kohistan, south, lies in the rapid, though continuous, decrease in metamorphic grade.

The Himalaya-Kohistan contact is known to be a brittle reverse fault, the Raikot fault (Lawrence et al., 1983; Madin et al., 1989). To the north, this fault dies out in the upper Darchan valley, and does not join the E-W strip of the Greenstone complex. The Himalaya-Ladakh contact is well exposed in the upper Turmik valley and is marked by a ductile shear zone with right-lateral strike-slip, clearly indicated by rotation at map scale of the syn-metamorphic folds (Pognante et al., 1993). This shear-zone in the same Greenstone complex strip. On the right bank of the Chogo Lungma glacier, the northern contact shows no evidence of normal faulting, but, in some places, thrusting of the greenstone complex over the Himalayan gneisses can be observed. Locally, in the Remendok valley, the northern contact is overprinted by a slightly deformed leucotrochilitic body.

3 – Taking into account all the previous observations, it appears that: during the main metamorphic stage, all three units have behaved as a single and continuous crustal piece. The ductile structures are post collisional. These structures do not result from indenting by a Himalayan indenter. In addition, the linearity of the main structures of southern Karakoram cannot be explained without a significantly more extensive Himalayan basement, that is not restricted to Nanga-Parbat indenter, but which probably also underlies Ladakh and Kohistan.

If the present geometry of Nanga-Parbat does not represent that of an indenter, it must result from other mechanisms. One such mechanism is doming in a NW-SE compressive regime with a strong transcurrent component, instead of a frontal collision. Nanga-Parbat from this perspective would correspond to a gneissic dome at crustal scale. Further analysis of its western side may tell whether the dominant regime has more recently rotated to that of transcurrent shortening.

Key words: Tectonics, structure, Nanga Parbat, Himalaya.

P/37. Pêcher, A. & Le Fort, P., 1998. Is the Dobani-Dasu ultramafic lineament an internal suture for Ladakh and Kohistan? Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 147-149.

In Ladakh, the contact between the Greenstone complex and the Askor amphibolite is underlined by a series of isolated pods and masses of serpentinised ultramafics, one of the major ones cutting the Turmik valley at Dasu. The Dasu lineament has been followed eastward into the Komara valley where a kilometer-thick body of metaperidotite is wrapped in a shell of foliated serpentinite, interlayered with chlorite-talc-magnesite schist and albite epidote-tremolite-chlorite rodingite. Westward we have encountered blocks of serpentine in the valley north of Skoyo. Further to the north-west, besides ultrabasic rocks and calc-silicate fels that occur in lower Remendok valley, in a similar structural position, boulders of serpentinized material occur now and then.

In Kohistan, almost exactly symmetrical to the Dasu lenticular stripe across the Himalayan spur, squeezed against the northern end of the Raikot fault, we have discovered a similar stripe of serpentinised ultramafics: the Dobani lineament. Twenty-five kilometers long, it rises from the village of Khaltaro, follows the right (west) bank of the Darchan river, crosses to the north of the Dobani peak (or Bilchar Dobani, 6134 m) in the upper part of the Gutumi glacier, forms a large kilometeric band on the northern side of the Bilchar valley, and finally thins out on the right bank of the Bagrot river between the villages of Datucho and Sinakkar. Further to the west, it does not cross as such the Dyor and Hunza valleys, but leads into the tectonic lineament, that follows the edge of the Bilchar meta-volcano-sedimentary formation. There the two intricated formations could form a tectonic melange.

In Ladakh the metaperidotites are usually antigoritic serpentinites with cumulitic textures, and two generations of olivine (magmatic and metamorphic). In Kohistan the serpentinised peridotites are accompanied by pyroxenites. The Dobani-Dasu ultrabasic lineament separates the island-arc into two units. It is possible to consider these serpentinites as a part of the ophiolitic sole of the island arc as described near Dras (Ladakh, NW India). Thus, the Chalt-Turmik volcanics, with the MKT lineament to the north and the Dasu-Dobani ultramafics to the south, compare well with the Dras volcanics that have tectonic melanges on their northern and southern sides. In our view,

it could mark the limit between the volcano-sedimentary back-arc basin and the island-arc itself that includes peraluminous crustal material of Katchura Gilgit type.

The ultramafics that divide Kohistan and Ladakh in two sub-units are a good marker of the global deformation of the arc. Parallel to the general structural trend, away from the NPHM, they are bent when getting closer to the contact with the Himalayan gneisses. To the east, the bending of the lineament marks and supports the right-lateral movement also evidenced in the Greenstone complex. To the west, the curvature of the Bilchar-Dobani ultramafics would also indicate a right-lateral movement, whereas the movement observed in the mylonitic Himalayan gneiss of the upper Darchan valley, is left-lateral and obviously not of the same age. The two dextral shear zones could represent a meridian vertical slicing of the Himalayan crust that has driven the NPHM doming and the Raikot fault.

Key word: Ultramafics, structure, Dasu, Ladakh, Kohistan, Himalaya.

P/38. Pêcher, A. & Le Fort, P., 1999. Late Miocene tectonic evolution of the Karakoram-Nanga Parbat contact zone (northern Pakistan). In: Macfarlane, A., Sorkhabi, R.B. & Quade, J., (Eds.), Himalaya and Tibet: Mountain root to mountain tops. Geological Society of America, Special Papers 328, 145-158.

In northern Pakistan, the northwestern syntaxis of the Himalaya is marked by the spur of the Nanga Parbat-Haramosh massif, bounded by the Arc formation of Ladakh and Kohistan, and located south of the Karakoram range. The three units are separated by two major tectonic features, corresponding to late reactivation of the southern Indus-Tsangpo suture and northern Shyok suture. Field mapping in the as-yet poorly known Nanga Parbat-Haramosh massif-Karakoram contact zone, together with structural, metamorphic, and geochronological data, has led to new constraints on the interpretation of this key zone, viz.: (1) the backarc belt continues without interruption from Ladakh to Kohistan; (2) the southern Karakoram, the Arc, and the northernmost part of the Nanga Parbat-Haramosh massif display the same recumbent isoclinal folds and related metamorphic schistosity as the major structural event; (3) ductile deformation ended after 6 or 7 Ma; (4) in front of the Nanga Parbat spur, there is no evidence of normal-type faulting, or of Karakoram indentation, either considering the lithological boundaries or the metamorphic fabric; (5) on both sides of the spur, the right-lateral and left-lateral cartographic displacements mainly reflect the late doming of the initial arc-massif contact, a south-directed shear zone. Thus, the three units, east of the Raikot fault, define an east-west-trending broad zone that has thermally and tectonically behaved as a single crustal piece. The northern part of the Nanga Parbat-Haramosh massif can be considered to be a large dome in the westward extension of the Karakoram domes, a line of domes that developed east of the Raikot fault and possibly initiated as a crustal-scale fold system, induced by broad and diffuse northwest-southeast dextral shearing in transpressive regime.

Key word: Tectonics, structure, NPHM, Ladakh, Kohistan, Himalaya.

P/39. Peltzer, G. & Tapponnier, P., 1988. Formation and evolution of strike-slip faults, rifts and basins during the India-Asia collision: An experimental approach. *Journal of Geophysical Research* 93, 15085-15117.

The processes which have governed the formation and evolution of large tertiary strike-slip faults during the penetration of India into eastern Asia are investigated by plane strain indentation experiments on layered plasticine models. The results show the influence of boundary conditions as well as that of the internal structure of the plasticine model on the faulting sequence. The ubiquity of strain softening in experimental deformation of a variety of rocks, as well as the widespread occurrence of shear zones in nature, suggest that long-term deformation of the continental lithosphere may also be primarily influenced by the geometry of large faults which rapidly develop with increasing strain. The deformation and faulting sequence observed in the plasticine indentation experiments may thus be compared to collision-induced strike-slip faulting in Asia, particularly to total offsets and rates of movements on the faults. The experiments also illustrate mechanisms for the formation of extension basins near active continental margins.

Key Words: Structure, deformation, collision, India-Asia.

P/40. Pelve, A.V., Burtman, V.S., Ruzhentsev, S.V. & Suvorov, A.I., 1964. Tectonics of the Pamir-Himalayan sector of Asia. *Proceedings 22nd International Geological Congress* 11, 441-464.

Key word: Tectonics, structure, Pamirs, Himalaya.

P/41. Pennington, W.D., 1979. A summary of the field and seismic observations of the Pattan Earthquake, 28th December, 1974. In: Farah, A. & DeJong, K.A. (Eds.), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 143-144.

The Pattan earthquake, magnitude 6.0, caused considerable loss of life and damage to property, resulting both from severe ground shaking and from rockfalls. This earthquake is the largest yet observed in the Indus-Kohistan Seismic Zone, west of the western Himalayan syntaxis, where the Himalayan arc terminates. The focal mechanism and aftershock distribution indicate thrusting in a NNE-SSW direction, similar to that which is expected for Himalayan thrusting, but not what would be expected from surface geologic mapping.

Key word: Earthquakes, seismology, Pattan, Himalaya.

P/42. Pennock, E.S., 1988. Structural interpretation of seismic reflection data from the eastern Salt Range and Potwar Plateau, Pakistan. M.S. Thesis, Oregon State University, Corvallis, 55p.

Approximately 1600 km of seismic reflection profiles from the eastern Salt Range and Potwar Plateau (SR/PP) of Pakistan are integrated with available magnetostratigraphic, surface geologic and well data, to categorize structural styles, determine the timing of deformation and estimate the amount of telescoping of the sedimentary cover. The eastern SR/PP is similar to other fold-and-thrust belts underlain by evaporites in that: 1) it is part of a zone of overthrusting that extends considerably farther over the Himalayan foreland than adjacent areas not underlain by evaporites; 2) the overall thrust wedge has a narrow cross-sectional taper; 3) structures verge toward the hinterland as well as toward the foreland; and, 4) fold trends are long and continuous, consisting of tight, salt-cored anticlines separated by broad synclines. Disharmonic folding of the sedimentary section relative to the underlying basement is due to effective decoupling along the intervening salt layer. Subsurface mapping on top of a strongly reflective package of Cambrian to Eocene strata reveals that many surface folds are cored by both foreland- and hinterland-dipping, blind thrusts, and some are fault propagation folds. In some cases, intersecting thrusts result in local triangle zones; other surface folds have a pop-up geometry. The dip of the basement towards the inner part of the fold-and-thrust belt is relatively gentle in the eastern SR/PP (1° - 1.5°) compared to the central SR/PP (2° - 3°). Mechanical considerations demonstrate that, unlike the relatively undeformed central SR/PP, a broad deformational zone has developed in the eastern SR/PP to provide a surface topographic slope necessary to maintain a critical taper of the thrust wedge. Furthermore, previous paleomagnetic studies indicate that deformation across much of the eastern PP preceded tectonic rotation. This implies that individual structural trends developed perpendicular to the transport direction and were then rotated into their current NE-SW alignment in response to ramping over a basement buttress in the central SR/PP. Cross-section balancing indicates that approximately 23.1 km of shortening has occurred across the foreland in the eastern SR/PP since 5.5 Ma, 17.8 km in the last 2.5 Ma. The shortening rate of 7 mm/yr for that time interval is roughly 15% of the 40-50 mm/yr convergence rate between the Indian and Eurasian plates.

Key word: Seismology, structure, Salt Range, Potwar.

P/43. Pennock, E.S., Lillie, R., Zaman, A. & Yousaf, M., 1989. Structural interpretation of seismic reflection data from the eastern Salt Range and Potwar Plateau, Pakistan. *American Association of Petroleum Geologists, Bulletin* 73, 841-857.

Consult the preceding account for further information.

Key word: Structure, seismology, Potwar, Salt Range.

P/44. Perri, M.C., Talent, J.A.T., Ahmad, I., Ali, A., Molloy, P.D. & Conaghan, P.J., 2000. Prevalence of Triassic limestone sequences in northern Pakistan. *Abstracts, Geological Society of Australia* 61 (Palaeontology Down Under 2000), 79-82.

Key word: Limestone, Triassic, Pakistan.

P/45. Pervez, M.K., 1987. Geology of a part of Attock-Cherat and Kalachitta Ranges in the vicinity of Nizampur, Pakistan. M.Phil. Thesis, University of Peshawar, 120p.

Rocks of the Attock-Cherat and Kalachitta Range are thoroughly mapped and studied to work-out their structural patterns. The two Ranges are separated by a well-defined Hissartang Thrust. The rocks of the Attock-Cherat Range, of Precambrian to Paleozoic age, consist of sedimentary and meta-sedimentary sequences. Lying unconformably on these are Mesozoic and Tertiary strata. Rocks of the Kalachitta Range in the study area range in age from Jurassic to recent. These are mostly limestone, shales and sandstones. Three main thrust faults (oriented E-W) divide the area into four blocks. The Khairabad thrust mars-off the northern block, the cherat thrust limits the central block and the Hissartang thrust separates the southern block from the Kalachitta range. These thrusts are the splay faults of the MBT, which runs south of the Kalachitta range. The push from north on these thrusts have been the major cause of the deformation of these Ranges. The big synclinalorium in the Kalachitta rocks north of the Indus River is resulted because of the movement on Hissartang thrust. A model is proposed to explain the structural relationship of the rocks of the Attock-Cherat Range, east of Indus River. During the movement along the Hissartang fault a splay fault was cutoff in this area producing a low angle Hissartang back thrust. The rootless patches of Jurassic limestone on Palaeozoic sequence, east of the Indus River, indicate that the Mesozoic strata are thrust over the Paleozoic rocks. Previously, the Hissartang thrust was considered to exist beneath the alluvium of Nizampur and Campbellpur Basins (Yeats and Hussain, 1986). As a result of present work it is relocated just at the southern foot of the Attock-Cherat Range. Similarly, the structural style of the central and southern blocks does not display a homocline system as was suggested by Yeats and Hussain (1986), but is dominantly a south verging overturned folded system.

Key word: Geology, sediments, stratigraphy, Kalachitta, Attock-Cherat.

P/46. Pervez, S., 1985-87. Geology and petrography of Luat-Thod Area, Neelum valley (A.K.) with special emphasis on granites. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 77p.

The project area is a part of Middle Himalayas and covers about 350 sq. km. located between Doarian and Thod in Neelum Valley (Azad Kashmir) at the scale 1: 25,000 of topographic sheet No. 43 F/13, 43 F/14 and 43 J/2 of survey of Pakistan. The studied area comprises of broader lithology of Salkhala formation containing predominantly metapelites, psammites and calcareous material. Various granitic and basic bodies are also outcropping the area. Basic bodies are present as dykes and sills. All the quartzofeldspathic rocks (Granites) of the area are the products of metasomatism (Granitization) and these are possibly the part of Nanga Parbat Haramosh massif. The area is rich in economic rocks and mineral deposits are discussed briefly.

Key word: Mapping, petrography, granites, Azad Kashmir.

P/47. Peters, J.J. & Lindsley, R.L., 1988. Pakistan garnet compositions. Mineralogical Record 12(2), 128-129.

Microprobe analyses for 1 spessartine and 4 almandines from the gem pegmatites of Pakistan yield Mn/Fe ratios of 2.5:1, 0.8:1, 0.8:1, 0.7:1 and 0.5:1, which corresponds with compositions of Alm28Sp70Pyr0, mAlm55Sp44Pyr1, Alm55Sp44Pyr1, ALm67,Sp40Pyr1(sic) and Alm66Sp32Pyr1, respectively.

Key word: Mineralogy, garnets.

P/48. Petrini, C.F., 1936. Chenni illustrativisulla compilazione della carta Topografica al 75.000 della spedizione. Appendix to: La Spedizione Geografica Italiana al Karakorum, 1929, 25-32. Arti Grafiche Bertarelli, Milano.

Key words: Topographic survey, Italian Expedition, Karakoram.

P/49. Petrov, I., Schmetzer, K. & Bank, H., 1977. Violette topase aus Pakistan. Neues Jahrb. Min. Mh. 483-484.

The optical and X-Ray data of the violet prismatic topaz from Katlang area Mardan are given here. From both the data it is concluded that the investigated topaz crystals are OH-rich with ~15% F. the violet color is due to Cr 3+ ions as in violet topaz from the river Sanarka (or, as recently called, Kamenka), Urals, USSR.

Key word: Gems, topaz, Katlang, Mardan, USSR.

P/50. Petrushevsky, B.A., 1977. The Indus-Pamirs zone: One of the most important transversal lineaments in Asia. *Bulleten Moskovskogo Obshestva Ispytatelei Priordy* 5 (In Russian).

Key word: Structure, tectonics, Indus-Pamir.

P/51. Petterson, M.G., 1984. The structure, petrology and geochemistry of the Kohistan batholith, Gilgit, Kashmir, N. Pakistan. Ph.D. thesis, Leicester University.

This is perhaps the most detailed study of the Kohistan batholith. In addition to geochemistry and petrology, several phases of magmatism were identified. Careful mapping around Gilgit shows that the batholith there is made up of repeated pulses of granitic plutons. Details of the work are represented in a series of papers in the following.

Key word: Structure, petrology, geochemistry, Kohistan batholith, Gilgit, Kashmir.

P/52. Petterson, M.G., Crawford, M.B. & Humayun, M., 1992. Sr, Nd and O Isotope Data from the Kohistan Batholith, N Pakistan: Constraints on the evolution of the Kohistan mantle and crust from 102 Ma to 30 Ma. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.70.

The 102 Ma-30 Ma Kohistan batholith forms a major part of the Kohistan arc terrane, N Pakistan. It intruded in three distinct stages which correlate with the existence of Kohistan; (i) as an island arc (102 Ma-85 Ma), (ii) as an Andean-type margin (85 Ma-40 Ma) and (iii) as a collisional zone trapped between the colliding Indian and Eurasian plates. Sr and Nd isotope data are now available for five granitoid plutons from the batholith: the Matum Das (102 Ma), Gilgit (54 Ma), Shirot (40 Ma) plutons and two acid sheet units (Parri and Indus Confluence) dated at 30 Ma. The range of isotope values for these units are: $^{87}\text{Sr}/^{86}\text{Sr}$ 0.7039-0.7052, E^{Sr} -6.8 to 10.36, $^{143}\text{Nd}/^{144}\text{Nd}$ 0.512861-0.512723, E^{Nd} 6.91 to 2.04.

The E^{Sr} and E^{Nd} data for the Matum Das, Gilgit and Shirot plutons plot within the mantle (upper left) quadrant on an $E^{\text{Sr}}-E^{\text{Nd}}$ diagram. The Indus Confluence, and most notably, the Parri acid sheets plot in the upper right quadrant on an $E^{\text{Sr}}-E^{\text{Nd}}$ diagram as they have both positive E^{Nd} and E^{Sr} values. The full data set follows a temporal evolutionary trend: E^{Sr} increases and E^{Nd} decreases with time. These data imply a mantle or primitive arc crust origin for the Matum Das, Gilgit and Shirot granitoids, with contamination of mantle derived magmas by immature Kohistan crust becoming more important with time. The Parri acid sheets are probably the result of upper crustal anatexis; possibly being melt derivatives of a thick meta-sedimentary sequence which crops out between Gilgit and Jaglot.

O18 data have recently been produced for a wide range of plutonic units including three of the above (Gilgit, Shirot and Parri). O18 values vary between 6‰ and 9.2‰; the leucogranites having O18 values >8‰; the bulk of the gabbro-diorites have O18 values between 6.5‰ and 7.7‰, whilst three gabbro-diorites have O^{18} values of 6-6.5‰. The high O18 for the leucogranites is consistent with a crustal melt origin. Munir Humayun interprets the O^{18} values of 6.8‰-7.7‰ for granitoids as indicating a primitive arc crustal melt origin, with the Nd and Sr isotope compositions being inherited from their precursor mantle source. MGP and MBC feel that the granitoid data could also be explained by subduction zone fluids ± subducted sediment elevating the O^{18} of a mantle source, followed by limited assimilation of high O^{18} crust.

Key word: Geochemistry, Sr and Nd isotopes, Kohistan batholith.

P/53. Petterson, M.G., Crawford, M.B. & Windley, B.F., 1993. Petrogenetic implications of neodymium isotope data from the Kohistan batholith, North Pakistan. *Journal of the Geological Society of London* 150, 125-129.

Neodymium data are presented for five granitoid (trondhjemite, granite and leucogranite) plutonic units from the Kohistan batholith aged 102 Ma to 29 Ma. These have present day $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of between 0.512980 and 0.512734, calculated initial $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of between 0.512861 and 0.512705 and Nd values of between 6.91 and 2.04. There is a decrease in ϵNd with time which is inversely correlative with a similar increase in ϵSr .

Three plutonic units (Matum Das, Gilgit and Shirot) formed from a source enriched in Sm and depleted in Rb or radiogenic Sr relative to bulk earth, whilst a fourth unit (the Indus Confluence acid sheets), is only slightly enriched in radiogenic Sr. These four units define a temporal trend from the least evolved Matum Das pluton to the most evolved Indus Confluence acid sheets. This trend was produced as a result of subducting oceanic sediment or seawater-altered oceanic crust which melted or dehydrated and increasingly modified the isotopic composition of an original mantle protolith situated above the subducting plate. The data preclude any significant input to the magmatism from ancient crust. New data presented here, together with other published data, indicate an immature metavolcanic crustal source for the Matum Das pluton, and a plutonic basement crustal source for the Indus Confluence acid sheets. These crustally derived units retain a mantle isotopic signature indicating that the geochemical signature of Kohistan evolved by remobilization of recently formed arc crust in addition to new inputs of mantle-derived magma.

A fifth plutonic unit (the Parri acid sheets) shows a clear compositional break from the other units, being significantly enriched in radiogenic Sr and Nd with respect to bulk earth. The source to the Parri acid sheets is interpreted as metasedimentary rocks with a high Rb/Sr ratio and a crustal residence time of c. 70 Ma.

Key word: Petrogenesis, Nd isotopes, geochemistry, Kohistan batholith.

P/54. Petterson, M.G. & Windley, B.F., 1985. Rb-Sr dating of the Kohistan arc-batholith in the Trans-Himalaya of N. Pakistan, and tectonic implications. *Earth and Planetary Science Letters* 74, 45-57.

The Kohistan arc-batholith in northern Pakistan is situated between the Indus Suture and the Northern Suture. It belongs to the Trans-Himalayan belt which continues eastwards as the Ladakh arc-batholith in northwest India and the Gangdese batholith in southern Tibet. In Kohistan the island arc consists (upward sequence) of the Chilas stratiform complex of norites, noritic gabbros and chromite-layered dunites which formed in the sub-arc magma chamber, plutons of tonalite and diorite, one of which has a Rb-Sr isochron age of 102 ± 12 Ma, the Chalt volcanics of basaltic tholeiites succeeded by andesites to rhyolites, and the Yasin Group sediments which formed in overlying intra-arc basins and which contain Albian-Aptian faunas. All these rocks were deformed by major fold structures which are correlated with the formation of the Northern Suture. NE-SW trending basic Jutal-Nomal dykes (north of Gilgit) cross-cut all the above structures and have a $^{39}\text{Ar}/^{40}\text{Ar}$ hornblende age of 75 Ma. Thus the Northern Suture must have formed in the period 102 ± 12 to 75 Ma. With the island arc attached to the Eurasian plate, further northward subduction of the Tethyan plate gave rise to an Andean-type batholith, two plutons of which have Rb-Sr isochron ages of 54 ± 4 Ma and 40 ± 6 Ma. The Dir-Utror Group of calc-alkaline lavas (and sediments with Eocene fossils) are remnants of the volcanic cover of the Andean-type batholith. We suggest that late Cretaceous blueschists formed during subduction under the active continental margin, and that continental collision and formation of the Indus Suture was in the Eocene. The batholith was intruded by layered aplite-pegmatite sheets at 34 ± 14 Ma and 29 ± 8 Ma (Rb-Sr ages) in post-collisional times. The $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratios of all the dated rocks range between 0.7039 and 0.7052.

Key word: Chronology, Rb-Sr isotopes, geochemistry, Kohistan batholith.

P/55. Petterson, M.G. & Windley, B.F., 1986. Petrology and geochemical evolution of the Kohistan-arc batholith, Gilgit, North Pakistan. *Geological Bulletin Peshawar University*, 19, 121-149.

The Kohistan batholith is the most north-westerly part of the Trans-Himalayan batholith which extend some 2700 kms from near Lhasa in the east to Pakistan in the west. Detailed framework of an area of 2500 km², centered on the town of Gilgit, had shown that the batholith had evolved in the three distinct stages:

An early bi-modal sequence of high-K gabbroic diorites and high SiO₂, low K tonalites, which have been deformed and folded, together with associated meta-volcanic and -sedimentary country rocks around a major syncline (the Jaglot Syncline). These early plutonics, which comprise 1/3 of the batholith, have a penetrative, gneissose fabric

which is orientated parallel to the major structural trends of the area. These rocks formed in an island arc environment. An undeformed sequence of basic dykes, gabbros, diorites, granodiorites and granites which cut the structure associated with the Jaglot Syncline. These rocks formed in an Andean-type continental margin.

Extensive swarms of layered aplite-pegmatite sheets, which formed after the terminal collision between India and Eurasia. Some of these rocks formed by crustal melting. Five rock units have yielded Rb-Sr whole rock isochron ages. These are 102 ± 12 Ma for an early, deformed tonalite, 54 ± 4 Ma and 40 ± 6 Ma for two second stage granitoids, and 34 ± 14 Ma and 29 ± 8 Ma for two late leucogranitic sheets.

Even the least evolved gabbros of stages 1 and 2 are enriched in Rb, K Ba, Sr, P and LREE relative to Nb, Zr, Ti, Y and HREE. With fractionation LFS/HFS, K/Na and LREE/HREE element ratios increase and the batholith displays a calc-alkaline trend with respect to Mg, Fe, Na and K. The main magmatic trend of the batholith can be explained by the fractionation of amphibole-plagioclase-magnetite $\pm$ clinopyroxene in the basic-intermediate rocks and plagioclase-K-feldspar-biotite and magnetite in the acid rocks. Zircon, apatite, and sphene were important accessory minerals. Low $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratios (0.7039-0.7052) suggest that the ultimate source for the majority of the plutonics was the upper mantle. However the stage 1 tonalite and some of the stage 3 leucogranites were formed by partial melting.

Key word: Petrology, geochemistry, Kohistan batholith, Gilgit.

P/56. Petterson, M.G. & Windley, B.F., 1991. Changing source region of magmas and crustal growth in the Trans-Himalayas: evidence from the Chalt volcanics and Kohistan Batholith, Kohistan, northern Pakistan. *Earth and Planetary Science Letters* 102, 326-341.

The Kohistan batholith and Chalt volcanics form a major part of the Kohistan island arc terrane in northern Pakistan. They record some 70–80 Ma of magmatism within the northwestern Himalayan orogen; the Chalt volcanics are Albian-Aptian (mid-Cretaceous), and currently available Rb-Sr age data for the batholith indicate an intrusive age span of 102 to 30 Ma. The volcanics are composed of medium-K, calc-alkaline andesites and low-K, high-Mg, tholeiites, some of which have boninitic and basaltic komatiitic chemistry. Three intrusive stages are recognised in the batholith: (1) (110–90 Ma) comprises low-K trondhjemitic and medium-high-K calc-alkaline gabbro-diorites with associated hornblende cumulates; (2) (85–40 Ma) comprises low-high-K, calc-alkaline gabbro-diorites (with hornblende cumulates, granodiorites and granites; and (3) (circa 30 Ma) comprises biotite $\pm$ muscovite $\pm$ garnet leucogranites. $^{87}\text{Sr}/^{86}\text{Sr}$ for the batholith range between 0.7039 and 0.7052.

Four magmatic source regions (Sce 1–Sce 4) have been identified. Sce 1 is a variably metasomatised mantle wedge situated above an active subduction zone during stages 1 and 2. Sce 2 is a harzburgite depleted with respect to major elements and incompatibles, whilst retaining “subduction-related” trace element ratios. Sce 2 melted during stage 1 within a fore-arc position during the subduction of young, hot oceanic crust to provide the necessary extra thermal input for harzburgite anatexis. Melts from Sce 2 produced the high-Mg tholeiitic volcanics. Sce 3 melted during stage 1 to produce the low-K trondhjemitic, and it is envisaged as incompatible element-depleted primitive arc crust with a similar composition to the depleted Chalt volcanics. Sce 4 melted at 30 Ma during stage 3 as India underthrust Eurasia: frictional heating and dehydration of the Indian plate caused crustal anatexis within the deep Kohistan arc and these melts formed the stage 3 leucogranites. The low $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratios for the great bulk (> 95%) of the batholith indicate that it represents a major juvenile addition to the continental crust. This conclusion has important implications for crustal growth theories of island arc accretion and batholith underplating.

Key word: Magmatism, orogeny, crustal growth, Chalt volcanics, Kohistan batholith.

P/57. Petterson, M.G. & Windley, B.F., 1992. Field relations, geochemistry and petrogenesis of the Cretaceous basaltic Jutal dykes, Kohistan, northern Pakistan. *Journal of the Geological Society of London* 149, 107-114.

A 75 Ma Cretaceous suite of low-medium-K basalt to basaltic andesite dykes intrudes the Kohistan terrane between Jutal and Chalt, Gilgit area, northern Pakistan. Orientational data suggest they intruded in response to NW–SE to N–S tension. The dykes cut the Albian–Aptian Chalt Volcanic Group and the 102 Ma Matum Das trondhjemitic pluton. They cut the fold structures and penetrative fabrics associated with the collision between Kohistan and Eurasia and thus constrain the age of formation of the Northern Suture. The dykes define two groups on the basis of trace element geochemistry and geochemical trends. A depleted D-type group has low concentrations of incompatible elements (2–8 x primordial mantle) and (Ce/Yb)_N ratios <1. An enriched E-type group is relatively enriched in both

low field strength and light Rare Earth elements and exhibits increasing incompatible element concentrations with increasing Zr. Trace element and field data suggest that the dykes are genetically linked and formed by partial melting of a mantle source which has been metasomatized by subduction-related processes. Models involving (i) different degrees of partial melting (ii) two-stage partial melting and (iii) partial melting of a heterogeneous source are considered.

Key word: Geochemistry, petrogenesis, basalt dykes, Cretaceous, Kohistan.

P/58. Petterson, M.G., Windley, B.F. & Luff, I.W., 1991. The Chalt volcanics, Kohistan, Pakistan, high-Mg tholeiitic and low-Mg calc-alkaline volcanism in a Cretaceous Island Arc. *Physics and Chemistry of the Earth* 17, 19-30.

The Chalt Volcanic Group, together with the Drosh volcanics form a thin, arcuate, 300 km long, linear belt cropping out to the south of the Northern Suture, Kohistan, N Pakistan. The upper volcanics are interbedded with sediments which have yielded fossils of Albian-Aptian age. Contemporaneous volcanics occur to the south of the Shyok Suture in Ladakh (the Dras volcanics). The Chalt volcanics comprise a sequence of lavas and volcanoclastics which vary in composition from high-Mg basalt and andesite to low-Mg basalt, andesite and rhyolite. They have undergone greenschist to lower amphibolite grade metamorphism. Geochemically the volcanics are divisible into two groups: (1) High-Mg basalts and andesites, some of which approximate basaltic komatiite and boninite in composition. This group has high MgO, Ni and Cr contents, low concentrations of incompatible trace elements such as Ce, Y, Zr, Ti, Rb and K, and it displays tholeiitic trends with fractionation; the closest modern analogues are boninites and low-K tholeiites. (2) Basalts, andesites and rhyolites which exhibit typical calc-alkaline trends with fractionation. These are enriched in low field strength elements (e.g. Rb, Ba, Sr, K) and LREE (e.g. Ce) relative to high field strength elements and HREE (e.g. Zr, Ti, Y). Concentrations of incompatible elements increase with fractionation; their closest modern analogues are medium-K calc-alkaline andesites. These two magma groups have separate mantle sources, an MgO-rich incompatible element depleted residual harzburgite type source for the high-Mg volcanics, and a mantle source enriched in LFS elements relative to HFS elements for the calc-alkaline volcanics. Evidence from the volcanics indicates lateral variations in magmatism and source composition along the Cretaceous Kohistan island arc. The arc was situated between the Indian and Eurasian plates, and it was produced as a consequence of north-directed subduction of Tethys.

Key word: Volcanism, Chalt volcanics, Kohistan, Himalaya.

P/59. Petterson, M.G., Windley, B.F. & Sullivan, M., 1990. A petrological, chronological, structural and geochemical review of Kohistan batholith and its relationship to regional tectonics. *Physics and Chemistry of the Earth* 17, 47-70.

The Kohistan batholith located west of Nanga Parbat, is situated entirely within the Kohistan terrane between the Northern and Indus sutures and is the most northwesterly component of the Trans-Himalayan batholith. It is an ENE-SSW elongate 300 km x 60 km body consisting of many plutons which intrude Chalt volcanics to the north and a meta-sedimentary sequence to the south. The batholith can be subdivided into three stages on the basis of field relations, petrology and geochronology: stage-I; an early bi-modal sequence of deformed gabbro-diorites and trondhjemitic, stage-II; gabbro-diorites, granodiorites and granites, with the magmatism becoming more acidic with time, and stage-III; dense swarms of leucogranitic sheets. Two magmatic types are recognised in stage-I and the early part of stage-II which are a low-K tholeiitic and a medium high-K calc-alkaline, respectively. Only the latter continued throughout the later part of stage-II and stage-III. Radiometric ages constrain the three magmatic stages to the following periods; stage-I, pre-Northern Suture which formed between 102 and 85 Ma; stage-II, post-Northern Suture and 40 Ma with most basic magmatism at 85-60 Ma and acid magmatism at 60-40 Ma; stage-III, ca. 30 Ma.

The three magmatic stages of the batholith correlate with the tectonic development of Kohistan arc, i.e. stage-I plutons formed in an island arc, stage-II plutons formed at an Andean-type margin, and late stage II plutons and stage-III plutons during syn- to post-Himalayan collision times (Kohistan collided with India at ca. 45 Ma). Sr isotope data suggest that stage-I and II plutons are mantle-derived, and that stage-III plutons are possible melts of the Kohistan crust. K-Ar and Ar-Ar mineral ages show that uplift rates in Kohistan are greatest within the Nanga Parbat syntaxis and that the Kohistan crust to the north and west of Gilgit cooled through the blocking temperature for biotite (330 °C) at about 60-40 Ma.

Key word: Petrology, chronology, structure, geochemistry, tectonics, Kohistan batholith, Himalaya.

P/60. Phillips, W.M., Quade, J., Shroder, J.F. Jr. & Poths, J., 1996. Cosmogenic ^3He in garnet, Raikot valley, Nanga Parbat, Northwestern Himalaya, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 116.

Garnet is common in gneisses and leucogranites exposed in the Raikot Valley where previous workers have documented high-grade metamorphism, partial melting, high strain, and rapid denudation during the Quaternary. With the ultimate goal of quantifying Nanga Parbat denudation rates and glacial histories, we are evaluating garnet for ^3He surface exposure dating. For successful ^3He work, garnet must a) retain cosmogenic ^3He ; b) possess low concentrations of ^3He inherited from pre-metamorphic surface exposure or mantle sources; and c) contain low Li, U, and Th in order for nucleogenic ^3He and radiogenic ^3He to be minimized.

Preliminary results from a road cut with $\sim 3\text{m}$ shielding from cosmic rays and from a weathered erratic are promising. Helium inherited during garnet growth (crush data) has radiogenic $^3\text{He}/^4\text{He}$ ratios, and variable but low ^3He and ^4He concentrations. Nucleogenic and/or muonic ^3He (shielded sample fusion data) is $<2\%$ of cosmogenic ^3He gained during long exposure (erratic fusion data). Using estimates of the ^3He production rate⁴ in $\text{Al}_{76}\text{Py}_{15}\text{Sp}_{5}\text{Gr}_4$, the glacial erratic sample has an exposure age of $55.1 \pm 4.1 \text{ ka}$. This is a minimum age due to shielding by heavy winter snow and possible (probably minor) erosion of the boulder.

Key word: Metamorphism, denudation, garnet, Nanga Parbat, Himalaya.

P/61. Piat, D., 1974. Le rubis himalayen de Hunza. Bulletin Association Frances Gemmologie 41, p.5.

The province of Hunza is situated in the far north of Pakistan and ruby crystals are found in calcite which is often penetrated by large pegmatite and biotite bands. The color is fine transparent rose.

Key word: Gemstones, ruby, marble, Hunza.

P/62. Picard, C., Kausar, A.B., Amossê, J., & Rahim, S., 1998. The Kohistan arc, northern Pakistan: an example of PGE and PGM distribution in convergence zones. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 149-151.

Latest studies on the distribution of PGE indicate that the highest absolute abundances of PGE concentrations are generally associated with chromitite and nickel sulphide occurrences in large ultramafic-mafic layered intrusions (Stillwater and Bushveld) or in greenstone belts of komatiitic affinity. Most of them are related to distensive tectonic regime or mantle plume activity. The Kohistan arc, northern Pakistan has several discontinuous and elongated ultramafic and mafic bodies that formed at the base of an immature intra-oceanic island arc in response to northward-directed subduction of neo-Tethys ocean lithosphere during Late Jurassic and Cretaceous. Each-either contain or have the potential for PGE mineralization.

Massive chromitite occurs in lenses and pods in dunite of Jijal complex and reach 2 to 3 meters thickness and 50 meters strike length. No chromite assemblages of large concentrations (1-2 vol.%) are known in ultramafic-mafic rocks from Thak Gah and Sapat areas. In the last two complexes, chromitite and Cr-rich spinel is the most common accessory phase which occur as low-grade disseminations (dunite and pyroxenite) as well as in layers (mm scale) in dunite. Jijal complex has also primary pyrrhotite, chalcopyrite, pentlandite, bornite and pyrite and they are sparsely distributed in the different cyclic units of this complex. Surprisingly, no megascopically visible sulphide phase has been found in Thak Gah and Sapat complexes.

The whole-rock abundance PGE + Au data from Cr-rich, Cr-poor, sulphide-rich and silicate rocks of Thak Gah ultramafic-mafic complex, Chilas; Sapat ultramafic-mafic complex, Kaghan valley; and Jijal ultramafic-mafic complex were determined to know the primary distribution of PGE in these arc-related rocks and their behaviour during normal igneous processes. Thak Gah complex mostly composed of layered dunite, pyroxenite, anorthosite, troctolite and gabbro covers an area as large as 5 sq. km, east of Chilas. The complex, interpreted as intruded in the Chilas gabbro-dioritic complex (Khan et al., 1989), displays restricted range of total PGE contents (7.71 to 33.54 ppb) and exhibits positive slope ($\text{Pd}/\text{Ir}=3.95$ to 50.33). The abundances of total PGE range from 13.13 to 33.54 ppb

in dunites; 7.71 to 13.10 ppb in pyroxenites; 6.44 to 15.74 ppb in layered gabbro and 9.04 to 20.45 ppb in gabbro norite. No PGE enrichment zone has been found in this complex.

The Sapat complex along with Jijal complex form a closely spaced group to the south of Kohistan arc and extends NE-SW immediately to the north of MMT. The complex occupies over 13 km² and has ultramafic sequence at the base and gabbro sequence at the top. Dunite (total PGE= 13.72 to 31.02 ppb) shows a strong Ir (1.93 to 4.06 ppb), Ru (4.12 to 8.29 ppb) enrichment and slight impoverishment in Rh, Pd and Pt resulting flat to slightly negative Pd/Ir ratio (1.31 to 0.36). Clinopyroxenite shows abundant concentration of PGE, ranging from 48.95 to 57.87 ppb, and exhibits extremely steep positive patterns (Pd/Ir=12.46 to 146.76). Layered gabbro has low total PGE concentration of 12.66 ppb and less steep positive pattern (Pd/Ir=10.13) as compared to clinopyroxenite. These data suggest that silicate melt feeding Thak Gah and Sapat complexes were carrying appreciable levels of PGE and Au.

The Jijal complex, northern Pakistan, is a 150 km² body of dunites, olivine clinopyroxenites, websterites, garnet websterites and garnet gabbro, resting tectonically over the gneissic basement of the Indian plate. Both the ultramafic and mafic phases contain minor amounts of base metal sulphides and chromites with which the platinum group elements (PGE) are associated. The abundances of PGE range from 9 to 86 ppb in olivine clinopyroxenites; 13 to 54 ppb in websterites; 17 to 54 ppb in dunites; 9 to 41 ppb in garnet clinopyroxenites and 9 to 27 ppb in garnet gabbro. Several PGE enriched horizons occurred through the series: 1) chromite- rich levels (1a to 1d) moderately enriched in Ir+Ru+Rh in lower dunites; 2) two disseminated sulphide bearing pyroxenites levels (2a and 2b) with strong concentrations of Ir-Rh-Ru-Pd-Pt, Cu and Ni (Σ Y.PGE = 345 and 1417 ppb); and 3) one disseminated sulphide bearing garnet gabbro horizon (3) with moderate Pt-Pd concentrations (Σ PGE 196 ppb) in upper part of the complex. The mineralogy of Pd- and Pt-bearing platinum group minerals (PGM) appears to be commonly associated with sulphide-bearing as intercumulus sulphides. The PGM's include merenskyite, temagamite and melonite. In addition Miller et al. (1991) have reported atheneite, tetraauricupride, electrum and hessite from the same complex. No PGE bearing phase was recognized in the chromite bearing levels.

Mantle normalized PGE profiles from the chromite-rich dunite present a sawtooth appearance with low Pt - Pd and high Ir, Ru, Rh which may be related to early ferrochromite crystallization correlative with high oxygen fugacity (Amoss & Allibert, 1993). However, most of the ultramafic and mafic samples show fractionated mantle normalized PGE patterns with relatively high (Pd/Ir)_n. These ratios mainly result from melt and fractionation processes. Pt and Pd were extracted during partial melting, and concentrated in the silicate melt whereas Ir and Ru were remained in the residual mantle. Crystallization of chromite and, to a lesser extent, olivine will further deplete the Ir and Ru in melt and any rock that subsequently forms from this fractionated magma will have more steeper positive slopes than the original liquids (i. e. higher Pd/Ir ratio).

Key word: PGE, ultramafics, Jijal, Chilas, Sapat, Kohistan arc, Convergence zones, Himalaya.

P/63. Picard, C., Rolland, Y. & Pêcher, A., 1998. The Masherbrum greenstone unit: transported arc or ophiolitic suture? Geological Bulletin, University of Peshawar 31. Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 151-153.

During summer 1997, field work has been conducted in Hushe, Thalle, and Skoro valleys (NE Pakistan). Main aim of this campaign was the study of volcanic rocks throughout the suture zone. In the northern part of this zone, a narrow strip of basic rocks, the Panmah ultramafic unit, has been interpreted as an ophiolite in an intra - Karakoram Mesozoic suture (Searle et al., 1989). Thus, it seems important to compare these basic rocks with the Shyok suture zone volcanic rocks. Our observations of this unit, on both sides of the Masherbrum glacier (see Figure 1B) have shown numerous imbricated scales, viz: ultrabasites of harzburgitic composition (cartoon 3, Figure 1B), gabbros locally flaserised and doleritic dykes (1). Lavas and greywackes (2). These lithological associations suggest some ophiolitic affinities compatible with the interpretation of an oceanic crust relict.

Structurally, the basic rocks are separated from crinoid bearing limestones (5, Fig. 1A-B) by a folded tectonic contact (4, Fig. 1B). Both the basic and the sedimentary units are metamorphosed in the greenschist facies and lie on the Hushe gneiss unit, metamorphosed in the amphibolite facies. This metamorphic contrast and the structural relations show that the basic + metasedimentary units form a klippe on the Hushe gneiss. Preliminary geochemical data (major elements, REE) suggest an arc signature. The basic rocks of the Masherbrum area could possibly be related to the Kohistan-Ladakh volcanics, located 30 km southwestwards, on the south side of the MKT.

Key word: Structure, metamorphism, greenstone, ophiolites, MKT.

P/64. Pickford, M., 1976a. A new species *Taucanamo* (Mammalia: Artiodactyla: Tayassuidae) from the Siwaliks of the Potwar Plateau, Pakistan. *Pakistan Journal of Zoology*, 8 (1), 13-20.

Key word: Mammals, *Taucanamo*, palaeontology, Potwar, Siwaliks.

P/65. Pickford, M., 1976b. An Upper Miocene Pholidote from Pakistan. *Pakistan Journal of Zoology* 8, 21-24.

Key word: Palaeontology, Pholidote, Upper Miocene, Siwaliks.

P/66. Pickford, M., 1977. Pre-Human from Pakistan. *New Scientist* 75, 578-580.

Key word: Pre-Human, Pakistan.

P/67. Pickford, M., 1978a. New evidence concerning the fossil Aardvarks (Mammalia, Tubalidentatata) of Pakistan. *Tertiary Research* 2, 39-44.

Key word: Mammals, Fossils.

P/68. Pickford, M., 1978b. The taxonomic status and distribution of *Schizochœrus* (Mammalia, Tayassuidae). *Tertiary Research*, 2(1), 29-38.

Key word: Palaeontology, Mammals, Fossils.

P/69. Pickford, M., 1982. Miocene Chalicotheriidae of the Potwar Plateau, Pakistan. *Tertiary Research* 4, 13-29.

Key word: Palaeontology, Miocene, Siwaliks, Potwar.

P/70. Pilbeam, D., 1978a. Rearranging our family tree. *Human Nature*, 1(6), 38-45.

Key words: Vertebrates, palaeontology

P/71. Pilbeam, D., 1978b. Rethinking human origins. *Discovery*, 13(1), 2-9, Peabody Museum of Natural History, Yale University, New Haven.

Key words: Vertebrates, palaeontology, Human origin, Siwaliks

P/72. Pilbeam, D., 1979a. Recent finds and interpretations of Miocene hominoids. *Annual Review of Anthropology* 8, 333-352.

Key words: Vertebrates, palaeontology, Miocene hominoids, Siwaliks.

P/73. Pilbeam, D., 1979b. Miocene hominoids from the Siwalik Group of Pakistan. *American Journal of Physical Anthropology*, 50, 471.

Key words: Vertebrate, paleontology, Miocene hominoids, Siwaliks

P/74. Pilbeam, D., 1980. Major trends in human evolution. In: Konigsson, L. K. (Ed), *Current Argument on Early Man*, 261-285. Pergamon Press, New York.

Key words: Vertebrate, palaeontology, hominoids, evolution, Siwaliks

P/75. Pilbeam, D., 1982. New hominoid skull material from the Miocene of Pakistan. *Nature* 295, 232-234.

Key words: Vertebrate, paleontology, hominoid skull, Siwaliks.

P/76. Pilbeam, D., Behrensmeyer, A.K., Barry, J. & Shah, S.M.I., 1979. Miocene sediments and faunas of Pakistan. *Postilla* 179, 1-45.

Five field seasons of work on the Siwalik sediments of Northern Pakistan have greatly expanded the knowledge of these Miocene sediments and their vertebrate faunas. Six long stratigraphic sections on the north limb of the Soan synclinerium near the town of Khaur were measured. These columns, the longest of which is over 3000 m provide the stratigraphic framework for the paleontological studies and give a detailed description of the lithological sequences in the Khaur region. The formational units of previous workers are poorly defined and of little practical value for biostratigraphy or chronostratigraphy. Three major lithological facies are recognized: a blue-gray sand facies; a buff sand facies; and a silt/clay facies. Intensive paleomagnetic sampling allows a provisional correlation to the La Brecque magnetic time scale. The paleomagnetic sampling also defined a series of isochrons, 1 of which was followed laterally along a 30 km-long belt of outcrop. Certain lithological horizons also may be reliable chronostratigraphic markers. Fossils are usually found only in the buff sands or their laterally equivalent fine-grained floodplain and levee deposits. Three types of fossil localities are recognized based on the characters of the fossil assemblages and the sediments. Localities in channel-related deposits were formed as composite events averaged over time and space, and therefore provide information suitable for paleoecological reconstructions. On the basis of appearances of key species a series of 11 biostratigraphic zones are provisionally defined. These span the sequence from the Lower Siwaliks to the base of the Upper Siwaliks. The faunas of the 3 lowest zones show similarities to the Asteracian faunas of Europe and to the East African middle Miocene faunas. Zones 4-8 appear to be a period of faunal endemism although there are some resemblances to European and Asian faunas.

Key word: Sediments, stratigraphy, vertebrates, Miocene, Potwar, Siwaliks.

P/77. Pilbeam, D., Barry, J., Meyer, G.E., Shah, S.M.I., Pickford, M.H.L., Bishop, W.N., Thomas, H. & Jacobs, L.L., 1977. Geology and palaeontology of Neogene strata of Pakistan. *Nature* 270, 684-689.

A joint study of the Potwar Plateau of Pakistan is yielding abundant material for stratigraphic and palaeontological reassessment.

Key word: Stratigraphy, Palaeontology, Potwar.

P/78. Pilbeam, D., Meyer, G.E., Badgley, C., Rose, M.D., Pickford, M.H.L., Behrensmeyer, A.K. & Shah, S.M.I., 1977. New hominoid primates from the Siwaliks of Pakistan and their bearing on hominoid evolution. *Nature*, 270, 689-695.

Siwalik deposits in the Punjab have yielded a rich collection of hominoid primate remains. They have important bearing on the evolution of the hominids. Together with other recent finds they indicate the need for some changes in hominoid classification.

Key word: Vertebrate palaeontology, hominoids.

P/79. Pilbeam, D.R., 1976. Neogene hominoids of South Asia and the origins of Hominidae. In: Tobias, P.V. & Coppens, Y. (Eds.), *Les plus anciens hominids*, 39-59. UISPP, IX Congress, Colloque VI. CNRS.

Key words: Palaeontology, Neogene hominoids, hominoid, Siwaliks.

P/80. Pilbeam, D.R., & Grant, E.M., 1974. Yale in Kenya and Pakistan: Paleontology in two continents. *Discover* 9(2), 73-81. Peabody Museum of Natural History, Yale University, New Haven.

Key word: Palaeontology, Kenya, Pakistan.

P/81. Pilbeam, D.R. & Jacobs, L. L., 1978. Changing views of human origins. *Plateau*, 51 18-31. Museum of Northern Arizona, Flagstaff.

Key word: Vertebrate palaeontology, human origin.

P/82. Pilbeam, D.R., Rose, M.D., Badgeley, C. & Lipschutz, B., 1980. Miocene hominoids from Pakistan. *Postilla*, 181.

Key word: Hominoids, Miocene.

P/83. Pilbeam, D.R. & Smith, R., 1984. New skull remains of *sivapithicus* from Pakistan. In: Shah, S.M.I., & Pilbeam, D.R. (eds.), *Geological Survey of Pakistan, Memoir 11*, 1-8.

Key word: Palaeontology, Pakistan.

P/84. Pilgrim, E.S., 1913. The correlation of the Siwaliks with mammal horizons of Europe. *Geological Survey of India, Records* 43(4), 264-326.

Key word: Palaeontology, Mammals, Siwaliks, Europe.

P/85. Pilgrim, G.E., 1910. Preliminary notes on a revised classification of the Tertiary freshwater deposits of India. *Geological Survey of India, Record* 40(3), 185-205.

Key word: Classification, Freshwater deposits, Tertiary.

P/86. Pilgrim, G.E., 1917. Preliminary note on some mammal collections from basal beds of Siwaliks. *Geological Survey of India, Records*, 48 (2) 98-101.

Key word: Palaeontology, Mammals, Siwaliks, Europe.

P/87. Pilgrim, G.E., 1926. The Tertiary Formations of India and interrelation of the marine and terrestrial deposits. *Proceedings, Pan-Pacific Science Congress 1923*, 896-931.

Key word: Marine deposits, Tertiary Formations, India.

P/88. Pilgrim, G.E., 1940. Middle Eocene mammals from northwest India. *Proceedings, Zoological Society of London, Series B*, 110(1-2), 127-152.

As this account does not have an abstract, the first few paras are taken for ready reference.

Mr. W. K. Edwards, Keeper of the Geological department of the British Museum, and Dr. A. T. Hopwood have very kindly invited me to study a small collection of vertebrate fossils which was presented to the Museum by Mr. E.S. Pinfold, of the Attock Oil Company. They were originally discovered by him in the Lower Khirthar series, south of Fort Munro in Dera Ghazi Khan district, on the right bank of the Indus. Better preserved specimens were collected by Mr. T. G. B. Davies and other geologists in three sites on the southern edge of the kala Chitta Range, in the Attock district of the Punjab, which runs almost from Rawal Pindi to the Indus River. These last lie near the top of the Lower Charat series, at a horizon which is believed to be identical with that of the first-named locally. The Lower Chharat series is now correlated, on the basis both of the stratigraphy and of the foraminiferal fauna, on the one hand with the Lower Khirthar series of Sind, Baluchistan, and the North-West Frontier Province, and on the other hand with the Lower Lutetian stage of the Eocene of Europe. Although remains are extremely fragmented, and, indeed for the most part generally indeterminable, yet an interest attaches to them beyond what such fragment would ordinarily possess, because, they include the first land mammals of Eocene age which have been found in India proper, and are of an even earlier age than those which for several years have been known to occur in the Pongaung series (probably Ludian) of Pakokku, Burma.

The fossils were collected from the following localities. A brief list of the specimens which each has yielded is added, while full descriptions of such of them as merit it will be found in the body of the paper.

1. Lammidhan, north west of Basal and 1-1/2 miles due west of Ganda kas village (lat. 33 38' 15"; long. 72 11' 20") on India topographical survey sheet no. 43 c/2, from the Planorbis Freshwater Beds of the Lower chharat stage, which is considered by Nuttall 1926, p.121), Lt. Col. L.M. Davies, and E.S. Pinfold to be the equivalent of the Lower Khirthar stage of other parts of India, and probably of Lower Lutetian age, contrary to the opinion formerly expressed by L.M. Davies (1926, 1927) and by Cotter (1933, pp 74, 95).

Key word: Mammals, Eocene, India.

P/89. Pillewizer, W., 1956a. Der Raikot-Gletscher am Nanga Parbat im Jahre 1954. *Zeitschrift für Gletscherkunde*, 3(2): 181-194.

Key word: Glaciers, Raikot, Nanga Parbat.

P/90. Pillewizer, W., 1956b. Die glaziologischen arbeiten im Hunza-Karakorum und am Nanga Parbat. *Erdkunde* 10, 15-22.

Key word: Glaciology, Hunza, Nanga Parbat, Karakoram.

P/91. Pillewizer, W., 1957. Bewegungsstudien an Karakoram-gletschern. *Petermanns Geogrrafische Mitteilungen Ergänzunsheft*, 262, 53-60.

Key word: Glacial movement, Karakoram.

P/92. Pillewizer, W., 1958. Neue Erkenntnisse uber die Blockbewegung der Gletscher. *Zeitschrift für Gletscherkunde*, 4(1-2), 23-33.

Key word: Glaciers, Block movement.

P/93. Pillewizer, W., 1960. Zwischen wuste und gletchereis. *Deutsche Forscher im Karakorum*. Published H. Haack, Gotha.

Key word: Desert, Ice, Glacier, Karakoram.

P/94. Pinet, C. & Jaupart, C., 1987. A thermal model for the distribution in space and time of the Himalayan granites. *Earth and Planetary Science Letters* 84, 87-99.

In southern Tibet, crustal thickening due to the India-Asia collision has led to the formation of two granite belts. One is located at the southern edge of the accretionary wedge of Tethyan sedimentary rocks, close to the contact with basement gneisses of the Tibetan slab. The other is found within the wedge itself, close to the Kangmar thrust trace. Available ages suggest that the granites appeared first in the southern belt and then in the Kangmar belt. This sequence seems to violate the chronology of thrusting. Another feature of the Himalayas is that melting started only about 20 Ma after the onset of thickening, which is much less than the thermal time constant of thick crust. We give a thermal model, based on the assumption of conductive heat transfer, which explains these features. The model relies on the geometry of a sedimentary accretionary wedge bounded by low-angle thrust faults and on the existence of a thermal conductivity contrast between old basement and young sedimentary rocks. The wedge of sedimentary rocks acts as an insulating cap and its southern edge heats up along the contact with basement rocks. On a horizontal cross-section, there is a temperature maximum along this southern edge, which explains why melting starts there. The early thermal evolution is sensitive to local conditions and granites first appear in the vicinity of the most radiogenic parts of the basement. The distribution of granites in space and time is seemingly random, reflecting different melting events in different radiogenic environments in the heterogeneous basement. This model predicts a relationship between radioactivity and age which is compatible with available data. The results emphasize that there are large horizontal temperature variations across a thickened region and that granite ages are not related simply to the timing of tectonic phases.

Key word: Thermal model, granites, collision, Himalaya.

P/95. Pinfold, E.S., 1918a. Notes on structure and stratigraphy in the northwest Punjab. *Geological Survey of India, Records* 49, 137-160.

The stratigraphy and structure of the northwest Punjab (present day Pakistan) is given in this account.

Key word: Structure, stratigraphy, Punjab.

P/96. Pinfold, E.S., 1918b. Conditions governing the occurrence of oil in the Punjab. *Journal of the Asiatic Society of Bengal, New Series* 14, 173-184.

The oil-springs of the Punjab are so numerous and prolific that they must have been known and used from very early times. A bibliography of the references to them up to 1891 is given as an appendix to a paper by Holland in the *Records of the Geological Survey of India*, volume xxiv, page 96. As far back as 1869 the Punjab Government made its first attempt to drill for oil, and a boring was put down by Fenner, of the P.W.D., at Jafar about five miles west of Fatehjang. There are no oil springs at Jafar and the geological evidence is unfavorable. The boring proved a failure, but this did not discourage the oil authorities and in the early seventies an expert, F. W. Lyman, was commissioned to examine and report on all the then known oil localities. His results and recommendations were published in a long report dated 1879. I have been unable to find any record of what borings were put down on Lyman's recommendations; some wells were drilled at Chharat, five miles northwest of Fatehjang, and others, possibly at Jaba in the Salt Range. The Chharat bores yielded some oil, but the venture was a failure commercially.

In 1890 a more ambitious attempt to develop the oil localities was made by a syndicate in which the Townsend brothers had the main interest. Wells were drilled by Canadians at Sudkal, near Fatehjang, at Jaba, and at Alugud in the Trans-Indus Salt Range. Some of these wells were carried down to over 700 feet; small quantities of oil were obtained at each locality, but the project was eventually abandoned. Still another failure has to be recorded. In 1912 Indolex Syndicate imported a Swiss geologist, Professor Preisswerk, under the direction of the Austrian oil authority, professor Zuber of Lemberg. A well was drilled on a closely compressed limestone anticline near Golra junction during cold season of 1913-14. The well was carried to about 1000 feet but obtained only a few gallons of oil.

Key word: Hydrocarbons, Punjab, Attock.

P/97. Pinfold, E.S., 1938. North West India. *The Science of Petroleum* 1, p.138.

Key word: Hydrocarbons, Punjab, Attock.

P/98. Pinfold, E.S., 1939. The Dunghan Limestone and the Cretaceous-Eocene unconformity in the Northwest India, Geological Survey of India, Record 74(2), 189-198.

Key word: Dungan Limestone, K-T unconformity, India.

P/99. Pinfold, E.S., 1940. Correlation of Laki beds. Geological Magazine 77, 481-483.

The Laki beds (Eocene) of northwestern India are thickest in the Suleiman foothills. These are correlated with the Laki of the Salt range, the Kohat district, and the Punjab.

Key word: Stratigraphy, Laki beds, Eocene, Suleiman foothills, Salt Range, Kohat.

P/100. Pinfold, E.S., 1947. The oil fields of North West India. Reviews, Institute of Petroleum Rev. 1, 281-184.

Key word: Hydrocarbons, Oilfields, Attock, Punjab.

P/101. Pinfold, E.S., 1953. Western Pakistan: The world's oil fields, The Eastern Hemisphere. Science of Petroleum 6.

Key word: Hydrocarbons, World oilfields, Punjab.

P/102. Pinfold, E.S., 1954. Oil production from Upper Tertiary fresh-water deposits of West Pakistan. American Association of Petroleum Geologists, Bulletin 38, 1653-1660.

Key word: Hydrocarbons, Tertiary, oil production.

P/103. Pinfold, E.S., Davies, T.G.B. & Gill, W.B., 1947. Scientific problems in the development of the oil field in the Northwest India. Transactions National Institute of Sciences, India 2(8), 231-240.

Key word: Oilfields, Punjab, India.

P/104. Pirzada, A.A., 1978. Geology of the Paras area, Kaghan valley. M.Sc. Thesis, Punjab University, Lahore, 153p.

Key word: Petrology, mapping, Kaghan valley, Mansehra.

P/105. Pirzada, A.A., Azhar, A.M. & Nasimuddin, 1997. Lithofacies variations in Nagri Formation across southwest Potwar Plateau. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 31-33.

Numerous surface radioactive anomalies at different stratigraphic levels in sandstones of Nagri Formation of Southwestern Potwar Plateau, along with other favorable factors for its uranium potential i.e. source, mobilization and trapping, was the prime motive behind the present study. To achieve this objective, four geological sections covering the whole thickness of Nagri Formation were studied. From NW to SE, these sections are Daud Khel,

Dhok Zamah, Dhok Miani and Thatla, 57 number of sandstone, clay/siltstone samples were got analyzed to ascertain petrographic composition.

Nagri Formation, an important and extensively outcropping formation of middle Siwaliks of Potwar Plateau has been traditionally presented as a thick sequence of multistoried sandstones of bluish grey color intervened by dull red mudstones and siltstones. However, during the course of present study, significant departures from the stratotype descriptions have been noted in South West Potwar Plateau (SWIPP). These variations are in thickness, geometry, grain size, sand-clay ratio, provenance etc. Nagri formation of south west Potwar represent comparatively finer facies which is evidenced from sand-clay ratio, relatively finer grain size of sandstones, and dominance of clay clast over other types.

Highly variable thickness of total Nagri was observed within a strike distance of about 80 km. From NW to SE, its thickness is 1050 m at Daud Khel, 441m at Dhok Zamah, 593 m at Dhok Miam and 750 m at Jhatla. If no tectonic thinning or thickening is involved (which has not been evidenced), then thickness variations are due to basin configuration of the Potwar foredeep during Nagri time.

Sandstones of Nagri Formation, from bottom to top and from NW to SE, are dominantly lithic arenites with the exception of Dhok Zamah where one sample from Middle Nagri and one sample from Lower Nagri show arkosic composition. The composition of rock fragments indicate that the source rocks of Nagri Formation are predominantly low-grade metamorphics and sedimentary, whereas contribution from igneous and volcanic rocks is very subordinate.

Key word: Sedimentology, stratigraphy, sandstone, Nagri Formation, Potwar Plateau, Siwaliks.

P/106. Pirzada, A.A., Din, N., Rashid, C.M. & Majid, A.A., 1995. Tectonic setting of the Potwar Plateau. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 23-24.

Potwar Plateau (PP) is a part of the Sub-Himalayan tectonic zone. It shows partial, differential salt induced decoupling which causes its lesser northward movement than its immediate surroundings. As a result of this underlying salt, PP is not only over spilling southwards but also westwards, onto the Kalabagh thrust, due to uplift and room available.

It is a composite tectonic unit which North Potwar Deformed Zone (NPDZ) and Southeast (SEPP) corner representing independent blocks. There is an interplay of basement and cover tectonics in which, generally, the basement reaction is in the form of faulting and cover reaction is in the form of folding. PP is bounded on three sides by thrusts and on eastern side by strike slip fault. All the boundaries are tectonically controlled.

NPDZ structures are not true thrusts but are shear boundaries between isoclinal folds along which thrusting took place due to continued stress. Soan Syncline is a result of thrusting on Northern and Southern sides of the PP. In East PP the anticlines have resulted from Salt build-up, mainly along basement normal faults, while synclines are undeformed areas between two anticlines, SEPP Corner is a triangular block formed due to transfer of stress, from Salt Range Thrust (SRT), onto Donmli-Diljabba Thrust. Southwest PP is much less deformed than rest of the PP where faulting predominates over folding in extant distribution and intensity.

Key word: Tectonic setting, stratigraphy, Potwar Plateau, Siwaliks.

P/107. Pivnik, D.A., 1988. Magnetostratigraphy and sedimentology of the Hazara intermontane basin, Pakistan. Geological Bulletin, University of Peshawar 21, 85-104.

The Hazara Intermotane Basin (named herein) is nestled within the Hazara Hill Ranges located on the hanging wall of the Main Boundary Thrust. The Havelian Group represents the fill of this basin and consists of unconsolidated silts, sands and gravels. Paleomagnetic investigations of the silts consisted of both thermal and alternating-field demagnetization experiments for nearly all of the sites of the two measured and sampled stratigraphic sections sampled. All sites are normally polarized and correlated with the Brunhes Chron (0.73Ma to present). Sedimentological analysis shows that the Havelian Group was deposited as a sandure, a large, silt-laden plain of glacio-fluvial sediments consisting of fluvial gravels, sands and windblown loess. It is interpreted that this sandur emerged from valleys of the Hills Ranges which contained Alpine-type glaciers in their upstream reaches. Minimum sedimentation rates determined for the Havelain Group range from 0.07 to 0.27 mm/yr, and are remarkably similar to those determined for the Potwar loess (Rendell, 1988). No evidence was found to suggest that the Havelian Group was deposited as a result of tectonic activity in the foredeep.

Key word: Magnetostratigraphy, sedimentology, Hazara intermontane basin.

P/108. Pivnik, D.A. & Johnson, G.D., 1995. Depositional response to Pliocene-Pleistocene foreland partitioning in northwest Pakistan. *Geological Society of America Bulletin* 107, 895-922.

Pliocene–Pleistocene synorogenic deposits of the Upper Siwalik Group in the northwest Pakistan foreland record changes in dispersal patterns, provenance, and sedimentary facies in response to Himalayan contraction. Three depocenters in the northern Pakistan foreland have been studied: the Peshawar and Campbellpore Basins, situated north of the ranges associated with the Main Boundary fault; and the Soan syncline depocenter, situated in the northern Potwar Plateau, south of the Main Boundary fault. In the Peshawar Basin, an early generation of northward-prograding alluvial fans and gravelly braided streams deposited at ca. 3.0 Ma was folded by en echelon pressure ridges bounded by high-angle reverse faults between 1.7 and 1.4 Ma. The alluvial fan and fluvial deposits were entrenched and infilled by a second generation of northward-flowing braid plain deposits. In the Campbellpore Basin, southwestward-directed fluvial and alluvial-fan deposition in response to uplift of the Kawa Ghar hills began at ca. 1.8 Ma. In the Soan syncline depocenter, deposition occurred at ca. 2.0 Ma as southeastward-flowing braided streams emanating from the Khair-i-Murat uplift, and a southwestward-flowing, gravelly, meandering river derived from highlands to the northeast.

Previous stratigraphic and structural interpretations of this part of the Himalayan foreland have included north-dipping, imbricated thrust faults and duplex structures to characterize the deformation patterns in the region. Recently acquired seismic and other geophysical and surficial structural data from the western part of the foreland indicate that the foreland has experienced strike-slip as well as contractile deformation. The structures that controlled depositional patterns of the Upper Siwalik Group are localized uplifts bounded by high-angle reverse faults and not regional thrust faults. The pattern of Pliocene–Pleistocene uplift and resultant deposition across the foreland does not indicate a progression of deformation in either the foreland or hinterland directions, typical of fold-and-thrust belts.

Key word: Depositional environments, Pliocene, Pleistocene, Siwaliks.

P/109. Pivnik, D.A. & Khan, M.J., 1996. Transition from foreland- to piggyback-basin deposition, Plio-Pleistocene Upper Siwalik Group, Shinghar Range, NW Pakistan. *Sedimentology* 43, 631-646.

Plio-Pleistocene synorogenic deposits of the Upper Siwalik Group in the Shinghar Range (Trans-Indus Salt Ranges) of north-western Pakistan record the transition from foreland-basin to piggyback-basin deposition on the hangingwall of the Salt Range thrust. The Siwalik and Upper Siwalik Groups are over 4 km thick in the Shinghar Range. The lower 3 km consists of the Miocene Siwalik Group, which was deposited by a south-flowing foreland trunk stream, the palaeo-Indus River. The upper 1.5 km consists of the Upper Siwalik Group, which is herein divided into three members. The lowest member includes deposits of the south-flowing palaeo-Indus River and is distinguished from the underlying Siwalik Group by the first appearance of conglomerate. The transition from the lower member to the middle member is interpreted as recording uplift on the Salt Range thrust. As the Salt Range thrust was active, the palaeo-Indus River was bifurcated to the east and west around the embryonic Shinghar Range and overbank and lacustrine deposition occurred, represented by the middle member. When the Shinghar Range achieved significant topography, the upper member was deposited by streams transporting gravel and sand that flowed north and west out of the range and into a piggyback basin that formed on the hangingwall of the Salt Range thrust. New and previously published palaeomagnetic stratigraphy and fission-track ages from volcanoclastic deposits within the Upper Siwalik Group provide tight constraints on the chronology of sedimentary-facies transitions and timing of uplift of the Shinghar Range. The integration of sedimentological and geochronological data indicates that motion on the Salt Range thrust and repositioning of the Indus River began at 1.0 Ma.

Key word: Depositional environments, basin evolution, Pliocene, Pleistocene, topography, Siwaliks.

P/110. Pivnik, D.A., Qayyum, M., Lawrence, R.D. & Beck, R.A., 1997. The edges of the Himalayan Suture, western Pakistan and Myanmar. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 189-190.

The western and eastern edges of the Himalayan suture, located in western Pakistan and western Myanmar respectively, are complexly deformed zones that have experienced multiple phases and styles of deformation and sedimentation. These include ophiolite emplacement, subduction, strike-slip faulting, compressional faulting, and flysch- and molasse-type deposition. The two edges of the suture are in many ways geological mirror images, but also have contrasting histories and resultant structural geometries. Western Myanmar has not experienced the intense collisional deformation that western Pakistan has, thus may serve as an analogue for the depositional and tectonic evolution of the western edge of the suture.

The western edge of the Himalayan suture, in western Pakistan and eastern Afghanistan, consists of, from hinterland to foreland: a plate bounding strike-slip fault (Chaman Fault); a deformed Tertiary sedimentary basin (Katawaz Basin); ophiolites; a belt of intensely deformed “melange” deposited in a foredeep (Kahi Melange); a major transpressional fault (Zhob Fault); telescoped Indian continental-margin deposits (Sulaiman Range); and an undeformed foreland basin (Indus Plain). The most recent interpretations of the structural and depositional history of the western edge of the suture involve Late Cretaceous obduction of ophiolites, Paleocene collision of India with Asia (Beck and others, in press), and Miocene to Quaternary compressional and transpressional deformation (Pivnik, 1995). During the Eocene, the Kohat Basin formed as a restricted marine evaporite basin on the formerly stable Indian continental shelf (Pivnik and Wells, 1996). The Katawaz Basin was formed by Eocene-Oligocene transtension, and hosted fluvio-deltaic and marine deposition that took place on transitional crust between the colliding landmasses. The sedimentary rocks in the basin record southward progradation of the paleo-Indus fan and river system, which presumably flowed south from the Himalayas (Qayyum and others, 1996). The course of the Indus shifted eastward to its present position during the Miocene, when northwest India moved past the Kabul block and the Katawaz Basin was crushed.

The eastern edge of the Himalayan suture, in western Myanmar, consists of, from hinterland to foreland; a plate bounding strike-slip fault (Sagaing Fault); a mildly deformed Tertiary sedimentary basin (Central Basin); ophiolites; a belt of “melange” deposited in a foredeep (Indo-Burman Ranges); an oblique subduction zone (Andaman Trench); and an undeformed foredeep basin (Bengal Fan). Although interpretations vary, it is generally recognized that a north-south striking subduction zone was established by the end of the Cretaceous, and that ophiolite obduction took place during the Eocene (Bhattacharjee, 1991; Brunnschweiler, 1966; Duarah and others, 1983; Mitchell, 1993; Sengupta and others, 1990; Srivastava and others, 1978). This, and subsequent deformation, is most likely related to collision of the northeastern edge of the India Plate with the Burma Plate. The Central Basin has hosted fluvio-deltaic and marine deposition throughout the Tertiary, recording southward progradation of the Irrawaddy deltaic and fluvial system. The basin has not been sutured closed, thus the present-day Irrawaddy Delta represents the recent expression in a continuum of deposition. Phases of deformation were distinct in the Central Basin, with extensional deformation occurring in the Miocene and compressional deformation occurring in the Plio-Pleistocene (Pivnik and others, in press).

The main difference between the two edges of the Himalayan suture is that the western edge has experienced intense collisional deformation, and the eastern edge has experienced a combination of collisional deformation, dominant in the north, and extensional deformation, dominant in the south. This has influenced the development and preservation of sedimentary basins and controlled the position of Tertiary volcanic arcs.

Key word: Tectonics, sedimentation, suture, Himalaya, Pakistan, Burma.

P/111. Pivnik, D.A. & Sercombe, W.J., 1992. Out-of-sequence, evaporite-controlled faulting and folding in the Kohat Plateau, NW Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.71.

Detailed surface mapping and recently acquired subsurface data in the Kohat Plateau of northwestern Pakistan show complex structural styles created by the overprinting of transpersonal structures on pre-existing compressional structures and the presence of a mid-level shale and evaporate decollement horizon. The Kohat Plateau is roughly divided into two regions; a northwest region (NW) and a southeast region (SE). Surface structural styles in the NW region include doubly-overturned anticlines (shishtaray structures) and synclines involving a lower Eocene through Pleistocene stratigraphic succession. Intensely folded (and locally overturned) with the stratigraphy of the NW region is a relict, southward-verging thrust belt, the Mir Khweli Sar I Thrust Belt (MKSTB), that involves mostly middle Eocene to Miocene aged rocks. What were originally low-angle thrust faults of the MKSTB can be traced for 10's of kms along the limbs of folds with lateral ramps exposed in numerous locations. The SE region of the plateau also contains shishtaray structures, however, many of these have had either their southern or northern limbs faulted

out along a lower Eocene shale and gypsum decollement, presumably in the latest stages of fault-propagation folding. Recent structural models of fault-propagation folds with boundary layers similar to gypsum have produced structures very much like those seen in the SE region. The MKSTB is not present in the SE region, and evaporate-floored thrusts are not present in the NW region. The absence of gypsum in the NW region is believed to have limited the propagation of faults, leaving unfaulted detachment folds exposed at the surface.

Newly acquired subsurface data from the Kohat Plateau indicate that previous models of duplex formation and typical foreland thrusting applied to adjacent areas do not apply to this section of the foreland. Instead, steeply dipping strata at depths of over 10,000 ft, steeply dipping faults that become shallow near the surface forming flower structures, and large vertical I displacements across faults suggest transpressional rather than purely compressional deformation. The near-surface, shallow thrusts form flats in lower Eocene shales resulting in detachment folds in the NW region. Localized ramps in lower Eocene gypsum and limestone allow the faults to surface in the SE region. Since low-angle thrusts of the MKSTB have been folded with the rest of the structures in the Kohat Plateau, an out-of-phase sequence of deformation is proposed, which involves the formation of a thrust belt (MKSTB) and subsequent deformation of this thrust belt by younger transpression-related folding and faulting. Based upon sedimentary-facies changes, compositional changes and unconformities within chronologically-constrained molasse deposits in and adjacent to the Kohat Plateau, it is believed that the transpressional phase of deformation occurred from approximately 2.6 to 1.8Mya, while the earlier formation of the MKSTB probably occurred between 3 and 8Mya.

Key word: Structure, salt tectonics, Kohat plateau.

P/112. Pivnik, D.A. & Sercombe, W.J., 1993. Compression- and transgression-related deformation in the Kohat Plateau, NW Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonics*. Geological Society of London, Special Publication, 74, 559-580.

Key word: Deformation, Kohat plateau.

P/113. Pivnik, D.A. & Wells, N.A., 1996. The transition from Tethys to the Himalaya as recorded in northwest Pakistan. *Geological Society of America Bulletin* 108, 1295-1313.

Early Cenozoic sedimentary rocks exposed in the Kohat Plateau of northwestern Pakistan record tectonic closure of the Tethys sea and development of a restricted marine basin that formed during Himalayan collision between India, Asia, and a series of microplates. In the Paleocene, initial subsidence of the basin was caused by the downward deflection of the Indian plate in response to loading of the Asian plate. The western margin of the early Eocene basin was dominated by deposition of shale, sandstone, and conglomerate derived from microplates located to the north and west of the Indian continental margin. The eastern margin of the basin was a carbonate shelf and sabkha flat. Salt deposition occurred subaqueously in the central parts of the basin. In the late early Eocene, redbeds derived from the northwest were deposited by a fluvial and/or deltaic system. This influx of clastic sediments marks the earliest record of terrestrial foreland-basin deposition in northwest Pakistan. During the middle Eocene, the basin was reflooded and a carbonate shelf developed. Relative sea-level rise may reflect subsidence of the Indian plate in response to continued crustal loading in the Himalayan suture zone. Uplift and erosion occurred between the late Eocene and Miocene, possibly related to a peripheral bulge south of the Himalayan suture zone. The main phase of Himalayan foreland-basin fluvial deposition began in the Miocene. Renewed uplift related to final collision of India and Afghanistan during the Pliocene is recorded by a thick sequence of conglomerate in the western Kohat Plateau. Correlation with Eocene sedimentary rocks from southern Pakistan to northern India delineates the depositional systems that developed as the Tethys sea closed during Himalayan convergence.

Key word: Basin evolution, tectonics, Tethys closure, Himalayan tectonics, Kohat plateau.

P/114. Pognante, U., 1991. Different P-T-t paths along the High Himalayan Crystallines: constraints on the formation and distribution of Miocene leucogranites. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 65-66.

On the ground of previous studies of the P-T metamorphic conditions and of new data emerged recently on the High Himalayan Crystalline (HHC), this paper suggest that different P-T-t paths exist not only in N-S cross sections, as

usually described, but also along the belt from western to eastern Himalayas. In the Kaghan nappe of northern Pakistan, the P-T-t path with an early (M1) eclogite-facies metamorphism ($P > 13$ kbar, $T = 650 \pm 50^\circ\text{C}$; Pognante and Spencer, in prep.) and a later exhumation at decreasing temperatures (Greco, 1989), are typical of subducted and collided tectonic sheets with low initial heat supply which were uplifted very rapidly and/or were imbricated with other nappes. In northern Pakistan the minerals give prevalent pre-Miocene cooling ages (Treloar et al. 1989).

East of Pakistan, occasional granulites formed during stage M1 (Burg et al. 1987. Pognante and Lombardo, 1989) instead of eclogites and relatively slow uplift rates are suggested by the prevalent Miocene cooling ages of minerals. The decompression path occurred at uniform or increasing temperatures which produced anatexis and formation of leucogranitic melts during stage M2 (e.g. Caby et al., 1983; Staubli, 1989; Pognante et al., 1990;) $P = 4-7$ kbar, $T = 600-750^\circ\text{C}$). This is typical of rocks involved in a continental event and derived from crust with normal or high initial heat supply (Thompson and England, 1984). The stage M3 produced an incipient retrograde recrystallization in Zaskar. In contrast, anatexis continued during stage M3 in Buthan and Nepal where leucogranite melts were produced also in the cordierite-andalusite field (Brunel and Kienast, 1986; personal observations in the Everest-Makalu area;) $P = 3-5$ Kbar, $T = 600-650^\circ\text{C}$). From the available data along the HHC also emerges that close relations exists between P-T-t paths and distribution and characters of the Miocene crustally derived leucogranites.

Intrusive leucogranite bodies are subordinate in western Himalayas. In the Khagan nappe, the lack of a heating stage during uplift and the crossing of the granite melting field only at medium-/high pressures, all should be responsible for the formation of small amounts of melt.

In Zaskar, extensive anatexis occurred during stage M2 (in the sillimanite $\pm$ kyanite field) but relatively small amounts of melt were produced. In the middle structural levels, collection and ascent may have been partly inhibited by high, viscosity of the dispersed melt which chiefly freezed "insitu" as migmatites and anatectic leucogranites (Pognante, in prep.). In Buthan and Nepal, anatexis continued after stage M2 with the production of more significant amounts of melt. In fact relatively low amounts of H₂O (or micas in case of dehydration melting) are required to produce a granitic melt at the low-pressure conditions of stage M3. Large portions of this melt were extracted and intruded to high structural levels (Le Fort et al., 1987) where they coalesced to form large lens-shaped leucogranite bodies.

Key word: Metamorphism, P-T-t paths, Zaskar, Kaghan, Azad Kashmir.

P/115. Pognante, U., Benna, P. & Le Fort, P., 1992. High-Pressure metamorphism in the High Himalayan Crystallines of the Stak Valley (North-Eastern Nanga Parbat-Haramosh Syntaxis, Pakistan). Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.120.

After the pioneering work of Zanettin (1964), the NE termination of the High Himalayan Crystallines (HHC) in the Haramosh syntaxis has been studied during a geological expedition in the Stak and Turmik valleys (NW Skardu, Pakistan). The eastern boundary of the HHC with the overlying low-grade sedimentary, metabasic and minor ultrabasic rocks of the Ladakh Unit (Le Fort et al., this vol.) is defined by a shear zone dipping toward east.

The HHC consists of paragneiss, orthogneiss, metabasic rocks derived from original dykes and rare calc-silicate rocks and marbles. Leucogranitic dykes are lacking or very rare, while deformed pegmatitic dykes are common at the uppermost structural levels. The rocks of the HHC show rather homogeneous metamorphic assemblages: Qtz-Pl-Or-Bt-Ms-Grt-Ky in the gneisses and Grt-Aug(Xrd < 0.14)-Pl-Rt-Qtz in the metabasic rocks. Except for the later growth of amphiboles (hornblende and actinolite) and biotite in the metabasites, apparently related to H₂O-infiltration along discrete fractures, evidence of decompressional re-equilibrations are rare. Only in the uppermost levels (a few tens of meters below the shear zone) an obvious metamorphic zonation and a pervasive greenschist-facies re-equilibration have been observed. Green amphiboles, albite, clinozoisite porphyroblasts and chlorite are widespread near the upper shear zone.

Grt-Cpx geothermometer and Grt-Pl-Cpx geobarometer in the Grt-granulites of the middle structural levels indicate $T = 700 \pm 50^\circ\text{C}$ at $P = 8-10$ kbar and $T = 600 \pm 80^\circ\text{C}$ at $P = 7-8$ kbar for cores and rims, respectively. Grt-Bt geothermometer and Grt-Pl-Ky geobarometer in the associated gneiss give comparable estimates with $T = 650 \pm 30^\circ\text{C}$ at $P = 9-12$ kbar and $T = 590 \pm 30^\circ\text{C}$ at $P = 7-8$ kbar for cores and rims, respectively. An incipient migmatization with formation of Ky-bearing leucosomes has been observed at these structural levels. In the gneiss of the upper levels, Grt-Bt geothermometry and Grt-Pl-Ky geobarometry give $T = 580 \pm 30^\circ\text{C}$ and $P = 6-9$ kbar.

The lack of a pervasive low-P re-equilibration of the high-P assemblages, the thermobarometric data and the study of garnet zoning profiles, all suggests that exhumation of the HHC occurred at decreasing T and, perhaps, at high rates. The metamorphic zonation with upward I decrease and the pervasive low-T recrystallization near the

extensional shear zone were probably induced by conductive cooling and shearing along the boundary with the “cold” Ladakh Unit.

These data are consistent with the evolution proposed for the eclogitic rocks recently found in the HHC of the upper Kaghan valley (SW Nanga Parbat-Haramosh syntaxis). For the Kaghan eclogites, petrological and geochronological data suggest rapid cooling and exhumation after the eclogitic peak (Tonarini et al., this vol.). In contrast, exhumation paths at increasing T and extensive anatexis with formation of leucogranite plutons characterize the HHC in eastern Himalayas (e.g. Pognante and Benna, this vol.).

Key word: High-P metamorphism, High Himalayan Crystallines, Stak valley, Nanga Parbat Haramosh.

P/116. Pognante, U., Benna, P. & Le Fort, P., 1993. High-pressure metamorphism in the High-Himalayan crystalines of the Stak valley, northeastern Nanga Parbat-Haramosh syntaxis, Pakistan Himalaya. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonics*. Geological Society, London, Special Publications 74, 161-172.

The High Himalayan Crystallines (HHC) from the little-known NE termination of the Nanga Parbat-Haramosh syntaxis (Stak and upper Turmik valleys, Pakistan) consist of kyanite-bearing gneiss with minor garnet-granulite and garnet-amphibolite. The HHC underwent a Himalayan metamorphism with a peak at high pressure (8–13 kbar) and high temperature (650–700° C). During exhumation the HHC rocks followed a rapid exhumation path at high temperature with little or no medium to low pressure re-equilibration. These lines of evidence, combined with geochronological and petrological data from Eocene eclogites recently found in the Kaghan nappe, indicate that, after subduction and high to very high pressure metamorphism, part of the HHC from northern Pakistan underwent very rapid cooling and exhumation. By contrast, exhumation along paths of increasing temperature are recorded by the HHC from regions located east of Pakistan (e.g. Nepal). These differences along strike in the HHC suggest that, during the Eocene collision between India and Eurasia, subduction and exhumation occurred at higher rates in northwestern than in central-eastern Himalaya. Additional information can be obtained in the preceding account.

Key word: High-P metamorphism, High Himalayan Crystallines, Stak valley, Nanga Parbat Haramosh.

P/117. Pognante, U. & Spencer, D.A., 1991. First report of eclogites from the Himalayan belt, Kaghan Valley (Northern Pakistan). *European Journal of Mineralogy* 3, 613-618.

Eclogite characterized by omphacite – garnet – quartz – rutile ± phengite assemblage are reported for the first time in the Himalayan belt. They occur in the High Himalayan Crystallines (HHC) and Tethyan metamorphic units of northern Pakistan. The eclogites formed at $\sim 650 \pm 50^\circ\text{C}$ and $P \sim 13\text{--}18\text{ Kbar}$, and represent the deepest rocks derived from the Indian plate known so far. They show an incipient decompresssional constant or increasing temperature of the HHC in India and Nepal.

Key words: Eclogite, Ultra high-P metamorphism, Kaghan, Himalaya.

P/118. Pogue, K.R., DiPietro, J.A., Hughes, S.S., Dilles, J.H., Rahim, S. & Lawrence, R.D., 1992. Late Paleozoic rifting in northern Pakistan. *Tectonics* 11, 871-883.

Late Paleozoic rifting in northern Pakistan was investigated using stratigraphic, structural, geochemical and radiometric analyses of samples and sites in the area. Derived clasts from Jafar Kandao is indicative of extensional tectonics that took place in the Early Carboniferous. The area underwent uplift during the early Permian and Carboniferous periods accompanied by magmatism. The tectonic history in the north parallels that of central Pakistan indicating continuity of the two areas before the Neo-Tethys opened up.

Key word: Rifting, stratigraphy, structure, geochemistry, Paleozoic.

P/119. Pogue, K.R., DiPietro, J.A. & Khattak, W., 1996. Precambrian stratigraphy and the Foreland-Hinterland transition in the Himalayan thrust belt of Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, USA, 118-119.

Recent investigation in the Indus syntaxis between Tarbela Lake and Besham have revealed critical relationships that permit the reconstruction of the pre-Himalayan configuration of the Precambrian of northern Pakistan which, in general, consists of Proterozoic and Archean (?) crystalline basement rocks overlain by a Proterozoic sedimentary and metasedimentary cover sequence. Both the thickness and metamorphic grade of the cover sequence increase to the north. South of the Main Mantle Thrust (MBT) Upper Proterozoic evaporites (the Salt Range Formation) unconformably overlie Proterozoic gneiss and granite (Gee, 1989). Between the MBT and the Panjal-Khairabad thrust (PKT), the Proterozoic sedimentary cover is represented by siltstone, argillite, slate and limestone of the Hazara Formation and its western equivalent, the Dakhner Formation. Gypsum intervals in the Hazara Formation imply that the Hazara and Salt Range Formations are lateral equivalents. The crystalline basement for the Hazara and Dakhner Formations is not exposed. Between the PKT and Tarbela Lake, the oldest exposed Precambrian rocks are slate and phyllite of the Manki Formation, which are interpreted as the metamorphosed equivalent of the Hazara/Dakhner Formation. The Manki Formation is overlain by stromatolitic limestone of the Shahkot, Utch Khattak, and Shekhai Formations. These limestones thin northward to be replaced by quartzite and argillite of the Tanawal Formation. Near Tarbela Lake, the Tanawal Formation overlies marble and graphitic schist of the Gandaf Formation, which is interpreted as a higher-grade equivalent of the Manki Formation. Northwest of Tarbela Lake, in Swat, higher-grade equivalents of the Tanawal Formation are mapped as the Manglaur Formation. The Gandaf Formation thickens northward in the Indus syntaxis and the deeper levels expose intervals of gneiss and sheared monzonite interpreted as a Proterozoic intrusive complex (the Kotla complex). North of Tarbela Lake, Gandaf Formation lithologies are included in the Karora Formation. In the northern part of the Indus syntaxis, the Karora Formation overlies the Besham Complex. The Besham Complex consists of gneisses that record early Proterozoic metamorphism (Baig, 1990; Baig and Snee, 1989; Treloar and Rex, 1990) that are intruded by granitic rocks and mafic dikes of Proterozoic and Paleozoic age. Near Besham, the unconformity of the Karora Formation with underlying early Proterozoic gneiss of the Besham Complex is marked by a conglomerate. However, at other locations, granitic rocks of the Besham complex intrude the basal part of the Karora Formation, obscuring this unconformity. The entire Precambrian sequence north of Tarbela Lake is extensively intruded by Cambrian granodiorite (the Mansehra and Swat Granites), Late Paleozoic alkaline granitoids (the Ambela intrusive complex), and Permian mafic dikes and sills. Precambrian rocks exposed north of Besham in the Nanga Parbat area are divided between the Iskere Gneiss, Shengus Gneiss, and Haramosh Schist (Madin, 1986). Radiometric dating implies that these units are equivalents of the Besham Complex, Mansehra-type granites, and the Karora Formation (Zeitler and others, 1989).

The relationships outlined above indicate that while the demarcation between basement and cover within the Precambrian can be defined in the southern part of the Pakistan Himalaya, it is obscure to the north. North of the PKT, much of the Precambrian sections were subjected to pre-Himalayan metamorphism and north of Tarbela Lake the entire section is extensively intruded by granitic plutons. Mechanically, these rocks would behave as basement, not as cover. Exposures of Proterozoic gneisses in the Indus syntaxis indicate that the Himalayan basal decollement must have stepped downward into crystalline basement south of Tarbela Lake. Involvement of the basement in thrusting probably first occurs at the PKT, which forms the southern limit of exposures of extensively metamorphosed rocks. The PKT thus forms the boundary between the foreland and hinterland in the Himalayas of Pakistan.

Key word: Stratigraphy, foreland-hinterland, Precambrian, Indus syntaxes, Himalaya thrust belt.

P/120. Pogue, K.R. & Hussain, A., 1986. New light on the stratigraphy of Nowshera area and the discovery of Early to Middle Ordovician trace fossils in NWFP, Pakistan. Geological Survey of Pakistan, Information Release, 135, 15p.

Key word: Stratigraphy, fossils, reef complex, Ordovician, Nowshera.

P/121. Pogue, K.R., Hylland, M.D. & Yeats, R.S., 1993. Stratigraphic and structural framework of Himalayan foothills, Northern Pakistan. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, p.73.

The integration of new paleontological, stratigraphic, and structural data permit analysis of the pre-Himalayan configuration of the Indian plate passive margin in northern Pakistan. Thick sections of Paleozoic metasediments exposed in the Peshawar basin were preserved in half grabens created during Late Paleozoic rifting. Rift highlands

were largely stripped of Paleozoic cover in Swat where Permian metabasalts overlie the Proterozoic Manglaur Formation and in the Attock-Cherat Range where Jurassic and Cretaceous rocks overlie the Proterozoic(?) Dakhner Formation. In the absence of a fossiliferous Paleozoic section, lithologic correlation of Proterozoic units is crucial to retro deformation and estimates of Himalayan shortening. The Proterozoic Salt Range Formation, Hazara (Dakhner) Formation, Manki Formation, Gandaf (Salkhala) Formation, and Karora Group are interpreted as a formerly continuous northward-deepening sequence.

The Khairabad and Nathia Gali-Hissartang faults divide the foothills region into three stratigraphically distinct structural blocks. The northern block consists of the Proterozoic Gandaf and Manki Formations overlain by younger Proterozoic (?) formations and fossiliferous Paleozoic and Mesozoic strata. The metamorphic grade in the northern block gradually increases northward from lower greenschist facies near the Khairabad fault to upper amphibolite facies in central Swat. The central block consists of weakly metamorphosed Proterozoic Hazara (Dakhner) Formation and locally Cambrian and younger Paleozoic(?) strata overlain by Cretaceous and Paleogene marine strata. The southern block consists of unmetamorphosed fossiliferous strata of Triassic to Eocene age. Proterozoic rocks in the subsurface of the southern block are probably transitional between the evaporite dominated Salt Range Formation and the shallow marine clastics of the Hazara (Dakhner) Formation.

Key word: Stratigraphy, structure, palaeontology, Paleozoic sediments, Himalayan foothills.

P/122. Pogue, K.R., Hylland, M.D., Yeast, R.S., Khattak, W.U. & Hussain, A., 1999. Stratigraphic and structural framework of Himalayan foothills, northern Pakistan. In: Macfarlane, A., Sorkhabi, R.B. & Quade, J. (eds.), *Himalaya and Tibet: Mountain root to mountain tops*. Geological Society of America, Special Papers 328, 257-274.

We present a geological synthesis of northern Pakistan between the Main Boundary and Main Mantle thrusts based on new stratigraphic and structural information. The Hazara (Dakhner) Formation and its metamorphosed equivalents form the basal Proterozoic sedimentary sequence in the Himalayan foothills of northern Pakistan. These units were deformed and metamorphosed prior to the deposition of the overlying Phanerozoic section. The Paleozoic section of the Peshawar basin was preserved in a half graben created during late Paleozoic rifting. Paleozoic rocks were mostly removed from elongate northeast-trending highlands bounding the half graben on the north and south. Whereas the northern highland was submerged by the Late Triassic, large parts of the southern highland remained subaerial until the Middle Jurassic.

The Hissartang fault of the Attock-Cherat Range is interpreted as being continuous with the Nathia Gali fault of Hazara. Both are the first faults north of the Salt Range thrust to expose Proterozoic rocks in their hanging walls. The Panjal fault of Hazara and Khairabad fault of the Attock-Cherat Range are also interpreted to be single continuous faults. The Panjal-Khairabad fault forms the southern limit of rocks that were metamorphosed by the Himalayan collision. Between the Panjal-Khairabad fault and Main Mantle thrust, there is now evidence for a Himalayan fault comparable to the Main Central Thrust of the central Himalaya of India and Nepal. The absence in Pakistan of a Main Central Thrust analog as well as other stratigraphic and structural contrasts precludes the extrapolation of central Himalayan tectonic subdivisions to northern Pakistan.

Key word: Stratigraphy, structure, MBT, MMT, Hazara Formation, Himalaya foothills.

P/123. Pogue, K.R., Quade, J., Hussain, A., Hinz, N. & Wright, H., 1999. Isotopic constraints on the age of metasedimentary rocks of the Peshawar basin, Pakistan. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 117-118.

The ages of many of the metasedimentary formations exposed in the Himalayan foothills that surround the Peshawar Basin have long been the subject of debate. The Manki, Shahkot, Utch Khattak, Shekhai, Dakhner, Darwaza, and Hissartang Formations and Inzari Limestone of the Attock-Cherat and Gandghar Ranges, the Khyber Limestone and Ali Masjid Formation of the Khyber region, and the Ambar, Tanawal, and Gandaf Formations of the northern Peshawar Basin (fig. 1) have been assigned inferred ages based largely on lithologic correlation. Early workers correlated these rocks with unmetamorphosed Paleozoic and Mesozoic rocks of similar lithology exposed to the south (e.g. Calkins et al., 1975). However, they were not aware of the significance of the intervening Panjal-Khairabad fault, a thrust fault with large displacement that is largely concealed beneath Cenozoic basin fill. Later studies (e.g. Pogue et al., 1992) described stratigraphic contrasts across this fault that are similar to those observed on either side of the Main Central Thrust (MCT) of India and Nepal.

An upper age limit of Early Ordovician on the Ambar Formation and stratigraphically lower units was established through the discovery of fossils in the overlying Misri Banda Quartzite (Pogue et al., 1992) and radiometric dating of the Mansehra Granite (Le Fort et al., 1980) which intrudes the Tanawal Formation. Rocks of the Attock-Cherat and Gandghar Range have been considered to be older than these units by most workers even though stratigraphic relationships are obscured by faulting and basin fill. Most recent workers infer a Proterozoic age for the majority of the rocks of the Gandghar and Attock-Cherat Ranges based on the presence of pronounced unconformities at the base of dated Paleozoic rocks and Late Proterozoic whole rock Rb-Sr model age dates on the Hazara Formation near Abbottabad (Crawford and Davies, 1975). These dates were interpreted by Baig et al., (1988) to represent the provenance age of Hazara Formation clastic material. Outcrops of the Hazara Formation however, are confined to the south side of the Panjal-Khairabad thrust and are never in depositional contact with the inferred Proterozoic rocks of the Gandghar or Attock-Cherat Ranges.

Until recently, it has not been possible to further constrain the ages of the undated Peshawar Basin formations. The only associated igneous rocks are ubiquitous diabase dikes of Permian age and the only fossils reported have been stromatolites. Since many of the undated units are carbonates, we concluded that it might be possible to collect samples suitable for stable strontium isotope analysis. Initial seawater ratios are best preserved in unmetamorphosed pure limestone from each undated formation at its southernmost exposure. All of the sampled formations lie in the hanging wall of the Panjal-Khairabad thrust. The metamorphic grade of rocks within this tectonic block increases dramatically northward.

As expected, many of the samples appeared to have acquired excess ^{87}Sr from silicates during metamorphism and were thus too altered to permit correlation with published seawater curves. However, five samples from the Attock-Cherat and Gandghar Ranges have $^{87}\text{Sr}/^{86}\text{Sr}$ ratios below 0.7065 indicating a minimum age of approximately 750 Ma. A ratio of 0.7074 for one sample from the Inzari Limestone in the southern tectonic block of the Attock-Cherat Range rules out the correlation of this unit with Paleozoic rocks exposed near Nowshera proposed by Pogue et al. (1999). This ratio gives an ambiguous age as it is shared by Late Proterozoic, Late Permian, and Mesozoic age for the Inzari Limestone based on the absence of fossils which are generally common in the Permian and Mesozoic carbonates of northern Pakistan. Samples of the Khyber limestone from near the Khyber Pass road yielded ratios as low as 0.7064 which indicates an unambiguous Proterozoic age.

These new data have important implications for the stratigraphy of northern Pakistan. All rocks stratigraphy below the Shekhai Formation, including the widely exposed Manki Formation, are at least 750 Ma in age. A Proterozoic age is also confirmed for the thick Khyber Limestone which crops out extensively in the Khyber region. Similarities in both age and lithology strongly imply a direct correlation between the Khyber Limestone and the Shahkot, Utch Khattak, and Shekhai Formation of the Attock-Cherat Range. Based on these constraints, the Precambrian/Cambrian boundary must lie somewhere between the Shekhai Formation and the Misri Banda Quartzite within the stratigraphic interval represented by the Ambar and Tanawal formations. The Proterozoic rocks of the Peshawar Basin region are probable correlatives with the upper part of the Vindhyan Supergroup of Peninsular India. The new age information also indicates a correlation of the Peshawar Basin Proterozoic section with recently dated protoliths for the Greater Himalayan sequence exposed in the hanging wall of the MCT in Nepal (Parrish and Hodges, 1996).

Key word: Stratigraphy, structure, metasedimentary, chronology, isotopes, Peshawar basin.

P/124. Pogue, K.R., Sak, P.B. & Khattak, W.U., 1995. A Geological Reconnaissance of the Indus Syntaxis, Northern Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Indus syntaxis is an elongate north-striking faulted anticlinorium centered in the valley of the Indus River between the northern Gandghar Range and the Besham area. At its southern extremity near Tarbela dam, northeast-striking rocks in the Gandghar Range are separated from northwest-striking rocks across the river by a complex fault zone marked by pervasively sheared and mineralized graphitic schist (figure 1). Calkins (1975) mapped this fault zone as the Darband fault. Recent activity along the Darband fault is indicated by offset Indus River gravels in drill cores and tilted terraces near the dam site (Yeats and Hussain, 1989). The Gandghar Range southeast of the dam site is composed of low-grade Proterozoic metasediments in two structural blocks separated by the Baghdarra fault. The southeastern block exposes the slates and phyllites of the Manki Formation overlain by a thick limestone interval that is divided between the Shahkot, Utch Khattak, and Shekhai Formations. A relatively thin section of Tanawal Formation quartzite overlies the limestone. The oldest rocks in the northwestern block are graphitic schist and minor marble exposed along the Baghdarra fault. The schist has a gradational contact with the overlying Manki Formation. A thick interval of Tanawal Formation quartzite is separated from the underlying Manki Formation by limestone of

the discontinuous Tobrah Formation. North of the Indus River, the oldest rocks are graphitic schist and marble that were mapped by Calkins (1975) as Salkhala Formation. Due to the ambiguity of the term "Salkhala" with regard to lithologic content, unit boundaries, and type section in Kashmir, these rocks will be referred to as Gandaf Formation in this study. The Gandaf Formation is overlain unconformably by the Tanawal Formation. A relatively complete Paleozoic and Mesozoic section overlies the Tanawal Formation in the Peshawar Basin to the west.

North of Tarbela Dam, the strike of rocks on either side of the syntaxis abruptly swings from east-west to north-south near Tarbela Lake. Rocks in the core of the syntaxis exposed along the lake shore consist of quartzofeldspathic gneiss intruded by granite bearing characteristic blue-gray microcline. The upper part of the gneiss contains discontinuous intervals of marble. At many localities the basal gneiss unit and granite is pervasively sheared. Based on its stratigraphic position, grade of metamorphism, and lithologic similarity, the basal unit is correlated with Indian plate basement rocks of the Besham Group. The gneiss passes gradationally into a northward-thinning interval of Gandaf Formation schist and marble. The Gandaf Formation is overlain by an enormous thickness of quartzite and quartz-mica schist of the Tanawal Formation. On the east side of the syntaxis, the Tanawal is intruded by porphyritic granodiorite of the Mansehra Granite. On the west side of the syntaxis, similar rocks belonging to the Ambela Granitic Complex intrude the Tanawal. The belt of granitic rocks on the west side of the syntaxis narrows and becomes increasingly mylonitized to the north. Where the belt crosses the Barundu River it is a 2 km-wide mylonitic gneiss. It is presumed that this narrow belt of granitic rock continues northward to join the Choga granitic gneiss. East of Tarbela Lake, the Tanawal Formation is unconformably overlain by lower Paleozoic dolomite and quartzite in the Sherwan synclinorium. The youngest rocks of the synclinorium are burrowed feldspathic quartzites similar to the Ordovician Misri Banda Quartzite of the Peshawar Basin. West of Tarbela Lake, the Tanawal Formation is overlain by a thick sequence of marble with interbedded amphibolite that may correlate with parts of the Peshawar Basin Paleozoic section.

Key word: Stratigraphy, reconnaissance, Indus river valley, Indus syntaxis, Gandghar Range, Besham.

P/125. Pogue, K.R., Wardlaw, B.R., Harris, A.G. & Hussain, A., 1992. Paleozoic and Mesozoic stratigraphy of the Peshawar basin, Pakistan: Correlations and implications. *Geological Society of America Bulletin* 104, 915-927.

The most complete Paleozoic sequence described from Pakistan is exposed in bedrock inliers and in ranges fringing the eastern Peshawar basin. Interbedded quartzite and argillite of the Precambrian and Cambrian Tanawal Formation is overlain unconformably by the Cambrian(?) Ambar Formation. The Misri Banda Quartzite unconformably overlies the Ambar and contains Ordovician Cruziana ichnofossils. New conodont discoveries restrict the ages of overlying formations as follows: Panjpir Formation, Llandoveryan to Pridolian; Nowshera Formation, Lochkovian to Frasnian; and Jafar Kandao Formation, Kinderhookian to Westphalian. The Karapa Greenschist, consisting of metamorphosed lava flows, separates the Jafar Kandao from Upper Triassic (Carnian) marbles of the Kashala Formation. The Upper Triassic and Jurassic(?) Nikanai Ghar Formation forms the top of the section.

Correlatives to the Peshawar basin stratigraphy are present locally in the Sherwan synclinorium of Hazara and in the Khyber Pass region. The sequence contrasts markedly with the Paleozoic and Mesozoic section exposed south of the Khairabad thrust in the Attock-Cherat Range. This thrust and its northeastern continuation in Hazara north of Abbottabad thus form the boundary in Pakistan between the Lesser Himalayan and Tethyan Himalayan sections, a function performed by the Main Central thrust (MCT) in the central Himalaya of India and Nepal.

The newly dated Carboniferous to Triassic horizons provide the first firm age constraints on the protoliths of the high-grade Swat metasediments. The dating of the metasediments has, in turn, provided age constraints on pre-Himalayan tectonism and associated intrusions. Two major tectonic episodes during the Late(?) Cambrian and Carboniferous produced positive areas north of the Peshawar basin that provided coarse detritus to the Misri Banda Quartzite and Jafar Kandao Formation.

Key word: Stratigraphy, structure, Peshawar basin.

P/126. Poretti, G., 1983. Geomagnetic profiles along the Karakorum Range. *Bollettino di Geofisica Teorica ed Applicata, Pamir-Himalaya*, 25, 317-328.

Key word: Geophysics, geomagnetism, Karakoram range.

P/127. Porter, S.C., 1970. Quaternary glacial record in Swat Kohistan, West Pakistan. *Geological Society of America Bulletin* 81, 1421-1446.

During three Pleistocene glaciations, large valley glaciers originating at altitudes of 12,000 ft or more occupied the northern part of the Swat River drainage basin and terminated at altitudes as low as 5800 ft. Discrimination and subdivision of the three principal drift sheets is based on various relative-age criteria, including moraine and terrace morphology, weathering characteristics of surface stones, and degree of soil development. The areal and altitudinal distribution of the three drifts, which are designated Laikot (oldest), Gabral, and Kalam, indicates a less extensive glacier cover during each successive glacial age (510 mi², 473 mi², and 430 mi², respectively). Laikot Drift is poorly preserved, strongly weathered, and retains little or no depositional morphology. Moraines and outwash terraces built during the Gabral and Kalam advances are well preserved in two intermont valleys at Kalam and Utror and permit subdivision of the two younger drifts into two and three units, respectively, of lesser stratigraphic rank. Moraines of Gabral age tend to be broad and smooth and have few surface stones, whereas those of Kalam age are bouldery and sharp-crested.

The altitude of the equilibrium-line (ELA) for existing glaciers in Swat Kohistan ranges from 13,000 to 14,000 ft. Assuming accumulation-area ratios of 0.6 ± 0.1 for Pleistocene glaciers in this region, steady-state ELA's during former glaciations are estimated to have been some 3000 to 3600 ft below their present levels.

Key word: Glaciers, Quaternary, Pleistocene, Swat.

P/128. Potts, G.J., Treloar, P.J. & Wheeler, J., 1992. Faulting history of the Nanga Parbat Syntaxis, Northern Pakistan; Constraints from modern earthquake data. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, p.73.

Faults and fault rocks have been examined along a 40 km traverse of the Indus gorge through the Nanga Parbat syntaxis of Northern Pakistan. Using field evidence the direction and sense of displacement have been determined for many of these. From this analysis hypothetical fault plane solutions have been derived and compared with published solutions obtained from modern earthquakes. The comparison shows that, of the faults observed in the field, only those, which display reverse oblique-slip displacement, have counterparts that are seismically active. The remaining faults must be considered either aseismic or inactive. Without geodetic information there is no way to test if the faults are moving aseismically and therefore the second possibility is considered in greater detail. Geometrically the "inactive" faults can be grouped into two sets of normal faults (with associated strike-slip faults). Thus it is necessary to consider the possibility that a period of normal faulting preceded the current regime of thrusting in the Nanga Parbat region and that the exhumation of this portion of the Himalayas was achieved by a combination of normal faulting and erosion.

Key word: Structure, earthquake, Nanga Parbat syntaxis.

P/129. Poupeau, G., Pecher, A., Benharbit, M. & Noyan, O.F., 1991. Ages traces de fission sur apatites et taux de denudation Plio-Quaternaires au Karakorum central. *Comptes Rendus de l'Academie des Sciences*, 313, 917-922.

Key word: Chronology, fission track ages, denudation, Pliocene, Quaternary, Karakoram.

P/130. Powell, C.McA., 1979. A speculative tectonic history of Pakistan and surroundings: Some constraints from the Indian Ocean, In: Farah, A. & DeJong, K.A. (eds.), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 5-24.

The position of India relative to Africa since the mid-Cretaceous, recently determined from ocean-floor magnetic-anomaly patterns between India and Madagascar, is traced from 80 my to the present. Three stages can be identified: I) Rapid northward flight of India from Late Cretaceous to Early Eocene; II) Small counterclockwise rotation of India about a close pole during the Eocene, and III) Slower northward movement from the Oligocene to the present. Using geological arguments, the various tectonic elements of the Late Mesozoic and Cenozoic fold belts

from Iran to western Tibet are positioned palinspastically relative to India and Africa at 70, 55, 40 and 20 m.y. before the present. From these reconstructions the history of the major tectonic elements is then traced from the Late Cretaceous to the present.

The tectonic history of the region is modelled in terms of two major convergence zones; a-northern one, the Albon-Hindu Kush convergence zone bordering the southern edge of the stable Eurasian plate, and a southern one, the Zagros Chitral convergence zone, lying at the southern edge of a complex of microcontinents, island arc and ocean-floored basins which is preserved at present as a wide orogenic belt in Iran and Afghanistan. The Eocene counterclockwise rotation of India, following its probable Late Cretaceous or Palaeocene collision with the Zagros-Chitral convergence zone, initiated the north-northeastward trend of the Pakistani fold belt. Continued convergence choked the Zagros-Chitral convergence zone, and a new intra-continental convergence zone on which the Himalayas grew was developed during the Oligocene and Miocene. The Pakistan fold belt is not a simple oroclinal bend of Himalayan structure, but has evolved as a consequence of the shape of the northwestern corner of India. The Salt Range, Tram-Indus Salt Range and Sulaiman fold-festoon structures may all be currently moving on shallow decollements as the Indo - Pakistani shield continues its northward convergence with Eurasia.

Key word: Tectonics, structure, Indian Ocean, Pakistan.

P/131. Powell, C.McA. & Coneghan, P.J., 1973. Plate Tectonics and the Himalayas. *Earth and Planetary Science Letters* 20, 1-12.

The Himalayas, commonly taken as the type example of continent-continent collision, have developed in two stages. The first stage involves convergence of the northward-drifting Indian subcontinent with a proto-Tibetan landmass during Late Cretaceous and Palaeocene, with collision before Middle Eocene. The second stage involves formation of a fundamental crustal fracture within the Indian block during Late Eocene and Oligocene, and underthrusting of the Indian subcontinent along this fracture from Miocene to Recent. The present elevated Himalayan mountain chain is not a direct result of the continent-continent collision, but of uplift during underthrusting along the deep crustal fracture.

Key word: Plate tectonics, Himalaya.

P/132. Powell, C.McA. & Vernon, R.H., 1979. Growth and rotation history of garnet porphyroblasts with inclusion spirals in a Karakorum schist. *Tectonophysics* 54, 25-43.

Idioblastic garnet porphyroblasts in the metapelitic layers of a Cenozoic garnet-staurolite-biotite-muscovite-plagioclase schist from the Hunza valley, Karakoram Mountains, Pakistan, contain both quartz and graphite inclusion spirals. Growth-zones within the crystals enable reconstruction of the growth and rotation history of each porphyroblast. All the observed microstructural features are adequately accounted for by the model of Schoneveld (1977), which involves growth of the porphyroblast during rotation relative to the matrix. Apparent rotation angles up to 540° have been found. In contrast, xenoblastic to sub-idioblastic garnet porphyroblasts in adjacent metapsammitic layers have only slightly curved inclusion trails.

The quartz spirals appear to have developed by the garnet overgrowing quartz concentrated in "pressure-shadow" domains around the growing porphyroblasts. However, none of the quartz spirals reach the margins of the final crystal outline, and the present "pressure-shadow" domains contain little or no quartz. Furthermore, microprobe analyses of growth-zones within the garnet crystals show a relatively abrupt change in the concentrations of MnO, MgO and FeO across a boundary coinciding approximately with the disappearance of quartz from the inclusion spirals. These changes may be related to a change in metamorphic reactions during garnet growth.

Key word: Metamorphism, tectonic history, garnets, Hunza valley, Karakoram.

P/133. Powell, D., Technical Services Limited, 1959. Report on the production and utilization of coal in Pakistan. 2nd Report to the Government of Pakistan, 136p, Final Report 238p.

Key word: Coal.

P/134. Powell, J.L., & Deans, T., 1968. Trace elements and Strontium isotopes in Carbonatites, Flourites and Limestones from India and Pakistan. *Nature*, 218, 750-752.

Carbonatites discovered in south-west Asia have typical trace elements, but some have unusually high ratios of strontium-87 to strontium-86. Related hydrothermal fluorites have quite different strontium isotope ratios and no distinctive trace elements, emphasizing difficulties in identifying ultimate sources of fluorites.

Key word: Carbonatites, fluorites, Sr-isotopes, India, Pakistan.

P/135. Preiswerk, H., 1921. On the geological features of the oil region in the northern Punjab (British India). *Geological Magazine* 58, 3-21.

In the great chains of mountains belonging to the alpine system, stretching from the Armenian upland throughout Eastern Mesopotamia, Western and Southern Persia, and Baluchistan up to the Indus, then in a great curve encircling the Indian tableland in the Kirthar and Suleiman ranges and the Himalayas, then in the east turning south to Burma there are several regions rich in oil, following the foot of the mountain-ranges on the border of the plains extending in front to the south. The most important of these oil-regions arrange themselves into three chief groups: the Mesopotamian-Persian region, the Baluchistan-Punjab region, and the Burmese region.

Key word: Hydrocarbons, Kirthar, Suleiman range, Punjab, Himalaya.

P/136. Preller, C., 1924. The glacier period in the valleys of Upper Indus and Kashmir. *Scottish Geographical Magazine*, 40, 20-27.

Key word: Glaciation, Indus valley, Kashmir valley.

P/137. Premoli, S.I., 1965. Permian fossils from the upper Hunza valley. Italian Expedition to the Karakorum and Hindu Kush (Desio, A., Leader), vol.4, 89-113. Brill, Leiden.

Key words: Palaeontology, Permian, Hunza, Karakoram.

P/138. Priest, J.E., 1962. Snow surveys in West Pakistan. *Pakistan Geographical Review* 17, 43-49.

The ultimate development of water resources in an area requires that all factors of the hydrologic cycle be investigated and evaluated. The Indus Waters Treaty of 1960 envisages the construction of two large dams on the Indus River System. These dams, which are a big step towards the full utilization of the waters of the Indus Basin, will provide storage to assure irrigation and power supplies at all times of the year. The water which will enter these reservoirs comes from two sources: the melting of snow and ice and monsoon rainfall. Melt supplies are most important the first half of each year, and rainfall assumes most importance from the beginning of July. Therefore the irrigation water supply necessary for maturing the rabi crop and for planting the kharif crop is derived from melt water. It is important to determine the comparative magnitude of this melt runoff.

The Jhelum River upstream of the proposed Mangla Dam (See figure 1), in which catchment snow studies have begun, is a good example. Its melt runoff derives primarily from snow fields as opposed to the huge ice fields which feed the Upper Indus River. The snow field in the Jhelum catchment represents at any one time during the spring, a reservoir of about five million acre feet. This is the equivalent of the Mangla first stage storage capacity. To manage intelligently the Mangla reservoir, it is obviously desirable to have knowledge of snow conditions prior to the melt season. By using techniques developed in other snowy regions it may be possible to predict subsequent runoff by knowing the winter and spring snow conditions.

Key word: Hydrologic cycle, Indus river system, dams.

P/139. Prior, D.J., 1985. Uplift evolution of the Hunza valley metasediments. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

In the Hunza Valley, N Pakistan, a suite of metasediments outcrops between the Northern Suture and the Karakoram Batholith. The metasediments sub-divided into two units: a phyllitic melange and a group of interbedded schists and

marbles. Metamorphic grade increases from south to north. The structure is dominated by one pervasive foliation. Parallels to this foliation are numerous shear zones and thrusts.

Porphyroblast textures indicate that the main period of metamorphic growth occurred during foliation development. Development of foliation ceased shortly after or coincidentally with the end of the metamorphic episode. Deformation of the main foliation is rare, except in the shear zones where complex progressive crenulations are developed. Porphyroblasts become deformed without retrogression in the shear zones and syntectonic garnets are sometimes present.

Across one shear zone, staurolite-garnet schists contact metamorphosed chlorite-garnet schists to an andalusite-biotite hornfels. This shear zone juxtaposed material of differing metamorphic grade whilst still close to peak metamorphic conditions. The hornfels assemblage indicates that uplift occurred at this time. This uplift is interpreted as the result of shear zone/thrust movement in lower grade rocks to the south.

Differential uplift, caused by shear zone movement, over the whole belt of metasediments is responsible for the present distribution of metamorphic assemblages. Younger K/Ar ages (4-5 Ma: Rex pers comm) in higher grade rocks result from their excavation from deeper hotter levels than their low grade equivalents which yield ages of c.30Ma (op cit).

Fission track ages (1-2Ma: Zeitler, 1985) of high and low grade rocks are comparable suggesting that there was little differential uplift across the metasediments at this stage. Considerable homogenous uplift recorded by combining zircon, apatite and sphene fission track ages (op cit) was probably all accommodated by movement on the Northern Suture. Uplift evolution is dominated by a complex interaction of deformation and metamorphism. Movement on shear zones and faults is the most important uplift mechanism. Tectonic uplift is an important control on the thermal evolution of this belt.

Key word: Metasediments, tectonic uplift, thermal evolution, Northern suture, Hunza, Karakoram batholith.

P/140. Prior, D.J., 1987. Syntectonic porphyroblast growth in phyllites: textures and processes. *Journal of Metamorphic Geology*, 5, 27-39.

Porphyroblast textures in a Karakoram phyllite reveal that porphyroblast growth was syntectonic with respect to a cleavage forming deformation. During and after porphyroblast growth it partitions the deformation such that zones of intensified cleavage are developed which wrap around the porphyroblast whilst the porphyroblast and its strain shadow undergo little deformation. Porphyroblast strain shadows comprise quartz, calcite and feldspar with little mica, and are probably formed by solution transfer during deformation. Unless the deformation is so strongly partitioned that no deformation of the porphyroblasts and their immediate surrounds occurs, inequidimensional porphyroblasts will rotate. Porphyroblasts undergo some dissolution after they have finished growing.

Key word: Petrography, porphyroblasts, syntectonic, Karakoram.

P/141. Prior, D.J., 1989. Metamorphism, deformation and uplift of the Hunza valley, Karakoram, N. Pakistan. *Journal of Metamorphic Geology*, 7, 47-54?

Key word: Metamorphism, deformation, Hunza valley, Karakoram.

P/142. Pschichholz, D., 1980. Smaragde aus Indien und Pakistan.

Key words: Gemstones, emerald.

P/143. Pudsey, C.J., 1982. Arc-related and continental margin sedimentation in Kohistan, W. Himalayas. 11th International Congress of Sedimentology, Hamilton, Ontario, p.37.

For further information, consult Pudsey 1986.

Key word: Sedimentation, continental margins, arcs, Kohistan.

P/144. Pudsey, C.J., 1986. The Northern Suture, Pakistan: Margin of a Cretaceous island arc. *Geological Magazine* 123, 405-423.

The Northern Suture is a fault separating the Cretaceous Kohistan island arc terrain (northwest Himalayas) from Palaeozoic sediments of the Asian Plate to the north. The Kohistan arc includes volcanic and sedimentary rocks (andesitic lavas, tuffs, volcanoclastics, slates and limestones), metamorphosed to greenschist facies and intruded by the two-phase Kohistan Batholith. Asian continental margin sediments are mainly of shelf type, are variably metamorphosed and intruded by the Karakoram Batholith. The Northern Suture is a zone of melange from 150 m to 4 km wide, and contains blocks of volcanic greenstone, limestone, red shale, conglomerate, quartzite and serpentinite in a slate matrix. It has a strong planar fabric; but in many places bedding is preserved in blocks and matrix, and depositional rather than tectonic contacts are seen between the two. The melange is inferred to be an olistostrom largely derived from the Kohistan arc, formed in a small back-arc basin between Kohistan and Asia. Limestone blocks in the melange are dated as Aptian–Albian; post-tectonic intrusions yield radiometric ages from 111 to 62 Ma. The Northern Suture therefore probably formed in the early Late Cretaceous during closure of the back-arc basin. The Tethys ocean lay south of Kohistan, where the Main Mantle Thrust represents the westward continuation of the Indus - Tsangpo Suture.

Key word: Tectonics, structure, Northern Suture, Kohistan arc, Himalaya.

P/145. Pudsey, C.J., Coward, M.P., Luff, I.W., Shackleton, R.M., Windley, B.F. & Jan, M.Q., 1985. Collision zone between the Kohistan arc and the Asian plate in NW Pakistan. *Transaction of the Royal Society of Edinburgh, Earth Sciences* 76, 463-479.

Key word: Collision, deformation, Kohistan arc, Asian plate.

P/146. Pudsey, C.J. & Gupta, V.J., 1985. Stratigraphic position of the Darband Formation, Kohistan, northern Pakistan. *Research Bulletin of Punjab University (Chandigarh)* 36, 57-60.

Key word: Stratigraphy, Darband Formation.

P/147. Pudsey, C.J. & Maguire, P.K.H., 1986. Magnetic profiles across the northern suture, Kohistan, NW Pakistan. *Geological Bulletin, University of Peshawar* 19, 47-60.

The northern boundary fault (Northern Suture) of the Kohistan island arc terrain separates Cretaceous arc sediments and volcanics from Palaeozoic shelf sediments of the Asian plate. Arc rocks are more magnetised than Asian plate rocks, and ultramafics along the suture are very strongly magnetised. Four magnetic profiles across the suture show the following features:

A gradual north to south decrease in total field of about 15 nT/km. Asian plate sediments are magnetically quiet and in only one profile does the Northern Suture have a magnetic anomaly. Within the arc sequence, anomalies are associated with the sediment / volcanic boundary and large anomalies occur over granodioritic plutons. We have modelled the best-defined anomaly across the arc sediment / volcanic boundary using a cartoon structure consistent with the surface geology.

Key word: Geophysics, magnetic profiles, Northern Suture, Kohistan arc.

P/148. Pudsey, C.J., Schroeder, R., & Skelton, P.W., 1985. Cretaceous (Aptian/Albian) age for island arc volcanics, Kohistan, N. Pakistan. In: Gupta, V.J. (ed.), *Geology of the Western Himalayas, Contributions to Himalayan Geology* 3, 150-168. Hindustan, New Delhi.

The authors describe the Aptian-Albian fossils from the volcanic rocks and associated sediments occurring along the northern margin of the Kohistan magmatic arc. The host Yasin Group has been known for long time for its fossil-rich character.

Key words: Palaeontology, Island arc volcanics, Cretaceous sediments, Kohistan,

Q/1. Qadir, A. & Ahmad, T., 1979. Petrology of south area, Kaghan valley, NWFP. Pakistan. M.Sc. Thesis, Punjab University, Lahore, 179p.

Key words: Petrology, Kaghan valley.

Q/2. Qadir, S.A., 1965. Geology of Hazara area. M.Sc. Thesis, Punjab University, Lahore, 36p.

Key words: Geology, structure, Hazara.

Q/3. Qadri, A.I., 1985-87. Geology and structure of Doarian Khojaseri area Neelum valley District Muzaffarabad Azad Kashmir, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 116p.

About 130 sq. km Doarian, Dudhnial, Khoja-Seri area a part of Neelum valley (Azad Kashmir) has been mapped at a scale of 1:50,000. The area is characterized by high relief and v-shaped valleys. The rocks of the area are metamorphic of lower Pre-Cambrian, injected by later intrusions of igneous bodies, granites with some basics. Regional metamorphism and accompanying penetrative deformation post-dates the granite intrusions, because the granite itself is involved in the deformation. Field evidences and laboratory studies favour magnetic origin for the granitic bodies. The area is tectonically highly disturbed being involved in Himalayan orogeny. For petrographic analysis thirty thin sections were studied. Petrogenesis of the rocks of the area is interpreted. Major and minor structures of the area are described. Geological history of the Project area is worked out in comparison with adjoining areas of Punjab Himalayas and northern peninsular India. Economic minerals found in the area are listed.

Key words: Geology, structure, Neelum valley, Azad Kashmir.

Q/4. Qadri, S.A.A., 1990. Shallow seismic reflection studies in Latambar area District Bannu (NWFP) to map the weathered and sub-weathered zones and to establish a velocity-lithology relationship. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan.

The object of the survey carried out in Latambar area was to map the low velocity zone in the project area and to establish a velocity-lithology relationship. Seven seismic cross profiles were shot, adopting a reverse shooting technique. In all 27 refraction spreads each with spread length 270m were observed. Time distance graphs were prepared for obtaining true velocities, depths and dip. The results so obtained have been tabulated and presented in the form of Isovelocity and Isopach maps. Integrating the available geological information with the interpreted velocity depth models, a possible relationship between the velocity and lithology has been established. The velocity in the weathered layer ranging from 300- 950 m/sec, indicates the Alluvium/loose weathered material composed of sand, silt and clay. Its thickness varies from 1 -8 meters. The velocity range of sub-weathered layer from 1000- 2400 m/sec exhibits the presence of sandstone with varying amount of clay and degree of compactness. Its thickness ranges from 11- 38 meters. The velocity below the sub-weathered layer picked at some locations ranging from 2400-3800 m/sec shows the presence of Sandstone/Limestone with varying percentage of clay which is relatively more compact.

Key words: Seismic reflection, Bannu.

Q/5. Qaiser, M.A., Akhtar, S.M. & Khan, A.H., 1970. Rodingite from Naranji Sar, Dargai ultramafic complex, West Pakistan. Mineralogical Magazine 37, 735-738.

The rodingite described here (which has been sold locally as 'jade') occurs at Naranji Sar (71° 46' E., 34° 28' N.), a hill south of the village of Mena, about 20 miles west of Dargai (with which it is connected by a jeep road), Malakand. The hill forms part of the northern edge of the Dargai ultramafic complex, consisting

mainly of peridotites such as harzburgite and dunite, the latter enveloping bodies of chromite. In addition, gabbroic rocks are found in places along the northern and eastern contacts with the metasediments (northward dipping phyllites, chlorite schists and, on the north side, talc schists), into which the ultramafic rocks are intruded. Within both the peridotites and gabbros intense serpentinization or chloritization or both is found locally. The rodingite occurs in strings of ovoid lenses, individually up to 2.5 m long and 0.7 m wide, in the altered gabbroic areas, at Naranji Sar trending nearly east-west, to the north and Musa Mena on the east.

Key words: Ultramafics, metasediments, rodingite, metasomatism, Naranji sar, Dargai.

Q/6. Qaiser, M.A., Akhtar, S.M. & Khan, A.H., 1972. Rodingite near Musa Mena, Malakand, West Pakistan. *Journal of Earth Sciences, Leeds* 8, 197-204.

Petrography and geochemistry of a rodingite are given. The rock comprises grossular, idocrase, serpentine, and some altered orthopyroxene.

Key words: Rodingite, ultramafics, metasomatism, Dargai, Malakand.

Q/7. Qaiser, M.A., Alauddin, M., Akhtar, S.M. & Khan, A.H., 1980. Talc-chlorite rocks in Attock slates. *Pakistan Journal of Scientific and Industrial Research* 23, 53-57.

Dark grey to whitish rocks from Attock Cherat, previously described as low grade soapstone, were found to contain talc with a subordinate amount of chlorite (penninite). Other impurities are quartz, calcite, dolomite, magnesite and pyrite. The mineral assemblage has in all probability resulted from magnesium containing solution of hydrothermal origin acting on illite of the slate.

Key words: Talc, clay, slates, Attock-Cherat.

Q/8. Qaiser, M.A., Alauddin, M., Chaudhry, M.A. & Khan, A.H., 1982. Mica from Mego Katz, Loe Shilman, Khyber Agency, North West Frontier Province. *Pakistan Journal of Scientific and Industrial Research* 25, 59-60.

Chemical, X-ray, and differential thermal analysis data are presented for Mica from Mego Katz, Loi Shilman, Khyber Agency. This mica has been identified as phlogopite with subordinate amounts of calcite and quartz. Its application for the manufacture of fire - resistance board, high temperature heat insulation bricks and decorative tiles were also studied.

Key words: Minerals, mica, Loe Shilman, Khyber Agency.

Q/9. Qaiser, M.A., Ali, M.K. & Khan, A.H., 1967. Mineralogy of some asbestos from Northwest Pakistan. *Pakistan Journal of Scientific and Industrial Research* 10, 116-120.

Chemical, X-ray, differential thermal analysis and thermogravimetric data are presented for asbestos from Charsadda Tehsil, Khyber and Mohmand Agencies. Asbestos from Charsadda area was identified to be chrysotile, Khyber and Mohmand minerals were tentatively grouped with tremolite-anthophyllite asbestos. Poor strength of fibers limits their commercial utilisation.

Key words: Mineralogy, asbestos, Charsadda, Khyber Agency, Mohmand Agency.

Q/10. Qaiser, M.A., Ali, M.K. & Khan, A.H., 1968. Study of some indigenous mineral by DTA. *Pakistan Journal of Scientific and Industrial Research* 11, 23-25.

Thermal characteristics of clays, asbestos, talc, bauxite, calcite, magnesite, and dolomite have been presented.

Key words: Minerals, clay, asbestos, magnesite.

Q/11. Qaiser, M.A., Ali, M.K. & Khan, A.H., 1970. Mineralogy of clay deposits near Bagh (33° 45' 30" N, 72° 11' 40" E), Campbellpur District, Rawalpindi Division. Pakistan Journal of Scientific and Industrial Research 12, 483-487.

X-ray, DTA, thermobalance and chemical analyses data have shown that Bagh clays are composed of kaolinite with subordinate amounts of diaspore, haematite and rutile (or anatase). The leaching of alkaline earths from ferruginous carbonate rocks resulted in the formation of brown laterites. Further weathering of laterites under restricted conditions gave rise to bleached clays.

Key words: Mineralogy, clay deposits, Attock.

Q/12. Qaisar, M.A., & Khan, A.H., 1969. Mineralogy of Asbestos from Kurram Agency. Pakistan Journal of Scientific and Industrial Research, 12(2), 163

Further information not available.

Key words: Mineralogy, asbestos, Kurram Agency.

Q/13. Qaiser, M.A., Siddiqi, F.A., Ahmad, N. & Hussain, A., 1990. Mineralogy & chemistry of Eocene shale from Margalla Range, near Islamabad, Pakistan. Abstracts, First SEGMITE Conference on Industrial Minerals, Peshawar, p.6.

Key words: Mineralogy, geochemistry, shale, Eocene Margalla, Islamabad.

Q/14. Qamar, B., 1988. Paleoenvironment and provenance study of Patala Formation, Kohat and Samana Ranges, N.W.F.P. M.Sc. Thesis, University of Peshawar, 72p.

Key words: Paleoenvironment, provenance, Patala shale, Samana Range, Hangu, Kohat.

Q/15. Qamar, M.I. & Naseer, M.A., 1972. Geology and petrology of Aligam–Kabal area, Swat. M.Sc. Thesis, Punjab University, Lahore, 55p.

Key words: Petrology, Swat.

Q/16. Qamar, N.A., 1974. Field report on geology and petrology of Dir (Toposheet No. 38 M/16). M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, Dir.

Q/17. Qasim, M., 1990-91. Structure, stratigraphy and petrography of the western limb of the Hazara-Kashmir syntaxis, Garhi Habibullah-Shinkari area, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 105p.

The Garhi Habibullah-Shinkari area lies along the western limb of the major northwest plunging antiformal structure known as the Hazara-Kashmir syntaxis. The 293 Km² area has been mapped in this study. The western limb of the Hazara-Kashmir syntaxis has been divided into four fault-bounded tectonostratigraphic zones. These are named as the Muzaffarabad-Balakot zone, the Garhi Habibullah-Abbottabad zone, the Panjal zone and the Mansehra zone. These zones belong to different tectonic and stratigraphic provinces which have been juxtaposed during the Himalayan thrusting.

The Muzaffarabad-Balakot zone lies to the east of Main boundary fault. This zone constitutes late Proterozoic to Cenozoic sequence. This sequence is involved in the Muzaffarabad-Balakot southwestward overturned anticline. The late Proterozoic Dogra formation forms the core of the Muzaffarabad-Balakot

anticline. The Dogra formation is unconformably overlain by the early Cambrian Muzaffarabad formation. The Ordovician (?) Yadgar formation disconformably overlies the Muzaffarabad formation. The Yadgar formation is unconformably overlain by the Paleocene-Eocene sequence which includes the Hangu Formation, Lockhart Formation, Patala Formation and Margala Hill Limestone. This was followed by the late Eocene Kuldana and Miocene Murree molasses. The most of the Paleocene to Miocene sequence along the overturned limb of the Muzaffarabad-Balakot anticline is faulted.

The Garhi Habibullah-Abbottabad zone lies between the Main boundary fault and Garhi Habibullah fault. This zone is involved in the Garhi Habibullah syncline. The Cambrian Abbottabad group lies in the core and Hazara formation along the limbs of the anticline. In the Garhi Habibullah syncline, the late Proterozoic Hazara formation is unconformably overlain by the Cambrian Abbottabad group of rocks. The Jurassic sequence has been eroded from the core of the syncline due to later Himalayan uplift.

The Panjal zone lies between the Garhi Habibullah fault and Panjal fault. The Panjal zone includes the late Proterozoic to Triassic rocks which are involved in the Tarkot anticline and Doga syncline. In this zone the Carboniferous Chushal formation unconformably overlies the late Proterozoic Hazara formation and grades into the Permo-Triassic Panjal formation. These rocks are metamorphosed up to lower green schist facies metamorphism. The Mansehra zone lies west of Panjal fault. It includes the late Proterozoic Hazara and Tanol formations and intrusive Cambrian Mansehra granite. The grade of metamorphism varies from chlorite-grade in the south to staurolite-grade in the north. The Panjal and Mansehra zones are intruded by Permian mafic dikes and sills of basalts and dolerites. These basalts and dolerites are fresh but at places show weak Himalayan metamorphic effects. The sedimentary, metamorphic and igneous rocks of these zones are classified by petrographic studies. The rocks of these zones have been affected by multiple pre-Himalayan and Himalayan deformational events. Four deformational events have been recognized as D1, D2, D3 and D4 deformations. D1 Hazara deformation is restricted to the late Proterozoic sequence. D2 deformation produced a barrovian type metamorphism which produced lower-green schist to amphibolite facies metamorphism in the Panjal and Mansehra zones. The effect of D2 deformation is weak or absent in Garhi Habibullah and Muzaffarabad-Balakot zones. D3 deformational event produced southeast-directed folds and thrusts in Mansehra, Panjal and Garhi Habibullah zones. Whereas D3 deformational event in the Muzaffarabad-Balakot zone produced southeast-directed folds and thrusts. The backsteepening and late extensional folding in all of the four zones occurred in the later phase of D3 deformation. However, the D4 deformational event is related to the northwest plunging antiformal and synformal structures which are related to the formation of the Hazara-Kashmir syntaxis.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis.

Q/18. Qasim, M., 1999-2000. Structure, stratigraphy and petrography of Aghar, Gulpur and Nar areas, District Kotli, Azad Jammu & Kashmir, Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 134p.

The geological and the structural mapping of Aghar, Gulpur and Nar areas of about 200 square kilometers was carried on the scale 1: 50,000 using the Toposheet No.43 G/15 of Survey of Pakistan. Then it was enlarged to the present scale 1: 18750. The lithostratigraphic units exposed in the area are mainly sedimentary in nature and range in age from Upper Miocene to Pliocene. These units are the Nagri Formation (Upper Miocene) and the Dhok Pathan Formation (Pliocene) of Siwalik Group of rocks. The Siwaliks are the molasse sediments which were derived from the upthrust mountain ranges of the Himalayas and adjoining foredeep area. The rocks of the area have been deformed during the two phases of deformation named as D1 and D2. D1 deformational event is related to F1 folds. F1 folds are the major anticlines and synclines of the area. These are Barali Anticline, Gulpur Syncline and Nar Anticline. F2 folds are formed during the second phase of deformation D2 due to change in plunge of F1 folds. About fifty rock samples were collected from different localities of the project area out of which twenty samples were selected for the petrographic studies. Tectonically, the Siwaliks lie in Sub-Himalayas and the project area is situated on the southern side of the Himalayan region, where the Siwaliks are deposited in the foreland basin. This foreland basin was formed in association with the collision of the Indian and Eurasian plates.

Key words: Structure, stratigraphy, petrography, Kotli, Azad Kashmir.

Q/19. Qayum, A.K. & Haq, I., 1980. Stratigraphy and structure of Gandili, southeast of Kohat District, North West Frontier Province. M.Sc. Thesis, University of Peshawar, 81p.

Key words: Structure, stratigraphy, Kohat, NWFP.

Q/20. Qayyum, M., 1982-84. Geology and petrotectonic study of Shino-Kaghan-Batal Area, Kaghan valley, District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 191p.

Key words: Petrology, tectonics, Kaghan valley, Mansehra.

Q/21. Qayyum, M. & Lawrence, R.D., 1998. Leading edge of the Himalayan thin-skinned thrust system in Pakistan: the Salt Range. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 154-155.

The 180 km, ENE trending Salt Range is the leading edge of the progressive, south migrating Himalayan thrust front. The presence of a basal salt layer is manifested by the very narrow cross-sectional taper (<10°) and great width (150 km N-S) of the overthrust wedge. Integration of approximately 450 km of seismic reflection data with available surface geologic, magnetostratigraphic, and exploration well data delineate different tectonic features in the Salt Range. These data reveal a concealed duplex structure under the roof sequence, help to determine the footwall and hangingwall geometries of the leading edge at successive evolutionary stages, estimate the lateral extent of a basement normal fault, constrain the ages of different structural features, and define lateral variations in the deformational style within the leading edge. We suggest an out-of-sequence evolutionary model of the Salt Range.

The newly interpreted, concealed duplex structure is the earliest structure of the Salt Range formed during 9-7 Ma. It evolved along a décollement that first ramps within the Salt Range Formation and then across the platform sequence to follow shady horizons of the overlying Murree Formation. The northern ramp is localized in the central Salt Range due to the development of the basement normal fault, around 7 Ma, in the north of concealed duplex structure. It is offset 15 km farther south along a lateral ramp in the western Salt Range, and is entirely within the sedimentary sequence. In the eastern Salt Range, however, it continues within the sedimentary sequence beyond the end of the basement normal fault and then changes into an oblique ramp. The development of basement normal fault interrupted the southward progradation of the thrust wedge. A thick salt pad, formed between 5-6 Ma on the down-thrown side, allowed the thrust wedge to ramp over the northern ramp at about 5 Ma. The topography, newly built by the ramping, resisted the southwards progradation of the thrust wedge and caused further out-of-sequence thrusting in the north. This was followed by the major horizontal translation of the thrust wedge over the roof sequence flat started about 2 Ma. A 130° of counter clockwise rotation has occurred along the northern ramp and the concealed duplex structures.

Key words: Structure, thin-skinned thrusting, Salt Range, Potwar, Himalaya.

Q/22. Qazi, M.A. & Khan, I.H., 1984. Technical feasibility using local iron ore resources of iron & steel manufacture. Abstracts, First Geological Congress, Lahore, 66-67.

Key words: Feasibility, iron ore, steel.

Q/23. Qazi, M.S., Zada, G. & Wahab, 1997. Structural analysis of area north and north east of Bannu, District Bannu, N.W.F.P. M.Sc. Thesis, University of Peshawar, 53p.

Key words: Structure, Bannu basin.

Q/24. Qazi, S.A., 1992. Subsurface investigations using seismic refraction technique for Ghazi Garijala Hydropower Project. Abstracts, First South Asia Geological Congress, Islamabad, 60-61.

Key words: Seismology, seismic reflection, structure, hydropower, Ghazi.

Q/25. Qazi, T.N., 2000. Geographic information system (GIS) and groundwater management. In: Abstract volume, 3rd South Asia Geological Congress (GEOSAS-III), Shams, F.A., Choudhry, M.N., Hassan, Mahmoodul, Kamran, M., and Rashid, S. (Eds.), Lahore, 108-109.

Key words: GIS, groundwater.

Q/26. Quade, J. & Cerling, T.E., 1995. Expansion of C4 grasses in the late Miocene of northern Pakistan: evidence from stable isotopes in paleosols. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 155, 91-116.

Stable-isotopic, clay-mineralogic, and bulk-chemical analyses were conducted on paleosols of the Neogene Siwalik sections in northern Pakistan in order to reconstruct floodplain environments over the past ~ 17 Ma. The stable carbon isotopic composition of soil carbonate (mean $\delta^{13}\text{C}$ (PDB) = -10.2‰) and associated organic matter (mean $\delta^{13}\text{C}$ (PDB) = -24.1‰) in paleosols representing 17– $\sim$ 7.3 Ma reveal that floodplain vegetation was dominated by C3 plants. At 7.3 Ma, a shift toward more positive carbon isotopic values began, signaling the gradual expansion of C4 grasses onto the floodplain. From 6 Ma to present, carbon isotopic values for paleosol carbonate (mean $\delta^{13}\text{C}$ (PDB) = +0.6‰) and organic matter (mean $\delta^{13}\text{C}$ (PDB) = -14.4‰) are uniformly enriched in ^{13}C , indicating the presence of nearly pure C4 grassland.

The scarcity of kaolinite and abundance of smectite and pedogenic carbonate in most paleosols suggest that rainfall in the region remained 1.0–1.25 m/yr or less for the entire 17 Ma of record. Paleosols in the lower portion of the section lack organic A horizons but have reddish B horizons often containing secondary iron-oxide nodules. Leaching depths of soil carbonate in these older paleosols are typically greater than those in the Plio-Pleistocene part of the section, where organic A horizons are common, and B horizons are markedly more yellow. The combined evidence suggests that the mature paleosols in the pre-7.3 Ma part of the record are dominantly calcareous Alfisols or Mollisols that once underlay nearly pure C3 vegetation, perhaps trees and shrubs, while calcareous Mollisols underlying C4 grassland dominate the upper part of the record.

The carbon- and oxygen-isotopic trends in the paleosol record in Pakistan are also evident in the diet of fossil mammals, and in paleosols from Nepal, thus demonstrating that these paleoenvironmental changes in floodplain vegetation may be continent-wide. Local effects, such as the development or intensification of the Asian Monsoon driven by uplift of the Tibetan Plateau, may have led to the expansion of C4 grasses. If, however, the expansion of C4 grasses proves globally synchronous, then a larger scale cause, such as a marked decrease in CO_2 , may be the driving mechanism.

Key words: Stable-isotope, clay, mineralogy, Siwalik, Floodplain, Miocene.

Q/27. Quade, J., Cerling, T.E., Barry, J.C., Morgan, M.E., Pilbeam, D.R., Chivas, A.R., Lee-Thorp, J.A. & Van der Merwe, M.J., 1992. A 16 Ma record of paleodiet using carbon and oxygen isotopes in fossil teeth from Pakistan. *Chemical Geology* 94(3), 183-192.

The Siwalik Sequence of northern Pakistan contains a 16-Ma record of paleosol carbonate and fossil teeth from which a record of paleovegetation can potentially be reconstructed and compared. The carbon isotopic composition of paleosol carbonate and organic matter from Siwalik strata reflects a major paleoecological change on the floodplains of major rivers beginning $\sim$ 7.3 Ma ago. By 6 Ma C3-dominated plant communities, probably composed of mostly trees and shrubs, were displaced by nearly continuous C4

grassland. We find that the carbon isotopic ratios in herbivore tooth enamel reflect this dramatic ecologic shift. Carbonate in enamel older than 7 Ma averages -11‰ in $\delta^{13}\text{CPDB}$, consistent with a largely C3 diet. Enamel from the Plio-Pleistocene averages $+1.9\text{‰}$ in $\delta^{13}\text{C}$, similar to the value displayed by modern C4 grazers. Analysis of post-burial carbonate cements, and the concordance with isotopic evidence from paleosols argues strongly against major isotopic alteration of the enamel, while coexisting bone may have been altered early in burial. This study confirms that enamel apatite is useful for paleodietary reconstruction much further back in the geologic record than was previously thought.

Key words: Carbon isotopes, paleosole, fossil teeth, Siwaliks, Himalaya.

Q/28. Quade, J., Cerling, T.E. & Bowman, J.R., 1989. Development of Asian monsoon revealed by marked ecological shift during the latest Miocene in northern Pakistan. *Nature* 342, 163-166.

Carbon isotopes from soil carbonate¹⁻⁴ and soil organic matter^{5,6} yield palaeoecological information because the carbon in the soil carbonate forms in isotopic equilibrium with local soil CO₂ (refs 1, 7), the isotopic composition of which is in turn determined by local plant cover. Siwalik Group sediments in northern Pakistan contain a well exposed palaeosol record spanning the past 18 Myr. Here we report on stable-carbon-isotope results from associated pedogenic carbonate which indicate a dramatic ecological shift from C3- to C4-dominated floodplain biomass beginning 7.4–7.0 Myr ago. The earlier C3 floodplain biomasses were probably mainly composed of trees and shrubs, whereas C4 grasslands dominated in the Plio-Pleistocene. Oxygen isotopes also exhibit a shift in the latest Miocene, probably corresponding to a major climate change which may have induced the forest-to-grassland transition. This dramatic ecological shift in the latest Miocene may mark the inception or a marked strengthening of the Asian monsoon system.

Key words: Paleoecology, monsoon, Miocene.

Q/29. Quade, J., Roe, L., DeCelles, P.G. & Ojha, T.P., 1997. The late Neogene $^{87}\text{Sr}/^{86}\text{Sr}$ record of lowland Himalayan rivers. *Science* 276, 1828-1831.

Fossil shells and paleosol carbonate from ancestral Himalayan river deposits provide a $^{87}\text{Sr}/^{86}\text{Sr}$ record of lowland Himalayan river water during the late Neogene. Reconstructed $^{87}\text{Sr}/^{86}\text{Sr}$ river values increased sharply in the late Miocene, probably marking the beginning of exhumation of high- $^{87}\text{Sr}/^{86}\text{Sr}$ metalimestones, more in the central than in the western Himalayas. These results imply that the marine $^{87}\text{Sr}/^{86}\text{Sr}$ record may not be a proxy for silicate weathering or consumption of atmospheric CO₂ resulting from that weathering.

Key words: Himalayan rivers, Hydro geochemistry, $^{87}\text{Sr}/^{86}\text{Sr}$, isotopes, Uplift.

Q/30. Quintavalle, M., Tongiorgi, M. & Gaetani, M., 2000. Lower to Middle Ordovician acritarchs and chitinozoans from northern Karakorum mountains, Pakistan. *Rivista Italiana de Paleontologia e Stratigrafia* 106, 3-18.

The lower Vidiakot section (Chitral, Pakistan) comprises the lower part (Yarkhun Formation and base of the Vidiakot Formation) of the terrigenous complex transgressively overlying the crystalline basement of Northern Karakorum. From this section, 8 of 15 samples contain moderately abundant and poorly preserved acritarchs and rare, badly preserved chitinozoans. Three different palynological assemblages have been distinguished which are referable to the chronological interval early Arenig-earliest Llanvirn.

The presence of *Arbusculidium*, *Coryphidium*, and *Striatotheca* in most samples confirms the palaeogeographic attribution of the Northern Karakorum Terrane to the northern Gondwana margin (Lower to Middle Ordovician Mediterranean acritarch Palaeo- province). Refined correlation with other areas and with the previously studied Ishkarwaz section (upper Yarkhun Valley, Chitral) enables the authors the Yarkhun Formation to be dated as early Arenig (British lower nitidus graptolite Zone) to latest Arenig (uppermost graptolite hirundo Zone). The base of the overlying Vidiakot Formation is here correlated with the uppermost hirundo-lowermost artus graptolite Zones (latest Arenig-earliest Llanvirn).

Key words: Palaeontology, Ordovician, Karakoram.

Q/31. Quittmeyer, R.C., Farah, A. & Jacob, K.H., 1979. The seismicity of Pakistan and the relation to surface faults. In: Farah, A. & DeJong, K.A. (Eds.), *Geodynamics of Pakistan*, Geological Survey of Pakistan, Quetta, 271-284.

The historical and modern seismicity of Pakistan and its vicinity is examined in terms of its relation to mapped surface faults. There are found to be three categories into which the seismicity may be classified: 1) earthquakes with large source dimensions that are associated with faults on the basis of either surface rupture of a mapped fault or aftershock area or focal mechanism that defines a trend that is consistent with a mapped fault; 2) narrow, elongate zones of earthquakes that may be related to movement along a single, continuous fault or a group of similarly oriented smaller faults; 3) diffuse activity that is not clearly related to any individual fault. The seismicity of this last category may in some places be the result of the scatter of epicentral locations of earthquakes occurring along shallow-dipping thrust faults. The seismic activity also defines portions of the Indus basin as seismically active even though no surface faults are mapped there.

Care must be employed when using only documented seismic activity to evaluate seismic hazards within Pakistan. The seismic record may be short when compared to recurrence interval for large earthquakes. Geologic evidence of recent fault movement, and geodetic measurements, will help alleviate this deficiency of the seismic record.

Key words: Seismicity, structure, Pakistan.

Q/32. Quittmeyer, R.C. & Jacob, K.H., 1979. Historical and modern seismicity in Pakistan, Afghanistan, NW India and SE Iran. *Seismological Society of America, Bulletin* 69, 773-823.

Please consult the preceding account for additional information.

Key words: Seismicity, Pakistan, Afghanistan, India, Iran.

Q/33. Quraishi, A.A. & Imam, S.A. 1960. Report on manganese showings of Galdanian, Hazara District, West Pakistan. *Geological Survey of Pakistan Information Release* 15.

Ferruginous rock containing very little manganese is present in the Galdanian Valley, situated about ten miles northeast of Abbottabad. The iron-manganese rock extends discontinuously over two miles with an average thickness of ten feet. The iron mineral is haematite, and in the weathered portion there is a local abundance of limonite. Manganese is found in the oxide form. Neither iron nor manganese is in suitable concentration for economic exploitation.

Key words: Manganese, Abbottabad, Hazara.

Q/34. Qureshi, A., 1981-83. Lithostructural mapping of Mansehra Susal and Matial Area District Mansehra with special reference to structural studies. M.Sc. Thesis, Punjab University, Lahore, 109p.

Lithostructural mapping with preliminary structural studies have been made of Mansehra, Khaki, Rihar area district Mansehra at a scale, of 1:1000. An attempt has been made to delineate the boundaries of igneous and metamorphic rocks precisely. Physiographic/Stratigraphic studies and various structural contour diagrams have been drawn to determine axis of minor folds. Orientation of joints has been determined with the help of Rose diagram. Thin sections have been studied to determine different phases of deformation. Attempt has been made to analyse the strain with Flinn's and Ramsay's plots.

On the basis of microscopic and mesoscopic analysis it has been tried to interpret the structure and macroscopic scale. On the basis of Kinematic Studies, structure of the area is interpreted.

Key words: Lithostructure, mapping, Mansehra.

Q/35. Qureshi, A.A. & Abdullah, S.K.M., 1960. Report on manganese-iron deposit of Churagali, Hazara District, West Pakistan. Geological Survey of Pakistan, Information Release 19, 6p.

Key words: Manganese, Iron, Churgali, Hazara.

Q/36. Qureshi, A.A., Bangash, M.A., Khattak, N.U. & Akram, M., 1996. Study of radioactive minerals from Loe Shilman Carbonatite Complex. The Nucleus, Special volume on Radioactivity, 3(4), 71–74.

The Loe Shilman Carbonatite Complex is the western extremity of a 200 km long Alkaline Belt which extends from Mansehra to Pak-Afghan border in an arcuate fashion around Peshawar valley. The complex is mainly composed of carbonatites with subordinate amount of related alkaline rocks with uranium, niobium and rare earths in ppm range and apatite in % age range. The techniques of alpha-autoradiography, XRD and XRF have been used to locate and identify the radioactive minerals in the Carbonatite. The radioactive mineral has been identified as betafite of primary origin which occurs as small black grains having somewhat parallel alignment; in addition a minor phase of pyrochlore has also been identified.

Key words: Radioactive minerals, Loe Shalman, Khyber Agency.

Q/37. Qureshi, A.A., Butt, K.A. & Khan, H.A., 1990. Fission track dating of carbonatite complexes of Pakistan. Abstracts, 2nd Pakistan Geological Congress, Peshawar, p.44.

Fission track dating on the zircon and apatite from Loe Shilman and Sillai Patti carbonatite have revealed that the carbonatite activity in this area took place in the Mid Tertiary (≈ 30 Ma). The younger fission track age of 19.09 ± 0.19 Ma on apatite from Loe Shilman 21.8 ± 0.4 Ma on apatite from Sillai Patti represent the time of a later thermal episode.

Key words: Carbonatites, fission track dating, Pakistan.

Q/38. Qureshi, A.A., Butt, K.A. & Khan, H.A., 1991. Emplacement time of Silai Patai carbonatite, Malakand, Pakistan, from fission track dating of Zircon and apatite. Nuclear track Radiation Measurement 18, 315-319.

Based on fission track dating of zircon and apatite, the emplacement history of Silai Patai carbonatite has been traced. It has been estimated that the carbonatite was emplaced along the thrust plane associated with the Indian-Eurasian plate collision during the Oligocene period followed by some thermal/tectonic episode during Early Miocene. This negates the previous proposal that all carbonatites found in Pakistan are a part of a 200 km long alkaline province associated with the rifting of Peshawar Valley during Late Cretaceous or Early Tertiary.

Key words: Carbonatite, Silai Patai, Collision, Oligocene, Malakand.

Q/39. Qureshi, A.A. & Jan, M.Q., 1977a. The ultramafic and high-grade metamorphic rocks near Jijal, Indus Valley, Swat. 24th Pakistan Science Conference, Islamabad, H1-H2.

Briefly describe the ultramafic rocks and high-grade mafic rocks from Jijal area. Further information is given in the following.

Key words: Ultramafics, metamorphism, petrology, Jijal, Indus Kohistan.

Q/40. Qureshi, A.A. & Jan, M.Q., 1977b. The ultramafic and high grade metamorphic rocks near Jijal, Indus Kohistan, Northwest Pakistan. Accademy Nazionale Lincei, Series VIII, 63, 259-268.

The Jijal area is occupied by ultramafic and mafic rocks metamorphosed in the granulite facies conditions. These rocks occur in the hanging wall of the Indus suture. The paper gives details of petrography, optical data for clinopyroxenes, and major element analyses of eight samples. The ultramafic rocks comprise diopsidite, websterite, peridotites, and dunite. The mafic consist of garnet-clinopyroxene-plagioclase-quartz granulites, but there also are large bodies of garnet-rich rocks (garnetites) and hornblendites (commonly garnetiferous).

Key words: Ultramafics, granulites, petrology, Jijal, Indus Kohistan.

Q/41. Qureshi, A.A. & Khan, H.A., 1992. Emplacement history and genetic relationship of various carbonatite complexes of Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.32.

In Pakistan, carbonatites are exposed at Naranji Kandao, Sillai Patti, Loe-Shilman, Jambil, Tarbela, Jawar and Jandai. The Loe Shilman, Jawar, Sillai Patti, Jandai and Jambil carbonatites represent Tertiary Alkaline silicate carbonatite magmatism in the Peshawar Plain Alkaline Igneous Belt. The Naranji-Kandao and Tarbela carbonatites belong to Late Paleozoic carbonatite magmatic activity.

The carbonatites are associated with distinct alkaline silicate magma associations. The Loe-Shilman potassic silicate suite comprise of biotite-rich alkali lamprophyres, gabbros and syenites. The Sillai Patti carbonatites are associated with alkaline ultramafic-mafic rocks. In Loe Shilman the evolution of carbonatites follows the general trend of differentiation of the order of crystal fractionation from calcite to dolomite and siderite. Loe-Shilman and Sillai Patti carbonatites as well as many of the African Rift carbonatites have a similar Sr-Nd isotope patterns (Tilton et. al., 1998). The lithospheric source for the carbonatites was probably transported within the Indo-Pakistan Plate after the breakup of Gondwanaland to the Himalayan collision zone.

Key words: Carbonatite, Silai Patai, collision, Oligocene, Malakand.

Q/42. Qureshi, A.A. & Khan, I.H., 1971-72. The ultramafics and highgrade metamorphic rocks near Jijal, Indus Kohistan, Swat. Part 1: Geology and Petrography. M.Sc. Thesis, University of Peshawar, 1-72.

An area of 28 sq. miles near Jijal in Indus Kohistan (Swat) has been mapped and detailed petrography is presented. It is occupied by ultramafic rocks in the south and metamorphic rocks in the north. The former mainly consist of clinopyroxenites with local patches of dunite and peridotites. The latter are represented by the garnet gneisses and related rocks, and are at the southeastern fringe of the upper swat hornblendic groups. The clinopyroxenites are mainly composed of diopside with minor serpentine, enstatite and olivine. Peridotites and dunites also contain clinopyroxene and serpentine, in some up to 50%. Some dunites are free of pyroxene. The rocks show widespread selective serpentinization.

The garnet gneisses contain epidotized plagioclase, garnet, hornblende and/or pyroxene, with muscovite their major constituents. Towards the south near the contact with ultramafics, these come poor in feldspar and very rich in garnet and pyroxene or hornblende. Such rocks are non-gneissose granoblastic. The rocks show amphibolite grade of metamorphism, however, hornblende granulite facies conditions are locally indicated by the presence of hypersthene.

Detailed studies of clinopyroxene and garnet in the ultramafics and gneisses, and their structural relationship suggest that they may not be genetically related. The ultramafics are apparently emplaced along a faulted contact between the gneisses and the schistose group. No contact metamorphic effects noted in the schists suggest that the emplaced ultramafic mass had lower temperature. The area investigated does not have much economical potential, however, garnet and building stone is of some importance.

See further information in the following.

Key words: Ultramafic-mafic rocks, high grade metamorphism, petrology, Jijal, Indus Kohistan.

Q/43. Qureshi, A.A. & Khan, I.H., 1971-72. The ultramafics and high-grade metamorphic rocks near Jijal, Indus Kohistan, Swat. Part 2: Chemistry and Pathogenesis. M.Sc. Thesis, Peshawar University, 72-107.

This thesis presents a preliminary geological map of the Jijal-Duber-Pattan area of the Indus Kohistan. The principal lithologies can be divided into a southern ultramafic part (peridotites and pyroxenites) and a northern high-grade part (metagabbros, ultramafic lenses). Petrographic details have been given for various rocks, along with (in Part 2) chemical analyses of the major elements in some rocks.

Key words: Ultramafics, metamorphism, chemistry, petrogenesis, Jijal, Indus Kohistan.

Q/44. Qureshi, A.A., Khattak, N.U., Chaudhry, M.N. & Khan, H.A., 1999. Thermo tectonic history of Loe Shilman carbonatite complex, NW Pakistan, based on fission tract dating of apatite and other radiometric ages. Geological Bulletin, Punjab University 33 & 34, 105-110.

The Peshawar Plain Alkaline Igneous Province (PAIP) consisting of alkaline granites, syenites, gabbros, albitites, carbonatites etc., occurs in the north of Peshawar Plain in an arcuate fashion. It stretches from Loe Shilman near Pakistan-Afghanistan border up to Tarbela through Warsak, Sillai Patti, Shewa-Shabazgarhi, Koga and Ambela. The Loe Shilman Carbonatite Complex comprises of sill like bodies emplaced along thrust plain of an east-west trending and northerly dipping fault zone in Paleozoic to Pre-Cambrian metasedimentary rocks. This paper presents the use of fission track age of apatite as paleotemperature indicator and its significance in the recognition of the emplacement time and tectonometamorphic history of the Loe Shilman Carbonatite Complex in combination with other radiometric ages.

The K-Ar date of 3.00 ± 2.00 Ma on biotite and V-Pb date of 30.00 Ma on calcitic indicate that the Loe Shilman rocks were emplaced during the Oligocene times. The fission track age of 18.87 ± 1.33 Ma on apatite from Loe Shilman, estimated by us, represents a time during the post-metamorphic uplift history of the area, when these rocks passed through the 115°C isotherm, corresponding to a depth of about 3.5 km from their present position, if a paleogeothermal gradient of 30°C per km is assumed to have prevailed. Based on present work, in combination with other available ages, we support the idea of emplacement of the complex in the Oligocene in contradiction with the earlier view of emplacement of these rocks in the Permo-Carboniferous.

Key words: Carbonatite, tectonics, Loe Shalman, Khyber Agency.

Q/45. Qureshi, A.A., Khattak, N.U., Karim, T. & Waheed, S., 2000. Geology and economic significance of the Loe-Shilman carbonatite complex, Khyber Agency, Pakistan. Geologica 5, 133-144.

The Loe-Shilman Carbonatite Complex consists of carbonatites, syenites, quartz-rich granitoids and gabbroic rocks emplaced along a faulty zone. The complex is the western extension of a 200 km long Alkaline Belt found in the north of the Peshawar Plain. The rocks in the north of the complex are mica schists and limestones of Paleozoic age while those in the south are slates/phyllites and some lime stones of Pre-Cambrian age. The carbonatitic rocks at Loe-Shilman are composed mainly of calcite and/or dolomite with amphibole, mica, pyroxene, pyrochlore/betafite and some ore.

In general, the carbonatites are one of the major sources of Rare Metals (Nb, Y, V, La, Ra, etc.), Earth Elements (REEs), apatite and some other minerals/elements. Uranium is sometimes present in these rocks and is recovered as by-product. Studies were carried out to look into the possibility of existence of these materials in commercially exploitable amounts in the carbonatites. There are reasonable concentrations of some Rare Metals (Nb-upto 3100 ppm, Y-upto 205 ppm, V-upto 890 ppm, and La-upto 588 ppm), REEs (Ce-upto 2900 ppm, Pr-upto 268 ppm, Nd-upto 394 ppm, Sm-upto 70 ppm), apatite (average more than 15%) and U_3O_8 (average 200 ppm). Due to various unique and special applications of Rare Metals, REEs and uranium in metal and nuclear industries and those of apatite as a source material for fertilizer and chemical industries, the Loe-Shilman carbonatites have a special importance.

Key words: Carbonatite, economic geology, Loe Shilman, Khyber Agency.

Q/46. Qureshi, A.A., Majid, C.A., Akram, M., Hussain, M.A., Mateen, A., Khattak, N.U., Javed, M., Hussain, S.S., & Khan, H.A., 1997. Characterization of emerald from Gujar Kili, Swat, Pakistan. *The Nucleus*, 34 (1–2), 57–63.

The green gem variety of beryl family having Cr as coloring agent is known as emerald. Thirteen emerald occurrences are known from Northern Pakistan which are located exclusively in ophiolitic melange of Indus Suture zone. The ophiolitic rocks are source of Cr which colors the beryl to make it emerald. Studies have been carried out for the characterization of emerald from Gujar Killi, a locality in Swat. The emerald is of high quality green to deep green variety. In general it has high Mg, Fe, Cr, V and low Al values as compared to average composition of the emeralds. Two mineralogical phases were identified in the Gujar Killi samples namely beryl and chrysoberyl on the basis of XRD studies. The Cr does not substitute any element rather it is present as an impurity in the crystal matrix. A new etchant (19N NaOH boiling) to reveal fission tracks in 45 minutes is reported.

Key words: Gems, emerald, Swat.

Q/47. Qureshi, A.A., Mateen, A. & Karim, T., 1993. Chemical characterization of carbonatite from Loe Shilman, Khyber Agency, Pakistan. Abstract volume 2nd All Pakistan Science Conference, Aitchisons College, Lahore.

Loe Shilman carbonatite samples were chemically analyzed for major elements in order to classify the carbonatites. On the basis of chemical characteristics the carbonatites were classified into three categories. Calico-Carbonatites: In these rocks the CaO: CaO+MgO+Fe₂O₃+MnO ratio is greater than 0.8. Magnesio-Carbonatites: In these rocks CaO: CaO+MgO+Fe₂O₃+MnO ratio is less than 0.8. Ferro-Carbonatites In these rocks CaO: CaO+MgO+Fe₂O₃+MnO ration is less than 0.8 and MgO is < FeO+Fe₂O₃+MO.

Key words: Carbonatite, chemistry, Loe Shalman, Khyber Agency.

Q/48. Qureshi, A.A., Mateen, A., Majid, C.A., Karim, T., Mehmood, K. & Khan, H.A., 1994. Analysis of a highly radioactive sample from the Northern Pakistan. *The Nucleus*, 31(1&2), 73–75.

A highly radioactive sample collected from the extreme upper part of Chitral, in the northern Pakistan, has been analyzed using alpha autoradiography, petrography and X-ray Diffraction techniques. The sample contains about 50% magnetite, 1% uraninite along with quartz, anorthite, garnet, ilmenite, thuringite wurtzite, tremolite, etc. The exact location of the sample is not known but the sample is of interest due to its high iron and uranium contents.

Key words: Geochemistry, radioactive minerals, Northern Pakistan.

Q/49. Qureshi, A.H., Haq, A. & Faruqi, F.A., 1974. Fusion study of Rajdhawari Feldspar. *Pakistan Journal of Scientific and Industrial Research*, 17(2), 71–75.

Key words: Minerals, feldspar.

Q/50. Qureshi, A.W., 1985. General geology of area of Kohat quadrangle, Shakerdara town, Kohat. M.Sc. Thesis, University of Peshawar, 68p.

Key words: Geology, mapping, Shakardara, Kohat.

Q/51. Qureshi, A.W., 1993. Sedimentology of Murree Formation (Rawalpindi Group) in Kohat-Potwar area. M.Phil. Thesis, University of Peshawar.

Key words: Sedimentology, Murree Formation, Kohat-Potwar.

Q/52. Qureshi, A.W. & Tanoli, S.K., 1992a. Lithofacies and tectonic setting of the Murree Formation, Kohat area, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.61.

Key words: Tectonics, lithofacies, Murree Formation, Kohat.

Q/53. Qureshi, A.W. & Tanoli, S.K., 1992b. Early molasse sediments (Murree Formation) in Pathan Algad, southern Kohat. Geological Bulletin, University of Peshawar 25, 85-93.

Of the southern most exposures of the Murree Formation in Kohat those of the Pathan Algad are considerably thick. These consist of interbedded maroon sandstone and red clay with subordinate conglomerate. The conglomerates within the formation are intrabasinal and lag in nature while conglomerate at base of the formation consists of reworked limestone clasts of the underlying Kohat Formation. Two main sand-bodies, one SBI starts at 13m level and is 21m thick and second SB2 at 52 level ranging 2-4m in thickness, were observed. These sand-bodies consist of main channel, point bar, and chute bar deposits. Interbedded sandstone and clay facies which overlie the composite sandstone facies represent levee or crevasse splay deposits. The red clay was deposited in flood plain areas out of suspension. As a whole the Murree Formation in this area displays typical meandering river deposits. Our analysis suggests that the Pathan Algad area lied the margin of the Murree river system where only occasionally the main river flowed. Additionally, there may be a considerable age difference between the exposures in Pathan Algad and those at Dhok Maiki, the stratotype in Potwar area.

Key words: Sandstone, clay, conglomerate, molasses, Murree Formation, Kohat.

Q/54. Qureshi, F.A., 1992-94. Sedimentary petrology of Early Cretaceous Lumshiwal Formation and Eocene Margala Hill Limestone and Lithostructure mapping of Dhamtaur area, Southern Hazara, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 213p.

A comprehensive study of Geology and structure of Dhamtaur area is presented along with special constraints on the sedimentology of Lumshiwal Formation of Early Cretaceous and Margalla Hill Limestone of Early Eocene. Large-scale (1:10000) geological mapping of a small segment of the Lesser Himalaya in the Dhamtaur area is presented. The lithostratigraphic unit range from Upper Paleocene to Precambrian, Hazara Formation being the oldest. Structurally the area comprises NW-SE trending major anticlinorium. The folds are tight to isoclinal and opposing southeast and northwest vergence on the two sides of the core formation. Some anticlines show plunge tot the southeast direction. Almost all faults have vergence parallel to the folds developed in the core on the two sides of the main anticlinorium. Most are reverse faults although some may be of the normal type. Faulting appears to be dipslip to oblique slip and in general involves a maximum displacement of few hundred meters.

A detailed study of sedimentary petrology/sedimentology of Lumshiwal Formation of Early Cretaceous and Margalla Hill Limestone of Early Eocene has been carried out. The object was to study the petrography environment of deposition and diagenesis of the above said formations.

The section of Lumshiwal Formation from Karlan Bazar at Abbottabad Nathia Gali Road, is medium to thick bedded glauconite sandstone. This formation is divided into twenty microfacies. The microfacies overlying Chichali Formation is poor in glauconite and are mainly quartz and carbonate cemented quartz arenites. The other microfacies are mainly quartz; glauconite and carbonate cemented, well to very well sorted, and mature to supermature quartz arenites. The maximum development of glauconite is from central to upper. Upper horizons selectively cemented with flint.

Key words: Sedimentary petrology, Lumshiwal Formation, Margala, Cretaceous, Eocene, Hazara.

Q/55. Qureshi, J.A., 1997-98. Geological mapping of Rawalakot area with special emphasis on engineering characteristics of geo-material. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 42p.

Geological mapping of Rawalakot area is prepared on the scale 1:12,500 and the total area of investigation is about 100 sq. km. Present work shows that the strength of the geomaterial which is studied for the mineralogical composition of the aggregate of the Murree Sandstone. Los Angle value, crushing value, impact value, specific gravity, water absorption, flakiness index and elongation index were performed according to ASTM standards and the parameters of the strength of material were deduced according to the mineralogical assembly of the Murree sandstone. It was seen that the percentage of quartz and cementing material like calcite in favourable conditions provide strength to the material and the deleterious material like clays due to its swelling potential damages the material when in contact with water. Reserves of the Murree Sandstone as geomaterial of different localities were also estimated for the quarry purposes

Key words: Mapping, engineering properties, Rawalakot, Azad Kashmir.

Q/56. Qureshi, K.A., Pasha, M.K. & Khan, A.A., 1992. Stratigraphic and structural evolution of Kala-Chitta Range, Punjab, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.61.

Key words: Stratigraphy, sedimentology, Mesozoic, Kalachitta.

Q/57. Qureshi, M.A., 1988-90. Geology and structure of Langrial-Bolda Area District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 83p.

Large scale geological map at a scale 1:10,000 of Langrial Bodla area is presented along with a complete record of Precambrian to Eocene rock units specially exposed in the area. On the basis of field observations and petrographic studies the depositional environments of rock units have been interpreted. Geological subsurface structures are described and illustrated with the help of cross sections. Almost all-major structures follow the general trend NE-SW, and is NW verging to upright. The major Nathiagali Fault is a high angle fault separating basement and the cover domain. The economic potential of limestone of various rock units, laterite, slates and aggregates have been discussed.

Key words: Mapping, Precambrian, Eocene, Abbottabad.

Q/58. Qureshi, M.A., Baig, M.S. & Munir, M.H., 1997. Reconnaissance microfacies analysis of the Upper Jurassic Samana Suk Formation, northern Hazara, Pakistan. Geological Bulletin, Punjab University 31 & 32, 145-151.

Key words: Reconnaissance, Jurassic, Samana Suk Formation, Hazara.

Q/59. Qureshi, M.I., 1985-87. Electrical resistivity survey for groundwater potentials in Masal Talao, Amir Khan Talao, Khachar Talao and Haji Talao, District Peshawar. Institute of Geology, Punjab University, Lahore, M.Sc. Thesis, 1-47.

Electrical resistivity survey in Masal Talao, Amir Khan Talao, Kachar Talao and Haji Talao (District Peshawar) was carried out in collaboration with Hydrogeology Directorate WAPDA Peshawar. The main purpose of the survey was to determine hydrogeological features such as depth to the bedrock, nature and thickness of aquifers, the quality of groundwater, and to select suitable sites for tubewell installation in the project area.

According to resistivity survey and drilling data the entire area is underlain by low resistive clay with occasional gravels. The overlying alluvium is composed of alternating layers of gravels and clays. Ground water appears to be quite fresh in the entire project area. Water table depth is from 13m to 40m in the area under investigation.

In the project area, twenty-seven probes were carried out. After interpreting the data, the V.E.S. No. 95, 93, 51, 40, 15 and 17 have been selected for the test drilling, however other probe sites also indicate the presence of aquifers in the area but of varying thickness.

The entire area appears to be favorable for tubewell installation, however the yield of water depends upon the nature of aquifers may range from half cusec to one and half cusec in the project area.

Key words: Geophysics, resistivity, groundwater, Peshawar.

Q/60. Qureshi, M.J., Tariq, M.A. & Abid, Q.Z. (Eds: Raza, S.M., Hussain, A. & Khan, S.H.), 1993. Geological Map of Pakistan. Geological Survey of Pakistan, Geological Map Series, Scale 1:1,000,000.

Key words: Maps.

Q/61. Qureshi, M.K.A., 1968. A report on the geology of Nawansher Giah area, Hazara. M.Sc. Thesis, Punjab University, Lahore, 86p.

Key words: Mapping, geology, Abbottabad.

Q/62. Qureshi, M.K.A., 1980. Copper showings in Warchha Sandstone and Sardhai Formation, Salt Range. Contribution to Geology of Pakistan, 1, 61-85.

The sampling of Warchha Sandstone and Sardhai Formation was carried out during 1972-73, in order to find out any possible economic mineral deposit.

The copper contents are sporadic and scanty, and present study is not successful to locate deposit of commercial potential. Nevertheless, the studies may be continued in adjoining parts to see, if any portion contains values higher than the one recorded during this survey.

Key words: Mineralization, copper, Warchha sandstone, Sardhai Formation.

Q/63. Qureshi, M.K.A., 1984. Carbonate microfacies in Samana Suk Formation at Azizabad section Hazara District, North West Frontier Province. Abstract, 1st Pakistan Geological Congress, Lahore, p59.

Key words: Carbonate, microfacies, Samana Suk Formation, Hazara.

Q/64. Qureshi, M.K.A., 1997. Stratigraphical and sedimentological studies of the Mesozoic rocks of the Kala Chitta Range, Northern Pakistan. Ph.D. Thesis, Punjab University, Lahore.

The present research deals with the stratigraphical and the sedimentological studies of the Mesozoic Rocks of the Kala Chitta Range, Northern Pakistan, based upon an extensive field work and detailed laboratory analyses. This study is the first comprehensive version on the depositional environments and the microfacies analysis of the dominantly carbonate shelf deposits. Standard microfacies have been identified among the carbonate succession, whereas the constituent minerals and elements in the siliciclastic rocks, most conspicuously of the Datta Formation (Lower Jurassic), have also been recognized by means of XRD, DTA and chemical analyses for the paleoenvironmental interpretation.

Age diagnostic Early Triassic ammonites from the Mianwali Formation and the planktonic foraminifers from the Upper Cretaceous Kawagarh Formation have also been recorded and illustrated. In addition, palynological data of different formations has been incorporated for the first time from the Kala Chitta Range.

Stratigraphic correlation with Hazara, Kohat, Salt Range, Trans Indus Range and Balochistan Basin has been attempted. New data about the structural framework of this linear fold -thrust belt has also been presented.

Key words: Stratigraphy, sedimentology, Mesozoic, Kalachitta.

Q/65. Qureshi, M.K.A., Butt, A.A. & Sheikh, R.A., 1994. The Kala Chitta foreland fold and thrust belt, Northern Pakistan. *Journal of Nepal Geological Society* 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, Nepal, 104-106.

The present structural framework of the Kala Chitta Range evolved through movement between two detachment surfaces. The Precambrian Attock Slates acted as a basal detachment surface above which large-scale horizontal compression took place to produce the main structural framework of the Kala Chitta Range. The Middle Eocene argillaceous Kuldana Formation behaved as the upper detachment surface giving rise to blind thrusts which were later exposed due to the vigorous erosion of the overlying folded Miocene strata. Despite the severe tectonic activity, strata older than the Triassic are not exposed in the Kala Chitta Range, which appears that these may not have been deposited at all. However, the Precambrian Attock Slates are believed to underlie the Mesozoic rocks because of the intervening position of the Attock Slates between the Kala Chitta Range and the Attock-Cherat Range.

In the Kala Chitta Range, the Triassic to Eocene rocks are repeated constantly in compressed folds and thin sheets. Interpretation of a regional decollement (Cotter, 1933) rooted in the Attock Slates and responsible for the major overthrusting, has proved to be of the fundamental significance for later researchers who are actually substantiating Cotter's concept in one way or the other (i.e. Lechner, 1947; Wadia, 1957; Gansser, 1964; Crawford, 1974; Lillie et al., 1987). The sedimentary veneer has glided and deformed over this surface and the Attock Thrust and the Main Boundary Thrust (MBT) represent the "splays off" of this detachment surface. Late Cenozoic movement along these thrusts has uplifted the Attock-Cherat and the Chitta-Margala Hill Ranges.

Apart from the movement over this basal decollement surface, the Kala Chitta fold-thrust belt has evolved by blind thrusting merging with a continuous upper detachment surface. The Middle Eocene Kuldana Formation is believed to have played the role of an upper detachment surface. This view is supported by the fact that the Kuldana Formation and the overlying molasse deposits which are well exposed all along the southern borders of the fold-thrust belt are not repeated in any of its internal folds. The presence of the Pre-Kuldana Formation deposition (i.e. Margala/Patala/Lockhart) in the footwall of almost all the exposed thrusts, regardless of which formation comprises the hanging wall, also provides a strong evidence that the Kuldana Formation has served as the upper detachment surface. This consistency shows that successive thrusts emplaced at the outer edge of the foothills flattened along a common upper detachment surface formed by the Kuldana Formation.

The recognition of the basal and the upper detachment surfaces gives a distinctive character to the deformational style of the Kala Chitta fold-thrust belt. The sequence of events describing briefly the changes in structural style with different erosion levels, and the development of blind thrusts beneath a continuous upper detachment at all stages of deformation are modelled. It was revealed from the model that the internal deformation of the Kala Chitta Range predates its ramping towards south over the MBT. However, the basement uplift to some extent, might have also been responsible for the initiation of thrusting in the Kala Chitta and the adjoining areas.

During its tectonic history, the Kala Chitta Thrust belt suffered a number of deformational phases. However, in a very generalized sense, the most effective and prominent are three distinct and partly overlapping phases. The first being a north-south trending compressional phase resulting in generally east-west trending fold axes and fault planes. The second NE-SW trending phase formed cross folds and duplex structures, while the third phase resulted into the thrusting and ramping of the whole Kala Chitta belt over the MBT in the south. The overall configuration of the Range indicates that during the final phase of thrusting over the MBT, differential block movement took place, the western block lagged behind in southward movement and much thrusting developed in its extreme northern part (Chhoi-Chak Jabbi area). On the other hand, the eastern block moved ahead towards south, developing extensive thrusting towards its south (Fatehjang-Mahura area). The major faults include the MBT, the Samul Pani-Chak Dalla Thrust, the Ghora Mar-Chak Jabbi Thrust, the Chhoi-Dunga Kas Thrust and their splays and offshoots.

Key words: Paleoenvironment, tectonics, structure, Kalachitta fold and thrust belt.

Q/66. Qureshi, M.K.A., Hassan, M. & Butt, A.A., 1992. Paleoenvironments and tectonic style of the Kala Chitta fold and thrust belt, Northern Pakistan. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, p.41.

Structural modelling of the Kala Chitta range has been attempted after having completed its geological mapping on 1:50,000 scale. The structural style of the Kala Chitta Range is believed to represent an example of a foreland-fold and thrust belt geometry after incorporating the structural entity of its northerly neighbour of the Attock-Cherat Range.

The present structural framework appears to have evolved through movement between two detachment surfaces. The Precambrian "ATTOCK SLATES" are believed to have acted as a basal detachment above which large scale horizontal compression has taken place to produce the main structural framework of the Kala Chitta Range. The middle Eocene argillaceous KULDANA FORMATION appears to have behaved as the upper detachment surface giving rise to blind thrusts which were later exposed due to the vigorous erosion of the overlying folded Miocene strata. The major individual structures are illustrated through a number of Cross Sections as a support to the proposed structural modelling.

Key words: Paleoenvironment, tectonics, Kalachitta fold and thrust belt.

Q/67. Qureshi, M.K.A., Kausar, A.B. & Khan, K.M., 1983. Geology of Surghar and Shinghar Ranges (topographic sheet No. 38 O/8), Mianwali and Kohat Districts. Geological Survey of Pakistan, Information Release 186.

Key words: Tectonics, stratigraphy, geology, Mianwali, Karak, Kohat.

Q/68. Qureshi, M.S., Khan, M.A., Sheikh, S.A. & Khan, N.A., 1989. Geotechnical characteristics of soil of Kundal Shahi Atthmuqam area, Azad Kashmir. Kashmir Journal of Geology 6 & 7, 133-146.

The paper deals with the physical characteristics of the soils to evaluate the behavior with respect to bearing capacity and competency to install hydel-power project and other civil engineering works in Kundal Shahi Atthmuqam area of Azad Kashmir. Other physical characteristics of the soils which decide the relative merits and demerits have also been investigated in addition to the field characteristics. The observed parameters shows variations in the samples but a limited range are well within the ASTM specifications. It appears feasible to utilize the localities for civil engineering works.

Key words: Geotechnical, soil, Azad Kashmir.

Q/69. Qureshi, N.H., 1961a. Coal resources of Pakistan. Natural Resources, University of Karachi 1, 47-50.

Along with others, this paper briefly describe the coal resources of the area of the present work.

Key words: Hydrocarbons, coal.

Q/70. Qureshi, N.H., 1961b. The mining of chromite in Pakistan. Proceedings, CENTO Symposium on Chrome Ore, Ankara, 54-60.

Key words: Ultramafics, chromite, mining.

Q/71. Qureshi, N.H., 1962a. Economic aspects of coal in Pakistan. Proceedings, CENTO Symposium on Coal, Zonguldak, 1961, 29-46.

Key words: Hydrocarbons, coal.

Q/72. Qureshi, N.H., 1962b. Industrial mineral and rocks of West Pakistan: Review of mining activities. Proceedings, CENTO Symposium on Industrial Rocks and Mineral, Lahore, 34-49.

Key words: Mining, industrial rocks.

Q/73. Qureshi, R.M., Hasany, S.M., Javed, T., Sajjad, M.I., Shah, Z., Rehman, H., Mateen, A. & Fritz, P., 1994. Isotopic and chemical characterization of coal in Pakistan. In: Ahmed, R. & Sheikh, A.M. (eds.), *Geology in South Asia--I. Proceedings of the First South Asia Geological Congress*, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 300-304.

Key words: Organic geochemistry, isotopes, coal.

Q/74. Qureshi, R.M., Hussain, S.D., Ahmad, M., Sajjad, M.I., Aravena, R. & Fritz, P., 1992. Special variation of tritium and Carbon-14 in shallow ground waters of Peshawar valley. Abstracts, First South Asia Geological Congress, Islamabad, p.61.

Key words: Groundwater, hydrochemistry, contamination, Peshawar.

Q/75. Qureshi, S.A., 1972. Geology of Dir–Bibiore area, Dir with special emphasis on Bibiore Granodiorite and Mixed Zone., M.Sc. Thesis, Punjab University, Lahore, 75p.

Key words: Granodiorite, Plutonic rocks, Dir.

Q/76. Qureshi, S.N., Ahmed, S., Khwaja, A.A., MonaLisa, & Naseem, S., 2000. Gravity modeling and seismicity of the area between Bannu and Kohat. Abstracts, Third South Asia Geological Congress, Lahore, p.82.

A part of active Himalayan fold-and-thrust belt has been investigated along a 131 km long gravity profile (Bannu to Kohat) by gravity modelling. Good agreement exists between the observed and calculated gravity values. The basement dips gradually towards North from about 9 km under Bannu to about 11 km below Kohat.

In this area of blind and emergent faults, variations in Bouguer anomaly coincides well with the known faults like Latamber, Bahadur Khel and Tappi. Other similar Bouguer anomaly variations suggest the presence of blind faults beneath the molasses and/or platform rocks at Domail, Khurram, Banda Daud Shah, Lachi and Gada Khel. Isostatic behavior reveals a local deficit of mass conditions between Latambar-Tappi area.

Seismically the area is active. Three events of $M_b = 4.9$ to 6.0 from Banda Daud Shah, Lachi and Shadikhel confirm the existence of faults. Their focal mechanism solutions are discussed.

Key words: Seismicity, gravity modeling, Bannu, Kohat.

R/1. Rab, A. & Qureshi, K.M., 1980. Petrography of Ambela Granite, Swat. M.Sc. Thesis, University of Peshawar, 45p.

Consult Rafiq (1987) for detailed description of the Ambela granite complex.

Key words: Petrography, granite, Ambela, Buner.

R/2. Rabbani, M.A., 1976. Geology of Kalaya and Ismail Zai, Tehsil of Orakzai Agency, North West Frontier Province, Pakistan. FATA DC, Records 1, 17p.

Consult the following account for further information,

Key words: Stratigraphy, Orakzai Agency.

R/3. Rabbani, M.A., 1978. Geology of Orakzai Agency, North West Frontier Province, Pakistan. FATA DC, Records 2, 1-47.

The stratigraphic sequence in the Orakzai Agency has been described in detail. The oldest rocks of the area comprise the Shinwari Formation (Fm) of Early Jurassic. These are followed by Samanasuk Fm (Middle Jurassic), Chichali Formation (Late Jurassic to Early Cretaceous), Lumshiwal Formation (Middle Cretaceous), Kawagarh Formation (Late Cretaceous), Hangu Formation (Paleocene), Lokhart Limestone (Paleocene), Patala Formation (Paleocene), Panoba Formation (Early Eocene), Sheikhan Formation (Early Eocene), Kuldana Formation (Early Eocene), and Murree Formation (Miocene).

Key words: Stratigraphy, Orakzai Agency.

R/4. Rabbani, R., 1983-85. Detail geological map of the Kohala Damsite. M.Sc. Thesis. Punjab University, Lahore, 90p.

The detailed geological map of the Kohala dams site No.1 and No.2 have been prepared. This field report consists of TWO Parts. Part 'A' deals with the General Geology of the Area. Introduction, Physiography, Stratigraphy, Structure, Tectonics and Economic Geology of the area has been discussed in this part. In Part 'B' various Engineering Geological Aspects have been discussed in detail. In this part, different factors of site investigation have been discussed. Recommendations and conclusions have been given at the end.

Key words: Mapping, dams site, Kohala.

R/5. Rabbi, F. & Khattak, N., 1983. Petrography and geochemistry of diorites and volcanics from Northern Dir. M.Sc. Thesis, University of Peshawar, 58p.

Diorites and quartz diorites are common in the Kohistan island arc. Those from northern Dir, commonly containing hornblende (with or without biotite) and variable amounts of quartz, are described in the work. Chemical analyses of selected samples are discussed from petrological point of view.

Key words: Petrography, geochemistry, diorite, volcanics, Dir.

R/6. Rabot, C., 1904. Explorations des glaciers du Karakorum. La Geographie 9, p.374.

Key words: Glaciers, exploration, Karakoram.

R/7. Raeburn, S.P. & Kerrick, D.M., 1995. Reconnaissance Lithological Mapping in the Karakoram Using Digital JERS-1 and Landsat-5 Satellite Data. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Kerrick and Caldeira (1993, 1994) hypothesized that the amount and advective flux of metamorphic CO₂ arising from post-collisional metamorphism in the Himalaya orogenic belt may have been of sufficient to have enhanced

atmospheric CO₂ contents and thus have contributed to early Cenozoic greenhouse warming. In reviewing uncertainties in their quantitative analysis of the amount of metamorphic CO₂ generated at depth, they emphasized the need for improved estimates of the proportion of CO₂ source rocks (carbonate protoliths) in the Himalayan-Karakoram orogenic belt. Accordingly, the primary purpose of our study was to further quantify the aerial abundance of carbonate-bearing and calc-silicate bearing lithologies. Because of the logistical difficulties in access and the limited lithologic mapping over the extensive area required for such estimates, satellite imagery was used to aid in such estimates. Using the Karakoram metamorphic complex as a case study, We have investigated the utility of remotely sensed visible and near infrared (VNIR) and short wavelength infrared (SWIR) digital satellite data for lithological discrimination in an area largely free of vegetative cover and bounded by the Hunza, Gilgit and Ishkuman rivers. A thematic map was compiled from two different data sets: Japanese JERS-1 SWIR data which has 4 spectral bands within the SWIR region, and a Thematic Mapper (TM) data which has 2 bands in the SWIR and 4 bands in the VNIR region. Limited JERS-1 data availability required acquisition of digital image data characterized by a low sun elevation angle and snow cover in high elevation areas, whereas acquired Landsat TM data had a higher sun elevation angle and less snow cover. Variation in the intensity of backscattered radiation as a result of topographical effects is a considerable problem in areas of high relief, and requires separate analysis of shaded and unshaded areas. Spectrally distinct units identified using band rationing and principal components analysis techniques were correlated with previously mapped regions in the Hunza valley (Searle, 1991) and extrapolated westward into the less well-mapped area between the Hasanabad glacier and the Karumbar valley. This study provides assessment the utility of digital satellite data in extending reconnaissance mapping to other inaccessible areas of high relief and limited vegetation in the Karakoram.

Key words: Reconnaissance, landsat imagery, carbonates, Hunza.

R/8. Rafiq, M., 1984. Extension of Skhakot-Qila ultramafic complex in Utman Khel, Mohmand Agency, NWFP, Pakistan. Geological Bulletin, University of Peshawar 17, 53-59.

The Utman Khel area in Mohmand Agency Contains bodies of ultramafic and mafic rocks covering an area more than one third of that of the Utman Khel mountains. The ultramafic rocks are emplaced as klippe over the metasediments of Paleozoic age. The central part of the complex generally consists of massive dunite, peridotite, and grades outward into massive to friable serpentinites. At several places, dunite, peridotite and serpentinite are altered to talc, carbonate and carbonate- quartz rock, particularly along shear zones. Steatite and blackwall-chlorite rock form small masses at the margins of the ultramafic rocks, adjacent to the contact with metasediments. Chromite occurs as podlike and lensoidal masses in 54 showings sporadically distributed over six different locations.

The characteristics displayed by the ultramafic rocks of the Utman Khel area are virtually similar to those displayed by the rocks of the Skhakot-Qila complex. Therefore it is appropriate to consider the ultramafic rocks of Utman Khel area as the extension of Skhakot-Qila complex.

Key words: Ultramafic, Utman Khel, Mohmand, Skhakot-Qila, Malakand.

R/9. Rafiq, M., 1987. Petrology and geochemistry of the Ambela granitic complex, N.W.F.P. Pakistan. Ph.D. Thesis, University of Peshawar, 272p.

The Ambela granitic complex is a middle to Late Paleozoic batholith consisting of oversaturated (70%), saturated (20%), undersaturated (5%) and basic (5%) igneous rocks. Petrographic study reveals three major divisions of the rocks: Group I includes granites and alkaline granites; Group II includes quartz syenites, alkali quartz syenites, syenites, alkali syenites and feldspathoidal syenites; and Group III consists of basic dykes. Chemical classification based on 166 major element analyses match the petrographic division and the rocks vary from peraluminous (partly metaluminous) to peralkaline in composition. Major, minor and trace element contents of these rock indicate a within plate (continental) origin.

Key words: Petrology, geochemistry, petrography, Ambela, Swat.

R/10. Rafiq, M., Ahmad, I. & Tahirkheli, T., 1983. A geological map of the surroundings of the Peshawar Plain. Geological Bulletin, University of Peshawar 16, 189.

This is an early attempt on presentation of the geology of the mountain area surroundings the Peshawar basin. Major structures in the area are also shown.

Key words: Mapping, Peshawar plain.

R/11. Rafiq, M. & Jan, M.Q., 1983. A discovery of emerald near Bucha, Mohmand Agency. Geological Bulletin, University of Peshawar 16, 188.

Light green beryl and emerald occur in talc-carbonate and carbonate-quartz rocks located about 200m north of Bucha village in eastern Mohmand Agency. The crystals reach up to 10×5mm in size, however, large crystals are translucent, fractured, and poor in quality. Transparent and clear crystals of light green beryl and emerald are less than 3mm in length and are, therefore, not of a high commercial value.

Key words: Gems, emerald, Mohmand Agency.

R/12. Rafiq, M., & Jan, M.Q., 1984. Emerald and green beryl from Bucha, Mohmand Agency, NW Pakistan. 1st Pakistan Geological Congress, Lahore, p.21

Deep bluey-green emerald and light green beryl occur sporadically in talc-carbonate and carbonate-quartz rock's near Bucha (34° 24'12" N, 71° 36' E). The host rocks have formed along shear zones due to alteration of enclosing ultramafic rocks. However, the source of solutions for this metasomatic process and introduction of Be is not clear. The beryl and emerald have high iron, emerald also having higher MgO content and refractive indices than most of the described natural emeralds. The crystals are variable in clarity and reach up to 10 mm in length; however, gem quality crystals are less than 3 mm long.

Key words: Gemstones, emerald, beryl, Mohmand Agency.

R/13. Rafiq, M. & Jan, M.Q., 1985. Emerald and green beryl from Bucha, Mohmand Agency, NW Pakistan. Journal of Gemmology 19, 404-411.

Deep bluey green emerald and light green beryl occur sporadically in talc carbonate- quartz rocks near Bucha (34° 24.5' N, 71° 36' E). The host rocks have formed along shear zones due to the alteration of enclosing ultramafic rocks; however, the source of solutions responsible for this metasomatic process and introduction of Be is not clear. The beryl and emerald have high iron, the emerald also having higher MgO content and refractive indices than most natural emeralds. The crystals are variable in clarity and reach up to 10 mm in length; gem quality crystals, however, are less than 3 mm long.

Key words: Gems, emerald, beryl, Mohmand Agency.

R/14. Rafiq, M. & Jan, M.Q., 1987. Fibrolitic sillimanite in sheared rocks of the Ambela granitic complex, northwestern Pakistan. Geological Bulletin, University of Peshawar 20, 181-188.

Two-mica granites in the northeastern margin of the Ambela granitic complex underwent cataclastic deformation. The resulting shear zones acted as pathways for the migration of a water-rich fluid phase that also contained boron and some fluorine. This resulted in 1) formation of fibrolitic sillimanite and white mica at the expense of feldspars and biotite, especially along micro-shears, 2) bleaching of biotite and release of Fe and Ti oxides, and 3) crystallization of tourmaline and fluorite. Some recrystallization / neo-mineralization of feldspar, quartz and muscovite also occurred due to shearing.

Key words: Granites, shear zones, deformation, Sillimanite, Buner.

R/15. Rafiq, M. & Jan, M.Q., 1988. Petrography of the Ambela granitic complex, NW Pakistan. Geological Bulletin, University of Peshawar 21, 27-48.

The Ambela granitic complex occupies the southeastern part of the Buner subdivision of Swat. It is a composite batholith consisting of a variety of oversaturated (70 %), saturated (20 %), and undersaturated rocks (10 %). The batholith may have formed over a considerable length of time, spanning from middle to late Paleozoic. Petrographic studies (800 thin section) allow a three fold grouping of the rocks. Group I include granites, alkali granites and

microporphyrites; these appear to represent the early magmatic episode of the complex. Group II includes quartz syenites, alkali quartz syenites, syenites, feldspathoidal syenites, carbonatite, ijolite, lamprophyre, and associated pegmatites and fenites. Considerable metasomatic changes were associated with successive alkali rich intrusive phases of this group of rocks. Basic dykes (Group III), intruding both Group I and II rocks, represent the last magmatic episode and constitute about 5 % of the complex. This paper presents petrographic details of the various types of rocks in the complex.

Key words: Petrography, Ambela granitic complex, Buner.

R/16. Rafiq, M. & Jan, M.Q., 1989. Geochemistry and petrogenesis of the Ambela granitic complex, NW Pakistan. Geological Bulletin, University of Peshawar 22, 159-179.

The Ambela granitic complex comprises three groups of rocks. Group I, the product of the first magmatic episode, consists of granites and alkali granites which occupy ~70% of the 900 Km² area of the batholith. Group II, following the granites sequentially, comprises quartz syenites, syenites, feldspathoidal syenites and related rocks. Following these, the area was invaded by dolerite dykes which occupy ~5% of the complex. These (Group III rocks) are not discussed in this paper. The granitic rocks range from dominantly peraluminous to metaluminous to mildly alkaline. These were derived from melts produced by crustal anatexis due to crustal thinning and rifting. Different degrees of partial melting and fractional crystallization led to variation the composition of these Group I rocks. With deepening of the zone of magma generation in the crust, the underlying mantle was activated, resulting in the influx of volatiles and alkalis. This led to the generation of magma batches which were successively more SiO₂ undersaturated and alkaline, resulting in the production of Group II rocks. The Ambela batholith appears to have developed during a major phase of crustal thinning and rifting towards the end of Paleozoic.

Key words: Petrography, geochemistry, Ambela granitic complex, Buner.

R/17. Rafiq, M. & Jan, M.Q., 1990. Petrogenesis of basic dykes from the Ambela granitic complex, NW Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.45.

Basic dykes intrude the upper Paleozoic granites, alkali granites, syenites and associated rocks of the Ambela granitic complex. These dykes mostly have N 25-450E trend, constitute about 5% of the complex, and from 1 to 7m thick bodies that at places extend for hundreds of meters. Textural, modal and chemical composition criteria have been used to classify these dykes into (1) dolerites of varied assemblages, and (2) Lamprophyres. The dolerites generally display ophitic to subophitic texture and consist of plagioclase (An₃₅₋₅₅), hornblende, pyroxene, epidote, ore (ilmenite and titaniferous magnetite), sphene, and rarely quartz, biotite, chlorite and apatite. The chemistry of the dolerite dykes is suggestive of continental tholeiitic affinity. The lamprophyres are restricted in occurrence and intrude the north-central part of the complex near Koga. Texturally these are panidiomorphic and are composed of amphibole, sphene, albite, apatite and ore. Field data and petrography suggest that these rocks represent the last episode of the alkaline magmatism in the complex.

Key words: Petrography, basic dykes, Ambela granitic complex, Buner.

R/18. Rafiq, M. & Jan, M.Q., 1991. Titanium content of a chloritoid-quartz-ilmenite band in ophiolitic melange near Prang Ghar, NW Pakistan. Geological Bulletin, University of Peshawar 24, 127-132.

Titanium is a valuable engineering metal and has many uses. In the greenstone of the Indus suture melange near Prang Ghar, a 200 m long and 1 to 3.5 m thick band consists essentially of chloritoid (31 to 59 vol. %), quartz (10 to 27%), and ilmenite + Fe-oxide (8 to 25%). The rocks contain very high Al₂O₃, total Fe₂O₃ and TiO₂, and low SiO₂, CaO, MgO and alkalis. The unusual composition may have formed from basaltic precursors of the greenstone by weathering (laterization) or alteration, followed by greenschist facies metamorphism. Chemical analyses of three samples, containing 5 to 10 wt. % TiO₂, warrant further investigation of the area.

Key words: Ophiolites, ultramafics, Indus Suture, Prang Ghar, Mohmand.

R/19. Rafiq, M., Khan, M.A. & Jan, M.Q., 1988. Myrmekite in the Ambela granitic complex, N. Pakistan: A product of deformation and replacement in the feldspar. Geological Bulletin, University of Peshawar 21, 159-165.

The Ambela Granitic Complex in N. Pakistan is locally intersected by strike-slip and thrust faults, which have resulted in the development of relatively, sheared granites. A characteristic feature of the deformed granites is the occurrence of myrmekite in the K-feldspar porphyroclasts, which is otherwise absent in the complex. A detailed petrographic study shows that the myrmekites are localised along those margins of the porphyroclasts which are not strained and which are adjacent to the trails of secondary muscovite. A comparison with the established examples of strain-related myrmekites suggests that though the deformation may be important in the genesis of the Ambela myrmekite, there may be a greater role of metasomatic replacement accompanying deformation.

Key words: Myrmekite, petrography, Ambela granitic complex, Buner.

R/20. Rafiq, M., Khan, M.A., Jan, M.Q. & Ahmad, I., 1988. Petrography and geochemistry of the inclusions from the Ambela granitic complex, N. Pakistan. Geological Bulletin, University of Peshawar 21, 141-145.

Petrography of twelve and geochemistry of three selected samples are presented for the inclusions of the Ambela granitic complex. The inclusions are silicic to intermediate in composition with a metaluminous chemical character. Major element geochemistry is inconclusive with regards to their origin, but incompatible trace elements are in correspondence with the concentration of these elements in the host granites and syenites. A closer match, however, is with the acidic volcanics which now make a part of the country rocks but were probably the early phase of the Ambela granitic complex.

Key words: Petrography, enclaves, Ambela granitic complex, Buner.

R/21. Rafiq, M., Shah, A., Hamidullah, S. & Sayab, M., 1997a. Petrogenetic study of Late Paleozoic sub-volcanic rocks from Peshawar Plain, N.W. Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.50.

Please consult the following account for additional information.

Key words: Petrogenesis, Paleozoic, Peshawar Plain.

R/22. Rafiq, M., Shah, A., Hamidullah, S. & Sayab, M., 1997b. Classification and genesis of late Palaeozoic, volcanic rocks from Peshawar plain, North West Pakistan. Geological Bulletin, University of Peshawar 30, 251-271.

Acidic microporphyries and rhyolites of Late Paleozoic age are intimately associated with acidic plutonic rocks, i.e., the Ambela granitic complex of alkaline igneous province of Peshawar plain. Basic rocks occurring as flows are also associated with these acidic rocks. Field evidences including the association of metasedimentary sequence of Carboniferous age, i.e., Jaffar Kandao and Baroach Formation, provide constraints on the date of their emplacement. The microporphyries and rhyolites have a fine-grained texture with feldspars and quartz as phenocrysts. The rocks are classified as A-type, mildly alkaline and peraluminous on the basis of major and minor element chemistry. Tectono-magmatic discrimination diagrams, Zr and Ta concentration, Hf/Th and Hf/Ta ratios, and low Sr reveals that these rocks are of crustal origin and were emplaced in intra-cratonic rift environment. The Th, Hf and Ta concentrations indicate crustal contamination, and Eu anomaly shows soda metasomatism due to the intrusion of late magmatic fluids in these rocks.

Key words: Petrogenesis, Paleozoic, volcanic, Peshawar Plain.

R/23. Rafiq, M., Shah, M.T., & Ahmad, I., 1984. Note on tremolite zone from the extension of Skhakot-Qila ultramafic complex Utmankhel, Mohmand Agency. Geological Bulletin, University of Peshawar 17, 178-179.

Tremolite rock occurs along the northeast and northwest contact of the ultramafic complex, west of Jindai Khwar near Balola in Mohmand Agency. Tremolite is mostly found in association with actinolite, talc and chlorite along shear zones. Palegreen to green and fibrous to bladed tremolite crystals vary from 3 to 16 mm in length. However, a greyish-green variety (about 2 mm in length) intermixed with talc and chlorite is not uncommon. The blades are commonly broken, bent, and usually tailed out into finely fibrous bundles of asbestiform tremolite. It has large 2V with an extinct angle varying from 15° to 20° , and n_a and n_p refractive indices of 1.60 and 1.61 respectively.

Tremolite mineral from the tremolite rocks was analysed for major oxides by wet chemical methods. These oxides were used for the calculation of mineral formula ($\text{Ca}_{1.68} \text{Na}_{0.20}$) ($\text{Mg}_{4.58} \text{Mn}_{0.02} \text{Fe}_{0.21} \text{Al}_{0.30}$) ($\text{Si}_{7.83} \text{Al}_{0.16} \text{O}_{21}$) (OH_2) on the basis of 23 oxygens; water was not included in the recalculation (Leake, 1978). The mineral was classified as tremolite. This analysis on comparison, has correlation with the tremolite from Feather River ultramafics (Ehrenberg, 1915) and also with tremolite from Ultimo, Italy (Pirani, 1951). In spite of optical properties and chemical data, the presence of tremolite was also established by examination of X-Ray Diffractometer powder pattern. The powder pattern of charge contained 90% tremolite, the remainder being actinolite, talc, and chlorite. Field relationship of tremolite rock with the ultramafics suggests that it may probably be the product of secondary processes. However, more detailed work is required to ascertain the possible origin of this rock.

Key words: Ultramafics, tremolite, Skhakot-Qila, Mohmand Agency.

R/24. Rafiq, M., Shah, M.T., Rehman, M. & Ihsan, M., 1984. Petrochemistry of the rocks from Babaji area, a part of the Ambela granitic complex, Buner, Northern Pakistan. Geological Bulletin, University of Peshawar 17, 31-42.

Geological mapping covering 50 km² around Babaji in Buner, shows that the area comprises of syenites, quartz-syenites and granites. The rocks are distinguished on the basis of field and petrographic observations. Petrochemically (19 analyses) the Babaji rocks are comagmatic and have the characteristics of an extensional type of plutonic suite, associated with rifting. There is a close correlation of available chemical indices of the studied suite with similar rocks elsewhere in the world.

Key words: Petrology, geochemistry, Ambela granites, alkaline rocks, Buner.

R/25. Rafique, M., 1964-65. Geology and Petrology of Hakle-Mansehra Area. M.Sc. Thesis, Punjab University, Lahore, 170p.

The area mapped lies in the core of syntaxial bend and is designated as "Hakle Area" after the name of the locality. One geologic map is given with extensive readings of joints, foliation, lineation and general bedding.

The area consists of acid igneous rocks and regionally metamorphosed sediments. The acid rocks are Granites (classified as Mansehra and Hakle Granite) whereas the metamorphic include chlorite biotite schists, quartzites and garnet mica schists. A detailed study of Hakle Granite has been made for the first time. From the systematic study of the rocks it is concluded that

Because of the chemical similarities (except Soda which is abundant in Granites) between the Granites and country rocks, a genetic relation can be traced. Again because of field observations and chemical and mineralogical similarities, Hakle Granite is traced to be a late differentiate of Mansehra Granite which underwent potash and boron metasomatism. The previous view of antipathic relationship between tourmaline and biotite of Hakle Granite is contradicted. Structurally the area is folded into anticlines and synclines, the granites occupying the cores of anticlines while metamorphic form the synclines. The space for granites was provided by marginal faults and stoping.

Key words: Petrology, structure, metasediments, granites, Mansehra.

R/26. Rafique, M., Ashraf, M., Din, A. & Faruqi, F.A., 1976. Evaluation of glass sand deposits of Pezu, Bannu District, NWFP, Pakistan. Geological Bulletin, University of Punjab 13, 87-92.

Eight different silica sand samples (of Jurassic age) collected from Pezu region was investigated for their grain size distribution, chemical analysis, and removal of Fe₂O₃ contents and melting behavior. It has been found that sand Nos. 9S and 10S from Chunda after water washing and grading are among the best sands of the country. Sand Nos.

1S (Nar Kasha Tangi), 5S and 6S Terkhobai Ster are the medium quality sands. Most of the iron oxide present in the sands in the form of heavy minerals is of para-magnetic nature and magnet treatment is unnecessary. Sand Nos. 9S and 10S exhibit a good melting behavior.

Key words: Glass, silica sand, Pezu, Bannu.

R/27. Rafique, M., Chaudhry, M.A. & Chaudhry, M.N., 1988a. Chemistry, mineralogy and utilization of Kotli Azad Kashmir dolomite for making colorless glass. *Pakistan Journal of Scientific and Industrial Research* 31, 449-454.

Five dolomite formations of Lateri, Sawar, Kamroti, Nikial and Tattapani of Kotli area of Azad Kashmir have been studied in detail for their use in the manufacture of colourless glass. It has been shown that raw samples due to high iron content (more than 0.1 %) are not suitable for colourless glass making. However, after beneficiation, the iron content is reduced to 0.058% and 0.08% which is acceptable for colourless glass making. Experimental glass meltings containing 3.2 % MgO with the beneficiated dolomite samples gave satisfactory results.

Key words: Mineralogy, chemistry, dolomite, glass, Azad Kashmir.

R/28. Rafique, M., Chaudhry, M.A. & Chaudhry, M.N., 1988b. Studies on economic potentials of nepheline syenite of Koga (Swat) for making colorless glass. *Pakistan Journal of Scientific and Industrial Research* 31, 663-668.

Six samples of Nepheline syenite collected from Koga area (Swat, NWF) have been investigated to find their suitability for the manufacture of colourless glass. This work involves geology, microscopic study, crushing grinding, grading, chemical analysis, magnet treatment and glass melting. The iron content in the raw samples varied in the range 0.87 to 2.7 % rendering them unsuitable for colourless glass making. After magnetic separation, Fe₂O₃ is reduced (0.06 %) to a level which is acceptable for colourless glass making. Two glass compositions containing Al₂O₃ 1.5 % and 4.0 % suitable for container and fiber glass have been melted to produce colourless glass. The results are satisfactory.

Key words: Nepheline syenite, glass raw material, Swat.

R/29. Rafique, M., Chaudhry, M.N. & Ashraf, M., 1987. Beneficiation and evaluation of a part of the nepheline syenite deposit of Swat as a raw material for glass manufacture. *Geological Bulletin, Punjab University* 22, 116-124.

For further information, consult Rafique et al. (1988b)

Key words: Nepheline syenite, glass, raw material, Buner, Swat.

R/30. Rafique, M. & Farooqi, F.A., 1984. Evaluation of optical quality Hazara sand North West Frontier Province. *Kashmir Journal of Geology* 2, 103-108.

A representative sample of sand from Hazara District was procured for investigation for optical glass making point of view. It was found that after water washing and grading, the reduction of iron content (Fe₂O₃) was so significant that this sand was quite suitable for the manufacture of optical glass.

Key words: Glass sand, Hazara, NWFP

R/31. Rahimuddin, M., 1971. Report on geology and petrology of Taghma area, Swat district, M.Sc. Thesis, Punjab University, Lahore.

Taghma area occurs in the southern amphibolites belt of the Kohistan arc. In addition to amphibolites, ultramafic rocks, gabbros and diorites are described from this area.

Key words: Petrography, petrology, amphibolites, Swat.

R/32. Rahim, M.A., 1981-83. Geological mapping and hydrological investigation of Kalabagh Dam Site, Area. M.Sc. Thesis, Punjab University, Lahore, 109p.

Key words: Mapping, hydrology, engineering geology, dams site, Kalabagh.

R/33. Rahman, A., 1961. A gravity study of the granites in the Mansehra area, west Pakistan. Geological Bulletin, Punjab University 1, 15-20.

The results of a gravity survey of the granites and metamorphics near Mansehra are given. The residual gravity anomaly pattern does not, in general, follow very closely the geological structures, and the main mass of granite is thought to be in the form of a sheet. One very marked and circumscribed negative anomaly occurs over a small tourmaline granite intrusion for which a possible form has been calculated. To explain the anomaly a higher density contrast had to be assumed than that given by measurements of actual rock samples.

Key words: Geophysics, gravity, metamorphic, granite, Mansehra.

R/34. Rahman, A., 1964. A preliminary investigation by the self-potential method of a known galena deposit at Sobrah, Hazara District, West Pakistan. Geological Bulletin, Punjab University 4, 103-104.

Shams (1963) has given an account of lead mineralization in the Abbottabad Area, Hazara District. Self-potential survey has been carried out on one of the three galena occurrences which he has mentioned in this area; the Sobrah Lead deposit has been investigated to determine its possible extension and, hence, the feasibility of the economic exploitation of the mineral. In 1959, extraction of Lead was started at the Sobrah deposit, but the work was abandoned after a short time. Since then, no further attempt has been made to reconsider the possibility of mining at this site. Moreover, there exists no account of any Geophysical survey, before the mining was taken up. The only evidences of the deposit are the exposed galena-containing rocks in the nala, in the form of a thin vein, (Shams 1963). This Lead occurrence at Sobrah is an impregnation of Galena in a zone of fracture between the Hazara Slates and the Tanol Formation. To carry out the self-potential survey, an ABEM Self-potential equipment, with porous pots (copper in copper sulphate) was used. In view of the very rugged topography of the area, the gradient method was employed. The gradient of Self-potential was observed between two points, 30 ft. apart, along the profiles shown in figure 1. Because of the hindrance due to the cultivated fields, the lines of the profiles were run only along the accessible paths or along stream beds. The data thus collected was found to be insufficient for drawing the equipotential contours; therefore, only the ranges of the gradient of Self-potential were shown in the map (Fig. 1.). The gradient of Self-potential in the range of 100 to 250 mV/30 ft. was taken as high, that in the range of 50 to 100 mV/30 ft. was considered as medium, while that lying below 50 mV/30 ft. was classified as low. The high and medium gradients were marked on the map, the low gradients were not taken into account.

The high Self-potential gradients were observed to exist between Station Nos. 37-38, 44-45, 100-101, 102, 136-138 and 138-139, and the medium SP gradients were found between Stations Nos. 38-39, 102-103, 103-104 and 147-148. The highest value of gradients (245 mV/30 ft.) was found between Stations No. 136-138 and 138-139. These values were rechecked for shorter electrode-spacings and at different times but were found to be consistent with a deviation of 20 mV/30 ft. A high S. P. gradient observed between stations Nos. 37-38 and 44-45 could be due to some deep-seated ore body, as it shows a scattered type of anomaly. In the map (Fig. 1) the high gradients of S.P., shown on profile IV, lie on a band which also contains the mining pits. The extension of the band is in a direction N 45° W, which coincides with the strike of the ore body, exposed in the mining pits. In order to determine the extension of the ore body in the direction of the strike, two profiles, Nos. V and VI were run. All the S. P. gradient values found on these profiles were lower than 50 mV/30 ft., which probably shows that the galena deposit of Sobrah does not extend continuously beyond the profiles Nos. V and VI. It requires, however, more work to determine whether there are other galena deposits in the direction of the strike. Thus the Sobrah Galena Deposit has a limited extension in the direction of its strike and does not call for a full-scale mining operation.

Key words: Geophysics, economic geology, lead deposits, galena, Abbottabad.

R/35. Rahman, A., 1990-92. Geological mapping of Nauseri-Muzaffarabad-Garhi Habibullah area and evaluation of landslide hazards on western limb of Hazara-Kashmir Syntaxis. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 55p.

The northwestern part of Muzaffarabad and western limb of Hazara-Kashmir syntaxis is the area of high landslide hazards. Steep slopes silty, sandy and clayey soils, heavy rainfalls, water seepages and under cutting of the river all contribute to the landsliding in the region. The instability of the area has been further increased by road widening and effect of Main Boundary Thrust (MBT), resulting in the form of major landslides such as, slumping, earthflows, rockfalls, sinkholes and combination of these. The active Lohar Gali landslide is investigated in detail because of its large size and proximity to roadways. Soil samples were collected to evaluate engineering properties of material involved in these failures. The investigated area is a limb of Hazara Kashmir Syntaxis of folded and faulted, low grade metamorphic rocks, which have been further deformed by the important Muzaffarabad fault and regionally significant Main Boundary Thrust (MBT).

In addition, a landslide map of the area was prepared by performing field work. All slope failures were classified according to their movement and state, of activity with varying water content (1.5-12.3%), liquid limit (16.1-39%), plastic limit (0-2.0%), shrinkage limit (14.5-28.8%), absorption (0.69-3.9%), compaction (114.5 lb/cu.ft), dry density at 13.55 optimum moisture content, specific gravity (2.51-3.2), slake durability (5.1-24%); grain size analysis and breaking characteristics. The results suggest that slope failure occur due to high swelling potential of soils, active faults and shear failures.

Key words: Mapping, landslides, hazards, Hazara-Kashmir syntaxis.

R/36. Rahman, A., 1992-93. Geological mapping and hydrogeological studies of Muzaffarabad area with special emphasis on pollution studies and waste disposal of Muzaffarabad city area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 123p.

Key words: Mapping, pollution, waste disposal, hydrogeology, Muzaffarabad, Azad Kashmir.

R/37. Rahman, A.U., 1970. Geological report on Dunga Gali, Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 83p.

A brief description of physiography of the area between Dunga Gali and Abbottabad is given with special reference to mass-wasting drainage, -its adjustment to structure, soils and terraces. The stratigraphy of rocks ranging in age from Paleozoic to Eocene is described. An attempt is made to reconstruct the environments of deposition of each formation. A description is given of structural observations made on faults, folds and bedding planes. A brief description of tectonic behaviour of each formation is also described. The Author has discussed very briefly the type of forces and tectonic framework which could create present tectonic style; and also attempted to reconstruct the evolutionary stages of the Himalayan geosyncline during its life span.

Key words: Geology, physiography, Abbottabad.

R/38. Rahman, F., 1968a. The study of alkali metasomatism across a granite contact near Batrasi, Mansehra area, Hazara District, northern West Pakistan. 20th All Pakistan Science Conference, Dacca, p.G4.

Key words: Metasomatism, petrology, granites, Mansehra.

R/39. Rahman, F., 1968b. The study of geochemistry of the alteration products of the Susalgali granite gneiss, near Ahl, District Hazara. Abstracts, 20th All Pakistan Science Conference, Dacca.

For details consult the Rahman, F. 1972a.

Key words: Geochemistry, granite gneiss, alteration, Hazara.

R/40. Rahman, F., 1969. The geochemistry of granites and the associated rocks of the Mansehra area, Hazara District. Ph.D. Thesis, Punjab University, Lahore.

Key words: Geochemistry, petrology, granites, Mansehra, Hazara.

R/41. Rahman, F., 1972a. The study of geochemistry of the alteration products of the Susalgali granite gneiss, near Ahl, District Hazara, NWFP, Pakistan. Geological Bulletin, University of Punjab 9, 1-12.

On the Battal-Mansehra road and close to the Ahl rest house north of Abbottabad, Hazara district, there is a huge deposit of soft, friable, white-looking material. This has been repeatedly investigated, in the past, by many workers taking it as a deposit of kaolin clay; the reports have been both in favor as well as against this assumption. However, these reports were almost never based on detailed technical investigation, which had been the cause of widely variable conclusion.

The present paper has been written on the basis of chemical, microscopic, differential thermal and infrared spectrophotometric analyses and also on the basis of geochemical relationships, which exist between the soft, friable deposit and the immediately associated Susalgali granite gneiss. Moreover, it has been discovered that the deposit has got the same mineralogy and almost the same chemical composition as that of the surrounding granite gneiss and the deposit can not be other than but an alteration product of the surrounding rock.

Key words: Geochemistry, granite gneiss, alteration, Hazara.

R/42. Rahman, F., 1972b. The determination of gold by radiochemical and non-destructive neutron activation/radioactive analysis in some of the sulphide ore samples from Pakistan. Geological Bulletin, Punjab University 9, 37-42.

Four sulphide ore samples were selected from different localities in Pakistan, and were analysed by both radiochemical as well as by non-destructive neutron activation techniques. Only the results on gold are being presented in this paper. The nuclear reactor JEEP-II located at Kjeller (Norway), has been used as a source of neutrons. The samples were irradiated at a flux 1.5×10^{13} n/cm²/sec for one hour in case of radiochemical neutron activation experiment, and for half an hour in case of non-destructive neutron activation experiment. Following irradiation and "cooling" for two days, the respective samples were used directly for non-destructive analysis, whereas others were put to gold radiochemistry. ¹⁹⁸Au, half life 2.697 days, has been assayed in both the experiments. A lithium-drifted germanium detector, Ge (Li), has been used, along with a 16 bit computer (NORD-I) with 4K memory, to measure the gold activity.

Key words: Sulphides, gold.

R/43. Rahman, F., 1975. Simultaneous estimation of eleven elements in sulphide ore samples from Pakistan. Norsk Geologisk Tidsskrift 55, 277-281.

Key words: Sulphide ore.

R/44. Rahman, F., 1978. Estimation of silver by radiochemical neutron activation method and study of its geochemical distributing in selected sulphide ore samples from Pakistan. Geological Bulletin, Punjab University 15, 7-14.

With the intention of studying distribution of silver metal in sulfide ore samples of different composition and different origin, a careful selection of four sulfide ore samples was made. Their silver metal content was estimated by employing radiochemical neutron activation technique. 100 - 200 mg of pulverised, homogenised ore samples were irradiated by thermal neutrons (at a flux of 1.5×10^{13} n/cm²/sec) for 24 hours alongwith standard rock samples and synthetic standards for silver. These irradiated samples and standards were allowed to cool for three

weeks and then their silver content was separated and estimated by making radioactivity measurements of ^{110m}Ag via 657.8 keV . Finally geochemical relationship of silver with other coexisting metallogenic elements, under the then existing environments, was envisaged.

Key words: Geochemistry, sulphides, silver.

R/45. Rahman, F., 1980. A short note on landslide of Amluknar, Dir District, North West Frontier Province, Pakistan. Geological Survey of Pakistan, Information Release 123, 8p.

Key words: Landslides, hazards, Dir.

R/46. Rahman, F., Khan, A. & Din, W., 1983. Regional geology of the Karak District, North West Frontier Province. Geological Survey of Pakistan, Information Release 131, 25p.

Key words: Geology, mapping, stratigraphy, Karak, NWFP.

R/47. Rahman, H., 1962. Stratigraphic Code of Pakistan: 2nd edition. GSP, Memoir 4(1), 8p.

Key words: Stratigraphic code, Pakistan.

R/48. Rahman, H., 1963. Geology of petroleum in Pakistan. 5th World Petroleum Congress, Frankfurt, Section 1, Paper 31, PD-3, 653-683.

Key words: Geology, hydrocarbon, petroleum, Pakistan.

R/49. Rahman, H. & Dunkle, D.H., 1961. A review of fuel resources. Natural Resources 1(1), 43-46.

Key words: Hydrocarbon, fuel, Pakistan.

R/50. Rahman, H. & Dunkle, D.H., 1966. On marine fishes from the Eocene of West Pakistan. USGS/GSP, (IR) PK-30, 8p.

Preliminary announcement of the discovery of marine Eocene fishes from the Zinda Pir Anticline, Dera Ghazi Khan District, west Pakistan, is made with discussion of the stratigraphic setting of their occurrence in the foreshore basin of the Tethyan Geosyncline, summarization of conflicting opinion as to the lower or middle Eocene age of the horizon and the current and future importance of their systematic and ecologic implications relative to local and regional geologic interpretation.

Key words: Palaeontology, marine fish, Eocene.

R/51. Rahman, H., Khan, M.Y., Hussain, F. & Ahmad, H., 1966. Fuel Map of Pakistan.

Key words: Energy, fuel, maps.

R/52. Rahman, M.A., 1979. Geology, mineralogy and genesis of uranium mineralization in Mauji-Reshian areas, Azad Kashmir, Pakistan. M.Sc. Thesis, University of Aberdeen.

Key words: Mineralogy, uranium mineralization, Azad Kashmir.

R/53. Rahman, M.A., 1980a. Betafite in carbonatite from Khyber Agency, North West Frontier Province. *Pakistan Journal of Scientific and Industrial Research* 32, 5-8.

Key words: Betafite, carbonatite, Khyber agency.

R/54. Rahman, M.A., 1980b. Electron probe data on brannerite and xenotime from District Muzaffarabad, Azad Kashmir. *Contributions to Geology of Pakistan* 1, 45-52.

Uranium mineralization hosted in the graphite schists of the Salkhala Series at Mauji-Reshian area in District Muzaffarabad Azad Kashmir indicated the presence of two sub-microscopic size mineral phases. These mineral phases were analyzed by mean of the electron probe microanalysis and identified as brannerite essentially a uranium titanium oxide and xenotime yttrium phosphorous oxide with thorium. Chemical data by the EPM on these minerals is provided and the results are discussed. The presence of the brannerite and xenotime in the graphite schists of the black shale origin is reported for the first time.

Key words: Mineral chemistry, microprobe data, Azad Kashmir.

R/55. Rahman, M.A., 1981. Uranium-thorium mineralization in some granitic bodies of the Parachinar area, NWFP, Pakistan. *Geological Bulletin, Punjab University* 16, 23-36.

A uranium-thorium mineralization distributed in some granite gneiss and pegmatite bodies occurs in the Parachinar area, N. W. F. P. Laboratory investigations involving petrography, autoradiography, minerography and chemical analyses were conducted on sixteen selected rock samples from the area. The result indicated that allanite and radioactive epidote, present as accessory constituents of the granitic bodies, were the sources for both uranium and thorium. Another notable mineral was uraniferous limonite, which was present as secondary uranium enrichment, depending upon mobility of uranium and iron during weathering process. The study suggests that the mineralization is present in the form of discretely disseminated grains of allanite and radioactive epidote as well as uraniferous limonite in minor amounts.

Key words: Radioactive minerals, uranium, granite, Parachinar, NWFP.

R/56. Rahman, M.A., 1984. Mineralogy and genesis of uranium and associated metallic mineralization in graphite schists, District Muzaffarabad, Azad Kashmir. *Abstracts, First Geological Congress, Lahore*, 65-66.

The graphite schist belonging to the Salkhala Formation of Precambrian age is widely distributed in District Muzaffarabad, Azad Kashmir. Geological and mineralogical studies conducted on the graphite schist in the Mauji-Reshian area has indicated the presence of uranium mineralization associated with pyrite, graphite, rutile, chalcopyrite, marcasite, covellite, tetrahedrite and galena. Goethite is present as a secondary mineral.

Laboratory studies involving fission track radiography, autoradiography, mineragraphy, electron probe microanalysis and neutron activation analysis has indicated the presence of uranium and thorium as brannerite and xenotime respectively, as disseminated phases together with secondary uranium concentration in the fracture-filled goethite veins as well as graphite schist breccia.

The ubiquitous association of uranium and pyrite and the higher carbonaceous content of the graphite schist suggest an uraniferous black shale origin for the mineralization. Brannerite and xenotime show detrital character and were probably deposited in the black shale sediments. Secondary uranium is probably derived from organ-uranium complexes which occur in the graphite schist below the zone of oxidation.

Key words: Mineralogy, metallic minerals, graphite schist, Salkhalas, Muzaffarabad.

R/57. Rahman, M.A., 1991. Uranium minerals from Pakistan: A review. *Acta Mineralogica Pakistanica* 5, 99-108.

In Pakistan, at least fourteen U-Th-bearing minerals species occur widely distributed in sandstone, granite, pegmatite, carbonatite and graphite schist rocks. The primary minerals are mainly associated with the acid

intrusives, carbonatites and graphite schists showing the disseminated type of occurrence. Invariably, the mineralizations are associated with minor concentration of uraniferous Limonite due to oxidation by weathering. Secondary U mineralization indicates wider distribution and is mainly associated with the fluvial sandstone of Upper Miocene age. The nature of U-mineralizations and their petrogenetic significance are discussed.

Key words: Radioactive minerals, uranium, Pakistan.

R/58. Rahman, M.A. & Chowdhury, N.A., 1971. A note on magnetic survey for Iron Ore near Malakand Agency, Pakistan. GSP, Information Release 42, Rep. 3.

Key words: Iron ore, geophysics, magnetic survey, Malakand.

R/59. Rahman, M.A. & Chaudhry, M.N., 1981. Geology and petrography of metamorphic rocks in Mauji and Reshian areas, District Muzaffarabad, Azad Kashmir. Geological Bulletin, University of Peshawar 14, 123-139.

Geological mapping was conducted in 13-km² area in Mauji and Reshian, District Muzaffarabad, Azad Kashmir. The work has involved detailed petrographic studies. Metasedimentary rocks in the Mauji-Reshian area consist of graphite, pelite and arenaceous schists with minor gypsum and calcareous bands belonging to the Salkhalas. These rocks are intruded by biotite granite gneiss and numerous dolerite dykes. The metasediments have been metamorphosed under the greenschist facies conditions. An almandine garnet schist has developed probably in the aureole around the biotite granite gneiss.

The mineralogical assemblage of the schist together with the presence of gypsum and calcareous bands in the area is indicative of flysch type deposits as a result of sedimentation under shallow water marine conditions. The graphite schist is characterized by extremely fine grained quartz averaging 50 µm in size, abundant carbonaceous material and ubiquitous presence of pyrite suggesting a black shale origin for these rocks.

Key words: Petrography, metamorphism, black shale, Salkhalas, Azad Kashmir.

R/60. Rahman, S., 1990-91. Structure, stratigraphy, micropaleontology and petrography of the western limb of the Hazara-Kashmir Syntaxis, Abbottabad and Manglaur areas, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 144p.

The Abbottabad and Manglaur area lies along the western extremity of the Hazara-Kashmir syntaxis. The area has been divided into two zones on the basis of structure and stratigraphy. Because the rocks of the blocks belong to different stratigraphic provinces and have become in contact with each other tectonically. These zones are Garhi Habibullah-Abbottabad (east of Panjal thrust) and Mansehra zone (west of Panjal thrust).

Rocks east of Panjal thrust in the area consist predominantly of Precambrian to Paleocene sedimentary and very low-grade metasedimentary rock units (Hazara Formation) that represents the first deformation and metamorphism in the Hazara area. Whereas, in west of Panjal thrust, the area consists of Cambrian granite gneisses and very low to low-grade metasedimentary (Tanol Formation) that represent D2 deformation and metamorphism associated with the Himalayan deformation phases. The grade of metamorphism varies from chlorite-grade in the south to biotite-grade in the north. The Mansehra zone is intruded by the Permian Panjal mafic dykes and sills of dolerite and basalts. These dolerite and basalts are mostly fresh. The sedimentary, metamorphic and intrusive igneous rocks of these zones are classified and characterized by petrographic studies. The stratigraphy of the area has been developed in which the Abbottabad group has been divided into three formations which are Sobrah, Kakul and Sirban formations. The redivision was marked by an unconformity between Sangargali and Mahmdagali of the Sobrah and Kakul formations.

The rocks have undergone at least three phases of deformation (D1, D2 & D3) and have been metamorphosed to greenschist facies. The first deformation D1 took place as a result of Hazaran orogeny and produced first fabric (S1) in the Hazara Formation which is generally parallel or slightly oblique to the original lithologic layering S0. D2 is associated thrusting and folding phase. Himalayan orogeny folded S1 into open and closed F2 folds that range in size from small kink bands to larger map scale folds. It caused development of penetrative S2 foliation axial planar

to F2 folds. D3 deformation phase associated with the formation of Hazara-Kashmir syntaxis and formed F3 cross folds.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis, Abbottabad.

R/61. Rahmanullah, Ahmad, I. & Khan, K., 1999. Petrography of uraniferous quartzo-feldspathic veins and their wall rock from Marghazar, Lower Swat, Pakistan. M.Sc. Thesis, University of Peshawar, 71p.

The Lower Swat area consists of the Cambrian-Ordovician Swat granite gneisses that have intruded the metasedimentary rocks of the Precambrian Manglaur Formation and are overlain unconformably by the Paleozoic-Mesozoic metasedimentary rocks of the Alpurai group. The Swat gneisses contain minor amounts of younger tourmaline granite gneiss particularly at their margins. Besides locally (e.g. in the Marghazar area) the Swat gneisses host several quartzo-feldspathic vein systems, some of which are associated with radioactive element(s) mineralization.

The Swat gneisses are mostly medium-grained xenoblastic and almost equigranular. However at places they display a porphyroblastic augen-flaser texture. They consist of a variety of minerals. These in the order of decreasing abundance include quartz, alkali feldspar, plagioclase, muscovite, biotite, tourmaline, garnet, apatite, zircon and epidote. The metasedimentary rocks that are in contact with the Swat granite gneiss in the Marghazar area and elsewhere in Lower Swat belong to the Marghazar Formation - the lower most unit of the Alpurai group. They are fine- to medium grained xenoblastic and almost equigranular. They consist of quartz muscovite, biotite. Tourmaline, alkali feldspar and iron ore. They show well-developed schistosity due to the preferred orientation of muscovite, biotite and tourmaline. The radioactive quartzo-feldspathic veins are mostly medium-grained, xenoblastic to hypidioblastic and almost equigranular. They consist of distinct layers, which are alternately dominated by quartz and feldspar. With the exception of the radioactive minerals, the mineralogical composition of the vein systems is almost similar to that of the wall rock. In the order of decreasing abundance, the vein minerals include quartz, alkali feldspar, plagioclase, radioactive minerals, Iron ore, epidote, muscovite, biotite and tourmaline. The vein systems are associated with typical wall rock alteration phenomena that include kaolinitization, chloritization and epidotization. Reflected light study reveals that the radioactive minerals in the vein systems consist of pitchblende uraninite and allanite.

Field observations and mineralogical and textural characteristics suggest that the vein systems and their associated radioactive element mineralization resulted from a hydrothermal activity. The preferred orientation displayed by the vein minerals themselves indicates that the hydrothermal activity took place during a major phase of deformation and as such the veins are syntectonic in origin. The source of the hydrothermal solutions which formed the vein systems and their associated mineralization seems to be the relatively young syntectonic tourmaline granite that occurs at the margins of the Swat granite gneisses.

Key words: Petrography, uraniferous veins, granite gneisses, Swat.

R/62. Rahmatullah, & Naser, Z.J., 1985. Geology, petrography and microfacies of Lumshiwal Formation Kalachitta Range, Nizampur N.W.F.P. M.Sc. Thesis, University of Peshawar, 156p.

Key words: Petrography, microfacies, Lumshiwal Formation, Kalachitta, Nizampur, NWFP.

R/63. Raja, M.A.K., 1985-87. The geology and petrography of volcanic and carbonate rocks of upper Haveli (District Bagh) & Balgiran-Manjhote District Muzaffarabad with special emphasis on Dara marble. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 110p.

The project area covers about 417 square kilometers located in District Bagh and Muzaffarabad, Azad Kashmir. The work has involved geological mapping of the area on a scale of 1:25,000 and 1:15,000 respectively. This thesis deals with the geology and petrography of Panjal Volcanics and carbonate rocks of the area. The geological sequence of the area consists of sedimentary, volcanics and metamorphic rocks. Lithologically metamorphic rocks present in the area are Schist, Slates, Phyllites, Quartzite and marble while sedimentary rocks comprise Sand stone, shales, silt stone, lime stone. Volcanic rocks belong to two distinct ages. Dogra trap are of Precambrian age and occur with in

the Dogra Slates. Panjal volcanics or Panjal trap flows are of Upper Carboniferous age and basaltic to andesitic in composition, while mineralogical studies of Dogra trap shows that they are of basaltic composition. Petrographic analysis of Panjal volcanics, Agglomeratic slates, limestone and marble have been carried out. The mineral assemblage in volcanics is plagioclase + chlorite + epidote + Quartz + Calcite, while of agglomeratic slates is Quartz + epidote + chlorite + Calcite + plagioclase the mineralogical assemblage of lime stone and marble is calcite + quartz + muscovite + magnetite. Pb-Zn mineralization in carbonate rocks of Khetar-Treri areas has been interpreted. The evidences are strongly supporting that Pb-Zn mineralization is the result of hydrothermal solution. Petrogenesis of Panjal Volcanics has been carried out. The evidences reveal shallow water or submarine origin of the Panjal Volcanics. Tectonically the area is highly disturbed, being involved in Himalayan orogeny.

Key words: Geology, petrography, volcanics, carbonate rocks, marbles, Muzaffarabad.

R/64. Raja, M.K., 1981-83. Geology and petrology of Lower Yasin Valley, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore, 85p.

The project, area lies in central Punial area, adjoining to Yasin Valley, Gilgit Agency. The area is located in Karakoram Mountains. Area is intensely disturbed tectonically being involved in Himalayan orogeny. Evidence is provided by crushing and strained effect on minerals. Project area is composed mainly of igneous rocks and metasedimentary rocks. These different rock units are shown on map which was previously prepared by enlargement of toposheet. The major units in the project area are granite, diorite, amphibolite and paragneisse.

Special emphasis was given to the mineralogical description and petrographic analysis of the rock units and is reported in detail. The petrogenesis of these rock units have been discussed as well.

Granite is considered to be a part of Karakoram axial granite, which is emplaced as a partially fused and mobile mass rich in alkali feldspar during synthetic phase of orogeny. Diorite is probably tholeiitic basaltic magma injection. Granodiorite produced during differentiation with decrease of calcic contents. Green stone is metamorphic product of basic igneous rocks. Extensive glaciations of quaternary period is evident and glacial deposits are found commonly. The economic mineral potential of the project area is also discussed.

Key words: Geology, petrology, Yasin valley, Gilgit.

R/65. Raja, M.K.K., 1986. Petrography of Metasedimentary Rocks of Barian-Kundul Shahi area, Neelum valley, Azad Kashmir, Pakistan. *Acta Mineralogica Pakistanica* 2, 158-160.

A detailed petrography of pelitic-psammitic rocks of 20-km² area with modal analyses of 16 thin sections is presented. These metasediments include schists of the Salkhala Formation, metamorphosed under greenschist facies to epidote-almandine subfacies conditions. The details of index minerals are given.

Key words: Petrography, metasedimentary rocks, Neelum valley, Azad Kashmir.

R/66. Raja, M.K.K., 1987a. General Geology and Petrography of Chham-Traran area, Jhelum valley, Azad Kashmir. Abstract with Programs, Mineral Resources and Geology of Pakistan.

For details consult the following account.

Key words: Geology, petrography, Jhelum valley, Azad Kashmir.

R/67. Raja, M.K.K., 1987b. General Geology and Petrography of Chham-Traran area, Jhelum valley, Azad Kashmir. *Acta Mineralogica Pakistanica* 3, 116-122.

A geological map of the Chham Traran area, Jhelum Valley is prepared at a scale of 1:50,000 and a detailed description of various rocks units is presented. Pelitic to psammitic, calcareous and carbonaceous rock sequence of the Salkhala Formation is intruded by a body of granite gneiss. The Panjal Formation (volcanics) is thrust over Precambrian Salkhala Formation and over ridden by the Upper Tertiary Murree Formation. Petrography and mineral assemblages of the Salkhala Formation resemble those of low-grade metamorphites. Presence of gypsum bands in the Panjal Formation is of volcanic nature. Economic Geology of the area is also outlined.

Key words: Geology, petrography, Jhelum valley, Azad Kashmir.

R/68. Rampini, L., 1991. Topographical report. In: Geodesy, Geophysics and Geology of the Upper Shaksgam Valley (North East Karakoram) and South Sinkiang. Scientific Report of the Italian Expedition to Karakoram 1988 (A. Desio leader). Consiglio Nazionale delle Ricerche-Milano, 93-98.

Key words: Geodesy, geophysics, Karakoram, Sinkiang.

R/69. Ramsay, J.G., F.R.S. 1987. The syntaxes of the western Himalayas. Tectonic Evolution of the Himalayas and Tibet. The Royal society Special meeting.

Syntaxial bends are regions where the overall structural trends of fold axes and fault traces make marked regional changes in directions. In the western Himalayas, several such re-entrants are known and in the two major bends of the Hazara and Nanga Parbat syntaxes the structural trends of folds and major suture lines change direction through angles of 180° . Although these syntaxes occur at differing tectonic levels both show overall features of elongated domes or partial domes, and new data suggest that there may be a physical and temporal connection between them.

Several mechanisms have been invoked for forming syntaxial bends: (1) geometric interference within cover structures produced during two separate orogenies or two phases within a single orogeny; (2) reactivation of pre-existing basement structures (folds or faults) during a later orogenic compression; (3) development of complex ramp-flat geometry during the formation of major thrust sheets, especially, that resulting from the formation of oblique-ramps or sidewall-ramps; and (4) differential displacement advance within thrust sheets perhaps associated with partial pinning in or around syntaxial zones.

In the Hazara syntaxis the geometric features of the large-scale structure and small-scale features of folds, cleavage, lineation, and vein systems support the evolution of this syntaxis by progressive change in the regional shortening directions from NE-SW, through N-S and finally to NW-SE directed contractions. The structural features of the Nanga Parbat syntaxis also suggest a complex polyphase movement history with the principal syntaxial form arising relatively late during the regional deformation sequences perhaps as a result of sinistral movement on a deep-seated shear zone.

Key words: Structure, Hazara, Nanga Parbat, Himalaya.

R/70. Ranjha, Z.U., 1993-94. Economic geology and petrology of graphite and other minerals in Naran-Pauldaran Area, middle northern Kaghan valley, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 90p.

Key words: Economic geology, petrology, graphite, Kaghan valley, Mansehra.

R/71. Rao, S.R.N., 1941. An algal flora from the Lockhart limestone (Ranikot Series) of the Samana Range (NW India). Mysor University Journal 2(7), 41-53.

Lockhart limestone is the name given by Lt.-Col. L. M. Davies to a compact, massive, grey limestone of some 200 feet in thickness, occurring in the region of Fort Lockhart on the Samana Range between Kohat and Thal. The Samana series as worked out by him consists of 12 beds; beds 8-12 (uppermost members of the sequence) are of Ranikot age, while the base of the series (bed 1) extends down to the Jurassic (or even the Triassic). The Lockhart limestone (bed 10) represents the uppermost portion of the Lower Ranikot and the lower portion of the Upper Ranikot.

Key words: Stratigraphy, Lockhart limestone, Ranikot, Jurassic, Samana Range, Hangu.

R/72. Rasheed, A., 1992-94. Geology of Sirgh area and sedimentary petrology of Kuldana Formation of Darya Gali, South Hazara, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 143p.

A comprehensive study of geology and structure of the area around Dhamtaur & Sirgah is presented along with a special section on the sedimentology of Kuldana Formation. Large scale (1: 10000) geological mapping of the area is, presented. The lithostratigraphic unit ranges from Precambrian to Eocene. Hazara Formation and Patala Formation being the oldest and youngest units respectively. Structurally the area comprises NE-SW trending double plunging folds constituting anticlinoria and synclinoria. The folds in general are cylindrical with a general vergence to the southeast. The folded sequence is disturbed mainly by reverse faults. A small number of normal faults also exist. Faulting is dip slip to oblique slip and in general involves a maximum displacement of few hundred meters. Apart from the regular faults decoupling is frequently noted at the formational boundaries leading to the slip and discontinuity of thin marker horizons. The lower Eocene Kuldana Formation is mainly composed of variegated Series of marl siltstone arenaceous mudstone and limestone. The siltstone horizons are rare but intercalation of sandstone may be found in places. The mudstone as well as calcareous mudstone are generally unfossiliferous. The conditions of deposition vary widely from subtidal to intertidal and supersubtidal. The red beds are either continental or supertidal. Alternately they may have derived their colour by diagenetic processes.

Key words: Petrology, Kuldana Formation, Hazara.

R/73. Rasheed, S., 1993-94. Geology and structure of Barian Area, Hazara, North West Himalayas and petrography of the Early Cretaceous Lumshiwai Formation. M.Sc. Thesis, Punjab University, Lahore, 136p.

Key words: Structure, petrography, Lumshiwai Formation, Hazara, Himalaya.

R/74. Rashid, A., 1984-85. The geology of Reshian-Nauseri area with special emphasis on petrology of granite & economic mineral deposits. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 171p.

The project area covers about 307 square kilometers, located between Reshian and Jura to the ESE and NE of Muzaffarabad, Azad Kashmir. The work has involved geological mapping of the area on a scale of 1:25,000. In this thesis an attempt has been made to introduce the detailed geology of the area. Bulk geological sequence of the area consists of sedimentary, volcanic, metamorphic and granitic rocks. The area is tectonically, highly disturbed being involved in Himalayan orogeny. For Petrographic analysis sixty thin sections were studied microscopically. Petrogenesis of the rocks particularly that of Jura and Reshian granites are interpreted. Tectonic setting and stratigraphy of the area are described briefly. Major and minor structures of the area are described with the help of figures and maps. Economic rocks and minerals found in the have been described in detail to some extent.

Key words: Petrology, granite, economic minerals, Azad Kashmir.

R/75. Rashid, A., 1990. Lateral and vertical building of sandstone bodies near Bori, Shakardara, District Kohat, N.W.F.P. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Sandstone, Shakardara, Kohat.

R/76. Rashid, C.M., Afzal, P.A. & Majid, A.A., 1997. Uranium potential of the Potwar Plateau. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 2p.

Present studies are aimed at decisively evaluating middle Siwaliks (MS) of Potwar region for its uranium potential through geological modeling based upon the AEMC previous work and work of other professional organizations. Numerous radioactive anomalies and availability of sufficient geological data on this region helped to achieve the desired results. Out of comprehensive platform studies only uranium mineralization part is being discussed.

The Potwar Plateau has been divided into four subregions i.e. Northwest (NW). Southwest (SW). Northeast (NE) and Southeast (SE) PP. 8] out of total 127 radioactive occurrences scattered all over the PP were sub to detailed studies. The time-space distribution of anomalous sandstone horizons (ASH). Stratigraphic levels of host rock i.e. lower, middle and upper within this formation, radioactive zones, primary/secondary uranium mineralization and controls of radioactivity were geologically and statistically analyzed.

The radioactive occurrence are clustered in 17 anomalous zones considered as representative, at least partly, of some, above regional clark, uranium remobilization. The anomalous zones have been further sub-divided in 8 first rate and 9 second rate, on the basis of their geological environment and to the density, zone, uranium return and controls there anomalies. Conclusion based upon the syntheses and interpretation of data are as follow:

On regional basis, six (sub) units may be singled out as displaying a much better load in first rate anomalous zones. Time wise, the DPF on a formation basis and the lower NF, then the middle DPF, on a member basis. Space wise, the WPP, more specially its SE corner (lower NF and middle DPF), central part (middle DPF) and NW corner (upper NF and upper DPF).

Key words: Economic geology, uranium, Potwar plateau.

R/77. Rashid, C.M., Afzal, P.A. & Majid, A.A., 1998. Multistage role of tectonic deformation on uranium mineralization in the neogene fluviatile middle Siwaliks of the Potwar Plateau, Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 165-166.

The evolution of uranium mineralization in the middle Siwalik (Nagri and Dhok Pathan Formations) of the Potwar Plateau is characterized by syn to post tectonic sedimentary deformation through space/time. This indicates a sequence of regional events, providing channel ways and media for remobilization and uranium trapping with some reductants or along permeability/ porosity barriers.

The syndiagenetic traps are mainly tectonically induced and associated in space i.e., on the lesser sloping, down thrown side of stream checking and reactivated basement faults. The post middle Siwaliks tectonic deformation caused Uranium epigenetic remobilization and its down dip concentration. It is enhanced to increasing of slope and or/ oxidation i.e., on the upthrown side of stream checking faults, water table checking lineaments.

Detailed analysis of different tectonic elements and their chronology and uranium favourability criteria (availability, remobilization and trapping) in each tectonic regions of the Potwar Plateau (PP) has been carried out. Some interesting correlation parameters have been revealed after studying the impact of the tectonic setting on the uranium mineralization. All the 81 uranium anomalies in the middle Siwalik are grouped into 8 first rate and nine second rate anomalous zones: depending upon extent, nature and controls of radioactivity/mineralization. All the four tectonic regions of the PP i.e. North Potwar Deformed Zone (NPDZ), South Western Potwar Plateau (SWPP), East Potwar Plateau (EPP) and South East Potwar Plateau Corner (SEPP Corner), show different tectonic controls of individual anomalies as well as anomalous zones. In NPDZ the anomalous zones are controlled by minor NW-SE faults and the tight synclinal structures. In the SWPP, the control of uranium is down faulted blocks and incipient gentle folds. In EPP and SEPP corner the anomalous zones are located along W-E to NE-SW thrust faults, mainly on the northern flank of anticlinal structures.

Distribution pattern of uranium occurrences and their relationship with tectonic features (ductile and brittle) indicate western Potwar Plateau comparatively more favourable than the eastern Potwar Plateau. In SWPP appear to be the most favourable area for uranium exploration due to good source (synsedimentary arial volcanism), syn to digenetic remobilization/trapping evidences in the central western Potwar along down faulted blocks and incipient gentle folds as well as epigenetic post tectonic remobilization/trapping along Salt Range Thrust (Fig. 2).

There are six large-scale tectonic units in the SWPP namely:

Either NE trending, north to south; Lower Soan trough, Tamman ridge, Dhok Mosahib Wala trough to the NE and Chakarala basin to the SW (a composite unit most likely subdivided by secondary ridges and troughs), Western Salt Range. Or NW-trending; from west to east; Southern Kalabagh Salt Ranges, Pachnand ridge (rather subdued, but partly closing and possibly offsetting the Dhok Mosahib Wala trough and Chakarala basin).

Moreover the matallotects might be further enhanced by the possible remobilization or trapping action of oil driven products migrating upwards through deep seated active faults from known underlying oil reservoirs and source rocks through release of CO₂, H₂S etc. in the underground waters. Evidences of such migrations upwards have been noted nearby majority of significant anomalous zones located over or close to known oil structures i.e., Jand (Dakhni oil field), Pindigheb (Dhulian), Khaur (Khaur), Tamman Talagang (Kot Sarang), Joyamair (Joyamair), Adhi (Adhi), Dina (Lehri gasfield), Chakarala (Dadhumber oil structure), Dhok Masahi Wala (Dhermud) producing or now barren.

At anomalies level, PanaKhel anomalous sandstone horizon Jand in Upper Nagri Formation indicates genetic relationship with hydrocarbon derived reducing fluids. Oil products contribution is also visible in the form of solid bitumen collected around the Nikki anomaly (Chakarala). It is first clue on the migration of oil products as far as the lower DPF.

Key words: Tectonics, deformation, uranium mineralization, Dhok Patan Formation, Nagri Formation, Siwaliks, Potwar.

R/78. Rashid, M.A., Hussain, M., Master, J.M. & Meissner, C.R., 1965. Mineral deposits of eastern Kohat region, West Pakistan. GSP Records 13(2), 16p.

Key words: Mineral deposits, Kohat.

R/79. Rashid, M.A. & Khan, A.L., 1991. Bed rock aggregate resources of the Attock District, Punjab, Pakistan. GSP, Information Release 409.

Reserve evaluation of selected bed rock aggregate resources of the area comprising Fateh Jang (43 C/10) and Kot Fateh Khan (43 C/11) quadrangles of Attock District in the Punjab Province, is presented.

Limestone and sandstone are the two rock types considered for evaluation. Vast reserves of alluvial clay, commonly used for pottery and brick making, sand and gravel, available in the area but outside the scope of the present work, have not been considered for estimation.

Limestone aggregate resources of the Jurassic Samana Suk, Paleocene Lockhart Limestone and Eocene Margala Hill Limestone Formations exposed in the area, have been estimated as 1734 million tonnes.

Sandstone aggregate resources of the Murree and Kamalial Formations of Miocene age, exposed in the area, have been estimated as 1266 million tonnes.

Key words: Aggregate resources, sandstone, limestone, Attock.

R/80. Rashid, S., 1993-95. Electrical resistivity survey for ground water exploration in Zulmkote Area, District Malakand, NWFP, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 110p.

Key words: Geophysics, electrical resistivity, groundwater, Swat.

R/81. Rashid, S., 1994-96. Geology and structure of Barian Area, Hazara, NW Himalayas and Petrography of the Early Cretaceous Lumshiwal Formation. M.Sc. Thesis, Punjab University, Lahore, 124p.

It is the study of Geology and Structure of the Barian area (50 km²) along with a special microfacies study of the Early Cretaceous Formation from Kalas. A large-scale geologic map of the Barian area at (1:10,000) is presented. The area comprised sedimentary rocks from Middle Jurassic to Early Miocene age, tectonically forming a part of the lesser Himalayan sequence in the Galiat area, Hazara. The paleogene and older sequence is mainly limestone and shales of shallow massive shelf facies. The overlying Neogene rocks are gypsiferous marls. Limestone and shale supratidal to Sabkha facies in the lower sandstone, shale continental molasse of Murree Formation in the upper part. Structurally the area comprised NE-SW trending cylindrical to double plunging folds constituting anticlinoria and synclinoria. The folded sequence is disturbed by numerous reverse faults. However, small number of normal faults also exist. Faults are either dip slip or oblique slip and except for the MBT, involves a maximum displacement of few hundred meters.

MBT is the major tectonic discontinuity of regional significance. At Darya Gali the thrust is a high angle feature dipping to the northwest with opposing dips in the rocks on the two sides. The surface expression of the MBT is accompanied by a fault-related escarpment and much degradation, accompanied by landsliding.

The Kalas section of Lumshiwal Formation comprises six facies and sixteen microfacies. The sandstone is predominantly medium grained and only four microfacies are fine grained. Quartz, carbonate and glauconite are the common cements while iron oxides and clay occur as subordinate cements. At Kalas presence of ooids in the lower part of Lumshiwal Formation indicates shallowing of basin and high-energy environment while glauconite in the upper part indicates reducing subtidal environment.

Key words: Structure, microfacies, petrography, Hazara, Himalaya.

R/82. Rashid, S., Ahmed, S. & Sheikh, M.I., 2001. Natural resources of Islamabad-Rawalpindi northern Punjab, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.47.

Islamabad, the capital of Pakistan is a planned city constructed since about 1960 at the foot of Margala hills just north of the old city of Rawalpindi. The limestone gravel, sand and clay are the most important material resources of Islamabad, which have been utilized as construction material resources. These are limestone/gravel for cement, aggregate for concrete, sand for mortar and clay for bricks and pottery. Huge reserves of these items (limestone, gravel, sand, aggregate and clay) are qualitatively and quantitatively present which can fulfil the demands of constructing materials with rapid increase of population of Islamabad/Rawalpindi Metropolitan area. Abandoned pits of gravels, sand and clay can be reclaimed for recreation parks, reserved forest, waste disposal and agriculture use.

Key words: Natural resources, Rawalpindi, Islamabad.

R/83. Rashid, S., Din, A. & Arif, M.R., 1964. Study of heavy minerals of Pakistani sands. Pakistan Journal of Scientific and Industrial Research 43?, p.16.

Key words: Heavy minerals.

R/84. Rashid, S., Khan, A.Q. & Asghar, K., 2000. Hydrological studies and groundwater potential of Islamabad region. Abstracts, Third South Asia Geological Congress, Lahore, 158-159.

Islamabad is the capital city of Pakistan situated between latitude 33° 29' and 33°-49' N and longitude 72°-50' to 72°-24' E bordered by Rawalpindi city in the South and Southeast, Margalla hills in the North and Murree Hills in the Northeast. Climatically the area lies in sub-humid region. Annual average rainfall is about 925 mm. Temperature ranges between 3° to 40 °C. Access to city is through Grand Trunk road and Motorway, connected with Peshawar and Lahore. The area is generally an uneven landform covered with alluvial deposits and bedrock outcrops of Miocene Rawalpindi Group (Murree Formation) skirted by Eocene Margalla Hill limestone in the North. The northern mountainous area rises abruptly and appears as Himalayan foothill extension. The area is drained by many perennial streams out of which Korang river, Gumrah Kas, Kantiwali Kas, Tanawala Kas, Bedarwali Kas and Lei Nala are the major constituents of drainage system. During rainy season the velocity of water is very fast in these hill torrents due to high relief and slope of the area.

Hydrogeologically, the area lies in Soan River catchment basin in Potwar Plateau formed as part of Indo-Gangetic synclinorium of Tertiary and Pre-Tertiary sediments, Consolidated and unconsolidated deposits exposed in the area are of sedimentary origin and belong to Eocene to Recent in age. The consolidated deposits are mainly composed of limestone, sandstone, clay, shale and conglomerates. These deposits do not serve as aquifer and water travels through joints, cracks and fissures only. Unconsolidated deposits of recent age are found as terrace gravel and alluvial fill.

Groundwater in Islamabad area occurs in alluvial deposits and hardrock deposits. The transmitting capacity of consolidated deposits is very low. Therefore, it can be considered only for small yields for requirements at the places of acute local shortage of water availability. Nevertheless alluvial aquifers are suitable for large scale groundwater development.

In order to locate the sites feasible for exploitation of groundwater, hydrogeological and geophysical surveys were carried out in 1979-80 referred to Hydrogeology Directorate, WAPDA by Capital Development Authority to overcome the acute shortage of drinking water in the capital city. The work was conducted to locate prospective sites by spot investigation in different sectors selected on priority bases fixed by Capital Development Authority.

The work was completed in two phases, phase-I included sectors F-10, F-11, G-9, G-10, G11, H-9 and National Park area and phase-II covered sectors F-8 and 1-9. Based on the findings of reconnaissance and geophysical survey test drilling and water sampling from various subsurface horizons at 21 locations were carried out. An aquifer test was also conducted to determine the aquifer parameters. Groundwater samples collected during survey and test drilling were got analyzed from WAPDA laboratory. The groundwater quality is good and suitable for drinking, agriculture and other domestic uses. Findings of these studies are summarized in this paper.

Key words: Hydrology, groundwater, Islamabad.

R/85. Rashid, S., Malik, M.H. & Khan, M.S., 2000. Elaboration of aquifer system and its application for protection of groundwater contamination in the Dhamrah Kas Basin, Wah Cantt. Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.161.

Interdisciplinary investigational techniques 1 (hydrogeological reconnaissance, Geophysical survey, Testhole drilling, installation of tubewells and capacity tests) were used for the interpretation of subsurface hydrogeology of the Dhamrah Kas Basin. A multilayered aquifer system spread over an area of about 150 Sq. Km was proved with the help of 20 test holes and 10 dug wells extending to a depth of 300 to 600 feet. The aquifer is classified as multilayered semiconfined fresh body with an average well capacity of 250-350 gallons. The shallow aquifer (A-Layer) is in severe danger of contamination near northern boundary of the basin through induced recharge from a polluted nullah. The bacterial contamination Coliform Faecal Coliform) has polluted shallow aquifer very severely. Treatment and protection measures are discussed, particularly for elimination of physical and bacterial pollution.

Key words: Aquifer, groundwater, Wah cantt, Attock.

R/86. Rashid, T., 1974-76. Lithostructure mapping and geology of Nilt Area, Hunza Valley, Gilgit. M.Sc. Thesis, Punjab University, Lahore, 79p.

Key words: Lithostructure, mapping, Hunza.

R/87. Rathur, A.Q., 1959. Salt Range, Potwar, Quetta, Hazara and Swat. M.Sc. Thesis, Punjab University, Lahore.

Key words: Salt Range, Potwar, Quetta, Hazara, Swat.

R/88. Rathur, A.Q., 1980. Occurrence of fossil Charophyta in Samana Suk Formation, Jurassic, Chichali Nala, Surghar Range, and their stratigraphic significance. Contributions to the Geology of Pakistan 1, 27-44.

Five species assigned to four genera of fructifications of Charophyta, from the Samana Suk Formation (Callovian), Surghar Range, Pakistan, are described. In one case, *Porochara obovate* (Peck) comb.nov. certain morphological characters have been used for statistical analysis to show its variation. The palaeological and stratigraphical significance of these forms is also discussed.

Key words: Palaeontology, stratigraphy, Samana Suk Formation, Jurassic, Surghar, Trans Indus Salt Range.

R/89. Rauf, A., 1974-76. Geology of Taghma Area, Swat District, NWFP Pakistan. M.Sc. Thesis, Punjab University, Lahore, 79p.

This report presents a geological map on a scale of 4.735 cms to a km (3 inches to a mile) and petrographic account of the rocks of Taghma area, which were previously mapped as a single units (Upper Swat Hornblendic Group of Martin et al. 1962 and Epidote Amphibolites of Jan et al. 1973). The present mapping on a larger scale has permitted the further sub division of the rocks of the area into various types of plutonic rocks, like peridotites, diorites, hornblendites and pegmatites; metamorphosed rocks, like amphibolites and gneisses; and their secondary alteration products such as China clay and serpentinites.

Petrographic description of various rock types have been included, which is based on the study of more than fifty thin sections, selected from two hundred rock samples collected during field work. The mineralogical data presented in this report includes the optical data on certain selected mineral; their micrometric measurements, refractive indices measured by liquid immersion method, determination of end member composition using 2V and extinction angles. Discussion and conclusions regarding petrogenesis, based on field relations, petrography and mineralogy of various rock units of the area are also given in this report. The structural features of the rocks are also described, based on the three hundred joints and foliation measurements. The foliation and joints orientation diagrams are also included. An account of the economic geology of the area is included, putting more emphasis on that of the china

clay deposits situated inside the Taghma area. Important features of field as well as of thin sections are expressed with the help of photographs.

Key words: Petrography, ultramafics, gabbros, diorite, amphibolites, Swat.

R/90. Ray, D.K., 1976. Geotectonics of Kashmir Himalaya: Karakorum-Hindu Kush-Pamir orogenic belts. *Atti dei Convegni Lincei* 21, 316p.

Key words: Geotectonics, Hindukush, Karakoram, Himalaya.

R/91. Raynolds, R.G.H., 1980. The Plio-Pleistocene structural and stratigraphic evolution of the eastern Potwar Plateau, Pakistan, Ph.D. Dartmouth College, Hanover, New Hampshire, 265p. 86 fig. 7 tabs, 1 pl.

Key words: Stratigraphy, structure, Pliocene, Pleistocene, Potwar plateau.

R/92. Raynolds, R.G.H., 1981. Did the ancestral Indus flow into the Ganges drainage? *Geological Bulletin, University of Peshawar* 14, 141-150.

The Late Miocene, Pliocene and Pleistocene Upper Siwalik Group molasse sediments of the eastern Potwar Plateau are shown to include two distinctive sandstone complexes. The older sandstone complex is white colored and carries granitic pebbles. The younger sandstone complex is brown colored and carries quartzite and igneous pebbles. Palaeocurrent measurements together with preliminary provenance analysis suggest that the white sandstones were deposited by and ancestral Indus River which flowed to the east-northeast across the Eastern Potwar Plateau. This river system was replaced between 4.5 – 5.0 MY ago by a southward flowing ancestral Jhelum River. It is possible that the ancestral Indus River may have drained into the Bay of Bengal Rather than into the Arabian Sea.

Key words: Indus River, sandstone, Miocene, Pliocene, Pleistocene, Potwar plateau.

R/93. Raynolds, R.G.H. & Johnson, G.D., 1985. Rate of Neogene depositional and deformational processes, northwestern Himalayan foredeep margin, Pakistan. In: Snelling, N.J. (ed.), *The chronology of the geological records*. Geological Society, London, Special Publication 10, 297-311.

The dynamics of molasse accumulation and the subsequent structural displacement of a foredeep basin during orogenesis have rarely been chronometrically defined. The Himalayan foothill belt of northern Pakistan and India constitutes a detailed record of molasse sedimentation in a classical foredeep setting. Subsequent deformation of this sedimentary sequence has resulted in the exposure of over 3000 metres of the Neogene and Quaternary aged Siwalik Group. Recently, the development of a magnetic polarity stratigraphy constrained by the fission-track dating of numerous intercalated volcanic ashes has permitted a precise chronostratigraphic statement to be made concerning the accumulation and deformational history of this non-marine sedimentary sequence. Data from numerous localities in northern Pakistan and India document the onset, development, and termination of various events in this sedimentation history with a precision of from ~20000 to ~50000 yrs. Sediment accumulation rates associated with the progressive migration of the foredeep depocentre have been determined to range from -20 to -50 cm/1000 yrs. The southward progradation of lateral facies changes at rates of up to 30 m/1000 yrs together with the southward advance of the basin depocentre at rates of over 20 m/1000 yrs suggest a rough equilibrium between the modelled northward plate motion of the Indian subcontinent and the southward displacement of depositional processes within the foredeep. This illustration of the dynamic involvement of proximal foredeep terraine in the continuing Himalayan orogenesis yields a model potentially useful in similar tectonic settings.

Key words: Stratigraphy, molasses, marine sediments, sedimentation, deformation, Potwar.

R/94. Raynolds, R.G.H., Johnson, G.D., Johnson, N.M. & Opdyke, N.D., 1980. The siwalik molasse: A sedimentary record of orogeny. Geological Bulletin, University of Peshawar 13, 47-50.

The Siwalik molasse basin lies on the southern margin of the Himalayan orogenic belt. Continuously exposed from the Sulaiman Range in western Pakistan to Assam in the eastern India, the Siwalik sediments consist of over 7000 meters of fluvial sediments ranging in age from late Miocene to Pleistocene.

The continuation of the mountain building activity which first uplift the source area to the north, is now responsible for the deformation and hence exposure of these sediments. This deformation characteristically diminishes in intensity southwards from a boundary thrust fault to the undisturbed Indo-Pakistan shield.

The Siwalik sediments have been extensively studied – initially because of their excellent record of late Tertiary mammalian evolution and more recently, because of their record of source area unroofing and changing sedimentary environments.

Key words: Orogeny, sedimentary, molasses, siwaliks.

R/95. Raza, H.A., 1981. Geothermal gradients in Pakistan. Geological Bulletin, Punjab University 16, 71-82.

Hydrocarbons are generated by thermal diagenesis of organic matter. The study of sub-surface temperatures and thermal gradients within the earth, therefore, offers clues for hydrocarbon exploration. Temperature ranges within which particular types of hydrocarbons, for example oil or gas, would form are now well known. Geothermal gradients as determined from bottom hole temperatures recorded during logging operations in 27 wells drilled in Pakistan show that general geothermal gradients in Pakistan are between 1 and 2°F per 100 feet. The gradients are comparatively higher in the south perhaps because of the Cretaceous/Paleocene igneous activity. Oil window i.e. the depth sector having prospects for liquid hydrocarbons, lies at variable depths in different regions but within the depth range 6,000 to 18,000 feet.

Key words: Hydrocarbons, geothermal gradient.

R/96. Raza, H.A., 1984. Estimating the volume of oil and gas resources in Pakistan. Abstracts, First Pakistan Geological Congress, Lahore, 2-3.

There are four standard methods of estimating ultimately recoverable oil and gas: (1) Past Performance extrapolation (2) Volumetric (3) Geologic-Analog (4) Play Analysis. Computer techniques can be combined with these methods to determine probability ranges. The basin area of Pakistan can be divided into a number of petroleum zones on the basis of similarities in producing horizons, types of hydrocarbons and kinds of traps. Some of the aforementioned methods are suggested for these zones to assess the quantity of oil and gas likely to exist in them. The choice of method has been based on the level to exploration in a particular zone.

Key words: Hydrocarbons, Pakistan.

R/97. Raza, H.A., 1986. Evolution of sedimentary basins in Pakistan and their hydrocarbon potential. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, p.12.

Sedimentary basins of Pakistan evolved as a result of plate interactions that went with the Paleozoic formation of the Pangean superplate and its subsequent fragmentation, Cenozoic collision of the Indian and Eurasian plates and subduction of the Arabian plate under Eurasian plate. The ultimate recoverable hydrocarbon resources of Pakistani basins amount to about 53x10⁹ bbl of oil and 143x10¹² cubic feet of gas; the Potwar, Sulaiman and Kirthar subbasins are current producers.

Key words: Hydrocarbons, sedimentary basin, plate collision.

R/98. Raza, H.A., 1991. Petroleum source rock in Pakistan. International Petroleum Seminar, Islamabad.

Key words: Hydrocarbons, source rocks, Pakistan.

R/99. Raza, H.A., 1992-93. Plate interactions, basin development and implications for hydrocarbon accumulation in Pakistan. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 33-34.

Hydrocarbons reside in sedimentary basins which are produced as a consequence of plate interactions. The lithosphere is formed of a network of 13 large plates which converge, diverge or slip-by relative to each other. In this process new crust is created while the earlier is destroyed.

Worldwide more than 600 basins are known which are classified into 5-8 main types based on location, tectonics and deposition. The concept of plate tectonics is the key element in basin classification. Pakistan's 3 sedimentary basins: Indus, Baluchistan and Pishin contain a number of distinct petroleum zones which exhibit varying prospectivities for occurrence of oil and gas. The area suitable for oil and gas exploration in Pakistan forms 2/3rd part of its total area.

Geologically, northern part of the Indus basin contains the most complete sedimentary column (Precambrian to Recent). The plate tectonics were active over Indus basin since Permian and the first collision of the Indian plate, where Indus basin sits, with the Eurasian plate occurred in Paleocene time. The subduction is an ongoing process. The Baluchistan basin contains sediments of Cretaceous-Recent ages. Its tectonics are comparatively young and involve subduction of oceanic crust of Arabian plate beneath Eurasian plate. Pishin basin is also a young basin (Cenozoic) containing flysch derived from surrounding high blocks. Its development took place in plate margin region. Indus basin is the only producing basin of Pakistan which contains more than 80 oil, gas and condensate discoveries including 2 world class giant gas fields, Baluchistan basin is under-explored and Pishin is a frontier, both hold prospects for future.

Key words: Tectonics, plate movement, hydrocarbon.

R/100. Raza, H.A., 2000. Exploitation and use of energy resources of Pakistan. In: Hussain, S.S. & Akbar, H.D. (eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 185-192.

Key words: Exploitation, energy resources.

R/101. Raza, H.A. & Ahmed, R., 1990. Hydrocarbon potential of Pakistan. Journal of Canada-Pakistan Cooperation, 4, 9-27.

Key words: Hydrocarbons.

R/102. Raza, H.A., Ahmed, R., Alam, S. & Ali, S.M., 1989. Petroleum zones of Pakistan. Pakistan Journal of Hydrocarbon Research, 1(2), 1-19.

Key words: Hydrocarbons, petroleum.

R/103. Raza, H.A., Ahmed, R., Ali, S.M., Sheikh, A.M. & Shafique, N.A., 1989. Exploration performance in Sedimentary zones of Pakistan. Pakistan Journal of Hydrocarbon Research 1(1), 1-7.

Key words: Hydrocarbons, sedimentary zones.

R/104. Raza, H.A. & Iqbal, M.W.A., 1977. Mineral deposits. In: Shah, S.M.I. (ed.), Stratigraphy of Pakistan. GSP, Memoir 12, 98-120.

Key words: Stratigraphy, mineral deposits.

R/105. Raza, H.A., Khan, A.M. & Jalal, A.I., 1992. Pakistan perspective on energy for the 1990s. *Pakistan Journal of Hydrocarbon Research* 4(1), 1-7.

Key words: Energy resources.

R/106. Raza, H.A. & Kemal, A., 1986. Geology of petroleum in Kohat-Potwar depression, Pakistan. *American Association of Petroleum Geologist, Bulletin* 70, 396-414.

Key words: Hydrocarbons, Kohat Potwar depression.

R/107. Raza, S.M., 1967. Stratigraphy and palaeontology of Gandhian-Dartian area, Hazara District, West Pakistan. M.Sc. Thesis, Punjab University, Lahore.

Key words: Stratigraphy, palaeontology, Hazara.

R/108. Raza, S.M., 1970. Cincoriola Haque from Dhak Pass Formation, Surghar Range, District Mianwali, Pakistan. *Geological Bulletin, University of Peshawar* 5, 111-114.

Haque (1956) described a new *Cincoriola* (pro *Punjabia*) and its two species, viz., *C. ovoidea* and *C. patalensis* from the upper horizons of the Patala Formation in Nammal Gorge, western Salt Range, Pakistan. The present investigation has recorded for the first time a rich assemblage from the Dhak Pass Formation in Lumshiwal Nala, Surghar Range, which is the oldest lithostratigraphic unit of the Paleocene Series in the region. *Cincoriola patalensis* Haque and new species *C. sp. A* is described. This genus is proved to be good time indicatrix for the Paleocene Epoch.

Key words: Palaeontology, Surghar Range, Trans-Indus salt Range, Mianwali.

R/109. Raza, S.M., 1983. Taphonomy and paleoecology of middle Miocene vertebrate assemblages, southern Potwar Plateau, Pakistan. Unpublished Ph.D. dissertation, Yale University, New Haven.

Part of the information in this works is summarized in Raza (1997) below.

Key words: Palaeontology, vertebrates, Miocene, Potwar Plateau.

R/110. Raza, S.M., 1984. Siwalik lithofacies and Himalayan orogeny; A preliminary appraisal. Abstracts, First Pakistan Geological Congress, Lahore, 53-54.

The rocks of the Siwalik Group of the Subhimalayan ranges can be arranged in three mega fining-upward sequence (MFUS) which roughly corresponds to the conventional tripartite subdivision of the Lower, Middle and Upper Siwalik subgroups. The three MFUS's can be recognized by their peculiar lithofacies, heavy-mineral compositions, and faunal characteristics. Recent calibration of the Siwalik sequences in the Potwar Plateau through the magnetic polarity stratigraphy suggest that the Siwalik Group ranges from 18 Ma B.P. to as recent as 600,000 years B.P. Within this temporal framework, each of the MFUS (in ascending order) spans approximately 8 million years, 5 million years and 4.5 million years, respectively. The transition from one to the next MFUS in various parts of the Potwar Plateau may fluctuate on the order of 10~ years.

The deposition of the fluvial Siwalik rocks along the southern foothills of the Himalayan orogenic belt are considered to be the consequence of underthrusting of the Indo-Pak Plate with the Asian plate (s). Thus, the appearance of various tectonic elements and the episodic uplift of the Himalayan mountains are expected to seriously effect and control lithofacies composition of the Siwalik rocks. An approximate correspondence exist

between the development of major Himalayan tectonic elements and the initiation of each of the MFUS. Three of the significant correlations proposed here are the appearance of MCT (around 20-18 Ma B.P.) and the beginning of the MFUS I (around 18 Ma. B.P.), the MBT and the MFUS II (around 10 Ma B.P.), and the MFT coinciding with the establishment of almost modern physiography (around 1 to 0.5 Ma B.P.).

Key words: Lithofacies, orogeny, siwaliks, Himalaya.

R/111. Raza, S.M., 1991. Stratigraphic events in the Neogene Siwaliks of the Indus Basin, Pakistan. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, 11-13.

Key words: Stratigraphy, Indus basin, siwaliks.

R/112. Raza, S.M., 1997. Vertebrate fauna and taphonomy of the Middle Miocene Chinji Formation in the stratotype Chinji area, southern Potwar Plateau, Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. GSP, Records 109, p.74.

Chinji Formation, ranging in age from 14 Ma to 10.8 Ma, is the basal unit of the Neogene Siwalik Group in the Upper Indus Basin. It is lithologically the most distinctive formation of the molassic rocks of the Himalayan foredeep belt being composed of red-brown mudstone and grey sandstone in the ratio of 3:1 to 5:1. The typical "Siwalik- aspect form" characterized by the association of small ruminants, suid, gamphotheres and muroid rodents have been well established during the Chinji times. Faunal distribution, especially the first appearance datum (FAD) in the Chinji Formation suggest two major immigration event at Ca. 14 to 13.5 Ma and 12 Ma. These two events record appearance of a host of bovid, tragulid, hominoid and giraffid species with close affinities with the contemporary East African fauna.

Taphonomic analyses of the Chinji Formation based upon carefully selected twelve localities to represent variety of all depositional context and also ensuring of no prior faunal collection from these sites. These fossil localities represent channel, channel related (e.g. abandoned channels) and floodplain (e.g. paleosol) environments. Each bone assemblage is unique in skeletal element composition, tooth/vertebra ratio, proportions of proximal and distal limb ends, taxonomic frequencies, and body-size distribution. However, tests for correlation and degree of association suggest a basic similarity in skeletal elements and taxonomic distribution regardless of sedimentary context.

The Chinji bone assemblages show a number of similarities to modern assemblages, such as relative abundance of skeletal elements, tooth/vertebra ratios, and proximal-distal limb proportions., Modern bone assemblages from different areas are as different as fossil assemblages from different localities (within similar sedimentary contexts). One important difference is that modern bone assemblages have exceptionally low bone densities. High bone concentration in relatively small areas in the Chinji Formation probably reflect relatively short time-periods of more-than-overage mortality rates. This model does not envisage catastrophies but rather such episodic events as droughts, epidemics, and low rainfall periods. These occur in modern African environments every 50-100 years and do not change overall community composition.

The autochthonous nature of the Chinji faunal assemblages is determined by sedimentary and taphonomic characteristics which permit paleoecological interpretation. Taxonomic frequencies and morphological characters of Chinji bovids, rhinocerotids, and suids, suggest that the Chinji faunal assemblages sample woodland-forest mosaic habitats.

Key words: Palaeontology, Miocene, Chinji Formation, Potwar Plateau, siwaliks.

R/113. Raza, S.M., 2001. The Eocene red beds of the Kala Chitta Range (Northern Pakistan) and its stratigraphic implications on Himalayan Fore Deep Basin. Geological Bulletin, University of Peshawar 34, 83-104.

The Eocene redbeds unit of the Western Himalayas Foredeep basin are critical in two aspects: first, it is the oldest Tertiary sequence containing detritus unequivocally derived from the incipient Himalayas and secondly, it contains a diverse fauna key for understanding the evolution of several modern mammal groups. This sequence is known as the Kuldana Formation in the Kohat-Potwar region (=Upper Indus Basin) and the Upper Subathu formation in Kashmir and Himachal Pradesh. This paper focuses on the lithostratigraphic details of the Kuldana Formation from the Kala

Chitta Range (Kohat-Potwar region), which also has yielded the best Eocene mammalian fauna in the region. It is a mudstoned dominant unit, mainly red to purple in the Lower Kuldana but green in the Upper Kuldana. The Lower Kuldana also contains channel sandstone, immature paleosols and fresh-water limestone with molluscs (*Planorbis*) and algae (*Chara*), suggestive of terrestrial deposition regime with shallow channels, ephemeral lakes and wide floodplains. The Upper Kuldana has relatively thicker limestone interbeds with common oysters and rare benthic foraminifera, indicating return to marginal and shallow marine environment as existed before the onset of Kuldana Formation. This marine transgression, correlated with the early Lutetian highstand, deposited the overlying limestone-dominant Kohat Formation. The Kuldana-Kohat couplet was restricted to the Kala Chitta and Kohat regions whereas the rest of the Western Himalaya foredeep turned into a lowland after the Kuldana and Upper Subathu deposition. The shift from marine to terrestrial environment as witnessed in the Kuldana/Upper Subathu sequence is related to early Eocene Himalayan orogeny, when the incipient Himalayas became highland and started shedding sediments to the Foredeep basin. By early late Eocene, the Neotethys drained out from the Paleogene foredeep and shifted to the Katawaz-Makran basin in the west, which then was the main depocenter for the sediments shed from the Himalayan orogene highlands. These tectonic events produced a chain of highlands along the north and western margin of the Indian plate, providing filter bridges for dispersal and migration of mammals to and from South Asia. The Eocene mammalian fauna from the Foredeep and also from the Ladakh basin is a curious blend of some endemic and a few migrants of Eurasian and North American affinities.

Key words: Stratigraphy, Eocene, Kalachitta, Himalaya fore deep.

R/114. Raza, S.M., Barry, J.C., Pilbeam, D., Rose, M.D., Shah, S.M. & Ward, S., 1983. New hominoid primates from the middle Miocene Chinji Formation, Potwar Plateau, Pakistan. *Nature*, 306, 52-54.

We report here eight new hominoid specimens, attributable to *Ramapithecus* and *Sivapithecus* 1,2, from the middle Miocene Chinji Formation of Pakistan. Hominoids previously described from the Chinji Formation cannot be precisely located although they most probably come from the upper two-thirds of the formation³⁻⁹. The new material, from the middle portion of the formation, is ~12–13 Myr old based on magnetostratigraphy (refs 10, 11 and N. Johnson, personal communication). Two earlier specimens are supposedly from the underlying Kamial Formation^{6,12}, although the best candidate for an earliest *Ramapithecus* or *Sivapithecus* is an undescribed molar, AMNH 19565B, collected by Brown¹³ from a locality believed to be basal Chinji¹⁴, for which magnetostratigraphy indicates an age of 14.5 Myr (ref. 11 and N. Johnson, personal communication). Small hominoids are definitely known in the older Manchar Formation in Sind¹⁵. Together with the material discussed here, the new specimens record the earliest phases of Asian hominoid evolution following dispersal from Africa–Arabia¹⁶, and the apparent division of large hominoids into 'African' (lineages leading to *Pan*, *Gorilla* and *Homo*) and 'Asian' (leading to *Pongo*) clades at a minimum of 13 Myr¹⁷⁻¹⁹, probably more.

Key words: Palaeontology, Hominoid, Miocene, Chinji Formation, Potwar Plateau, siwaliks.

R/115. Raza, S.M., Friend, P.F., Hutt, J.A. & Jah, M.A., 1992. Neogene evolution of the ancestral Indus River systems. Abstracts, First South Asia Geological Congress, Islamabad, p.35.

Key words: Indus River, neogene.

R/116. Raza, S.M., Hussain, A. & Khan, S.H. (eds.), 1993. Geological Map of Pakistan, (Scale 1:1,000,000). Compiled by Qureshi, M.J., Tariq, M.A. & Abid, Q.Z., Geological Survey of Pakistan, Quetta.

This is a revision and improvement on a larger scale of the 1: 2,000,000 scale Geological map of Pakistan by Baker and Jackson, 1964. A significant aspect of this map is the coverage of the unmapped territory in the northern area (now Gilgit-Baltistan) of Pakistan.

Key words: Geological map.

R/117. Raza, S.M. & Khan, I.A., 1994. Mineral resources of Pakistan: Annotated Bibliography (Part 1). Geological Survey of Pakistan, Records 105, 78p.

This is bibliographic compilation is a useful document for researchers, and those interested in mineral exploration and development. It provides information on the mineral resources of Pakistan up to 1993. The document comprises three sections and two appendices. The sections comprise metallogenic provinces of Pakistan: An Introduction; Mineral commodity references; and annotated bibliography. Appendices give information on current literature on coal and selected books on the geology and mineral resources of Pakistan. Pakistan has been divided into nine metallogenic provinces. Mineral commodities are given in alphabetical order.

Key words: Bibliography, mineral resources.

R/118. Raza, S.Q., 1959. Salt Range, Potwar, Hazara, Bakrala Ridge. M.Sc. Thesis, Punjab University, Lahore.

Key words: Salt Range, Potwar, Hazara.

R/119. Raza, S.Q. & Khattak, A.K., 1972. Gypsum deposits of Kohat District, NWFP, Pakistan. GSP, Information Release 48, 29p.

Key words: Economic geology, gypsum, Karak, Kohat.

R/120. Raza, T.A., 1993-95. Sedimentology of Murree Formation and lithostructural mapping of Barian Area, Southern Hazara, Northwestern Pakistan. M.Sc. Thesis, Punjab University, Lahore, 120p.

A detailed geological study of a small part of the Attock-Hazara Fold and Thrust Belt in Khaira Gali-Kuldana Area of Galliat was carried out. Geological mapping at the scale of 1:21120 of an area of 50 km² was carried out in detail. The lithostratigraphic units in the study area range in age from Middle Jurassic to Upper Eocene age. Samana Suk limestone of Middle Jurassic age is oolitic dolomitic limestone and represents shallow carbonate shelf sedimentation. The Chichali Formation is composed of black shale condensed sequence deposited in a basin of restricted circulation and represents deepening of basin. This continues into glauconitic Lumshiwal Formation deposited in middle subtidal conditions. Further deepening of the basin deposited pelagic Kawagarh Formation of Cretaceous age. It was deposited in lower subtidal conditions near the shelf edge. This was followed by sudden regression due to contact between Kohistan Island Arc and Indian plate, which resulted in general uplift and continental conditions. Residual Hangu Formation of Danian age was thus developed on to of Kawagarh Formation. This was followed by a rise in sea level and deposition of shelf foraminiferal Lockhart Limestone of Paleocene age which is overlain by Patala Shale, Margala Hill Limestone and Chorgali Limestone and Marl. All these are open shelf foraminiferal deposits. At this point in time collision between India and Asia took place and mixed marine-continental Kuldana Formation developed. This was followed by a rise of Himalaya, which shed debris in the foredeep. This formed fluvial Murree Formation Molasse.

The sedimentary package is composed of lower marine sequence from Jurassic to Middle Eocene dominated by carbonates with a residual laterite horizon of Damina age. The upper part of the package starts from mixed marine fluvial sequence (Kuldana Formation) and an upper molassic sequence (Murree Formation) of Upper Eocene to Miocene age. Structurally the area is mapped in detail and is composed of Chumbu Anticlinorium, Khaira Gali Synclinorium, Kali Mitti Synclinorium and Darya Gali Anticlinorium. The area is also cut by Thrust faults. General trend of the rocks in northeast to southwest. The rocks are cross-folded and double plunging. The folds are tight to isoclinal with a general vergence to southeast. Murree Formation of Upper Eocene to Miocene age is a molassic fluvial sequence deposited by a meandering river system. This sequence was derived from rising Himalaya after the collision of India with Asia in Eocene times. Facies, microfacies, diagenesis and provenance of this formation were studied in detail. For the purpose of forgoing sedimentological studies a section between Darya Gali and Kuldana Chowk was measured and sampled in detail. The Murree Formation is composed of an alternating sequence of gray to greenish gray sandstone and chocolate, maroon and brown shales. Conglomerates-breccias, limestones and marl are minor lithologies. This sequence was derived from rising Himalaya to the north as well as upper part of Kohistan Island Arc. The sandstone is lithic arenites, which are texturally sub-mature and compositionally immature.

Key words: Sedimentology, lithostructure, Murree Formation, Hazara.

R/121. Razvi, M.A., 1984. Seismic exploration of geothermal areas. First Pakistan Geological Congress, Lahore, 43-44.

Different seismic methods for exploring geothermic areas have been used widely in USA, Japan, New Zealand and other countries with great success. Two such methods, refraction and reflection have generally been in practice. In volcanic areas, mostly reflection and partly refraction methods have been applicable. The velocity distribution in such areas are highly complicated. It is very difficult, therefore, to pinpoint cap rock, hot fluid reservoir, fault structure, heat source and other such information's from these data. To overcome this difficulty two remedies have been tried. First is to remove noises and multiple reflections by digital data processing and the second one is to calculate (besides conventional arrival time) wave energy absorption caused by fluid viscosity and high frequency and to study the wave length of a seismic wave to estimate geophysical state in such areas. By first method, very deep structures related to heat source have been discovered and from the second it has been obvious that areas of low frequency wave pattern correspond usually to fluid reservoir. Comparison of geological, geophysical and geochemical data with seismic data will increase the applicability of seismic methods for confirming the suitability and utilization of geothermal potentials for electric power generation and other facilities.

Key words: Geophysics, seismology, geothermal.

R/122. Razzak, S.D.A., 1982. The stratigraphy, petrography and structural geology of Kohat pass, North West Frontier Province, Pakistan. M.Sc. Thesis, Peshawar University, 204p.

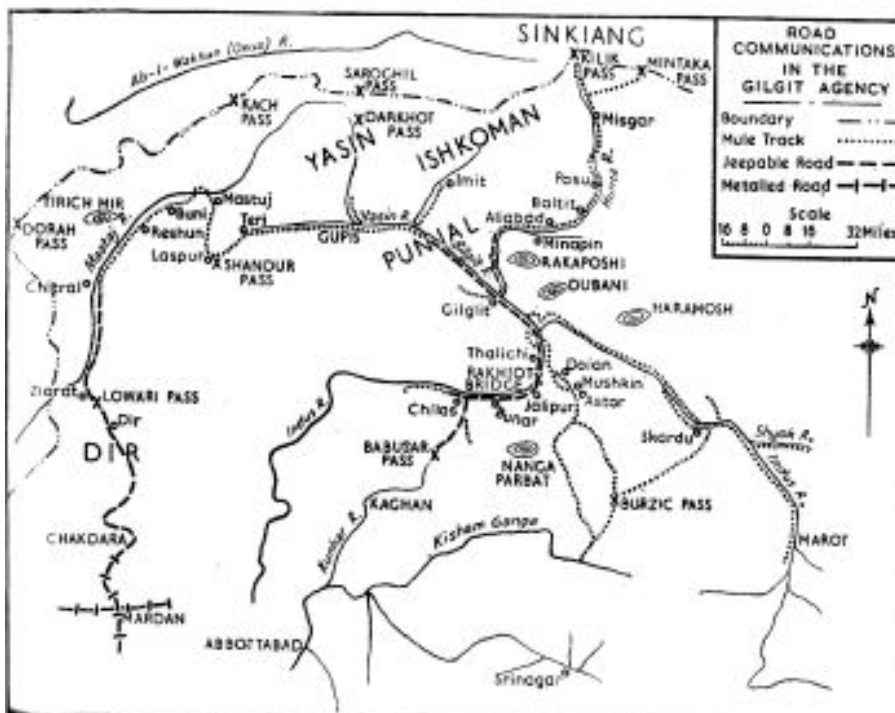
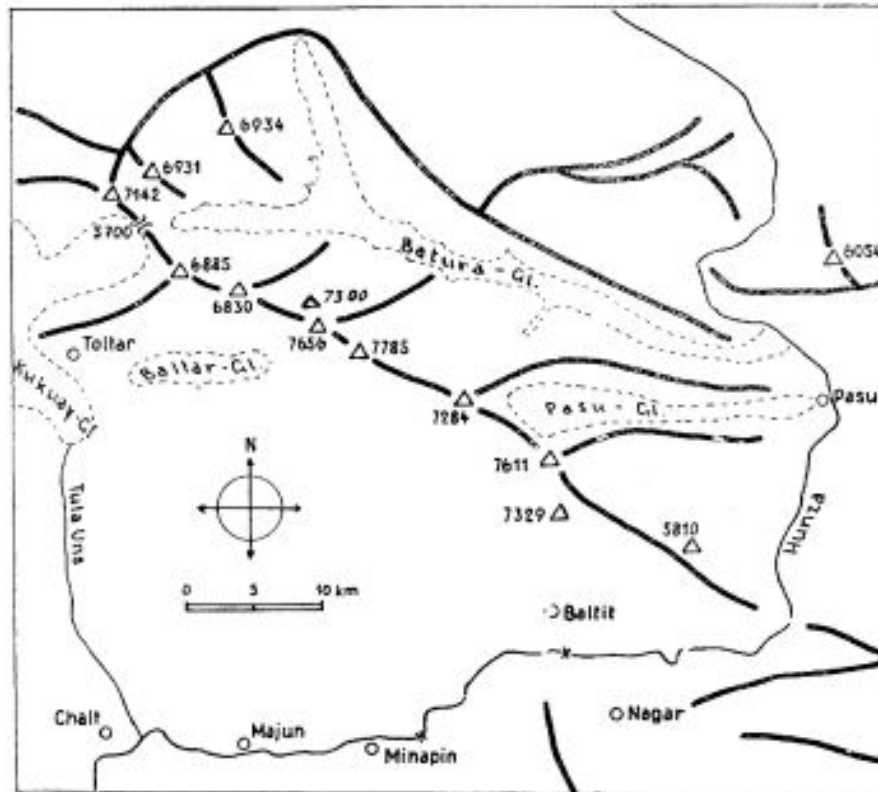
Key words: Stratigraphy, petrography, structure, Kohat Pass.

R/123. Rebitsch, M., Klamert, G. & Meyer, D., 1955. The Batura Glacier. The Himalayan Journal 19, 120-130.

Report of the German-Austrian Himalaya-Karakoram Expedition, 1954, Translated by Eleanor Brocket? and Anton Ehrenzweig

The Austro-German expedition had intended to attempt Rakaposhi, but found on arrival that a party from Cambridge, under George Band and Tissieres, had a prior claim to the south-west approach. They explored other approaches but found them impracticable. Splitting into groups, they then set out to explore the Baltar, the Kukuay, the Batura, the Minapin, and the Hassanabad glaciers. Rebitsch has given us the story in detail of their doings on the Batura ridge.

As it's a very long document with no abstract, we are including two maps of produce by Astro-German expedition group.



Key words: Glaciers, Batura, Hunza, Karakoram.

R/124. Reddy, S., 1991. A microstructural and argon laserprobe study of fault rocks developed during Himalayan continental collision: a preliminary study. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 67-68.

Areas of NW Pakistan and Nepal have been selected to investigate the processes and timing of microstructural development associated with fault and shear zone development. In NW Pakistan, a series of ductile-brittle thrust faults associated with the collision of India with the Asian plate, are developed within the Indian plate in the footwall of the Main Mantle Thrust (MMT). These range from synmetamorphic to postmetamorphic in origin, developed at a series of metamorphic grades and are thought to have given rise to the apparent metamorphic inversion observed in the footwall of the MMT itself records of complex deformation history involving thrusting and emplacement of the Indian plate onto Kohistan arc material and subsequent normal reactivation and overprinting (Williams, 1989).

Recent studies have illustrated that the late normal faults are important structural features throughout the Himalayas and show displacement up to about 20-km (Burg et al, 1984). Within the Langtang area of Nepal the North Himalayan Fault is recognized as a large normal fault which places basement gneisses of the Higher Himalayan Group against low grade Tethyan metasediments (Burchfiel and Royden 1985; Herren 1987). Metamorphic grades across the normal shear zone are variable and decrease within the footwall towards the contact with the hangingwall sediments. Within the hangingwall itself, cataclasites associated with the extension developed below greenschist conditions. Beneath the normal fault, high strain rocks of the MCT record inverted metamorphism, but in this case the inversion is considered to be the result of high heat production in the footwall and the insulation effect of the low thermal conductivity sediments in the hangingwall.

Previous studies which have attempted to date deformation within Himalayan fault and shear zones have largely relied on indirect dating methods. These methods have included bracketing deformation by dating pre- or post-deformational intrusions, dating metamorphic recrystallization at temperatures close to individual mineral cooling temperatures and by relating deformation to the rapid cooling established by analyzing a suite of minerals with different isotope blocking temperatures. However, the recent advances in the geochemical investigation of argon isotopes utilizing the laser microprobe system, provide a powerful tool, which is capable of analyzing minerals of different generations with different textural relationships. This enables mapping of mineral grain age contours ("chrontours") and the characterization of argon diffusion profiles across single grains which in turn may be used to constrain the complexities of mineral growth and/ or the thermal phases within a rock. The technique can therefore provide valuable information on timing and understanding of processes taking place in fault zones which record protracted deformation histories characterized by multistage mineral growth, dissolution and fracturing.

This study focuses on the application of the laserprobe to the investigation of the temporal variations of deformation processes and development of fault zones and integrates detailed microstructural observations, utilizing the SEM, with laserprobe dating techniques. This work represents a research program, which has only recently been started. At this workshop meeting, the specific problems associated with these fault zones, and the methodology by which they are hoped to be solved, are presented.

Key words: Tectonics, continental collision, MMT, Kohistan, Himalaya.

R/125. Reddy, S.M., Kelley, S.P. & Magennis, L., 1992. A Microstructural and ^{40}Ar - ^{39}Ar laserprobe study of a greenschist facies shear zone from the Liachar Thrust, Northwest Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 74.

A sample of banded amphibolite from the Liachar Thrust Zone exposed on the 'Tato Road Section' in northwest Pakistan has been studied using microstructural and ^{40}Ar - ^{39}Ar laserprobe techniques in order to place temporal constraints on deformation within this tectonically complex zone and to understand the relationship between deformation and the resetting of argon isotopes within a natural system.

Early Himalayan amphibolite-grade banding associated with the south-directed overthrusting of the Kohistan arc over India along the Main Mantle Thrust (MMT), has been steepened by relative uplift along the western margin of the Nanga Parbat syntaxis and subsequently overprinted by a discrete shear zone associated with westwards thrusting of the Nanga Parbat Indian basement back onto Kohistan. The shear zone in this sample comprises two overlapping but discrete displacement planes approximately 3mm apart, which are connected through a complex link zone. This zone is characterized by plastic deformation along with fluid infiltration and mineral growth.

Laserprobe analyses of minerals in the zone of deformation show a large variation (over three orders of magnitude at a sub-millimeter scale) in the distribution of apparent ^{40}Ar / ^{39}Ar ages due to the heterogeneous distribution of excess argon between different minerals. Amphiboles both outside and inside the fault zone record old ages, which are

associated with the incorporation of excess argon within the mineral lattice, probably during formation of the amphibolite-grade MMT fabric. Excess argon is also extremely abundant within quartz and feldspar augen (apparent ages > 4Ga). However, biotites exhibit much lower concentrations of excess argon, indicating their equilibration in a relatively excess argon poor fluid (biotite is normally susceptible to a high concentration of excess argon). The difference between excess argon components in amphibole and feldspar and that in the biotite seems to preclude a simple thermal resetting of biotite. It is suggested that the excess component in the biotite was associated with syn-deformational fluid infiltration and the ages of c. 10 Ma obtained from the biotite represent minima for the deformation.

Key words: Tectonics, continental collision, MMT, Liacher thrust, NPHM, Himalaya.

R/126. Reddy, S.M., Kelley, S.P. & Magennis, L., 1997. A microstructural and argon laserprobe study of shear zone development at the western margin of the Nanga Parbat-Haramosh massif, Western Himalaya. *Contributions to Mineralogy and Petrology* 128, 16-29.

Consult the preceding paper for further information.

Key words: Tectonics, continental collision, MMT, Nanga Parbat, Himalaya.

R/127. Reed, F.R.C., 1910. Pre-Carboniferous life-provinces. Geological Survey of India, Record 40(1), 1-35.

Key words: Palaeontology, Pre-Carboniferous, India.

R/128. Reed, F.R.C., 1911. Devonian fossils from Chitral, Persia, Afghanistan and the Himalayas. Geological Survey of India, Record 41(2), 86-114.

This is one of the earliest account on the palaeontology of the Chitral area. It compares the Devonian fossils of Chitral with those of the Himalayas, Persia and Afghanistan.

Key words: Palaeontology, Devonian, Chitral, Afghanistan.

R/129. Reed, F.R.C., 1912. Silurian fossil from Kashmir. GSI Records 42(1), 16-33.

Key words: Palaeontology, Silurian, Kashmir.

R/130. Reed, F.R.C., 1922. Devonian fossils from Chitral and the Pamirs. Geological Survey of India, Memoirs, *Palaeontologica Indica* (New Series) 6(2), 1-136.

This monograph describes in detail the Devonian paleontology of Chitral and compares the fossils with those of the Pamir Mountain.

Key words: Palaeontology, Devonian, Chitral, Pamir.

R/131. Reed, F.R.C., 1925. Upper Carboniferous fossils from Chitral and the Pamirs. Geological Survey of India, Memoirs, *Palaeontologica Indica* (New Series) 6(4), 1-134.

This monograph describes in detail the Upper Carboniferous paleontology of Chitral and compares the fossils with those of the Pamir Mountain.

Key words: Palaeontology, carboniferous, Chitral, Afghanistan.

R/132. Rehana, I. & Yawar, W., 1996. Construction of elemental determination profile for pyrochlore carbonatite ore. Proceedings, Second SEGMIITE International Conference on Export

Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, 146-148.

Key words: Carbonatite, ore processing.

R/133. Reinemund, J.A., Davis, A. & Rossman, D.L., 1969. Operation, plans and proposed evaporite minerals programme for West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-54, 22p.

Key words: Mineral deposits, evaporate, West Pakistan.

R/134. Rehman, A., 1981-83. Lithostructural mapping of Mansehra Susal and Matial Area District Mansehra with special reference to structural studies. M.Sc. Thesis, Punjab University, Lahore, 109p.

Lithostructural mapping with preliminary structural studies have been made of Mansehra, Khaki, Rihar area district Mansehra at a scale, of 1:1000. An attempt has been made to delineate the boundaries of igneous and metamorphic rocks precisely. Physiographic/Stratigraphic studies and various structural contour diagrams have been drawn to determine axis of minor folds. Orientation of joints has been determined with the help of Rose diagram. Thin sections have been studied to determine different phases of deformation. Attempt has been made to analyse the strain with Flinn's and Ramsay's plots. On the basis of microscopic and mesoscopic analysis it has been tried to interpret the structure and macroscopic scale. On the basis of Kinematic Studies, structure of the area is interpreted.

Key words: Lithology, lithostructure, Mansehra.

R/135. Rehman, A. & Saifullah, 1989. Factors affecting change in groundwater levels and storage in Naraji area Swabi. M.Sc. Thesis, University of Peshawar, 53p.

Key words: Groundwater, aquifer, Swabi.

R/136. Rehman, F., Khan, A. & Wahabuddin, 1983. Regional geology of Karak quadrangle, Karak District, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 131, 25p.

The report presents interim results of regional geological mapping on 1:50000 scale of about 645 sq. km. covered by 38 O/4 quadrangle in Karak district of North West Frontier Province, Pakistan. The mapped area, a part of the Kohat evaporate basin, is entirely underlain by sedimentary rocks ranging from Eocene to recent. The area is moderately folded with some accompanied faulting. Minerals of proved economic value include rock salt, gypsum and limestone. Clays including calcium – bentonite also occur in limited quantity.

Key words: Mapping, stratigraphy, structure, economic minerals, Karak.

R/137. Rehman, F., Khan, A. & Wahabuddin, 1986. Geological map of Gumbat (38 O/11), Kohat District, scale 1:50,000. Geological Survey of Pakistan, Map Series 3.

Key words: Mapping, structure, Kohat.

R/138. Rehman, H., 1963. Industrial minerals and rocks of Pakistan, review of mining activities. CENTO Symposium on Industrial Rocks and Minerals, Lahore, 34-49.

Key words: Industrial minerals.

R/139. Rehman, H., Ali, M. & Eldin, G., 1998. Petrography of diorites from Gabral valley, upper Swat, North Pakistan. M.Sc. Thesis, University of Peshawar, 90p.

The Gabral valley occurs in the uppermost part of Swat Kohistan. North of the Utror village, it is occupied by granitoids of the Kohistan batholiths. In this thesis, field features and petrographic characteristics of diorites, within or without quartz, are described in detail.

Key words: Petrography, diorites, Kohistan batholiths, Swat.

R/140. Rehman, I., 1993. Structural model for the evolution of a part of the eastern Kalachitta Range: Hasanabdal-Fatehjangh transect. M.Phil. Thesis, University of Peshawar, 59p.

The eastern part of the Kalachitta Range occupying the southern periphery of the hill ranges exposes a suite of shelf platform rocks of Mesozoic-Cenozoic age. Stratigraphic column comprises the Samana Suk (Jurassic), the Lumshiwal (Cretaceous), the Lockhart and Patala (Paleocene), the Margala, Chorgali, Kuldana and Kohat (Eocene) and the Murree (Miocene) Formations. The structure of the area is characterized by two distinct styles of deformation controlled by two detachment levels. The lower detachment is at the base of the Samana Suk Formation and the upper one is within the Patala Formation. The deformation between the two detachment levels is controlled by thrusting in the form of a duplex structure, in which the lower detachment is acting as sole or floor thrust and the upper one as roof thrust.

This duplex is best exposed at Katha colony, where the Jurassic Paleocene strata is repeated four times in the form of south verging horses. No folding except for that related with thrusts (open hanging wall anticlines) has been observed in the sequence between the two detachment levels. In contrast the structural style in the Cenozoic strata overlying the upper detachment is fold dominated, with both hinterland and foreland vergence. The structural model of the area is of a forward verging duplex separated from the roof sequence by a passive back thrust in Patala shale. This structure is expressed at the surface by fault related folds with north-south vergence.

Key words: Stratigraphy, structure, Mesozoic, Cenozoic, Kalachitta Range.

R/141. Rehman, I., Badshah, S. & Khan, H., 1985-86. Geology and structure of a part of Karak Quadrangle District Karak. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Mapping, structure, minerals, Karak.

R/142. Rehman, J. & Zeb, A., 1970a. Geology of the Shah Dheri-Kabal area, Swat. M.Sc. Thesis, University of Peshawar, 52p.

For further information, consult the following account.

Key words: Mapping, geology, Swat.

R/143. Rehman, J. & Zeb, A., 1970b. Geology of the Shah Dheri-Kabal area, Swat. Geological Bulletin, University of Peshawar 5, 96-110.

This paper presents a geological map and petrography of about 20 square miles of the Shah-Dheri-Kabal area in upper Swat. The previously undivided (? Precambrian) Hornblendic Group of Martin et al, 1962, which covers most of the area, has been divided into Homogenous Amphibolites and Banded Gneisses, Dioritic Rocks, Alpine ultramafic Rocks, and Quartz Diorites and Simple Pegmatites. With the exception of the amphibolites and gneisses, the rocks are considered to be connected with Himalayan orogeny and may be middle Cretaceous to early Tertiary. The Amphibolites, gneisses, and dioritic rocks have generally been metamorphosed to Amphibolite-grade; hornblend, epidote and, in some, garnets are very common. The group has a thrust-faulted contact with the rocks of the lower Swat-Buner Schistose Group (Siluro- Devonian or possibly Ordovician), which cover the southern most part of the area. These are represented by low grade eugeosynclinal sediments metamorphosed to phyllitic schists, marble and green schists. The area is of some economic importance due to the presence of china clay, corundum and magnetite (the latter to the north of the area investigated)

Key words: Geological map, petrography, amphibolites, ultramafic rocks, diorites, Swat.

R/144. Rehman, M. & Haqqani, F., 1983. Petrology of a part of Ambela granitic complex (Babaji syenites) Buner-Swat, North West Frontier Province. M.Sc. Thesis, University of Peshawar, 84p.

Geological investigation in Ambela area aimed at preparation of a thesis in master degree in geology. The area under investigation cover almost 60 square km and consists of syenites, quartz syenites and granites. The rocks studied are a part of Ambela granitic complex and intruded into the Lower Swat Buner schistose Group of Martin et al.

The main syenite and granitic bodies are elongated with general trend of NEE. Contacts between the various rock units are predominantly NEE, and parallel to the general trend of the complex. The rocks comprises of babji Syenite in a northern most zone of Ambela granitic complex.

Petrographic studies and field investigations reveal that it is a calcalkaline type complex, a part of the alkaline igneous province of Peshawar plain which is intruded as a large batholith mass in the compressional release fractures formed at the basal part of the Indian plate.

Key words: Petrology, granite, Ambela, Buner, Swat.

R/145. Rehman, N. & Faisal, S., 2001. Structure and stratigraphy of a part of North Waziristan south of the Mir Ali and Miran Shah Road. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.73.

The detailed mapping of the study area has resulted in establishing five lithostratigraphic units, ranging in age from Triassic to Cretaceous (Mesozoic sequence). The oldest rocks in the area consist of Spalga Formation of Triassic age, followed by shelf sediments comprising Sarobi and Isha formations of Jurassic age. These units are unconformably overlain by rocks of Cretaceous age, which include Tappi and Zer Ghar formations. The Mesozoic sequence exposed along Mir A-Miran Shah road contains well-preserved fossils of their respective ages: Structurally the area is very disturbed. The structural geometry of the area comprises macroscopic and mesoscopic scale folds and thrust faults. The general structural trend is north-south with slight swing towards northeast and northwest. This longitudinal trend is well followed by the axial trend of the macroscopic scale folds. However, some mesoscopic scale folds do not follow this general trend. A large thrust sheet is spread over the entire mapped area and plays an important role in the tectonics of the area. The thrust sheet is divided into three major thrusts i.e. Miran Shah, Tal and Isha thrusts. Generally, all these thrust faults trend north-south and have moderate surface dips. This thrust sheet emplaces the Triassic rocks over the Jurassic rocks. It is folded along the buckling of the underlying rocks suggesting that thrusting pre- date the folding. The cross sectional view indicates that east verging anticlinal and synclinal folds dominantly control the structure of the area. The folds are open to tight and symmetric to asymmetric inclined towards east. All the structural geometry belongs to compressional regime and an eastward directed tectonic transport associated with the oblique subduction of Indian plate underneath the Afghan plate.

Key words: Structure, stratigraphy, Mesozoic, sediments, North Waziristan.

R/146. Rehman, O. & Ali, S., 1969. General geology of alluvials of the rivers Kabul, Swat, Sardaryab, Khiyalai and Jindai River Charsadda. M.Sc. Thesis, University of Peshawar, 58p.

Key words: Alluvial deposits, Peshawar basin.

R/147. Rehman, S.S., 1986. The geology and tectonic setup of western margin of Nanga Parbat-Haramosh loop, Gilgit, Northern Pakistan. M.Phil. Thesis, University of Peshawar, 123p.

Part of the western margin of the Nanga Parbat-Haramosh loop has been studied in detail in the present work. The loop represents the tectonic boundary between the Kohistan island arc to the west and the Indian plate to the east. Major rock types, west of the fault are pyroxene-granulites and a sequence of interlayered amphibolite-gneiss-marble. Chemical constraints of these rocks are indicative of their derivation from an igneous parent, in an island arc-type environment. The rocks east of the fault are mostly schists and gneisses of the Nanga Parbat granitoid

group. The fault which separates the two contrasting lithologies is a young, right lateral, reverse fault. It trends roughly north-south and dip steeply east, with an east-side-up displacement, It is the northern extension of Raikot fault locally named Shahbatoot fault. Beside this, two other major active faults are present in the area, both showing evidences of recent activity. Indus River has been laterally offset for about 15 km along Shahbatoot fault. Three episodes of folding have also been recognised in the area, all of them related to younger tectonics and are produced by rapid uplift of the Massif.

Key words: Tectonics, structure, NPHM, Himalaya.

R/148. Rehman, S.S., 2000. Conservation of surface water in Pakistan--The controversy of Kalabagh Dam. Abstracts, Third South Asia Geological Congress, Lahore, 163-164.

Despite the fact that Pakistan's economy is heavily dependent on agricultural produce, contributions to her GDP from this sector has been steadily declining from over 35% in 1970's to 24% at present. This has been partly attributed to deficit water availability. The Tarbela reservoir was commissioned in 1974 with a gross storage capacity of 11.62 million acre feet (MAF) but now its live storage capacity is just 11.21 MAF. The Warsak reservoir has completely silted up, while Mangla and Chashma storages have also depleted by 1 MAF. Thus our storage capacity has consequently fallen by about 2.5 MAF so far and if we didn't add to our existing facility, we will soon be faced with acute shortage of irrigation water and hence, decline in crop yield. Increasing population and high demand for more food requires vertical and lateral increase in agriculture productivity, which can only be achieved by conserving surface water and its judicious use. In fact not only the lost reservoir space has to be reclaimed but new storage must be built to preserve the 85% discharge available in summer.

Record shows that the mean annual runoff of the Indus river at Basha has been 50 MAF while at Kalabagh it has been about 90 MAF. Downstream Kalabagh the Indus is joined by the Jehlum and Chenab rivers thereby increasing its total volume to about 147 MAF, annually. Presently about 104 MAF is utilized for irrigation through canals while the remaining 33 MAF is discharged to the Arabian Sea downstream Kotri. According to the revised design, the Kalabagh dam will store 6.1 MAF of water and pose little threat to Sindh and Baluchistan because there will still be a balance outflow of 84 MAF annually available downstream Kalabagh whereas, the water of Jehlum and Chenab rivers will continue unchanged. Thus the interests of lower riparians would not be sacrificed but instead it would only reduce the water discharged downstream Kotri to the sea. The option of Basha dam instead of Kalabagh is not right in terms of conservation of surface water as the available volume at Basha is about 50% less than that available at Kalabagh. It would severely affect the inflow into Tarbela reservoir, particularly during the low discharge months of winter. Besides, it would not be possible to draw canals from the reservoir because of its location and terrain. Thus Basha or Kachura dams can be accepted as additional reservoirs but not as an alternative to the Kalabagh dam. In view of the ever-increasing demand for higher crop yield and cheap electricity, the construction of new dams has attained urgent national priority. The construction of Kalabagh dam is, therefore, a matter of national interest and must be undertaken without further delay.

Key words: Water conservation, Basha dam, Kalabagh dam.

R/149. Rehman, S.S. & Majid. M., 1989. Petrology of a part of the western limb of the Nanga Parbat-Haramosh Loop, northern Pakistan. Geological Bulletin, University of Peshawar 22, 181-195.

A part of the western limb of Nanga Parbat-Haramosh loop has been studied in terms of petrography and geochemistry of the constituent rocks. In this area a recent fault, the Raikot fault, separates the tectono-stratigraphic zones of the Kohistan Island arc in the west from the Nanga Parbat massif (which forms the basement of the Indian plate) in the east. Major rock types, west of the fault, include a sequence of inter-layered amphibolite-gneiss and gabbros / gabbro-norites. Chemical constants of these rocks are indicative of their derivation from an igneous parent, in an inland arc-type environment. East of the fault, the rocks are schists and gneisses of the Nanga Parbat-Haramosh Group. These rocks, on the basis of major-oxide geochemistry, are shown to be formed from a Proterozoic granitic protolith of I-type origin and are geochemically distinct from the S-type Mansehra and equivalent granites in the Indian Plate.

Key words: Petrology, structure, NPHM, Himalaya.

R/150. Rehman, S.S. & Sabir, M.A., 1997. Qualitative and quantitative analysis of suspended load with physicochemical characteristics of water from N.W.F.P. rivers, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.51.

Key words: Hydrogeology.

R/151. Rehman, Z., 1990-92. Sedimentary petrology/sedimentology of Eocene Margala Hill Limestone and lithostructural mapping of Changla Gali Area in Galiat region, Southern Hazara, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 121p.

A Comprehensive study of Geology and structure of Chhangla Gali area is, presented along with special constraints on the sedimentology of Margalla Hill, Limestone. Large scale (1: 7000) Geological mapping of a small segment of the Lesser Himalaya in the Chhangla Gali area is presented. The lithostratigraphic unit range from Upper Jurassic to Upper Eocene, Samanasuk Formation being the oldest. Structurally the area comprises NE-SW trending double plunging folds constituting anticlinoria and synclinoria. The folds are tight to isoclinal with a general vergence to the southeast. The folded sequence is disrupted by a number of high angle dip slip strike faults especially within or on the margins of anticlinoria. A detailed petrographic study of a section of Margalla hill Limestone that comprises 63 microfacies ranging from mudstone, wackestone and packstone, with intercalated marls. The deposition of Margala hill limestone took place in open marine shallow shelf conditions. Diagenetic dolomite and neomorphism of syndepositional micrite has taken place under various conditions during different phases of tectonic activity.

Key words: Sedimentary petrology, Margala Hill limestone, Eocene, Abbottabad.

R/152. Rehman, Z.U., Ahsan, N., Ghazanfar, M. & Chaudhry, M.N., 1998. Lithofacies and microfacies studies of Margalla Hill limestone, Jabri area, southern Hazara, Pakistan. Pakistan Journal of Geology 7, 78-98.

Key words: Microfacies, Margalla hill limestone, Abbottabad, Hazara.

R/153. Rehmani, J., 1997. Gold-silver and base metal prospects south of Skardu and part of northern Deosai Plateau, District Skardu, north Pakistan. M.Sc. Thesis, University of Peshawar, 58p.

Key words: Precious metals, base metals, Skardu, Deosai Plateau.

R/154. Reichert, C., 1967. Nature of Permian glacial record, Salt Range and Khisore Range, West Pakistan. Neues Jb. Geol. Paleont. 127, 167-184.

Key words: Glacial record, Permian, Salt Range, Khisore Range.

R/155. Rendell, H.M., 1984. New perspectives on the Pleistocene and Holocene sequences of the Potwar Plateau and adjacent areas of northern Pakistan. In: Miller, K.J. (ed.), The International Karakoram Project, Volume 1, 389-398. Cambridge University Press.

The Pleistocene and Holocene sequence of the Potwar Plateau requires re- examination, particularly in the light of the development of new dating techniques. Some preliminary results of work on the post-Siwalik deposits of the Soan valley are presented. A revision of the relative chronology of the Pleistocene deposits is suggested, and the possibilities of the construction of an absolute chronology are discussed.

Key words: Pleistocene, Holocene, Potwar Plateau.

R/156. Rendell, H.M., 1987. Magnetic polarity stratigraphy of upper Siwalik sub-group, Soan valley, Pakistan: Implications for early human occurrence of Asia. *Earth and Planetary Science Letters* 85, 488-496.

The results of a detailed paleomagnetic study of a 68 m section of Upper Siwalik sediments in the Soan syncline, northern Pakistan, are presented. A palaeolithic artefact and other pieces of struck quartzite were found in situ in a gritstone/conglomerate horizon near the base of the section. Incremental thermal demagnetization was used to remove later magnetic overprints in these sediments, since alternating field demagnetization was shown to be inappropriate. With the exception of the lowest stratigraphic level, the Upper Siwalik sediments examined in the Riwat section show reverse polarity magnetization. The declination values are consistent with a 16° ($\pm 4^\circ$) counterclockwise rotation of the Soan syncline tectonic block since deposition of the sediments. On the basis of the palaeomagnetic analyses and the tectonic and stratigraphic context of the section, our current best estimate of the age of the artefact-bearing horizon is $2.0 \pm 0.2\text{Ma}$.

Key words: Stratigraphy, paleomagnetism, Soan syncline.

R/157. Rendell, H.M., 1989. Loess deposition during the late Pleistocene in northern Pakistan. In: Derbyshire, E. & Owen, L.A. (Eds.), *Quaternary of the Karakoram and Himalaya*. *Zeitschrift für Geomorphologie* 76, 247-255.

Key words: Sedimentation, loess deposits, Quaternary, Pleistocene.

R/158. Rendell, H.M., 1992. The paleoclimatic significance of the loess deposits of northern Pakistan. In: Shroder, J.F. Jr. (ed.), *Himalaya to the Sea: Geology, Geomorphology and the Quaternary*. Routledge, London, 227-235.

The evidence of glacial/interglacial cycles within the Quaternary sediments record of the Potwar plateau and adjacent areas of northern Pakistan is reviewed. Thermoluminescence (TL) dating of the loess deposits of the potwar provide a chronology for the late Pleistocene and enables comparison with the record from deep-sea cores from the Indian Ocean and Arabian sea. The record of loess deposition and preservation is used to infer changes in the degree of penetration of the southwest monsoon into the northern part of the subcontinent during the late Quaternary.

Key words: Sedimentation, loess deposits, Pleistocene.

R/159. Rendell, H.M., 1995. Luminescence dating of Quaternary sediments. *Geological Society of London*, special publication, 89, 223-235.

Luminescence techniques have the potential to date Quaternary sediments from a range of depositional environments. Recent developments of optical dating complement thermoluminescence dating techniques, extending their applicability. The age range of samples that can be dated shows a strong dependence on the material involved. Recent work on both dune sands and loess indicates that accurate dating to beyond 500 ka may be possible in certain circumstances. The age range limits for other material may be closer to 100 ka. Examples are given of luminescence dating of material from a range of sedimentary environments.

Key words: Sedimentation, loess deposits, Quaternary, Pleistocene.

R/160. Renz, H. & Riechel, M., 1939. Palaeontologie. In: Visser, Ph.C. & Visser-Hooft, J. (eds.), *Wissenschaftliche Ergebnisse der Niederländischen Expedition in den Karakorum und die Angrenzenden Gebeite 1922, 1925, 1929-30*, Bd 3, 3-293.

Key words: Palaeontology, Netherlands 1922 Expedition to Karakoram.

R/161. Rex, A.J., Searle, M.P. & Tirrul, R., 1985. Field relationships of the Karakoram granite batholith along the Baltoro glacier transect, Baltistan, North Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

Key words: Granite, glacier, Baltoro, Karakoram.

R/162. Rex, A.J., Searle, M.P., Tirrul, R., Crawford, M.B. & Prior, D.J., 1988. The geochemical and tectonic evolution of the Central Karakorum, North Pakistan. Philosophical Transactions of the Royal Society London, 326, 229–255.

The Karakoram granite batholith (KGB) of probable mid-late Cretaceous age in Northern Pakistan has been studied along the Baltoro glacier transect. The batholith is 15-20 km wide and extends for at least 100-km in a WNW-ESE direction from Snow Lake and the northern Biafo glacier to the Hushe and Kondus valleys. Major compositional and structural differences exist between the Baltoro area and the Hunza Valley. Along the Baltoro glacier transect the composition of the KGB ranges from biotite granodiorite to muscovite and garnet-bearing monzogranite. Amphibole is totally absent. Locally developed K-feldspar phenocrysts and minor K-feldspar megacrysts granite represent late metasomatic activity. A rare occurrence of orbicular granite with compositionally layered spherical orbicals up to 15-cm diameter was discovered near the Trango Towers in the central part of the KGB. Both the batholith and the country rock to the south are affected by widespread intrusions of pegmatites, aplite and leucogranitic bodies. These intrusions are rich in biotite, muscovite and garnet; tourmaline and other phases indicative of high volatile content are mostly absent. A prominent feature of the batholith is the development of at least 3 joint sets, one dipping approximately 45°N, one subvertical and another subhorizontal.

Both the northern and southern contacts of the KGB are intrusive. The northern contact shows a superbly developed contact metamorphic aureole along the Vigne glacier and Mitre peak near Concordia. Metamorphic protoliths are Baltoro black slates and progressive HT/LP mineral assemblages in hornfels include biotite, andalusite (chiastolite) and sillimanite. The southern margin of the KGB at Paiyu is also intrusive into vertically foliated sillimanite-garnet gneisses. The southern part of the KGB in the Masherbrum area comprises a large migmatite terrain with a vast network of leucogranitic dykes intruding both biotite-rich gneisses, restite and leucosome.

The complete absence of mafic dykes, the absence of an extrusive volcanic component and the abundance of leucogranitic crustal melt material all support the model of a high-heat production (HHP) granite terrain of late orogenic to post orogenic setting. The KGB shows little strain and no strong foliation is developed unlike the high-grade metamorphic terrain to the south.

Key words: Geochemistry, tectonics, structure, Karakoram batholith.

R/163. Rex, A.J. Tirrul, R., Searle, M.P., Barnicoat, A., Rex, D.C., Crawford, M.B. and Windley, B.F. 1986. Geological and tectonic evolution of the central Karakoram Range. The Royal Society Discussion Meeting on Tectonic Evolution of the Himalayas and Tibet, Organized By Professor R.M. Shackleton, F.R.S., Professor J.F. Dewey, F.R.S., And Professor B.F. Windley.

The central Karakoram north of the Main Karakoram Thrust (MKT) includes three major geological zones. The southern Karakoram metamorphic series and the northern Karakoram terrane are separated by the composite Karakoram batholith. Four major metamorphic-deformation events and three magmatic events are geochronologically well constrained and allow a refined model of tectonic evolution. Low-pressure metamorphism (M1) associated with the Hushe gneiss complex preceded subduction-related magmatism of mid-Cretaceous age. Barrovian metamorphism (M2) was synchronous with crustal thickening during the Eocene that followed the late Cretaceous closing of the Shyok Suture between the Kohistan microplate and the Karakoram. Initial crustal underplating resulted in Oligocene peraluminous magmatism. Continued crustal thickening allowed melting of crystalline basement material and intrusion of the Baltoro plutonic unit at 20 Ma with peripheral contact metamorphism (M3). Retrogressive metamorphism (M4) occurred along the hangingwall of the MKT, a later Tertiary break-back thrust feature.

Key words: Tectonics, metamorphism, MKT, Karakoram.

R/164. Rey, R., 1989. Einige Aspekte über die Geologie des Kaghan-Tales, NE-Pakistan. Thesis (Diplomarbeit), ETH, Zurich.

This account gives a brief about geology of the Kaghan valley and surroundings.

Key words: Geology, structure, Kaghan valley, Mansehra.

R/165. Reynolds, P.H., Brookfield, M.E. & McNutt, R.H., 1983. The age and nature of Mesozoic-Tertiary magmatism across the Indus suture zone in Kashmir and Ladakh (NW India and Pakistan). *Geologische Rundschau* 72, 981-1004.

The authors report new Ar⁴⁰/Ar³⁹ ages: 180--150 and 90--100 Ma from monzodiorite and tremolite-actinolite schist of the Kohistan Complex; 44 ± 0.5, 39.7 ± 0.2 Ma from dikes cutting the Ladakh-Deosai Batholith Complex; 130-145 Ma from a diorite in the Shyok melange; and 7.8 ± 0.1 Ma from a late stage monzogranite of the Karakorum Batholith. A 261 ± 13 Ma age from gneiss of the Karakorum Batholith is of uncertain significance.

These dates, previously published ones which we summarize here, and some Sr isotope data suggest the following, (due to subduction switching between the Indian and Asian margins during closing of the Tethys Ocean): Late Cretaceous emplacement of the Dras-Kohistan Cretaceous Island arc, followed by rapid cooling between about 85 and 45 Ma. A quiet phase tectonically on the northern Indian plate during the Palaeocene to early Eocene, when subduction was occurring on the Asian margin.

Key words: Magmatism, Indus suture, Mesozoic-Tertiary, Kashmir, Ladakh.

R/166. Riaz, M., 1990. Structure and stratigraphy of the Northern Gandghar Range, Hazara District, Pakistan. M.Phil. Thesis, University of Peshawar, 48p.

The structure of the northern Gandghar Range is shown to be controlled by the folding and faulting processes. Folding and faulting has apparently exaggerated the true thicknesses of the strata. The majority of the folds (F2) are southeast vergent indicating a southeast-directed thrusting. The other group of folds (F1) is oriented perpendicular to the F2 folds, and indicate a compression direction from the NE, distinctly different from those of the F2 folds which is from the NW. The thrusting system developed in the northern Gandghar Range locally defines a small schuppen or imbricate zone. The stratigraphic status and ages of all the rocks of the northern Gandghar Range have been revised. This study indicated that all the rocks of the northern Gandghar Range are of the Proterozoic or early Paleozoic age.

Key words: Structure, stratigraphy, Gandghar Range, Haripur, Hazara.

R/167. Riaz, M., Hylland, M.D., Ahmad, S. & Ghauri, A.A.K., 1991. Structure and stratigraphy of the northern Gandghar Range, Hazara, Pakistan. *Geological Bulletin*, University of Peshawar 24, 71-84.

The northern Gandghar Range comprises four structural blocks, separated by the Baghdarra, Sirikot and Darrah faults. In contrast to the southern Gandghar Range none of them shows a complete succession of stratigraphy. The stratigraphy of the northern Gandghar Range is different from that of the southern Gandghar Range in two ways. Firstly, the northern Gandghar Range has an additional stratigraphic unit, the Tanawal formation that is completely missing from the southern Gandghar Range. Secondly, the Utch Khattack Formation which is so widely developed in the southern Gandghar Range is not found in the northern Gandghar Range. The deformation of the northern Gandghar Range is accomplished by thrusting and associated folding. The nature deformation of each block suggests a piggy-back style of thrusting and attitudes of folds indicate two distinct phases of deformation.

Key words: Structure, stratigraphy, Gandghar Range, Haripur, Hazara.

R/168. Riaz, M., Khan, M.K. & Khan, G.N., 1998. Geology of Koi Barmol and adjoining areas, District Mardan, N.W.F.P. M.Sc. Thesis, University of Peshawar, 76p.

Key words: Structure, stratigraphy, Mardan.

R/169. Riaz, M., Latif, A. & Qasim, M., 1983-84. Geology of southern part of Attock-Cherat Range east of Indus River. M.Sc. Thesis, University of Peshawar, 51p.

Key words: Structure, stratigraphy, Attock Cherat range.

R/170. Richards, H.C., 1960a. Mining in Pakistan: Part-1, Coal mining in Pakistan. Mining Journal 254(6448), 266-268.

Key words: Mining, coal.

R/171. Richards, H.C., 1960b. Mining in Pakistan: Part-3, Other Mineral Production of Pakistan. Mining Journal 254(6500), 324-325.

Key words: Mining.

R/172. Richards, R.L., 1962. Evaporite deposits in Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 267-274.

Key words: Evaporite deposits, Pakistan.

R/173. Richards, R.P., 1996. Twinned hambergite from the Gilgit District, northern Pakistan. Canadian Mineralogist 34, 615-621.

Hambergite crystals from a locality in northern Pakistan occur attached to elbaite, and show two different habits on the same specimen. Neither habit has been previously described. Crystals of the first habit are twinned by reflection on {110} and consist of plates flattened parallel to the twin plane, and bounded by {001}, {100}, {010}, {210}, {110}, and {341}. Crystals of the second habit, including the main crystal on the specimen, are also twinned and have a conspicuously hemimorphic habit. They are double twins by reflection on {110}, composed of a large central crystal in twinned relationship to two platy crystals, one on each side. Twin boundaries are marked by re-entrant grooves, and by optical discontinuity observable even in unpolarized light at low magnification under a binocular microscope. The forms present include those on the platy twins, face {241}. The difference between the two habits results from differences in the effect of twinning on crystal growth in the presence of one or two twin planes. The observed hemimorphism is a property of the twinned aggregate, and does not call into question the holohedral symmetry of untwinned hambergite.

Key words: Hambergite, twinning, Gilgit.

R/174. Ringuette, L., 1996. Thermobarometry of the garnet-bearing rocks of the Jijal Complex (western Himalayas, northern Pakistan). M.Phil. Thesis, Leicester, United Kingdom, Leicester University, 146p.

A summary of this thesis is presented in the following two accounts.

Key words: Ultramafics, garnet, Jijal complex, Kohistan, Himalaya.

R/175. Ringuette, L., Martignole, J. & Windley, B.F., 1998. Pressure-Temperature evolution of garnet-bearing rocks from the Jijal complex (western Himalayas, northern Pakistan): from high-pressure cooling to decompression and hydration of a magmatic arc. Geological Bulletin, University of Peshawar 31, 13th Himalayan-Karakoram-Tibet International Workshop, 167-168.

The Kohistan terrane located in the western Himalayas is an oceanic arc of Early Cretaceous age accreted to the Asian plate and subsequently obducted onto the Indian plate. It can be observed along a complete tilted section from ultramafic/mafic rocks to supracrustal volcanics. The 150-km² Jijal complex constitutes the lowermost exposed part of this arc, and consists of rocks that probably crystallized in the vicinity of the crust/mantle boundary.

Petrographic observations of garnet-bearing rocks of the Jijal complex attest to the magmatic origin of several mineral species like garnet, plagioclase, clinopyroxene and amphibole, which are incorporated within, or pseudomorphosed by metamorphic minerals. According to experimental data on crystallization of basaltic magmas at high-pressure, garnet may appear on the liquidus of partially hydrated basalts if pressure reaches 2.0 GPa. Very high-pressure granulite, amphibolite and greenschist facies assemblages partly or completely overprint the magmatic assemblage. Consequently, many incompatible phases are present at the thin section scale. Very high-pressure granulite assemblages consist of garnet, clinopyroxene, plagioclase, quartz, $\pm$ amphibole. Most of these minerals are unzoned but their composition varies from grain to grain attesting to disequilibrium at the scale of the thin section, probably due to relict compositions inherited from the magmatic stage. However, most garnets are zoned and display a net increase of grossularite content at their rims, compensated by a simultaneous decrease in the almandine and pyrope contents; this results either from an increase in pressure under isothermal conditions, or from an isobaric cooling, the latter being more likely if magmatic garnet crystallized around 2.0 GPa. The jadeite content of clinopyroxene ranges from 7-19 wt.% and increases toward the rims of magmatic clinopyroxene grains; this increase is also compatible with isobaric cooling of the initial magmatic assemblage. Moreover, the Ca-tschermak content of clinopyroxene ranges from 1-16 wt.%, with Al^{IV}/Al^{IV} increasing toward the rims of the grains. Thermobarometric calculations based on Grt-Qtz-Cpx-Pl net transfer reaction and Grt-Cpx exchange reaction give P-T estimates covering a very wide range of 1.2-1.9 GPa and 750-1150°C. If the magmatic sequence of the Jijal complex is continuous, then the calculated depth-pressure range largely overpasses its thickness, estimated at around 12 km [2]. Similarly, the temperature range shows that relict magmatic compositions have probably been included in the calculations. Therefore, these values reflect disequilibrium or rather a mixing of magmatic and metamorphic equilibria. Nevertheless, average pressures and temperatures calculated for garnet and clinopyroxene cores are 60 MPa lower and 45°C higher than those calculated for the rims. Consequently, the post-magmatic stage of metamorphism is a very high-pressure granulite facies resulting from nearly isobaric cooling. The superimposed lower grade hydrous assemblages consist of tremolite-anorthite corresponding to amphibolite facies conditions, tremolite (anthophyllite)-epidote of the transitional epidote-amphibolite facies, and finally actinolitic hornblende-chlorite assemblages of the greenschist facies. The above assemblages attest to a switch of the isobaric cooling path to a major decrease in both pressure and temperature. This magmatic and metamorphic evolution can be correlated with already known tectonic stages: the 120-80 Ma [3] magmatic stage of the arc (magmatic assemblages); the partial cooling during the 80-65 Ma-old post-accretion stage (very high-pressure granulite facies conditions); the abduction of the arc onto the Indian plate, starting at around 65 Ma [4] (hydration of the granulitic assemblages with the development of amphibolite to greenschist facies assemblages).

Key words: Ultramafics, garnet, Jijal complex, Kohistan, Himalaya.

R/176. Ringue, L., Martignole, J. & Windley, B.F., 1999. Magmatic crystallization, isobaric cooling, and decompression of the garnet-bearing assemblages of the Jijal sequence (Kohistan terrane, western Himalayas). *Geology* 2, 139-142.

The Jijal ultramafic-mafic sequence is the lowermost exposed part of the Kohistan terrane. Petrography and geothermobarometry show that garnet-bearing assemblage of the Jijal sequence consist of a mosaic of magmatic and metamorphic equilibria. Garnet-bearing magmatic assemblage started their crystallization at a depth >50 km, either at the base of a thickened arc-type crust or within rising magmatic batches in the upper mantle. Quasi-isobaric cooling of magmatic assemblages occurred in the high-P, high-T granulite field without reaching the eclogite field. Subsequently, these assemblages were partly retrograded under amphibolite-to greenschist-facies conditions. This succession of equilibria attests to a switch from a high-P quasi-isobaric cooling regime to a major decompression followed by final cooling at the upper-crustal level. This P-T evolution is best explained by a yet unrecognized tectonic event that consists of partial exhumation of the base of the Kohistan terrane during its accretion to the Asian plate. Final cooling and unloading in turn, could be related to extension following the obduction of the Kohistan terrane onto the Indian plate.

Key words: Ultramafics, petrography, geothermometry, Jijal complex, Kohistan.

R/177. Rizwani, I.A., 1983. A methodologic approach to evaluate a deposit with reference to high aluminous clays of Attock. Second National Seminar on Development of Mineral Resources, Peshawar, 1, 4p.

Key words: Economic geology, clays, Attock.

R/178. Robertson, A.H.F. & Collins, A.S., 1999. Significance of the Shyok Suture Zone (Northern Suture) in NW Pakistan (Skardu area): Twofold division into Cretaceous Kohistan arc-margin and Eurasian (Karakoram) continental margin units. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 128-130.

The Shyok Suture Zone (Northern Suture) in Northern Pakistan is a critical lineament that separates the Karakoram Terrane to the north (Eurasia) from the Kohistan Terrane to the south (Cretaceous island arc). The Shyok Suture Zone was widely interpreted as a narrow back-arc marginal basin that opened in the Early Cretaceous between the Kohistan arc and the Eurasian (Karakoram) margin. However, it was recently proposed that the Kohistan arc was formed at a near-equatorial palaeolatitude above a S-dipping subduction zone (Khan et al., 1998). In this model, Kohistan drifted northwards, after its formation, as part of a Neothyan oceanic plate that was simultaneously subducted northward beneath the Eurasian margin and sutured to Eurasia during the Late (pre-75 Ma). The site of any oceanic basin between the Kohistan arc and Eurasia (Karakoram) now forms the Shyok Suture Zone. The Shyok Suture Zone was previously summarized as “*mélange* including sedimentary and tectonic *mélanges* with blocks of volcanic rocks, limestone, quartzite and serpentinite in a shaley matrix” (Geological Map of North Pakistan: Searle and Khan, 1991); however, few detailed studies have been published (an exception being Pudsey, 1986).

We are presently investigating the Shyok Suture Zone in NW Pakistan (Baltistan), centred on Skardu. Ligma/Tarmac area (Le Fort et al., 1994) the suture zone was recently interpreted as a low-grade (greenschist) metamorphic tectonic *mélange*, divided into a “Southern Band”, a volcanic-sedimentary unit, and a “Northern Band”, comprising “tectonic lenses” including ophiolitic lithologies. We first mapped a corridor across the Shyok Suture Zone from the Askole Amphibolite (Gilgit Complex) in the SW (near Dasu) to the Main Karakoram Thrust exposed in tributaries NE of Shigar, combined with detailed units from the structural base upwards: Based ultramafic unit (ophiolitic; ca. 1-km)-overlain by talc-rich sediments (Dasu);

Lower volcanogenic unit: (ca. 4-km)-An intact succession of green volcanoclastic turbidites and volcanogenic debris flow deposits, micaceous shales, fissile tuffs, basic-intermediate-acidic lava flows/breccias and local limestone lenses (upper Turmik valley/lower Skoro valley/Bauma-harel area); Carbonate-volcanogenic unit (ca. 2-km)-Dominated by the “Pakora Limestone”, which is redeposited carbonate (calciturbidites) interbedded with subordinate carbonate debris flow deposits and micaceous sediments. It forms lenses up to 800-m thick and is intercalated with volcanogenic sediments and minor lava flows (Ganto-La/Munbluk/Tisar areas); Upper volcanogenic unit (ca. 4-km)-Heterogeneous volcanogenic sediments (structurally thickened), dark phyllite, pale tuff, silicic and intermediate lava/lava breccias and calciturbidites (Ganto La/Tisar/Skoro R./Bauma-harel areas); Serpentine-basalt-chert complex (<250m)-Imbricated tholeiitic basalt (pillow lava/breccia-analysis in progress), red radiolarian chert and serpentinitized ultramafic rock intercalated with greenish volcanoclastic sediments (Bauma-harel area/Skoro R.); Conglomerate-sandstone-shale (ca. 0.5-km several slices)-Reddish sediments (fluvial?) including well-rounded clasts of mainly volcanogenic lithologies forming thrusts sheets, found locally between units vi) and within viii) (Bauma-harel area); Terrigenous shale-sandstone unit (>2-km)-Dark micaceous shales, subordinate quartzose sandstones and siltstones (turbiditic?) (Bauma-harel R/Skoro R.); Shale-sandstone-limestone-conglomerate unit (>2-km)-Early Carboniferous (and older?) to early Mesozoic? Shallow to deeper marine succession (Bauma-harel area). Serpentinized shear zone-marking the Main Karakoram Thrust, cuts obliquely across units iv-viii and overlain by high-grade metamorphic rocks (Eurasian).

Units are interpreted as: i) oceanic arc basement: ii-iv) a coherent (in the SW) to thrust imbricated (in the NW) Lower Cretaceous arc-margin succession (northward younging; apparent thickness ca. 10-km). Limestones are channelized calciturbidites and not tectonic blocks or slices; v) probably imbricated oceanic arc basement in view of the close association with volcanoclastic sediments; alternatively a highly dismembered remnant of oceanic crust that lay between Kohistan and Eurasia; v-vi) Late Paleozoic-Early Mesozoic? mixed carbonate/siliciclastic shelf sediments overlain by terrigenous unstable slope succession with minor volcanics=imbricated upper levels of the Eurasian margin. Secondly, we investigated Cretaceous volcanic/sedimentary units in a structurally separate area

further S (S of Skardu), previously mapped as Kohistan arc (Yasin Group). Two main points are of note in making a comparison with the Shyok Suture Zone further north (see above):

General facies similarities suggest correlation as relatively proximal units of mainly unit iv) above; Large scale thrust imbrication exists, with included thin slices of serpentinized ultramafic rocks and fluvial? “molasses”.

Thirdly, we investigated lithologies further E (Thalle and Hushi valleys), areas previously mapped as part of the Karakoram Batholith. Well exposed volcanogenic successions there (intersliced with local “molasses”) can be generally correlated with unit iv) (Shigar area). Abundant siliceous tuffs are interbedded with relatively thin bedded lithoclastic/silicic turbidites? However, these rocks are found without the redeposited limestone abundant further west. Overall, the areas studied divided into: Coherent, or thrust imbricated Cretaceous Kohistan arc-margin volcanogenic sediments, volcanics and redeposited limestone, associated oceanic basement (serpentine/lava slices); Paleozoic/Early Mesozoic? Shallow to deeper-marine continental margin successions of Eurasian (Karakoram) affinities. Accreted units e.g. large-scale “olistostromes”, or exotic tectonic melange are restricted to a thin sliver separating rocks with Kohistan affinity from rocks with Eurasian affinity. Petrographic studies do not indicate the presence of any terrigenous (Eurasian-margin) derived sediment within the inferred Kohistan-arc-margin units. This suggests that there must have been a barrier to sedimentation (e.g. an ocean) between Kohistan and Eurasia. However, any intervening Neothyan oceanic crust was subducted with little or no trace. The regional evidence favours collision of the Dras/Kohistan arc with the Eurasian (Karakoram) margin along the Shyok Suture Zone late Cretaceous time (pre-75 Ma). The arc was exposed and underwent shallow fluvial erosion prior to large-scale thrust imbrication, possibly related to Late Cretaceous arc/Eurasian margin collision. Tertiary overthrusting along the Main Karakoram Thrust today conceals much of the suture zone.

Key words: Structure, tectonics, Shyoke suture, Cretaceous, Skardu, Karakoram.

R/179. Robinson, J., Beck, R., Edwin, G. & Vincet, R.K., 2000. New structural and stratigraphic insights for northwestern Pakistan from field and Landsat Thematic Mapper data. *Geological Society of America Bulletin*, 112, 364-374.

The remote Waziristan region of northwestern Pakistan includes outcrops of the India-Asia suture zone. The excellent exposure of the Waziristan ophiolite and associated sedimentary lithosomes and their inaccessibility made the use of Landsat Thematic Mapper (TM) data desirable in this study. Landsat TM data were used to create a spectral ratio image of bands 314, 514, and 715, displayed as red, green, and blue, respectively, and a principal component analysis image of bands 4, 5, and 7 (RGB). These images were interpreted in the context of available geologic maps, limited field work, and biostratigraphic, lithostratigraphic, and radio-metric data. They were used to create a coherent geologic map of Waziristan and cross section of the area that document five tectonic units in the region and provide a new and more detailed tectonic history for the region. The lowest unit is comprised of Indian shelf sediments that were thrust under the Waziristan ophiolite. The ophiolite has been tectonically shifted and consists of two separate tectonic units the top thrust sheet is a nappe comprised of distal Triassic to Lower Cretaceous Neo-tethyan sediments that were underthrust during the Late Cretaceous by the ophiolite riding on Indian shelf strata the uppermost unit contains unconformable Tertiary and younger strata. The crust sheets show that the Waziristan ophiolite was obducted during Late Cretaceous time and imply that the Paleocene and Eocene deformation represents collision of India with the Kabul block and/or Asia

Keywords: Geologic mapping, tectonics, remote sensing, Himalaya.

R/180. Roccati, A., 1909. Sopra alcune rocce e sabbie del bacino del ghiacciaio Hispar (Himalaya Nord-occidentale). *Revisite di Mineralogia e Cristallografia Italiana* 39, 33-46.

Key words: Glaciology, Hispar, Himalaya.

R/181. Roccati, A., 1910a. Etudes sommaire du materiel lithologique rapporte par M. le Dr. Calciati du bassin du Glacier d'Hispar. *Bulletin de la Societe Fribourgeoise des Sciences Naturelles* 17.

Key words: Lithology, Hispar basin, Karakoram.

R/182. Roccati, A., 1910b. Etudes sommaire sur le bassin du Glacier d'Hispar (Himalaya N.W.). In: Workman, W.H. & Workman, F.B. (eds.), *The Call of the Snowy Hispar. A Narrative of Exploration and Mountaineering on the Northern Frontier of India*. Appendix II. Constable, London, 283-285.

Key words: Glaciers, Hispar, Himalaya.

R/183. Roccati, A., 1914. Sulle rocce dell Karakorum sud orientale. *Bollettino della Reale Societa Geografica Italiana* 51, 1086-1093.

Key words: Lithology, southeastern Karakoram.

R/184. Roccati, A., 1915. Studio litologico e mineralogico del materiale raccolto dal conte Dott. Cesare Calciati nella Spedizione al Karakorum sud-orientale durante l'estate del 1911. *Bollettino della Reale Societa Geografica Italiana* 34, 2-78.

Key words: Lithology, mineralogy, Karakoram.

R/185. Roe, J., 1996. Biogeographic and geologic importance of Neogene Siwalik Chacidae (Teleostei, Siluriformes) from Pakistan. *Journal of Vertebrate Palaeontology* 16(3), Supplement, 60-61.

Key words: Palaeontology, biogeography, fossils, siwaliks.

R/186. Rolfo, F., 1994. Studio geologico-petrografico dei terreni compresi tra Himalaya e Karakorum nella regione ad est della sintassi Haramosh-Nanga Parbat (Baltistan, Pakistan Settentrionale). Ph.D. Thesis, University of Turin.

Key words: Petrography, NPHM, Karakoram, Himalaya.

R/187. Rolfo, F., Compagnoni, R., Le Fort, P., Lemennicier, Y., Lombardo, B. & Pecher, A., 1995. Metamorphic Evolution of the NE Nanga-Parbat-Haramosh massif and the Ladakh terrain in the Chogo Lungma-Turmik area (Northern Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Petrographical and geothermobarometrical data from the north-eastern sector of the Nanga Parbat-Haramosh Massif (NPHM) and the overlying Ladakh Terrain are used to constrain the metamorphic history of the thickened Indian Plate crust and of the Ladakh paleo-arc in this tectonically key area (Le Fort et al., personal Communication).

The NPHM consists of high grade paragneiss and orthogneiss, minor granulite (possibly deriving from Permian basaltic dykes) and rare diopside-bearing marbles; near the contact with the Ladakh Terrain, deformed pegmatitic dykes are common (Pognante et al., 1993). In both ortho- and paragneiss the mineral assemblage is quartz-plagioclase-biotite-muscovite-garnet-kyanite-rutile $\pm$ Kfeld spar. Kyanite, defining a S_1 inclusion fabric, is also enclosed in syn-tectonic garnet porphyroblasts. Locally, both fibrolitic sillimanite and kyanite have been found in a single garnet porphyroblast: the former in the core and the latter in the rim. This petrographic evidence, together with the results of geothermobarometry and study of garnet zoning, suggests an early compressional evolution from the sillimanite to the kyanite stability field, followed by a decompressional cooling path in which kyanite is stable during different stages of recrystallization. In mafic granulites, geothermobarometry of the assemblage clinopyroxene (Di-Hd₇₄Jd₂₄Ts₂)-plagioclase-garnet-quartz-rutile $\pm$ hornblende $\pm$ biotite suggests $T=650^{\circ}$ - 700° C and $P=12$ - 15 kb for the metamorphic peak. This climax is followed by a retrograde decompressional evolution in which clinopyroxene is partly replaced by a symplectite of plagioclase (An₃₀) and diopside (Di-Hd₈₀₋₉₀Jd₃₋₈Ts₂₋₈Acm₃₋₄).

The Ladakh Terrain includes medium-grade hornblende-bearing gneisses, the “Askore Amphibolite” of Desio (1963), minor ultramafics and a low-grade volcano-sedimentary series, the “Greenstone Complex” of Tahirkheli & Jan (1979) or “Turmik Fm” of Desio et al. (1985). The “Askore Amphibolite” is intruded by syn- to post-tectonic plutons and related dyke swarms, ranging in composition from granodiorite to gabbro: both the syn-tectonic intrusives and their host rocks share the same metamorphic evolution in the epidote-amphibolite facies. The commonest mineral assemblage in the gneisses is garnet. This assemblage defines the regional metamorphic foliation, and is overprinted by a later static recrystallization at comparable P-T conditions. In spite of similar peak temperatures ($660 \pm 70^\circ\text{C}$), preliminary thermobarometry reveals a marked difference between garnet-epidote-andesine amphibolites exposed close to the NPHM at the top of Turmik Valley, which have apparently equilibrated at high pressures ($10.3 \pm 0.4\text{ kb}$), and biotite-epidote-oligoclase amphibolites outcropping at the mouth of Turmik Valley ($P = 6.2 \pm 0.5\text{ kb}$).

Lens-shaped bodies of metaperidotite, possibly representing relics of the island arc oceanic basement, separate the “Askore Amphibolite” and the “Greenstone Complex”. These metaperidotites are usually antigoritic serpentinites often with talc and magnesite, in which relict cumulus structures are locally recognizable. The ultramafites exhibit a polyphase metamorphic evolution, characterised by an early serpentinization of magmatic olivine, followed by the static growth of porphyroblastic olivine and/or tremolite and, finally, by antigorite development. At the northern tip of the NPHM, where the maximum tectonic thinning of lithological units occurs, cumulitic peridotites are transformed into chlorite-talc-magnetite rocks, which still preserve the original cumulitic structure.

The “Greenstone Complex” mainly consists of low-grade quartz-albite-epidote-Chlorite-carbonate arenaceous slates and conglomeratic schists, in which the clasts are dacite and andesite (possibly deriving from the erosion of the Ladakh paleo-arc) and minor marble, quartzite, amphibolite and serpentinite. Markers of this series are interlayers of light-green quartz-plagioclase-muscovite-chlorite-biotite-epidote phyllites with rhombohedral porphyroblasts of dolomite, and rare plagioclase porphyroclasts almost completely pseudomorphosed by low-iron epidote.

Further north-eastward, a thick band of calcite marbles (“Pakora Limestone” of Le Fort et al., in press) with still preserved remains of post-Valanginian rudists and belemnites in dark calcschist layers (Le Fort et al., 1992), separates “Turmik Fm” from the “Blanzgo Fm” of Desio (1963). The latter includes minor marble and quartzite bands, biotite-amphibole greenschists, oligoclase-andesite biotite-epidote gneisses, phyllitic calcschists, amphibole±epidote prasinites and rare serpentinite lenses. Some muscovite-carbonate schists contain porphyroblasts of Fe-rich chloritoid, whereas graphitic schists contain porphyroblastic kyanite. Sharp differences in mineral assemblages (from lower to upper greenschist facies), together with field evidence of local shearing, suggest that this unit, the nearest to the Main Karakorum Thrust, is actually a thrust stack of sub-units with different metamorphic histories.

Key words: Petrography, metamorphism, NPHM, Himalaya.

R/188. Rolfo, F., Compagnoni, R., Lombardo, B. & Visona, D., 1997. HP-HT Coronitic Reaction in metadolerites and metamorphism of the Higher Himalayan crystallines in the North-Eastern Nanga Parbat-Haramosh Massif, Baltistan (N Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 197-198.

Metamorphism of basalt and dolerite dykes hosted in the north-eastern sector of the Nanga Parbat-Haramosh Massif (NPHM) has been studied in the Stak valley, north of the Indus river, and in Susrut Nala, south of the Indus. Petrographical and geothermobarometrical data on these metabasics are used to constrain the metamorphic history of the thickened Indian plate in the area of maximum convergence with the Asian plate and the intervening Ladakh-Kohistan paleo-island arc (Le Fort et al., 1995).

The north-eastern NPHM consists of a layered unit of high grade paragneiss and minor orthogneiss, both with kyanite-bearing leucosomes. The gneiss hosts granulitized dykes of basalt and dolerite, and metagabbro bodies. Near the contact with the Ladakh Terrain, deformed pegmatitic dykes are common. Boulders of marble, calc-silicate rocks and serpentinitized lherzolite have been found in the moraine of the Kuthiah glacier on the eastern flank of Haramosh. The main petrographic features of ortho- and para-gneiss in the Stak valley have been described by Zanettin (1964), Pognante et al. (1993) and Rolfo et al. (1995). In both ortho- and para-gneiss, the mineral assemblage is quartz + plagioclase + biotite + muscovite + garnet + kyanite + rutile ± K-feldspar. The stable assemblage biotite, muscovite and kyanite defines the main metamorphic foliation; staurolite, which appears in equilibrium with the foliation-forming assemblage, has been found only rarely. A higher grade, possibly earlier, mineral assemblage of quartz - K-feldspar-plagioclase-biotite-garnet-kyanite was only found in gneiss samples from Skango Lungma (middle Stak valley). Usually kyanite defines a S1 inclusion fabric in syn-tectonic garnet

porphyroblasts, but locally, both fibrolitic sillimanite and kyanite have been found in a single garnet porphyroblast, the former in the core and the latter in the rim.

The basalt and dolerite dykes which, occur in the gneiss are usually concordant with the main metamorphic foliation. Geochemically, most dykes have tholeiitic basaltic composition, though a few of them are picritic basalts, with MgO~16,wt % and normative diorite up to 30%. The peak, granulite-facies assemblage of the basalt dykes in Stak valley is garnet + clinopyroxene + plagioclase, with rutile as ubiquitous accessory mineral. Amphibolite facies retrogression is present in some dykes, particularly in the more deformed portions and at the selvages. It is characterized by the growth first of amphibole and later of biotite, and by titanite development at the expense of rutile. In these metabasaltic dykes, geothermobarometry of the granulite assemblage clinopyroxene (Di-Hd81 Jd17 Ts2)-plagioclase (An14-18)-garnet (Aim57-59 Prp16-19 Grs21-24)- quartz - rutile suggests T around 700-750°C and P around 12-13 kb for the metamorphic peak. This climax is followed by a retrograde decompressional evolution in which clinopyroxene is partially replaced by tschermakitic amphibole or, more rarely, by a symplectite of plagioclase (An30) and diopside (Di-Hd80-90Jd3-8Ts2-8Acm3-4).

Coarser-grained metadolerite dykes have been found in a few outcrops of Stak valley, the texturally best preserved metadolerite occurring at the junction of the Goropha and Lecho valleys. This metadolerite has a peculiar coronitic texture and is essentially undeformed, except for minor shearing at the margins. Its importance lies in the possibility it affords of investigating mineral reactions through which the metabasics have passed during the granulite transformation, whereas the mineralogy and structure of the granulitized metabasalts do not allow to see back beyond the P and T at which the granulite assemblage equilibrated.

The coronite metadolerite preserves the original igneous subophitic texture originally defined by euhedral plagioclase laths, anhedral clinopyroxene and orthopyroxene, and minor ilmenite. The igneous clinopyroxene, with a dusty appearance for the presence of very small inclusions, has a metamorphic composition with moderately high Na-content ($\leq$ Jd17) and still contains thin orthopyroxene exsolution lamellae. The inclusions are tiny needles of rutile and ilmenite exsolved from the igneous zoned clinopyroxene. Coronas around clinopyroxene mainly consist of garnet (A1n49-51 Prp22-5 Grs23-27). Orthopyroxene is pseudomorphically replaced by a fine-grained clinopyroxene aggregate (compositionally similar to the large pyroxene crystals) + minor plagioclase (An18-22) $\pm$ biotite and is surrounded by a corona of asymmetrically zoned garnet (A1m55-50 Prp23-26 Grs20-23 from the inner towards the outer corona). This indicates that the granulite facies reaction: Pl + Opx $\rightarrow$ Grt + Cpx has taken place. The partially preserved igneous plagioclase (An40) is usually replaced by a metamorphic oligoclase (An16) often crowded with thin needles of kyanite. Small idioblastic garnet (Aim50-56 Prp20-24 Grs29-20 from core to rim) occasionally grows in the original calcic core. A thick corona of zoned garnet (Aim5348 Prp27-24 Grs24-19 from the inner towards the outer corona) surrounds the original Fe-Ti-oxides, which are transformed to an aggregate of rutile + ilmeno-magnetite.

In the coronite metadolerite, geothermobarometry of the peak mineral assemblages gives P=13-14 kbar and T around 800°C. The highest temperatures are thus preserved in the less deformed rocks. Subsequent deformation and re-crystallization during the retrograde path account for the less extreme conditions recorded in most of the mafic dykes and in the gneiss, where muscovite appears to be stable and to define, together with biotite and kyanite, a metamorphic foliation. Post-granulite-facies retrogression and hydrous infiltration in the metadolerite is recorded by the high-T growth of K-rich (up to 0.51 atoms p.f.u.) hornblende and of biotite, which requires the introduction of K-rich fluids from the host gneiss during the post-peak metamorphic stage. These retrograde reactions were apparently quenched by the fast uplift and cooling of the NPHM. U/Pb ages on monazite (Smith et al., 1992) and ³⁹Ar/⁴⁰Ar ages on micas (Villa et al., 1996) suggest that the granulite-facies metamorphism is Mio-Pliocene, as also shown by the Pliocene ages of white micas in the gneisses and pegmatite dykes of the middle Stak valley (Lauris et al., 1996).

Both the mafic dykes and the host gneiss exposed in the North-Eastern Nanga Parbat-Haramosh Massif show a consistent, relatively simple metamorphic evolution. However, some evidence for a polymetamorphic history is given by the presence of dykes which are slightly discordant to the main metamorphic foliation of the hosting gneiss, and by sillimanite inclusion trails inside garnet porphyroblasts of the gneiss, whose growth is related to a HT-MP event predating the HT-HP event.

Key words: Dolerite dykes, metamorphism, NPHM, Baltistan, Himalaya.

R/189. Rolfo, F., Lombardo, B., Compagnoni, R., Le Fort, P., Lemennicier, Y. & Pecher, A., 1997. Geology and metamorphism of the Ladakh terrane and Shyoke suture zone in the Chogo Lungma-Turmik area (northern Pakistan). *Geodynamica Acta* 10, 251-270.

Metamorphism of the Askore Amphibolite, metabasaltic and metasedimentary medium-grade hornblende-bearing schists at the northernmost portion of the Ladakh Terrane and of the Shyok Suture Zone, mainly a low-grade volcano-sedimentary series, has been studied in the area between the Chogo Lungma glacier and the Indus river halfway between Skardu and Rondu. In the Askore Amphibolite the peak assemblage in the amphibolite facies defines the regional metamorphic foliation, and is overprinted by a later static recrystallization at comparable P-T conditions. In spite of similar peak temperatures (630 - 650 degrees C), geobarometry based on amphibole composition reveals a marked difference between garnet - epidote - andesine amphibolites exposed just above the Main Mantle Thrust at the head of Turmik valley, which equilibrated at high pressures (about 10 kbar) in late Miocene (Tortonian), and biotite epidote - oligoclase amphibolites outcropping at the mouth of Turmik valley, which equilibrated at pressures of c. 6 kbar before late Eocene (Priabonian). The Dasu Ultramafite and other smaller lens-shaped bodies of low-to medium-grade metaperidotite separate the Ladakh Terrane from the Shyok Suture Zone. They are antigorite serpentinites, often with talc and magnesite, in which relict cumulitic structures are locally recognisable. The ultramafites may represent remnants of oceanic lithosphere separating the Ladakh-Kohistan island from the Asian plate, or they may be deep crustal rocks stripped from the basement of the arc. The mostly greenschist-facies Shyok Suture Zone shows the lithology of a calc-alkaline volcano-sedimentary series. It is supposed to be a remnant of a back arc basin of early Cretaceous age, separating the arc from the southern margin of Asia. Chloritoid, kyanite and biotite have been found in individual thrust sheets occurring at different structural levels and totally subordinate in volume to very low-and low-grade rocks. Such sharp differences in mineral paragenesis, together with field evidence of local shear, suggest a complex internal structure for the Shyok Suture Zone. From the head of Chogo Lungma glacier to the Basha valley, close to the contact with the Karakorum Metamorphic Complex, the rocks of the Shyok Suture Zone record a late Miocene metamorphic event at medium pressures and temperatures. Thermobarometric and geochronological evidence suggests that this event can be related to the exhumation and thrusting of the Karakorum metamorphic core over the Shyok Suture Zone.

Key words: Metamorphism, Ladakh, Shyok suture, Skardu.

R/190. Rolland, Y., Maheo, G., Villa, I.M., Pecher, A. & Guillot, S., 2001. NW Himalayan belt granulites, mantle heat advection in a transpressive regime. *Journal of Asian Earth Sciences* 19, p.55.

In the Karakoram metamorphic complex (KMC), the oblique India - Asia convergence has been accommodated by (1) horizontal strike slip motions along the dextral Karakorum Fault (KF) and by (2) intense horizontal shortening with huge isoclinal fold structures and south-vergent nappe stacking (Fig. 1). Within the KF zone (Pangong Massif), granulitic assemblages (melonite scapolite $\pm$ clinopyroxene $\pm$ pargasite $\pm$ plagioclase or orthoamphibole $\pm$ rutile $\pm$ spinel $\pm$ pyrope) are found. Thermobarometry on the metabasites yield conditions of T, 800°C and P, 5.5 kbar. These conditions suggest that the KF, accommodating the lateral extrusion of Tibet, should be a lithosphere-scale shear zone, similar to the Red River fault. Ar $\pm$ Ar data show that the granulitic metamorphism occurred before 32 Ma, and that retrogression in the amphibolite facies conditions occurred at ca. 18 Ma. 2. In the KMC, granulitic assemblages (sillimanite $\pm$ K $\pm$ feldspar $\pm$ garnet) associated with migmatitic layers post-date the southwest vergent nappe piling and polyphased M1 metamorphic history (pre-37 Ma). M2 metamorphic conditions are estimated at T, 750 $\pm$ 800°C and P, 5 $\pm$ 6 kbar. M2 granulitic isograds define an E $\pm$ W thermal anomaly, also marked by migmatitic domes. Far from the zone, in the Shyok Suture zone, Ar $\pm$ Ar amphibole cooling ages range from 52 to 38 Ma. At the rim of the domes, ages decrease from 20 to 13 Ma, and at the core of the dome, young U $\pm$ Pb monazite ages of 6 $\pm$ 7 Ma date the M2 metamorphic peak. Chronological, metamorphic gravimetric (Caporali, 2000) and magmatic data, and the presence of young (9 Ma) mantle-derived plutons in domes area (Lemennicier, 1996), clearly indicate that metamorphism is related to heat advection from the mantle. We propose that this late M2 tectonometamorphic and magmatic evolution is due to Indian slab detachment, initiated at 20 $\pm$ 25 Ma.

Key words: Granulites, metamorphism, tectonics, Himalaya.

R/191. Rolland, Y. & Pêcher, A., 1999. Late structural and metamorphic evolution along the Shyok Suture zone and the Main Karakorum Thrust (NW Himalaya). *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 132-133.

The contact between the Kohistan-Ladakh Arc and the Asian paleomargin (Karakorum) is defined in Indian Ladakh as the Shyok suture zone. Westwards, in the Skardu area (Pakistan) the Arc-Karakorum contact is an imbricate

South vergent thrust system, the MKT (Main Karakorum thrust), with thrust contacts underlined by serpentinite strips. Still farther west, north of the Nanga-Parbat /Haramosh spur (Himalayan high grade gneisses), the MKT is no more a thrust, but a recent vertical and rectilinear fault. Actually, the Arc-Asian margin boundary is often unclear: geochemical studies suggest that some amphibolitic series of the South Karakorum metamorphic pile are parts of the Ladakh Arc, abducted onto the Asian margin, then metamorphosed and deformed during the early south-vergent tectonics (from 67 ± 2 Ma to 35 ± 5 Ma) period of the apparently syntectonic Mango Gusar granite emplacement.

Late metamorphic evolution along the MKT/Shyok suture is marked by local high temperature anomalies, best studied in Skardu area, but also known in Indian Ladakh, South of the Shyok suture zone and Karakorum fault. North of Skardu, late metamorphic isogrades draw an E-W elongated pattern, ablate to the MKT and the earlier structural pattern. It underlines a lineament of kilometric scale domes, from the Baltoro glacier in the east to the Nanga Parbat Himalayan spur in the west. Various thermochronological data from gneisses in the domes or from syn-doming plutonic cores (Hemasil syenite) indicate young ages, most of them less than 10 Ma, to the north as well as to the south of the MKT. Thus they can be interpreted in the light of the very recent to present stress and kinematic data.

The recent tectonic pattern was investigated using strain trajectories, as marked by the late metamorphic foliation, and the stress directions obtained by inversion of post metamorphic striated planes:

-The isogrades pattern, the E-W alignment of domes and the lack of small scale extension shear criteria suggest that the thermal anomalies are linked to a transpressive deformation regime, with along strike and down dip movements on the MKT/Shyok zone,

The MKT, as the dextral Karakorum fault, offset the young metamorphic patterns confirming that the MKT is not the suture, but a very young reactivation of a former contact,

-In the western part of the study area, the stress pattern is quite heterogeneous: the maximal principal stress can be vertical (in the core of the domes, e.g. the Haramosh dome), or horizontal and either parallel or perpendicular to the MKT (shortening perpendicular and parallel to the belt). In the eastern part (Ladakh Shyok zone), preliminary studies give maximal stress position either vertical (in the Ladakh batholith) or gently plunging and perpendicular to the Shyok suture (both side of the batholith, in the Indus and Shyok/Nubra valleys).

As a whole, stress, strain and thermal patterns can be linked to a transpressive deformation regime partly controlled by inherited major crustal discontinuities, with very irregular exhumation and partitioning of the deformation during the oblique Indian-Asian convergence.

Key words: Metamorphism, structure, Shyoke suture, MKT.

R/192. Rolland, Y., Picard, C. & Pêcher, A., 1998. Geology of the Ladakh-Karakorum suture zone (NE Pakistan). Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 168-170.

On the northern side of the MKT/Shyok suture zone, in the Karakorum, the authors distinguished two metasedimentary units: (i) a low-metamorphic unit, characterised by limestones (1 and 3, fig 1). In those limestones up to now very poorly mapped and dated, we have found several occurrences of fossils (mainly bryozoa and crinoid), leading to a late Paleozoic age, (ii) underlying this unit, a amphibolite facies metapelitic unit (5, Fig 1), passing (?) to the Hushe series (Searle and al., 1989).

South of the Karakorum units, an imbricated pile of sedimentary, volcano-sedimentary, volcanic and plutonic rocks is observed, bounded by steeply-dipping irregular contacts, with intricated serpentinitised ultramafic rocks (7). Thus, in this area MKT is a complex melange zone, rather than a well-defined contact as described farther West. The base of the volcanic series (9) are made of alternating basaltic flows (locally displaying pillow-lava structures) and greywackes. Towards the top of the series the lavas are more differentiated and are interbedded with pyroclastic deposits.

The volcano-sedimentary units (the "Greenstone Complex") is made of reworked volcanic and sedimentary deposits, with: (i) metric to hectometric-scale basic volcanic blocks enclosed in a carbonaceous matrix (unit 8b) and (ii) olistolithes constituted of limestone and sandstone blocs enclosed in a shaly volcano-detrital matrix (unit 8a).

Those series are overlain by late discarding molassic deposits, with a shallowing upwards sequence (unit 8c).

To the South, the plutonic rocks (diorites and granodiorites, 1 1) of the Ladakh batholith intrudes the volcano-sedimentary units (9) of the suture zone. Hectometric non-assimilated blocks of marble (10) are visible inside the northern part of the pluton. The lithological and geochemical characters of the volcanic rocks show some affinities with volcanic series of the Shyok suture zone between Karakorum and Ladakh of North western India and of the MKT zone between Karakorum and Kohistan.

Key words: Metasediments, metamorphism, Shyoke suture, MKT.

R/193. Rosenberg, P.S., 1985. Himalayan deformation and metamorphism of rocks, south of Main Mantle Thrust zone, Karakar Pass area, southern Swat, Pakistan. M.S. Thesis. Oregon State University, Corvallis, U.S.A., 67p.

Karakar pass is located to the south of the Indus Suture or Main Mantle Thrust, between lower Swat and Buner. It comprises sedimentary rocks that have undergone Barrovian type metamorphism. The area also contains granitic plutons, including those with abundant tourmaline. The thesis gives details of Early Tertiary Himalayan deformation and metamorphism.

Key words: Deformation, metamorphism, Buner, Swat.

R/194. Rosenberg, P.S., Lawrence, R.D. & Khan, I., 1984. Deformation and metamorphism of rocks south of the Main Mantle Thrust in Southern Swat, Pakistan. EOS 65, p.1094.

Rocks south of the Main Mantle Thrust (MMT) in Swat, Pakistan consist of metamorphosed shelf sediments of the northern margin of the Indian subcontinent. They form the rear of the Himalayan fold and thrust belt in this area. Rocks in the area include fossiliferous marble (Siluro-Devonian?), graphitic schist, calcschist, amphibolite, quartz-mica-garnet schist and concordant bodies of granitic gneiss. These rocks have undergone at least two main deformations. D₁ produced a pervasive regional foliations (S₁) in both granitic gneisses and metasedimentary rocks. S₁ is generally parallel original layering (S₀) but locally axial-planar to small, tight to isoclinal F₁ folds. D₂ folded S₁/S₀ into open to tight F₂ folds that range in size from small crenulations to folds of kilometer scale. D₂ locally caused the development of an S₂ crenulation cleavage or transposed S₁/S₀. Some rocks have a second crenulation that may be related to D₂ or may represent an as yet undefined D₃. The area has undergone regional metamorphism that was syn- and post-kinematic with respect to D₁. Mineral paragenesis (clinozoisite-amphibole-oligoclase-biotite-garnet-quartz) indicates metamorphism reached transitional greenschist-amphibolite facies to lower amphibolite facies. Temperature-pressure conditions associated with D₂ were sufficient only to allow recrystallization of quartz, carbonate, muscovite and possibly chlorite. Both D₁ and D₂ probably relate to the collision of the Indian subcontinent with Kohistan rocks north of the study area (Maluski and Matte, 1984) suggests D₁ ended 30 my ago. Rapid uplift, probably associated with major Himalayan thrusting, occurred 20 my ago (Zeitler, 1981) and is the youngest possible age of D₂.

Key words: Deformation, metamorphism, MMT, Swat.

R/195. Rossi Ronchetti, C., 1965. Rudiste e nerinee del Cretaceo di Yasin (Pakistan nord-occidentale). In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), Scientific Reports IV (1), 229-272. Paleontology-Zoology-Botany. Brill, Leiden.

The Yasin group occurs along the northern fringe of the Kohistan Island Arc and apparently overlies the Chalt volcanics. The group contains highly fossiliferous Cretaceous (Aptian-Albian) sediments and volcanic rocks. This paper describes rudistid pelecypods and nerineid gastropods (including one new species of each) from an Yasin area to the west of Gilgit, northern Pakistan.

Key words: Palaeontology, Yasin group, Kohistan arc.

R/196. Rossi Ronchetti, C., 1967. Molluscs from the Upper Cretaceous at Burji-la. *Rivista Italiana di Paleontologia e Stratigrafia* 73, 811-827.

A group of molluscs fossils from the valley of Burji –la in Baltistan has been studied. They are considered to belong to Turonian (Cretaceous).

Key words: Palaeontology, Cretaceous, Burji-la, Baltistan.

R/197. Rossi Ronchetti, C. & Farioli, M.A., 1959a. Rudists and nerineids of north-west Pakistan Cretaceous. *Rivista Italiana di Paleontologia e Stratigrafia*, 65, 91-96.

From the study of the fossils from the type locality near the Yasin Guest House, the authors conclude that the Yasin Group is Lower Aptian or thereabouts in age. For further information, consult Rossi Ronchetti, C., 1965.

Key words: Palaeontology, Rudistid, Nerineid, Yasin group, Gilgit.

R/198. Rossi Ronchetti, C. & Farioli M.A., 1959b. Rudistids and nereids of northwest Pakistan Cretaceous. *Review Italiana Palaentologia* 65, 355-360.

Consult Rossi Ronchetti, C., 1965.

Key words: Cretaceous, palaeontology, Rudistids, Nerineids, Yasin Group, Gilgit.

R/199. Rossi Ronchetti, C. & Mirelli, A.F., 1958. Rudistids and nereids of north West Pakistan, Cretaceous. 20th International Geological Congress, Mexico 7, 355-360.

Consult Rossi Ronchetti, C., 1965.

Key words: Palaeontology, Yasin group, Gilgit.

R/200. Rossman, D.L. & Abbas, S.G., 1982. An ultramafic chromite bearing rock complex near Dargai, Peshawar division, Pakistan. USGS project report PK-59

The Dargai ultramafic complex in Peshawar Division, Malakand Agency, Pakistan, contains 52 chromite prospects and 4 small deposits. The complex is believed to have been emplaced along a major thrust fault which lies along the front of the Himalayan mountain range. Rocks making up the complex include dunite and harzburgite and a few small gabbro bodies concentrated along the north side of the mass.

Two sets of compositional layering are present. One set is universally steeply dipping and strikes east, parallel to the long direction of the complex. The other set, called the subhorizontal set, is nearly horizontal, but is visible with certainty only on the upper slopes of Bada Sar mountain where the layers extend over an area of several square miles. However, traces of a flat - dipping dunitic zone are visible in the upper part of the main east - trending ridge which extends most of the complex; the extent the subhorizontal may be considerably greater than can be positively shown.

The bulk of the chromite occurs as layers, some of which are parallel to the subhorizontal layering; it is likely that the subhorizontal layering formed by crystal settling, and can, in this respect be regarded as primary. The steeply dipping layers in the peridotite probably transect the subhorizontal set, and at places the structure of the steeply dipping set passes at angles through the chromite zones. The steeply dipping set probably formed from flowage and recrystallization of the original rock.

This differential movement probably has been responsible for destroying or masking the subhorizontal layering in most areas. In many places the steeply dipping layered structure extends across the chromite zones at large angles. This transecting relationship is particularly well shown at the Barjokanri deposit.

Recommendations for further work include: detailed tracing out of all chromite layers and exploration on thickened portions; some surface excavation at the Barjokanri deposits; an economic feasibility study of the possibility of finding, mining, and concentrating disseminated chromite; and developing a practical method of pelletizing chromite fines.

Key words: Ultramafic rocks, chromite, Malakand Agency.

R/201. Rothlisberger, F. & Geyh, M.A., 1985. Glacier variations in Himalayas and Karakorum. *Zeitschrift fur Gletscherkunde* 21, 237-249.

Key words: Glaciers, Himalaya, Karakoram.

R/202. Rowley, D.B., 1996. Age of initiation of collision between India and Asia: a review of stratigraphic data. *Earth and Planetary Science Letters* 145(1-4), 1-13.

The collision of India with Asia is perhaps the most profound tectonic event to have occurred in past 100 Ma. It is responsible for the uplift of the Himalayas and Tibetan Plateau and has been argued to have been responsible for geological, geochemical, and climatological consequences of global extent. Yet the age of initiation of this collision remains poorly constrained. The literature is replete with estimates that range from the Late Cretaceous (> 65 Ma) to latest Eocene (< 40 Ma) with little consensus in between. This paper reviews the available stratigraphic evidence from the Himalayan region, and concludes that only in the western Zaskar-Hazara region is the age well constrained as starting in the Late Ypresian ($\sim < 52$ Ma). To the east only in the Malla Johar region of the Tethyan Himalayas have potentially syn-collisional sediments been recognized south of the Indus Yarlung Zangbo suture. However, here the correlation of the upper part of the Sangchamalla Flysch is contentious, with correlations ranging from Late Cretaceous to Middle Eocene (Lutetian). In the most eastern sections of Tertiary rocks thus far recognized within the Tethyan Himalayas north and east of Everest (Mount Qomolangma) normal, shallow shelf-type carbonates extend into the Lutetian, without evidence of a change in sedimentation to the top of the section, so the start of collision must be still younger. Along-strike of the Indus Yarlung Zangbo suture thick submarine delta-fan complexes derived from erosion of the Himalayan-Tibet system provide independent estimates that agree with a diachronous collision initiating in the late Ypresian in the west and progressing into and perhaps through the Lutetian in the east. The stratigraphic and magmatic history along the north side of the suture are compatible with such a diachronous history. This diachroneity has important implications for estimates of the accommodation of strain within this orogenic system.

Key words: Tectonics, stratigraphy, collision, Hazara, Tibetan plateau, Himalaya.

R/203. Rowell, G., 1976. The Karakorum opens up. *Mountain*, 49, 18–35.

The construction of the Karakoram Highway provides an easy access to the central Karakoram and eastern Hindukush. The Highway crosses obliquely the northwest Himalayan terrain, followed northward by Kohistan and central Karakoram mountain ranges.

Key words: Karakoram Highway.

R/204. Ruschelli, M.A. & Cita, M.B., 1959. Cretaceous microfossils from Western Pakistan and Afghanistan. *Institute of Geology, Palaeont. Geog. Fisen. University of Milano* 100, 231-252.

Key words: Cretaceous, microfossils, Pakistan, Afghanistan.

R/205. Rushton, A.W.A., 1973. Cambrian fossils from the Hazira shale, Pakistan. *Nature* 243, 130-142.

Until recently the Abbottabad Group in the Hazara area, western Pakistan, was thought to be Upper Carboniferous-Permian in age. But when Latif found Hyolithid shells in the Hazira Shale Formation at the top of the Abbottabad Group, he suggested that a Lower Palaeozoic age was more probable; on lithological grounds he favoured a Cambrian age for the Hazira Shale². Preparation of Latif's material not only confirmed the presence of Hyolithids (*Circotheca?* and *Linevitus?*) but yielded spicules of the Heteractinellid sponge *Chancelloria* Walcott. *Chancelloria* is known from the Middle Cambrian of North America³, the Ordian of Australia⁴, and from the Lower Cambrian in England⁵. A Cambrian age for the Hazira Shale is therefore fully confirmed. If the Tanakki boulder bed at the base of the Abbottabad Group is of glacial origin¹, it becomes feasible to correlate it with the widespread late Precambrian glaciation.

Key words: Palaeontology, carboniferous, Permian, shale, Hazira, Abbottabad, Hazara.

R/206. Russel, D.E. & Gingerich, P.D., 1980. Une nouveau primate omomyide du Eocene du Pakistan. *CRNS Accademy des Sciences, Paris* 291, 621-624.

Key words: Palaeontology, Eocene.

R/207. Russel, D.E., Thewissen, J.G.M. & Sigogneau, R.D., 1983. A new dichobunid artiodactyls (mammalia) from the Eocene of north-west Pakistan; II, Cranial osteology.

Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B: Palaeontology, Geology, Physics and Chemistry 86, 285-300.

Key words: Palaeontology, Eocene.

S/1. Sabir, M., 1963. Geology of Banda Atai Khan, Bodla, Hazara. M.Sc. Thesis, Punjab University, Lahore, 30p.

Key words: Geology, structure, Hazara.

S/2. Sabir, M.A. & Rehman, S.S., 2000. Hydrological characteristics of Indus Kohistan. Abstracts, Third South Asia Geological Congress, Lahore, p.144.

Key words: Hydrology, Indus Kohistan.

S/3. Sabir, M.A., Rizvi, S.I., Mehmood, T. & Sarwar, A., 1985. Ground water conditions in bajaur Agency, N.W.F.P. M.Sc. thesis, department of Geology, University of Peshawar.

This study describes the effects of ground water due to pumping out water from 110 tube wells in Bajaur agency, installed by F.A.T.A.D.C. In this study special emphasis was given to record the decline and to ascertain the rate of decline of ground water level due to pumping. Individual tube wells performance in terms of specific capacity test and the properties of the aquifer were also studied.

The study area comprises major portion of Bajaur agency. The area in the west is connected to Mohmand agency, and in the east is connected to Dir. The total survey area measures 788 sq miles. This area is in the form of plains. The top layer of the plains in which these tube wells are installed, is mostly of clay alternated by gravels, boulders, clay and sand. The area is basically igneous and metamorphic in nature.

The main source of irrigation is ground water and only a few farmers resort to barani cultivation. In addition to tube wells, dug wells are also present in this area but used for domestic purposes only. In Bajaur area water is available at various depths ranging from 50 feet to 200 feet which is fit for drinking and irrigation purposes.

Key words: Hydrology, groundwater, Bajaur Agency.

S/4. Sadin, M., 1976. Geology of the northern part of Khyber Agency. M.Sc. Thesis, Peshawar University, 25p.

Key words: Geology, Khyber Agency.

S/5. Sadin, M. & Shah, H., 1989. Geological map of Thana quadrangle, Topographic Sheet No. 43 B/2. GSP.

The Thana area in Malakand Agency and Swat is occupied by metamorphosed pelitic and calcareous rocks with intrusions of granitic rocks. The various lithologies are marked on the detailed geological map

Key words: Geological map, Thana, Malakand.

S/6. Saeed, A.S., Alam, M. & Khan, M.W., 1985. Groundwater conditions of Rustam area Mardan, N.W.F.P. M.Sc. Thesis, University of Peshawar, 71p.

Wapda has recently started work on ground water investigation in Rustam area. The main objective of the present work in Rustam is to:

1. Increase agriculture production, through improvement of water supply, drainage and through soil reclamation.
2. To improve the economic and financial condition of the farmers.
3. To stimulate economic activity in the area.
4. To provide subsoil drainage, by tube wells, where feasible and by open drains, where tube wells are not feasible.
5. To provide water to present unagricultural areas, if available after supply to the present commanded area.
6. To improve the subsurface water supply to those areas where cultivation is done by rain fall.

The project area is irrigated by persian wells, but most parts of this area in the north of Rustam is cultivated by rain fall.

It has been established from lithologic logs of the test wells drilled in this area, that the subsurface geology of this area includes moderate water-bearing sand and gravels with a considerable thickness of clay over certain area of Rustam unit. The aquifer is generally overlain by clay, silt and clayey shale ranging in thickness from few feet to several feet. The aquifer is not confined in the area, because the water level is very low in test wells. Generally water table ranges in the area from 30-40 feet. Due to low water bearing zones and deep water table there is no water logged area in Rustam valley.

Agriculture production of the area has declined due to non-availability of water for irrigation throughout the year. Mostly the people of this area cultivate their land farms with the help of rain water supply. The analysis of the surrounded wells water and soil sample show that the area has an excellent quality for agriculture. The water contain about 108 ppm of dissolved solids. Majority of the water sample contain less than 540 ppm of dissolved solids. Average contents of solid range from 102-280 ppm

Soil texture is moderately coarse to fine and medium to fine with good porosity and high capillarity. The rate of infiltration is very good. The soil is generally calcareous pedocals and reclaimable with water leaching and is highly productive. The soil of Rustam area is generally nonsalinized, because there is no water logging. Due to fertility of the soil, the production can increase with development of water subsurface resources. Rustam area has pure water of bicarbonate type and permeability is good also. Generally the aquifer of the area is low and has deep water table, so salinity is not seen everywhere.

Key words: Groundwater, Rustam, Mardan.

S/7. Saeed, G. & Karim T., 1989. Magnetite deposits of Sherwan area, Abbottabad district, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 438.

Key words: Mineral deposits, magnetite, Abbottabad.

S/8. Saeed, Q.M., 1982-84. Micropaleontology and stratigraphy of the Jhalar Area-the Kala Chitta Range, Attock District. M.Sc. Thesis, Punjab University, Lahore, 91p.

A geological map of the Jhalar area -the Kala Chitta Range, on a scale of 1" to 0.789 mile or 1:50,000 and covering an area of 16.43 square miles has been prepared to discuss the stratigraphy and micropaleontology of the area. An attempt has been made to discuss the importance of foraminiferal content of these rock units, for determining the depositional pattern and age. The geological sequence of the Kala Chitta Range with a view to recognize the continuity or unique aspects of the lithostratigraphic units in the adjoining area. The various geological events that occur in the area and their geological implications have also been discussed. In the Kala Chitta Range there are some eighteen lithostratigraphic units but the area under discussion comprises ten lithostratigraphic units mostly of marine environments and with non-marine units.

Key words: Micropaleontology, stratigraphy, Kalachitta Range, Attock.

S/9. Safdar, M., 1983-85. Geology and tectonics of Burawai Area, Upper Kaghan valley, District Mansehra, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 125p.

Nearly 114 sq. km. in the vicinity of Burawai, upper Kaghan valley has been geologically mapped, at the first time. This thesis presents first time accounts of geomorphology, lithostratigraphy, petrography and economic geology of the area. The area constitutes rocks representing old Indo-Pak basement rocks, comprising pelites, calc-pelites and marbles have been metamorphosed to kyanite and sillimanite grades. These are intruded by para-autochthonous sheet granites also metamorphosed. Major structure comprises an open synform possibly part of a larger structural basin. The western part comprises the nose of a larger antiform. Marble, biotite mica and kyanite are important mineral deposits which deem further exploration and evaluation. This thesis also includes petrogenesis of the rock units as well as numerous sketches sections and photographs, illustrating the geology of the area.

Key words: Tectonics, structure, Burawai, Kaghan, Mansehra.

S/10. Safdar, M. & Hasan, R., 1964. A study of barite deposits of Hazara. Pakistan Journal of Scientific and Industrial Research 17, 111-117.

Key words: Barite, Hazara.

S/11. Sahibzada, M.Z., 1973. Geomorphological analysis of Peshawar region. Journal of the University of Peshawar 15.

Key words: Geomorphology, geography, Peshawar.

S/12. Sahibzada, Z.A. & Khan, M.Z., 1984. Petrology of a part of Ambela granitic complex, Buner-Swat. M.Sc. M.Sc. Thesis, University of Peshawar, 58p.

This is a cursory study of a part of the Ambela granitic complex. Petrographic information accompanies geological map. Major element chemistry of selected samples is also presented.

Key words: Petrography, geochemistry, Ambela, Buner.

S/13. Sahni, M.R., 1939. Mesozoic brachiopoda of the Bannu District. Geological Survey of India, Memoir, Palaeontologica Indica (New Series) 27(1), 23p.

Key words: Palaeontology, Mesozoic, brachiopods, Bannu, India.

S/14. Sahni, M.R. & Sastri, V.V., 1957. A monograph of the orbitolines found in the Indian continent (Chitral, Gilgit and Kashmir), Tibet and Burma, with observation on the age of associated volcanic series. Geological Survey of India Memoirs, Palaeontologica Indica (New Series) 33(3), 44p.

Key words: Chronology, tectonics, Indian Continent.

S/15. Said, M., 1972. Land-use and land resources of Dera Ismail Khan District. Board of Economic Inquiry, NWFP, University of Peshawar, Publication 84, 160p.

This detailed document deals with various aspects of land, its resources and its use. The chapter on Physical and Human aspect gives information on physiography, surface water, groundwater and landforms. The latter have been divided into active flood plain, meander flood plain, rolling sand plain, hilly sandy plain, alluvial fans and piedmont plain. There is a brief mention of sandstone, shale, conglomerate and limestone (covering 11.1% of the District) of the hilly areas.

Key words: Land-use, land resources, D I Khan, NWFP.

S/16. Said, M., 1975. The Quaternary chronology of the Bar Daman area, Peshawar Valley. Abstracts, 3rd All Pakistan Geographical Conference, Islamabad, p.7.

Key words: Chronology, Quaternary sediments, Peshawar.

S/17. Said, M., 1975. Some observation on the development of alluvial fans in the Khattak foot hills. Abstracts, 3rd All Pakistan Geographical Conference, Islamabad, . p.4.

Key words: Alluvial Fan, Khattak foot hills.

S/18. Said, M., 1985. The effects of Tarbela Dam on the sediments load of the Indus River as recorded at the Attock Bridge. Presidential Address, Engineering Section, 23rd Annual Conference of Scientific Society of Pakistan, Lahore.

Key words: Tarbela Dam, sediments load, Indus River, Attock Bridge.

S/19. Said, M., 1991. Natural hazards of the Hunza Valley. Pakistan Journal of Geography 1, 45-52.

For more information, see Said (1992b).

Key words: Hazards, landslides, Hunza.

S/20. Said, M., 1991. Natural hazards in the Northern Areas of Pakistan. Culture Area Karakorum, Newsletter 1, 7-8.

Key words: Hazards, landslides, Pakistan.

S/21. Said, M., 1992a. Natural hazards of the Hunza valley. Culture Area Karakorum, Newsletter 2, 9-10.

For more information, see Said (1992b).

Key words: Hazards, landslides, Pakistan.

S/22. Said, M., 1992b. Natural hazards of the Hunza Valley. Proceedings, National Seminar on Progress of Geography in Pakistan, University of Peshawar, 75-83.

This is a report of a study conducted in 1991 between Danyor and Hindi. It describes geological hazards such as earthquakes, with mention of some of the major earthquake since 1871. Geomorphological hazards have been commented upon (mass-movement, rock falls, rock slide, debris slide, and mud flows), together with the accounts of floods in the Hunza River and tributary streams, glacial hazards, eolian hazards (sandstone), biotic hazards and climatic hazards.

Key words: Hazards, landslides, Hunza.

S/23. Said, M., 1995. Natural hazards of Hunza and Astor valleys. In: Stellrecht, I. (ed.), Pak-German Workshop on Problems of Comparative High Mountains Research with Regard to the Karakorum, Tübingen, October 12-14, 1992. Culture Area Karakorum, Occasional Papers 2, 33-43.

Key words: Hazards, landslides, Astor Valley, Pakistan

S/24. Said, M., 1998. Natural hazards of Shigar valley, Northern Areas, Pakistan. In: Stellrecht, I. (ed.), Karakorum-Hindukush-Himalaya: Dynamics of Change. Culture Area Karakorum, Scientific Studies 4. Rudiger Koppe, Köln.

Key words: Natural hazards, Shigar Valley, Tectonics.

S/25. Said, M. & Majid, M., 1977. The Pleistocene history of the terrestrial deposits of Bar Daman area, Peshawar valley. Journal of Science and Technology, Peshawar University 1, 39-47.

The detailed mapping of the Bar Daman area, has revealed the presence of a variety of surface deposits, ranging from siltstone to gravel, sand and loess. It appears that during the second Himalayan glaciation, this area was covered by a fresh water lake, in which siltstone, mainly older loess, reworked by torrents was deposited. This lake was drained away during the following warm phase, and in places, sand was laid on the top of the siltstone by aggrading streams, the early phase of the third Himalayan glaciation is recorded by fac gravels. A fossil soil reflects warm and wet conditions, perhaps an interstadial. The last phase of the third glaciation is characterised by cold and dry conditions as is shown by the thick deposits of loess. The last glaciation is recorded by the formation of fans, while Holocene is marked by large scale changes in the drainage of this area.

Key words: Pleistocene, terrestrial deposits, Bar Daman, Peshawar.

S/26. Saif, S.I., 1970. Chromite occurrences in Utmankhel area of Mohmand Agency, NWFP, Pakistan. Geological Bulletin, University of Peshawar 5, 134-135.

The Utmankhel area lies adjacent to Charsadda Tehsil of Peshawar district and its boundary starts about seven miles north of Tangi. In the area under investigation the Peshawar plain skirts the hills where the elevation culminates from 1550 to 5520 feet. The ultramafic outcrops form a linear belt from two to five miles wide and extend for over 25 miles. The important localities in the Utmankhel area from where the chromite has been reported are in the vicinity of Babu, Bucha, Prang Ghar, Daghai and Balola villages. The mineralization is sporadic and lenticular.

Key words: Chromite, geochemistry, Utmankhel, Mohmand Agency.

S/27. Saif, S.I., 1971. A geological traverse through Mohmand Agency and Bajaur, NWFP West Pakistan. Geological Bulletin, University of Peshawar 6, 74-81.

Traverses in Mohmand Agency and Bajaur reveal that the area is underlain by a variety of metamorphic and igneous rocks. Slates, phyllites, schists, amphibolites and interbedded crystalline limestone cover extensive part of the area. Granite, microgranite and diorites are the igneous rocks found in addition to a thick ultramafic body, which is closely associated with the carbonate horizon.

Extensive marble reserves of various grades and shades have been encountered. The carbonate horizon mostly yields pure white, greenish and brownish marble, as well as several varieties of limestone. Big economical blocks of marbles can be extracted. This part of the metasedimentary terrain may be the northern termination of a large fold having connection with the Mullangori structure.

Key words: Metamorphic, igneous, granite, diorite, marble, Mohmand agency.

S/28. Saifullah, 1997. Heavy and trace metal abundance related to pollution in Peshawar city, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar.

Key words: Heavy metals, trace metals, health hazards, pollution, Peshawar.

S/29. Saleem, M., 1969. Geophysical investigations of Upper Swat. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geophysics, seismicity, Swat.

S/30. Saleem, M., 1983-85. Electrical Resistivity for groundwater potentials in Shekhan, Landai Bala and Shahabkhal Area, District Peshawar. M.Sc. Thesis, Punjab University, Lahore, 31p.

Electrical resistivity survey in Shekhan, Landai Bala and Shahabkhal area was carried out in collaboration with Hydrology Directorate WAPDA Peshawar. The main purpose of the survey was to determine hydrogeological features like depth to bed rock, nature and thickness of aquifers and the quality of groundwater to select suitable sites for tubewell installation in the project area.

According to the resistivity survey and drilling data the entire area is underlain by low resistive clay. The overlying alluvium is composed of alternating layers of gravels and clays. Groundwater appears to be quite fresh in the entire area and seems to be under artesian pressure at many places. The water depth varies from 50 to 70 meters in the area under investigation.

In the project area, thirty one probes were carried out. After interpreting the data, the V.E.S. No. 6, 7, 8, 10, 16, 19 and 22 have been selected for the test drilling, however other probe sites also indicate presence of aquifers in the area but of varying thickness. The entire area appears to be favorable for tubewell installation, however the yielding of water depends upon the nature of aquifers may vary from half cusec to one and half cusec in the project area.

Key words: Resistivity, groundwater, drilling, aquifers, Peshawar.

S/31. Saleem, Z.A., 1963a. Gravity and magnetic studies in Swat State of Pakistan. Abstracts, 15th All Pakistan Science Conference, Lahore, p. F9-10.

Key words: Gravity, magnetic study, Swat.

S/32. Saleem, Z.A., 1963b. A geophysical study of the Swat Granite and associated rocks. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geophysics, geography, granites, Swat.

S/33. Saleemi, A.A., 1978. Modal investigations of some granitic complexes of the northwest Himalayas, Pakistan. Geological Bulletin, Punjab University 15, 32-38.

Modal analyses are given of 21 rocks from northwards extension of the Hazara granitic complex in the Battal-Batgram area, and 11 rocks from the Nanga Parbat granitic massif, along with their brief descriptions. The data were plotted in the Streckeissen's triangular diagram for quartzofeldspathic plutonic rocks and discussed. The results are compared with those from the previously investigated Hazara granitic complex and the Lower Swat granitic complex. The conclusions are generalized with reference to theories of origin complexes of the northwest Himalayas.

Key words: Petrography, granitic complex, Hazara, Nanga Parbat.

S/34. Saleemi, A.A., 1997. Industrial application of illite-smectite rich clays from Karak, northwestern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.55.

For additional information, consult the following.

Key words: Illite-smectite, clays, Industrial uses, Karak.

S/35. Saleemi, A.A. & Ahmed, Z., 2000a. Mineral and chemical composition of Karak mudstone, Kohat Plateau, Pakistan: Implications for smectite-illization and provenance. Sedimentary Geology 130, 229-247.

The Karak mudstone interbedded in an Eocene evaporite sequence, is dominated by R-1 ordered illite-smectite with a 20 to 30% expandable component. Minor phases include kaolinite, chlorite, illite/muscovite, plagioclase, potash feldspar, quartz, dolomite and pyrite. The present illite-smectite was probably originally smectite or highly expandable illite-smectite which underwent conversion to illite-smectite with a low expandable component in a comparatively low-temperature (ca. 100°C) closed-system sedimentary basinal diagenetic environment at a depth of ca. 5 km. Al^{3+} and K^{+} necessary for the conversion reaction were provided through the breakdown of potash feldspar. Burial under a 5 km thick pile of sediments produced some of the observed structures. Whole-rock chemistry presented here suggests that the mudstone formed by severe weathering of acidic source rocks. The influx of freshwater probably flushed out Ba, Rb, Ca and Mn from the restricted basin.

Key words: Mudstone, illite-smectite, clays, sedimentary deposit, Karak.

S/36. Saleemi, A.A. & Ahmed, Z., 2000b. Acid activation and bleaching capacity of illite-smectite rich clays from Karak area, North West Pakistan. Late Abstracts, Third South Asia Geological Congress, Lahore, p.1.

Key words: Acid treatment, bleaching, illite-smectite, clays, Karak.

S/37. Saleemi, B.A., 1974. Geology of Kotegram and Akhagram quadrangle, District Dir, NWFP., West Pakistan. Geological Survey of Pakistan, Information Release 80.

Key words: Geology, lithology, Kotegram, Dir.

S/38. Salim, A., Sulaiman, E. & Ullah, M., 1988. General geology of a part of Karak District, N.W.F.P., Pakistan. M.Sc. Thesis, University of Peshawar, 40p.

The present work describes the general geology of a part of Karak district (Bahaderkhel and Latumber) on scale of 1:12,500. Various lithological units present in it include, from bottom to top, Bahaderkhel Salt, Jatta Gypsum, Kuldana Formation, Kohat Formation, Kamlial Formation, Chinji Formation and Nagri Formation. The strata of the study area are moderately to highly folded and faulted under the effect of Himalayan orogeny. The folds and faults are classified on the basis of size as regional, local and minor. The folds are generally gentle to open. Major faults strike SW-NE. The map view expression of both normal and reverse slip faults have been observed by the presence of graben faults and tear faults respectively. The tear faults can be easily observed by omission and repetition of stratigraphic sequences. Tear faults are the result of inability of translating a huge regional block as a single unit. The salt tectonic of varying intensities result in the squeezed out diapiric, plug like and domal exposure of Bahaderkhel Salt in the core of the Bahaderkhel anticline. The outcrop pattern very closely shows that all younger formations are sharply wrapping around the Salt and gypsum core. The economic deposits of the area include Rock salt, Gypsum and limestone. The typical favourable structural setting makes the whole region a promising target for the exploration of oil & gas.

Key words: Geology, geomorphology, stratigraphy, Karak.

S/39. Sameeni, S.J., 1994. Microfaunal studies of Lower Margalla Hill Limestone of Bandi area, Hazara, Pakistan. Pakistan Journal of Geology 2 & 3, 45-52.

This paper deals with the micropalaeontological studies of Lower Eocene Margalla Hill Limestone from Bandi area Hazara. Fifteen species of age diagnostic larger foraminifera are recorded including three typical Paleocene species of the genus *Ranikothalia* are reported for the first time from Margalla Hill Limestone and association of the genus *Ranikothalia* along with typical Eocene species confirms its presence in the Lower Eocene (YPRESIAN) deposits of Pakistan.

Key words: Palaeontology, biodiversity, Margalla Hill Limestone, Bandi, Hazara.

S/40. Sameeni, S.J. & Mirza, K., 2000. Planktonic foraminifera from the Upper Cretaceous Kawagarh Formation of Jabri area, Hazara, Northern Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 161-162.

Key words: Foraminifera, Cretaceous, Kawagarh Formation, Jabri area, Hazara.

S/41. Samiullah, Sharafatullah & Nasrullah, 1986. Geology and structure of Karak Quadrangle, Kohat. M.Sc. Thesis, University of Peshawar, 62p.

The present work describes the geology and structures of a part of Karak bounded by latitudes 33° 8' 0" to 38° 11' 27" N and longitude 70° 56' 53" to 71° 1' 37" E of Karak quadrangle. The map was enlarged from 1:50,000 survey of Pakistan toposheet scale. The area is moderate to highly folded and a few faults of considerable extent and significant movement have been observed. The folds are open, plunging with their axes trending EW. In the area, a central anticline is bordered by the two adjacent synclines one on each side.

The Stratigraphy of the area is as follows;

Pliocene	Siwalik Group	Nagri Formation
		Chinji Formation
Miocene	Rawalpindi Group	Kamlial Formation
Eocene		Kohat Formation
		Kuldana Formation
		Jatta Gypsum
		Bahadur khel salt

The rocks of the above two ages (Pliocene and Miocene) are considered to be fluvial in nature and are thought to be composed of the Himalayan Molasse, while the rocks of the Eocene age are thought to be most probably the deposits of evaporite basin.

The rocks have been moderately to highly folded and faulted, and shows two distinct phases of deformation, in harmony with the earlier phases of Himalayan orogeny. The first phase of deformation give rise to the three major F1 folds while the second phase of deformation give rise to the secondary intraformational folds. The faults occurring in the area are mainly two sets. One set comprises of only one fault which is thrust fault. The second set is composed of four diapiric, gravity faults. Both the two sets of faults appear to be associated with the second phase of deformation and are the youngest. The investigated areas has great geological importance partly because of the fact that the younger little deformed rock assemblages here are suited for petroleum exploration. Besides, the presence of abundant economic minerals like rock salt, gypsum and limestone, also make it economically viable area.

Key words: Geology, structure, Karak quadrangle, Kohat.

S/42. Sano, S., 1993. Origin of chromite ore deposit: A review. View of petrologic approach on origin of chromite ore deposit in Pakistan ophiolites. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 5, 97-112.

Describes relationship of ophiolite type and chromite ore deposits, and their origin. Gives a brief account of the Malakand occurrence and notes their similarity with the island arc deposits.

Key words: Ophiolite, chromite, Malakand, Island arc.

S/43. Sano, S., Khan, S.R., Nakagawa, M. & Ohta, E., 1994. Chromite ore deposits in dunite of the Malakand Ultramafic body, Pakistan. Abstract Geological Society of Japan, Annual Meeting, Sapparo, Japan.

Key words: Chromite, dunite, ultramafic, Malakand.

S/44. Sano, S., Nakajima, T. & Khan, S.R., 1996. Geology and isotope geochemistry of the Jijal complex, Kohistan, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 127-135.

The Jijal ultramafic-mafic complex in northern Pakistan is a small body of a few tens of square kilometers, but has drawn big attention as to be a root zone of the so- called "Kohistan paleo-island arc" (e.g., Jan and Howie, 1981; Bard, 1983), or, a possible fossil of the uppermost mantle to lower crust in the surface-exposed crust- mantle cross section. This short report presents a geological overview of the Jijal complex based on our field survey along the

Karakoram Highway in 1992 and the following petrographical work, as well as the newly obtained Sr-Nd isotopic data on the Jijal complex and their petrogenetic implications.

Key words: Geology, geochemistry, Jijal Complex, Kohistan.

S/45. Sarhad Development Authority, 1977. Feasibility study of the Target Area-1 (Kakul) of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Phosphate, Abbottabad, Hazara.

S/46. Sarhad Development Authority, 1977. Feasibility study of the Target Area-2 (Lagarband) of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Phosphate, exploration, Abbottabad, Hazara.

S/47. Sarhad Development Authority, 1977. Overall evaluation of the designated Hazara phosphate area. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Economic geology, phosphate, exploration, mining, Abbottabad, Hazara.

S/48. Sarhad Development Authority, 1978. Technical proposal for the exploration and mining planning of the Lagarband area of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 1.

Key words: Economic geology, exploration, mining, phosphate, Abbottabad, Hazara.

S/49. Sarhad Development Authority, 1978. Commercial proposal for the exploration and mining planning of the Lagarband area of the Hazara Phosphate Project. P.D.N.C.B. Consultant Limited, London, Volume 2.

Key words: Exploration, mining, phosphate, Abbottabad, Hazara.

S/50. Sarkar, S.S., 1964. On the rates of evolution of some mammals from India and Pakistan. International Geological Congress, New Delhi 22(8), 282-292.

Key words: Evolution, habitat, mammals, siwaliks, India, Pakistan.

S/51. Sartenaer, P., 1965. Rhynchonelloidea de Shogran et Kuragh (Chitral), Italian Expedition to Karakorum and Hindu Kush. Brill. Leiden, Scien. Rep., 1(4), 55–56.

This paper describes Devonian Rhynchonelloidea from Shogran and Kuragh in Chitral.

Key words: Devonian, Rhynchonelloidea, Chitral.

S/52. Sarwar, A., 1997. Litho and stream sediment geochemical investigations for base metals and precious metals in Timargara, Maidan and Jandul Area, District Dir, Northern Pakistan. M.Phil. Thesis, University of Peshawar, 164p.

The area of study (about 900 sq. km.) is a part of the Kohistan island arc in the northern part of Pakistan. The Kohistan island arc, which is a part of Kohistan-Ladakh island arc, represent a cross section through an intra-oceanic

island arc sequence which develop as a result of the northward subduction of Neotethyan oceanic lithosphere during late Jurassic and Cretaceous time. It is bounded by the Main Mantle Thrust (MMT) in the south and Main Karakoram Thrust (MKT) or Shayok suture in the north in the Pakistani terrane.

The area of study is located immediately north of the MMT in Dir district. It has a complex geology and is mainly composed of amphibolites, metadiorites and metagabbroanorites, metagranodiorites, metagranites and metavolcanics with subordinate amount of hornblendites, ultramafites and tonalites. The area has been investigated for preliminary geology, however, no detail geochemical investigation has been carried out for precious and base metals mineralization. This study has main emphasis on the rocks and stream sediments (both pan concentrates and -80 mesh fine fraction) geochemical survey for gold and base metals in order to delineate areas likely to contain mineralization and be worthy of follow-up work.

The area has been divided into 56 drainage cells ranging from 2-50 km² with an average density of about one site per 15 km². From each cell a pan concentrate and -80 mesh fine fraction were collected for geochemical analyses of Au, Ag, Cu, Zn, Pb, Co, Ni, and Cr, by atomic absorption. The visible gold as piece, speck and color was identified in the pan concentrates at the site. The floats were also examined for alteration and other geological phenomenon at each site. The pan concentrates are dominantly composed of magnetite whereas zircon, quartz, pyroxene, garnet, hornblende, feldspar, tourmaline, chromite and rock fragments occur as minor constituents.

The geochemical data for rock samples, pan-concentrates and fine fractions of stream sediments have been displayed and evaluated by considering various geostatistical methods.

Geochemical maps have also been prepared on the basis of single and multi-elements consideration in order to pin point areas of most interest. These studies show that panconcentrates have higher concentration of all the elements as compared to that of fine fraction. These elements are silicate bounded rather than sulfide bound in stream sediments. The higher concentration of Cu, Pb, Zn, Ni, Cr, Co and Ag could be related to the bed rock rather than to specific mineralization in the area. The anomalous gold, however, could not be directly related to the bed rock but it could possibly be related to the existence of gold-bearing mineralization in the north and north-eastern part of Samarbagh area, the detail geochemical survey is, therefore, recommended for follow-up in the region.

Key words: Stream sediment, geochemistry, precious metals, Timargara, Dir.

S/53. Sarwar, G. & DeJong, K.A., 1979. Arcs, Oroclines, Syntaxes - the curvatures of Mountain Belts in Pakistan. In: Farah, A. & DeJong, K.A. (Eds.), *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 341-350.

The bent mountain belts of Pakistan are discussed in terms of the convergence of the Indo-Pakistan subcontinent with the Eurasian blocks to the west and north of it. The triangular northwest part of the Indo-Pakistan block was compressed simultaneously from the west, east and north, the latter compression being the most severe. Deformation occurred along the margins and crustal material was expelled, mainly to the south. The Pamir Himalaya Arc, the Nanga Parbat-Haramosh massif, the Hazara-Kashmir Syntaxis, the Bannu-Potwar thrust sheet, the Salt Range Composite Orocline, and the Sulaiman Arc are explained as a result of this north-south compression. The Quetta Syntaxis is seen to result from obstruction of the southward moving sedimentary cover of the Sulaiman Arc by the thick wedge of Neogene sediments in the Sibi trough. Finally, based on geological evidence, it is suggested that a large block (the Khuzdar-Karachi Block), behaving as an independent tectonic unit, is being rotated counter-clockwise at the western margin of the Indo-Pakistan plate. The Khuzdar Knot and the Karachi Arc form the southern and northern parts of the Khuzdar-Karachi Block respectively.

Key words: Orogeny, syntaxes, mountain belts, Pakistan.

S/54. Sarwar, M., 1971. A Javanese Rhinoceros recorded from the upper Siwalik of Azad Kashmir, Pakistan. *Geological Bulletin, University of Peshawar* 6, 49-53.

A mammalian fragmentary collection comprising a right upper third premolar, a fragment of the occipital region and a thoracic vertebra, made from the Pinjor Zone of the Upper Siwaliks of Azad Kashmir, Pakistan, is here referred as *Rhinoceros kendengindicus Dubois*. This species was discovered by Dubois in 1908 from Java but was hitherto unrecorded from the Siwalik Hills.

Key words: Vertebrate palaeontology, Rhinoceros, Pinjor zone, siwaliks, Azad Kashmir.

S/55. Sarwar, M., 1972. Taxonomy and distribution of the Siwalik Proboscidea. Department of Zoology Bulletin, Punjab University, New Series, 10, 1-172.

Key words: Vertebrate palaeontology, taxonomy, proboscidea, siwalik.

S/56. Sarwar, M., 1978a. A record of the genus *Mammuthus* Burnett from the Pinjor Formations of the Pakistan Siwaliks. Punjab University, Geological Bulletin, 15, 78-80.

Key words: Vertebrate palaeontology, *Mammuthus* Burnett, Pinjor Formation, siwaliks.

S/57. Sarwar, M., 1978b. On the stegodont ancestry of the elephant. Punjab University, Geological Bulletin, 15, 62-68.

Stegodont ancestry of the family Elephantidae has been suggested, Genus *Antelephas* descended from *Stegodon* and in turn gave rise to the genus *Elephas*. *Elephas planifrons* has been regarded as ancestor of the later elephants and the mammoths.

Key words: Vertebrate palaeontology, elephant, stegodont.

S/58. Sarwar, M., 1980a. A new mammoth from the upper Siwaliks of Pakistan. Journal of Science Research, University of Punjab, 9 (1-2), 43-48.

Key words: Vertebrate palaeontology, mammoth, siwaliks.

S/59. Sarwar, M., 1980b. Dental morphology and distribution of *Tetralophodon punjabienis* progressus, Sarwar. Pakistan Journal of Zoology, 12 (2), 199-204.

Key words: Vertebrate palaeontology, morphology, *tetralophodon*.

S/60. Sarwar, M., 1981a. A new Elephant from the upper Siwaliks of Pabbi hills, Panjab, Pakistan. Geological Bulletin, University of Punjab 16, 131-137.

Elephas corrugatus, new species, from Pinjor Zone of the Upper Siwaliks exhibits a combination of primitive and advance dental characters. In a comparison with the known Asiatic elephants, it has proved to be a specialized form. It was a short-lived abortive offshoot of the species, *Elephas planifrons*.

Key words: Vertebrate palaeontology, elephant, siwaliks, Pabbi hills, Punjab.

S/61. Sarwar, M., 1981b. Evolution of the molar ridge-plates in elephants. Punjab University, Geological Bulletin, 16, 138-140.

Elephas corrugatus, a new species, from Pinjar Zone of the upper Siwaliks exhibits a combination of primitive and advance dental characters. In a comparison with the known Asiatic elephants, it has proved to be a specialized form. It was a short lived abortive offshoot of the species, *Elephas planifrons*.

Key words: Vertebrate palaeontology, elephants, siwaliks.

S/62. Sarwar, M., 1987a. Milk molar morphology in *Stegodon dhokawanensis* Sarwar, Punjab University, Geological Bulletin, 22, 92-94.

A left maxillary portion bearing a deciduous fourth premolar (P.U.P.C.* 66/3) of some stegodont skull is described from Pabbi Hills of district Gujrat, Punjab. On the basis of dental features, it has been referred to the species,

Stegodon dhokawanensis described by Sarwar in 1977. Thus, P.U.P.C 66/3 provide information about the morphology of the milk dentition in the species *Stegodon dhokawanensis*.

Key words: Vertebrate palaeontology, morphology, Pabbi Hills, Gujrat, Punjab.

S/63. Sarwar, M., 1987b. The presence of a Chinese stegodont proboscidean in the Siwaliks of Azad Kashmir, Pakistan. Punjab University, Geological bulletin, 22, 72-75.

A stegodont fourth upper premolar is described from the Dhokpathanian of Bhimbhar district Mirpur, Azad Kashmir, Pakistan. The tooth being primitive in structure of its ridge-crests and the crown heights has been compared with the primitive stegodonts. A detailed study has indicated that it is conspecific with the Chinese species, *Stegodon sinensis* Owen. This is the first Stegodont species common to Chinese Tertiary and the Siwaliks. The discovery of Chinese species from the Siwaliks means that the proboscides migration was possible across Himalayas during Lower/ Middle Pliocene.

Key words: Vertebrate palaeontology, proboscidean, Pliocene, siwaliks, Azad Kashmir, Himalaya.

S/64. Sarwar, M., Aftab, F. & Akhtar, M., 1988. The first bunolistriodont suid from the Siwaliks. *Acta Mineralogica Pakistanica*, 4, 87-89.

Key words: Vertebrate palaeontology, bunolistriodont, siwaliks.

S/65. Sarwar, M. & Akhtar, M., 1987. A New Sivatherine Giraff from Pabbi hills of Potwar Pakistan. *Kashmir Journal of Geology* 5, 95-100pp.

A large-sized giraffid upper second molar has been described. A thorough investigation has revealed that it may be included in the genus *Bramatherium* but as a new species, *Bramatherium geraadsi*.

Key words: Palaeontology, giraff, Pabbi hills, Potwar.

S/66. Sarwar, M. & Akhtar, M., 1989. A case of extreme forward inclination in the molar plates of the Genus *Anancus* Aymard. *Kashmir Journal of Geology* 6 & 7, 183-184.

A molar fragment of the genus *Anancus* is described. It shows an extreme forward inclination of the molar ridge-plates.

Key words: Vertebrate palaeontology, molar plates, *Anancus aymard*, siwaliks.

S/67. Sarwar, M. & Akhtar, M., 1991a. A new anthracotheriid genus from Vasnal, Punjab, Pakistan. *Kashmir Journal of Geology*, 8 & 9, 157-160.

Key words: Vertebrate palaeontology, Anthracotheriid, Vasnal, Punjab.

S/68. Sarwar, M. & Akhtar, M., 1991b. First Description of the Lower Molar in the Clawed Horse *Macrotherium Salinum* Cooper (*Perissodactyla: Mammalia*). *Kashmir Journal of Geology* 8 & 9, 161-164.

A posterior chalicothere mandibular fragment bearing the partially erupted last molar is described. A comparison with the known Siwalik forms has indicated that it belongs to the species *Macrotherium Salinum* Cooper. It is the first description of the lower last molar in the said species.

Key words: Vertebrate palaeontology, mammal, *Perissodactyla*, siwaliks.

S/69. Sarwar, M., Akhtar, M., Ahmad, Z. & Rahim, S.A., 1989. A transitional gomphotheriid from Dhokpathan type locality. *Kashmir Journal of Geology* 6 & 7, 153-156.

A right lower last molar from Dhokpattan type locality is described. It shows Tetralophodon/ Stegotetrabelodon characteristics of the crown.

Key words: Vertebrate paleontology, Gomphotheriid, Azad Kashmir.

S/70. Sarwar, M., Bakr, A. & Akhtar, M., 1986. A new genus of the family Hyaenidae gray from the upper Siwalik beds of the Punjab. Geological Bulletin, University of Punjab 21, 87-94.

Two fragments of an anterior half a hyaenid skull from Neogene Upper Siwaliks of district Attock, Pakistan are described here as a new genus, Romeria. The conclusion is based on the overall morphology of cheek teeth, location of the first molar and the size of the third incisor.

Key words: Vertebrate palaeontology, Hyaenidae, siwaliks, Punjab.

S/71. Sarwar, M. & Nafees, G., 1984. Evolution of the Siwalik Bunodont and Bunolophodont Proboscidea. Kashmir Journal of Geology 2, 109-115.

A comparative study of the bunodont and bunolophodont Siwalik mastodonts indicates that Hemimastodon crepusuli (Pilgrim, 1908) was related to Palaeomastodon (Phiomia) and was a member of the relict probosidean fauna that continued on surviving in the Sub-Continent. Genera Synconophus and Stegolophodon, which are the product of local evolution, have been regarded as descendant of the genus Gomphotherium.

Key words: Vertebrate palaeontology, evolution, Bunolophodont, Proboscidea, Siwaliks.

S/72. Sarwar, M., Rahim, A., Nasreen, S. & Roohi, G., 1987. A New Bunodont Suid from Siwaliks of Pakistan. Kashmir Journal of Geology 5, 87-on ward.

Three mandibular rami bearing two crowned and bunodont artiodactyle teeth and an isolated bunodont tooth have been recovered from various localities of Middle and Upper Siwaliks of Punjab, Pakistan. This new material is described as Dicoryphochoerus mirkhalensis sp. n. It was fairly gigantic suid and was probably the culminating species of the genus.

Key words: Vertebrate palaeontology, bunodont, siwaliks.

S/73. Sarwar, M., Rahim, S.A., Munir, S. & Nazir, F., 1986. A new Lamellibranch from the upper Siwaliks of Pabbi hills, Punjab, Pakistan. Geological Bulletin, University of Punjab 21, 50-54.

An internal cast of a unionid has been described from the Pinjorian of Pabbi Hills of district Gujrat. A careful examination has revealed that it is a new species of the genus Trapezoideus Simpson. This new species, Trapezoideus sardhokensis as it is named, was a large trapezoid, extremely compressed laterally and with extremely compressed umbones.

Key words: Vertebrate palaeontology, Lamellibranch, siwaliks, Pabbi hills, Gujrat.

S/74. Sattar, A., 1985-87. Mineralogical/geochemical studies of rocks, soils and water, Khanaspur Dewal Area. M.Sc. Thesis, Punjab University, Lahore, 103p.

This report gives an account of Mineralogical and geochemical studies carried out in Khanspur and Dewal area. The prescribed area lies to the north of Murree, in extreme east of Abbottabad and southwest of Muzaffarabad. Except an area of about 6 sq. km. which belongs to District Rawalpindi, the area lies in Abbottabad District, N.W.F.P. It is a mountainous region with fairly high relief. Geological mapping of approximately 56 sq. km. on lithostratigraphic basis, at the scale 1:10,000 was carried out. The stratigraphic succession ranges from Datta Formation

(Jurassic) to Murree Formation (Miocene). The lithology is mainly limestone, shales and sandstone. Extensive sampling of rocks, soils and water was carried out and these samples were studied in laboratory and data regarding these studies are given in this report. A brief systematic description of various rock units in hand specimen and thin

section is included. A brief description of chemical staining techniques applied to the limestones and that of performed limestone analysis is also given. A chapter regarding the detail geochemical studies of soils of the project area is also included. This chapter gives an account of all the parameters necessary for soil study and according to these parameters, the soils of the area are categorized as non-sodic, non-saline. Geochemistry of two main streams of the area has also been studied in detail and the data regarding the chemical analysis of the water are reported and interpreted by various graphical techniques. According to these data, the mineral components and other parameters lie within the safe limits, established for water to be used for domestic and agriculture purposes. Chemical characteristics of waters of various springs of the area, originated in different rock units have also been studied and interpreted in detail. Spring waters are also fit for irrigation and drinking purposes. Finally, there is a general discussion about the waters of the area and the effect of various encountered rock units on the chemistry of water passing through them.

Key words: Minerology, geochemistry, Khanaspur.

S/75. Sattar, A., Chaudhry, M.N. & Mateen, A., 2001. Petrology of amphibolites from higher Himalayan crystalline unite, upper Kaghan valley, NW Himalaya, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 9-10.

The Higher Himalayan Crystalline unit in the Upper Kaghan Valley is composed of a lower basement and an upper cover. The lower basement is composed predominantly of granitoids, migmatites, micaceous quartzites and pelite schists. Marbles, calc-pelite gneisses, graphitic schists, quartzites and amphibolites are subordinate lithologies. The cover to this basement is composed of amphibolite sheets intercalated with marbles grading upward to a sequence of calc-pelite gneisses and marbles which are in turn overlain by pelite schists and micaceous quartzites sequence.

The amphibolites in the Upper Kaghan Valley occur either as feeder dykes in the basement or more commonly as extensive sheets in the basal portion of the cover where these are inter-bedded with marbles and calc-pelites. These metabasic rocks are predominantly garnet amphibolites composed of amphibole, calcic plagioclase, and almandine. Quartz, sphene and magnetite occur as accessories. At places due to retrogression some epidote and chlorite may also be found. Around Besal these rocks have been subjected to eclogite facies metamorphism and are comprised essentially of almandine±omphacite. Quartz, rutile and kyanite occur as accessories. Coesite may occur at places.

Major and trace element geochemical data were plotted on variation and discrimination diagrams and spidergrams with normalization to known basaltic compositions. This data strongly suggest a within plate extensional regime for these metabasic rocks. To be more precise, these are tholeiitic flood basalts with minor sub alkaline to alkaline trend. The geology of the area also supports this conclusion since the emplacement of these bodies is entirely within continental crust and there are no ultramafic and felsic bodies genetically associated with them. Furthermore they occur as concordant sheet like bodies indicating a flood basalt type origin.

Key words: Petrology, amphibolites, Kaghan, Himalaya.

S/76. Satti, M.Z., 1991-92. Geological mapping of Nauseri-Yadgar Area and evaluation of geotechnical properties of rock aggregates of the area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 123p.

The dolomite, limestone and sandstone concrete aggregates have been investigated from Yadgar to Nauseri Area. The evaluation of mechanical properties effect the quality of the aggregates presently being used in civil engineering projects. Mineralogically alkali-aggregate reactive minerals involve silica particularly chert, chalcedony, chlorite and clay minerals. The alkali carbonate reactions involve argillaceous dolomite, dolomitic limestone and agrillites. Concrete deterioration due to alkali silica reaction have been investigated from nearly all major geographical regions of Azad Kashmir. In Yadgar dolomite chert is found. Chert is common in gravels, derived from various limestone formations. These chert seem to show a low level of alkali expansivity, but when this is combined with other forms attack on concrete. It may contribute to durability failures. Siliceous limestone, some of which contain chalcedony are known from Batmang area and some example appear to be a major fracturing concrete deterioration. Agrillites associated with alkali expansive reaction in concrete have been described particularly from Margala Hill Limestone. The test result reveals the use of concrete aggregates from the area after treatments.

Key words: Geotechnical, limestone, aggregate, Azad Kashmir.

S/77. SavoiaAosta, Aimoni Duca di Spoleto, 1930. Spedizione nel Caracorum. Boll. R. Soc. Geogr. Ital.,ser.VI, 7, 3-20.

Key words: Karakoram Expedition.

S/78. Savia Luigi Amedeo Duca Degli Abruzzi, 1910a. Viaggio di esplorazione nel monti del Caracorum. Riv. Club. Alpino Ital., 29 suppl. Fasc.1.

Key words: Italian Expedition, exploration, Karakoram.

S/79. Savia Luigi Amedeo Duca Degli Abruzzi, 1910b. Esplorazione ai Monti del Caracorum. Boll. R. Soc. Geogr. Ital.ser. IV, 47, 435-469.

Key words: Italian Expedition, exploration, Karakoram.

S/80. Sawada, Y., Kausar, A.B., Kubo, K., Takahasi, Y. & Takahasi, Y., 1996. Sedimentary structures in the Chilas igneous complex of the Kohistan arc, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15*, 173-181.

The Kohistan island arc is exposed in the western Himalaya of northern Pakistan, where it is bounded by the Main Karakoram Thrust (MKT) to the north and the Main Mantle Thrust (MMT) to the south (Fig. 1) The Kohistan arc consists of a series of east-west trending Cretaceous to Miocene sedimentary, volcanic, plutonic and metamorphic rocks. It is widely interpreted as an island arc sequence which developed above the northward subducting Tethyan oceanic plate. Based on Rb-Sr and K-Ar Ages of syn-collisional leucogranites intruded into the Rakaposhi volcanics (Petterson & Windley, 1985;1990; Treloar et al., 1989), the collision between the Asian continent and Kohistan arc probably took place between 102 to 75Ma. Following this, the main collision of amalgamated Asian continent-Kohistan arc with the Indian continent commenced at about 50Ma (e.g. Patriat & Achach, 1984) during which the Kohistan block obducted onto the Indian continent. South of MKT lie the slates, turbidites, volcanoclastic sediments and limestones of the Albian to Aptian "Yasin Group" (Pudsey, 1986) which may have been deposited within and intra-arc basin. The Yasin Group overlies the submarine to subaerial basic to intermediate arc-type tholeiitic volcanics intercalated with limestones of the "Rakaposhi (Chalt) volcanics". The Rakaposhi volcanics and metasediments were intruded by tonalite and diorite during the late Cretaceous to Miocene. These plutons form a vast complex of intrusions in the northern part of the Kohistan arc, termed the Kohistan batholiths by Petterson & Windley (1985)

Key words: Sedimentary structures, Chilas complex, Kohistan arc.

S/81. Sawada, Y., Kubo, K., Kausar, A.B. & Takahashi, Y., 1993. Primary magma of the Chilas complex in the Kohistan arc, northern Pakistan. *Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 7*, 97-119.

A description of the Chilas in the Kohistan island arc is given together with preliminary trace- and RE elements geochemistry.

Key words: Magma, geochemistry, Chilas complex, Kohistan arc, Northern Pakistan.

S/82. Sayab, M., 1997. *Geology of Nanga Parbat Syntaxis along the Astor valley transect, N. Pakistan. M.Sc. Thesis, Department of Geology, University of Peshawar*, 130p.

The Nanga Parbat-Haramosh syntaxis represents the youngest phase of thermal, tectonic and metamorphic activity in the Himalaya. The massif is an active crustal scale antiformal structure comprising Indian plate basement gneisses and cover sequence. The Nangaparbat rocks in the Indus gorge section have previously been divided into grey Iskere gneiss and pink Shengus gneiss. During recent mapping along the Astor valley transect, south of Indus valley, several new lithological units have been identified. These include 1) Mushkin grey gneiss 2) Harchu pink gneiss and 3) Rattu formation. The Mushkin gneiss is a medium-grained, locally porphyroclastic gneiss of grey colour probably representing the basement complex.

Harchu pink gneiss is clearly derived from a sedimentary protolith (as suggested by the preserved relicts of quartzite and calc-silicate components. In addition, certain lithologies of the unit also contains preserved sedimentary cyclic sequence. The Rattu formation comprises meta-pellites, marbles, calc-silicates pods and lenses and is considered to represent a metamorphosed cover sequence. Structural cross-section from north-west to south-east reveals that the Nanga Parbat sequence consists of two crustal-scale antiformal structures with a tight faulted synform in between. It is noticeable that the Mushkin grey gneiss exhumed with respect to the cover sequence at the margins. Field and petrographic data shows that Rattu formation and Harchu pink gneiss reaches up to kyanite and sillimanite metamorphic grades, whereas the Mushkin grey gneiss lacks these minerals. The Mushkin grey gneiss exhibits a great variety of migmatitic (metatexis) structures, indicating that the Mushkin grey gneiss has experienced more severe metamorphic conditions than any other rock unit in the Astor section. Our preliminary studies indicate possibilities of correlation between Mushkin and Harchu gneisses from the Astor valley with the Iskere and Shengus gneisses from the Indus valley, respectively.

Key words: Structure, petrology, Nanga Parbat Syntaxis, Astor, Himalaya.

S/83. Sayab, M., Butt, K.A., Khan, M.A. & Rafiq, M., 2001. Parallel, sub-parallel drainage pattern in the Surghar-Shinghar Range controlled by Neo-tectonic extension fractures associated with Main Frontal Thrust. Abstracts, 4th Pakistan Geological Congress, Islamabad, 73-74.

The Surghar-Shinghar Range at the eastern margin of the Bannu basin is a N-S oriented antiform in the hanging wall of the Surghar Thrust. The range is bisected by a set of N-S compressional fractures parallel to the axis of the anticline. Orthogonal to this set of fractures is an E-W oriented set of extensional fractures. The age of the Surghar anticline and associated structures is constrained by the sediments involved in the deformation. The Siwalik sediments in the Surghar-Shinghar Range are not older than 7-8 Ma. The involvement of these sediments together with the recent alluvium in the deformation suggests a role of neo-tectonics in the origin of Surghar-Shinghar Range. Based on the stress and strain analyses, we suggest that compressional and extensional fractures in the rocks of the Siwalik Group are the product of the compressional tectonics associated with the Surghar Thrust (Main Frontal Thrust) at the eastern margin of the range.

A study of geomorphology of the Surghar-Shinghar Range using field observations, aided by Landsat TM and SPOT satellite images, suggests predominance of a parallel, sub-parallel drainage pattern across the range. A parallelism between the drainage pattern of the range and the E-W extensional fractures suggests a role of structural control on the geomorphology. The E-W extensional fractures are dilated by seasonal drainage, forming steep gorges, especially in the Siwalik sediments. The Siwalik sediments mostly consist of friable to moderately hard sandstone interbedded with varying proportions of shale horizons. The extensional fractures in these lithologies facilitate drainage along these lines, thereby controlling the geomorphic processes.

Key words: Neo-tectonics, drainage, Main Frontal Thrust, Surghar-Shinghar Range, Trans-Indus Salt Range.

S/84. Sayab, M., Khan, M.A., Butt, K.A. & Pervaiz, K., 1999. Analyses of joints and associated neo-tectonic deformation band shear zones in the Siwalik Group of southern Surghar-Shinghar Range, Trans-Indus Ranges, Pakistan. Geological Bulletin, University of Peshawar 32, 25-39.

This study presents field observations on joints and deformation band shear zones (DBSZs) at the southern flank of the Sarkai-Mochi Mar (SMM) anticline, which is the southern most structure of the Surghar-Shinghar Range. The eastern flank of the anticline is eroded to form steep scarps, exposing the high angle trace of the Surghar Thrust (the Dara Tang fault). Two joint sets NS/NNE and EW/WNW are observed at the southern flank of the SMM-anticline, where the strike of the strata is about east west. These joints are restricted to the hard sandstone bands of the Dhok Pathan and Nagri formations. Field observations show that NS/NNE oriented joints are compressional and E W M

oriented joints are extensional in geometry. The orthogonal relationship of compressional and extensional joints yields rectangular blocks (15x6cm) in the hard sandstone bands. Minor folds with fold axes and axial planes parallel to the compressional joints (NS/NNE) are not uncommon.

The area also contains two sets of strike-slip DBSZs that cut across the sedimentary strata at high angles. The NS steeply oriented DBSZs are strongly banded foliated, with mesoscopic dextral sense of movement. These DBSZs are common and well developed on the south-eastern part of the SMM-anticline. The second set with ~501°- 600° orientation comprising incipient tabular DBSZs with sinistral movement, cut across the fabric of the NS oriented DBSZs. The two DBSZs form a conjugate geometry.

The frequency of these DBSZs is high close to the trace of the Dara Tang fault. Since, the Dhok Pathan Formation is the youngest lithological unit in the area (0.8Ma), the presence of both the joints and DBSZs in the upper levels of the formation suggests on-going neo-tectonics in this region. Based on field evidences, three deformational phases have been suggested for the formation of joints and shear zones. The compressional and extensional joints with a component of folding are formed simultaneously in the first deformation phase. This is followed by the second deformation phase in the form of NS oriented banded shear zones. The third deformational phase is characterized by the oriented tabular shear zones, which sinistral cut the NS oriented banded shear zones at an angle of about 500-600°. The dynamics of the SMM anticline in the context of regional tectonics suggest that the structure experienced compression from west to east during the fold formation. The southern flank of the SMM anticline, where the strike of the beds is east west, is recognized as the plunging hinge area of the fold. Thus, the east-west oriented beds experienced east-west compression and north-south extension in the form of joints and minor folds. We assume that the origin of both compressional and extensional joints in the Mochi Mar and pan of the Qabul Khel areas may be related with the folding of SMM anticline. As the north-south oriented Dara Tang fault (Surghar Thrust) cuts across the sedimentary strata passing at the core of the SMM anticline the DBSZs in the area appear to be dynamically related with this fault.

Key words: Neo-tectonic, deformation, siwalik group, Trans-Indus Salt Range.

S/85. Sayab, M., Khan, M.A. & Jan, M.Q., 1997. Geology of the Nanga Parbat syntaxis along the Astor valley transect, Northern Pakistan. Geological Bulletin, University of Peshawar 30, 285-296.

The Nanga Parbat-Haramosh syntaxis represents the youngest phase of thermal, tectonic and metamorphic activity in the Himalaya. The syntaxis is an active crustal-scale antiformal structure comprising Indian plate basement gneisses and cover sequence. The Nanga Parbat rocks in the Indus gorge section have previously been divided into grey Iskere gneiss and pink Shengus gneiss. Along the Astor valley transect, south of Indus valley, several new lithological units have been identified. These include 1) Mushkin grey gneiss 2) Harchu pink gneiss and 3) Rattu formation. The Mushkin gneiss is medium-grained, locally-porphyroclastic gneiss of grey colour probably representing the basement complex. Harchu pink gneiss is clearly derived from a sedimentary protolith (as suggested by the preserved relicts of quartzite, calc-silicate components and preserved sedimentary structures). The Rattu formation comprises meta-pellites, marbles, calc-silicates pods and lenses and is considered to represent a metamorphosed cover sequence. Structural cross-section from north-west to south-east reveals that the Nanga Parbat sequence consists of two crustal-scale antiformal structures with a tight faulted synform in between. It is noticeable that the Mushkin grey gneiss exhumed with respect to the cover sequence at the margins. Field and petrographic data show that the Rattu formation and Harchu pink gneiss reaches up to kyanite and sillimanite metamorphic grades, whereas the Mushkin grey gneiss lacks these minerals. The Mushkin grey gneiss exhibits a great variety of migmatite structures, indicating that the Mushkin grey gneiss has experienced more severe metamorphic conditions than any other rock unit in the Astor section. Our preliminary studies indicate possibilities of correlation between Mushkin and Harchu gneisses from the Astor valley with the Iskere and Shengus gneisses from the Indus valley, respectively.

Key words: Tectonics, petrology, Nanga Parbat Syntaxis, Himalaya.

S/86. Sayab, M., Khan, M.A., Khattak, M.U.K. & Jan, M.Q., 1997. Geology of the Nanga Parbat syntaxis along the Astor valley transect. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.56.

Key words: Structure, Nanga Parbat Syntaxis, Astor, Himalaya.

S/87. Sayab, M., Khan, M.A. & Rafiq, M., 1999. Rotated and displaced clay balls as kinematic indicators along shear zones in sandstones of the Siwalik group of Surghar-Shinghar Range, Trans-Indus Ranges, Pakistan. *Geological Bulletin, University of Peshawar* 32, 89-104.

Neo-tectonic events in the Siwalik Group of Surghar-Shinghar Range are characterized by compressional, extensional and conjugate shear fractures. The compressional fractures are in the form of reverse faults mainly along clay ball scoured surfaces. The sense of shear in these fractures is interpreted from rotated and displaced clay ball geometry. Shearing along these weak planes provide kinematics of clay ball geometrical behavior and their mechanical strength characteristics under surface PIT conditions. Most of the displaced clay balls are moderately hard due to the presence of carbonates, while others constitute some fine carbonaceous material. Thus, the displacement in the clay balls is controlled by their hardness. Some displaced clay balls show nice geometrical arrangement of Riedel fracture sets accommodating strain during shearing. Despite near-surface conditions (i.e., incohesive-brittle) the clay balls, due to the inherited plastic character of clays, form structures resembling those in plastic regimes of deformation. These structures include asymmetric rotated clay balls with tail edges just like in porphyroclasts, while others are equally rotated forming oxidized boundaries within the sandstone matrix with no tail edges. The kinematics of both rotated and displaced clay balls show reverse sense of shear all along the compressional faults.

Key words: Shear zones, sandstone, siwalik, Trans-Indus Salt Range.

S/88. Sayab, M., Mazhar, F., Butt, K.A. & Khan, M.A., 2001. Structure of the Surghar Range at its southeastern flank with emphasis on Surghar Thrust. Abstracts, 4th Pakistan Geological Congress, Islamabad, 38-39.

Field observations are made on the southeastern flank of the Surghar Range. The east verging Surghar anticline is deeply eroded in this part of the range, exposing steep scarp of the Surghar Thrust, together with the older formations in its hanging wall. The thrust runs along the eastern margin of the Surghar anticline, bringing Punjab foreland alluvium in contact with upper Permian and Mesozoic rocks in the northern, and Neogene rocks in the southern parts of the fault trace. A number of thrust splays are recognized in the area to the south of Mitha Khattak village, where the thrust splits into several oblique-slip faults. These shear zones are typically brittle, generally cutting across the strata. These shear zones are lined with cataclasites and show distinct asymmetric kinematic indicators commonly found associated with reidel fractures.

Overall the N-S trending Surghar Range is divisible into two anticlines; Makarwal anticline in the north and Sarkai-Mochi Mar anticline in the south. These two are separated by an exceptional low topographic relief, which is defined by a syncline termed Gulapa-Darsola syncline in this study.

Key words: Structure, Surghar Thrust, Trans-Indus Salt Range.

S/89. Sayab, M., Qadir, A. & Khan, M.A., 2000. Structural styles, kinematics and shear zone geometries in sandstone of Pliocene Dhok Pathan Formation, Qubul Khel, Southern Surghar Range, Bannu Basin, Pakistan. Late Abstracts, Third South Asia Geological Congress, Lahore, 3-4.

Key words: Structure, sandstone, Pliocene, Dhok Pathan formation, siwaliks, Bannu basin.

S/90. Scally, F.A. de, 1989. The role of avalanche snow transport in seasonal snow melt, Himalaya Mountains, Pakistan. Ph.D. Thesis, University of Waterloo, Ontario.

Key words: Glaciers, avalanche, Himalaya.

S/91. Scally, F.A. de, & Gardner, J.S., 1990. Ablation of avalanched and undisturbed snow, Himalaya Mountains, Pakistan. *Water Resources Research* 26, 2757-2767.

Avalanche deposits represent a significant storage of winter snow on the south slope of the Himalaya Mountains, Pakistan, complicating the annual snowmelt cycle because of the differences in ablation of avalanche-transported snow and undisturbed snow. Measurements show very high rates of melting of both snow types, particularly of avalanche snow late in the melt season. The high rates are a function of the low latitude of the study area and the low elevation of the avalanche snow deposits, as well as heat release by condensation. Air temperature was closely correlated with daily snowmelt and appears to hold promise as a predictor, however, data constraints prevent an energy balance analysis of this relationship. Gravimetric measurements show that condensation is important in the snow surface energy exchange and can represent a significant source of energy for snowmelt. Rainfall during warm conditions also makes a more significant contribution to snowmelt than shown in previous studies. The derived temperature-based melt factors or coefficients compare well with published figures from other mountain areas, but their confidence limits are sufficiently wide to produce significant errors in the prediction of basin snowmelt runoff.

Key words: Glaciers, snow ablation, Himalaya.

S/92. Scarascia, S., Colombi, B., Guerra, I. & Luongo, G., 1982. Preliminary report on seismic measurements along the profile Lawrencepur-Astor. *Rend. Acc. Naz. Lincei*.

Key words: Seismology, Lawrencepur-Astor.

S/93. Schärer, U., Copeland, P., Harrison, T.M. & Searle, M.P., 1990. Age, cooling history and origin of post-collisional leucogranites Karakoram Batholith, a multi-system isotope study. *Journal of Geology* 98, 233-251.

U-Pb dating on zircon and monazite from different varieties of leucogranites in the Karakoram Batholith reveals two distinct pulses of plutonism at $25.5 \pm 0.3/-0.8$ and $21.4 \pm 0.3/-0.6$ Ma. In both granites, these minerals contain inherited components, documenting the presence of Precambrian material in the magma source. A crustal origin of the granites, and long crustal residence times of the source rocks are confirmed by highly negative ϵ^{Nd} , strongly positive ϵ^{Sr} , and T^{Nd} DM in excess to 1 Ga. A biotite gneiss and a granitic dike from the Karakoram Metamorphic Complex south of the batholith yield very similar ϵ^{Nd} , ϵ^{Sr} , Sr , T^{Nd} DM. In a Pb evolution diagram, initial isotopic compositions for both the granites and the rocks from the metamorphic complex plot far above the reference field for MORB documenting very close affinity to the Eurasian (Tibetan) continental crust. The striking similarity of isotope signatures between leucogranites and the rocks in the metamorphic complex strengthen the view that granite source material lies in the metamorphic complex. $^{40}Ar/^{39}Ar$ step heating analyses from the leucogranites yield isochron ages of 6.4 ± 0.1 and 7.4 ± 0.2 Ma for biotite, 6.6 ± 0.1 and 6.4 ± 0.1 Ma for muscovite, and 4.6 ± 0.2 Ma for K-feldspar. The two rocks from the metamorphic complex define isochron ages of 10.6 ± 0.1 and 4.7 ± 0.1 Ma for biotite, 14.9 ± 0.3 Ma for muscovite, and 8.9 ± 0.4 and about 4 Ma for K-feldspar. All K-feldspars analyzed contain trapped non-atmospheric Ar components to various degrees. The radiometric ages show that the leucogranites cooled from $750-650^{\circ}C$ at 25-21 Ma to $250-350^{\circ}C$ at 6 Ma, i.e., their cooling through the Ar blocking temperature in mica and K-feldspar occurred 15 to 20 Ma after granite emplacement. This strongly suggests a major and rapid uplift in latest Miocene to Pliocene times. In contrast to the leucogranites, cooling of portions of the metamorphic complex reached mica-K-feldspar blocking temperatures about 5 to 10 Ma earlier, documenting earlier uplift in the Karakoram Metamorphic Complex than in the Karakoram Batholith.

Key words: Geochronology, cooling history, leucogranites, Karakoram Batholith.

S/94. Schlinger, C.M., Khan, M.J. & Wasilewski, P., 1989. Rock magnetism of the Kohistan island arc, Pakistan. *Geological Bulletin, University of Peshawar* 22, 83-101.

In Northern Pakistan a section of island arc crust is exposed in Kohistan, northwest Himalaya. To better understand how magnetism and magnetic mineralogy depend on metamorphism, crystalline rocks of the Kohistan island arc have been studied, by means of field and laboratory investigations. The results are based on susceptibility and sampling traverses over 500 km in length, and rock magnetic and petrographic study of collected samples. Measurements and sampling concentrated on two profiles through Kohistan, one following the Swat River, the other following the Karakoram Highway. Of the lithologies sampled along these two profiles, the main sequence of interest consists of

rocks of the Kohistan island arc. With the exception of volumetrically minor serpentinized ultramafic rocks, the magnetic lithologies are pyroxene granulite, and gabbro-norite of the Chilas complex. Amphibolites, garnet granulites, metasupra-crustals and Kohistan arc diorites and granites are only weakly magnetized. The same is true Karakoram batholith granitoids. As far as prograde metamorphism of moderate to high-grade mafic rocks in the section is concerned, magnetic pyroxene granulites are strongly magnetized, relative to amphibolite facies equivalents and garnet granulites. Considering all lithologies, the calculated Koenigsberger's ratios are generally less than 2 (110 of 127 samples), commonly less than 1 (89 samples), and rarely in excess of 10 (3 samples), which indicates that the magnetization of these rocks is rarely dominated by remanence. The directions of natural remanent magnetization (NRM) are scattered, with a mean declination not far from zero, and a positive mean inclination. Petrographic and electron microprobe study of mineral assemblages and textures related to retrogressive metamorphism of pyroxene and garnet granulites shows that amphibolite facies overprinting along planar zones was an Fe-Ti oxide-consuming event. Lamellae of magnetite in magnetite-ilmenite intergrowths were replaced by silicates during retrogressive metamorphism of the pyroxene granulites. Regional-scale magnetic structure in this part of the crust is defined by magnetic contrasts between the Chilas complex and the surrounding Kamila amphibolites and Kohistan granites and diorites.

Key words: Magnetism, metamorphism, Kohistan Island Arc.

S/95. Schmetzer, K. & Bank, H., 1975. Geschliffene grossular-chlorit-epidot-hornfelse aus Pakistan. Zeits. Deutschen Gemmologischen Gesell 24, 245-247.

Material from Pakistan was found to have refractive index 1.730 and specific gravity 3.38-3.40. known as grossular, it consists of the minerals listed in the title.

Key words: Gemology.

S/96. Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Khan, M.A., Seeber, L. & Zeitler P.K., 1999. Tectonics of Nanga Parbat, western Himalaya: Synkinematic plutonism within the doubly vergent shear zones of a crustal-scale pop-up structure. Geology 27, 999-1002.

Detailed mapping and geochronologic investigations from the eastern, southern, and western Nanga Parbat-Haramosh massif reveal two thrust-displacement shear zones that have a spatial and temporal link with granite plutonism from ca.10 to 1 Ma. The shear zones define a crustal-scale antiformal pop-up structure, with dominant west-northwest-vergent and subordinate east-southeast-vergent thrusting. This substantially different than the surrounding area where the main exposed Himalayan structures are oriented parallel to the orogenic trend and are early to middle Miocene or older. Structures mapped throughout Nanga Parbat demonstrate that its rapid and young exhumation is not due to orogen-scale structural unroofing, and that sustained high erosion rates are required. The observed west-northwest-directed shortening is proposed to be a result of different arc-parallel motion accommodated at the syntaxial bend of the northwest Himalaya.

Key words: Tectonics, geochronology, synkinematic plutonism, Nanga Parbat.

S/97. Schneider, D.A., Edwards, M.A., Kidd, W.S.F. & Zeitler, P.K., 1999. Geochronologic summary and lithotectonic architecture of the Nanga Parbat-Haramosh Massif, NW Himalaya. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 137-138.

The Nanga Parbat-Haramosh massif (NPHM), most notable for its extremely young metamorphic and igneous ages, represents the most northerly exposure of Indian craton. Reworking of the Indian craton in the last 10 m.y. has been of a large enough scale to apparently fully overprint the Himalayan signature. Previously reported leucogranite crystallization ages for NPHM are markedly younger from those reported elsewhere in the Himalaya. Undeformed leucogranites within the massif show a southward younging of accessory mineral U- (Th)-Pb ages: a 10 Ma pluton in the north, to 5 Ma dikes along the Indus and Astor Valleys, and ~2 to 1 Ma dikes, stringers and larger plutons in the south near the main summit (Zeitler and Chamberlain, 1991; Zeitler et al., 1993; Schneider et al., 1997). To the SE and SW of the summit, leucogranites again increase in age: in the SE, a dike which cross cuts the Rupal shear yields monazite ages from 17-9 Ma as well as the Early Miocene Southern Chichi pluton (Schneider et al., this vol.):

to the SW, the much larger, and deformed, Jalhari granite yields monazite ages from 8-2 Ma, and in a separate sample 13 Ma. Thermochronologic results from basement micas are very young and indicate a similar southward-younging pattern, also with a marked age increase to the SE and SW, yielding typical Himalayan cooling ages in those areas.

In the central portions of the massif are found the highest-grade rocks and youngest ages. Zeitler et al. (1993) obtained a ~1 Ma zircon U-Pb age for the Tato pluton. Subsequently, for the Mazeno Pass pluton, the opposite (southern) side of the Nanga Parbat summit ridge from the Tato pluton, we (Schneider et al., 1997) obtained strikingly coincident zircon and monazite U-Th-Pb ages of 1.4 Ma. That the 1.4 Ma age is obtained on both zircons and monazites for a larger body of granite illustrates the degree of very young melting.

A number of the granites cross-cut large crustal scale shear zones, hence post-dating the displacement on, and constraining the timing of, the shear zones. Along the NW margin, a small, undeformed tourmaline-bearing granitic dike, which crosscuts the high strain fabric of the MMT yields an age of 7 Ma, requiring that deformation along the MMT ceased by at least that time. This is in agreement with the conclusions of Pêcher and Le Fort (in press) which suggest that ductile deformation ended around 7-6 Ma on the Nanga Parbat-Karakorum suture to the north. Deformation in the north was due to doming and the entire northern section of the massif behaved as a single crustal block (Pêcher and Le Fort, in press).

Along the Rupal shear zone, south of the Nanga Parbat summit, the 2-1 Ma Rupal dikes also provide key timing constraints on structures and fabrics of the Rupal valley; the oldest crystallization age gives the minimum age of deformation. In this case the oldest dike dated in this study gives an age of 2.3 Ma. Thus, cessation of ductile deformation had to occur before 2.3 Ma. Furthermore, dike emplacement was coeval with cooling where the dike ages are similar to the Ar/Ar biotite cooling ages in the valley. This suggests the dikes were emplaced into shallow crustal levels, the melt having possibly migrated along the Rupal shear and into fractures accompanying the general uplift and erosional unroofing. The ages and structural orientation of the Rupal dikes compare well with those of the dikes and stringers on the north side of the summit which give ages between 3 and 1 Ma (Zeitler et al., 1993). These were emplaced, and somewhat deformed, into the Raikot-Lichar shear zone. Furthermore, monazites from two deformed granites along the WNW margin of the massif (at Jalipur and Diamir) yield ages as young as 5-3 Ma. This implies that deformation in southern Nanga Parbat (south of Indus-Astor confluence) has ceased much more recently (4-3 Ma) than the north (Haramosh; 7 Ma), and the southern NPHM, like the north, may have behaved as a single crustal block, bounded to the south by the Rupal and Diamir shear zones.

Crystallization ages on the SE margin of the Rupal valley are significantly older. Both the geochronology of a thin leucogranite dike (mentioned above) which cross-cuts the fabric of the SE Rupal shear in Chichi valley and the thermochronology of the shear zone rocks constrain the age of that portion of the Rupal shear zone to having ceased by 10 Ma, if not older (Schneider et al., in press).

The basement lithology is fairly monotonous with ages from zircon cores showing a ubiquitous Early Proterozoic inheritance, typically clustering around 1870-1850 Ma. This, as noted by Whittington et al. (1998), is similar to the Early Proterozoic inheritance of the Lesser Himalayan sequence in the central part of the orogen and therefore differs from the High Himalayan Crystallines that are common to the NW Himalaya which NPHM has long been considered a part. The Early Proterozoic zircon inheritance exists in all of the massif's units: gneisses, schists, metasedimentary rocks and larger granite bodies (Zeitler et al., 1989; Zeitler and Chamberlain, 1991; Zeitler et al., 1993; Schneider et al., 1997; Schneider, unpub data). Only a few isolated granites do not contain inheritance: the smaller leucogranite dikes and, surprisingly, the larger Jutial pluton (Schneider et al., 1997). Markedly younger than the other units in the massif, Zeitler et al. (1989) report zircons from a sample of the Shengus gneiss, in NE Nanga Parbat, yielding a 500 Ma inheritance; this sample lies near the generally agreed upon 'basement-cover' contact. Our new results from granitic rocks at Manugush (Bunar Gah, SW Nanga Parbat) indicate a yet another unit, which yields a Cambro-Ordovician age. Zircons from the porphyroclastic garnet-muscovite, -kyanite gneiss with cm long feldspar laths yield concordant U-Pb ages of 480 Ma. A petrologically similar augen gneiss (termed 'lath unit') was described by Edwards (1998) on the SE side of Nanga Parbat (Astor Valley); Foster et al. (this vol.) have obtained —500 Ma monazite ages from the cores of garnets within the lath unit. These samples also occupy the contact between the Nanga Parbat gneisses and the cover sequence. Based upon 1) the 'basement-cover' relationship across a large area, 2) the age, and 3) the similar petrologic nature between the W and E localities, we suggest that the Cambro-Ordovician lath unit was originally a largely continuous unit within the mass if, intruding into the 'basement-cover' contact. Edwards (1998) has suggested that the unit was intruded during, and subsequently underwent some of, the deformation associated with the main displacement of the MMT. The unit may be faulted and eroded away on the active western margin of the massif. Other sections of the NW Himalaya (Pakistan and India) and in Nepal also contain Cambro-Ordovician intrusions which, based on geochemical data, were generated by anatexis of continental crust (Miller and Frank, 1992).

In summary, the Nanga Parbat massif is mostly Early Proterozoic basement with interleaved deformed Cambro-Ordovician granites, reworked and exposed as recent as 2-3 Ma in the summit region. The overall structure, concentric metamorphic isograds and age pattern indicate the appearance of a young gneiss dome 'popping-up' on conjugate shear zones through Indian cover metasediments which have 20-30 Ma cooling ages.

Key words: Geochronology, lithotectonic, Nanga Parbat-Haramosh Massif, Proterozoic, NW Himalaya.

S/98. Schneider, D.A., Edwards, M., Kidd, W.S.F., Zeitler, P. & Coath, C.D., 1998. Magmatism and deformation within Nanga Parbat-Haramosh Massif, Pakistan Himalaya. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 176-178.

Background: A general association of young plutonism, deformation, and cooling within the Nanga Parbat-Haramosh massif (NPHM), Pakistan Himalaya, is clearly recognized (e.g., Zeitler and Chamberlain, Tectonics, 1991). Previously reported leucogranite crystallization ages for NPHM are markedly younger from those reported elsewhere in the Himalaya. Undeformed leucogranite dikes within the massif give U-(Th)-Pb zircon and monazite ages of <2 to 7 Ma (Zeitler and Chamberlain, Tectonics, 1991; Schneider et al., EOS, 1997) with the youngest ages found near the summit regions. Leucogranite dikes occurring near or within major shear zones are typically emplaced into tension gashes that are at a high angle to the principal shear zone orientation and with fracture geometries that are suggestive of subvertical opening. Larger intramassif plutons include 1) Tato, U-Pb zircon rim ages of ~1 Ma (Zeitler et al., Geology, 1993), 2) Mazeno Pass, U-Th-Pb zircon and monazite ages of ~1.4 Ma and 3) Jutial, U-Th-Pb zircon and monazite ages ~10 Ma (Schneider et al., EOS, 1997). The Tato and Jutial plutons lie on the NPHM western margin and have intruded into the active Raikot-Liachar fault system; the Mazeno Pass pluton has intruded along the northwestern tip of the Rupal-Chhichi shear zone (RCSZ). This shear zone is comprised of a large belt of NW dipping, porphyroclastic granitic orthogneiss with a ubiquitous non-coaxial fabric that is consistent with accommodation of southeast vergence of southern NPHM (Edwards et al., 12th HKT, 1997a). Notably, the RCSZ is coincident with a rapid increase in Ar/Ar biotite cooling ages to the southeast (Schneider et al., EOS, 1997). Another significant break in biotite cooling ages occurs across a broad ~N-S trending zone in southwest NPHM. Argon biotite cooling ages on the western side of this zone are 20-30 Ma, whereas on the eastern side (towards the summit) cooling ages are 6 Ma and younger (Schneider et al., EOS, 1997). We present here new geochronologic data from leucogranites within NPHM, which, together with new field observations (Edwards et al., this vol) and previous data (summarized above), can provide significant new constraints on the spatial and temporal association between plutonism and deformation within NPHM.

New data: Edwards et al. (this vol) report a large plutonic sequence (the Jalhari granite) that grades into granitic and porphyroclastic orthogneiss as a result of syn to post-deformational plutonism. This granite and gneiss belt is a ~5 km wide, ~30 km long N-S trending zone that marks the large cooling age discontinuity on the southwest corner of Nanga Parbat. Sense of shear is east side up, consistent with upward and westward displacement of NPHM. Ion microprobe Th-Pb monazite analyses of a deformed, biotite-rich portion of the Jalhari granite (near the village of Diamroi) yielded ages between ~3 and 9 Ma. These ages fall along a line which increases with increasing Th/U ratios. Backscatter/SEM images of the analyzed monazite grains indicate some that have a non-uniform texture, notably lacking clear core-rim zoning patterns. This chaotic textural pattern is too fine to allow analysis of any single composition within a grain, despite the very small beam size (~15-20 microns) of the ion microprobe. However, a few texturally homogeneous grains were analyzed; these yielded the youngest of our obtained ages (~3-4 Ma). Near Garal, 13 km south of the village of Diamroi, we sampled an undeformed medium grained granite, which is adjacent to, and possibly part of, the same Jalhari granite. Ion microprobe analyses of monazite grains yielded Th-Pb ages of 12 Ma. Th/U ratios of these monazites fall along the same trend as those of the Diamroi (deformed) granite. Our interpretation of the Jalhari granite is as follows:

an initial pulse(s) intruded and crystallized as young as ~12 Ma, 2) ongoing synkinematic magmatism (as represented by the patchy monazite grain textures indicative of multi-stage growth history) resulted in further pulses that juxtaposed deformed and undeformed portions of the granite, and 3) final crystallization was around 3.5 Ma. This 3.5 Ma lower age limit is consistent with our cooling ages on the southwestern side of the massif, inboard and east of the Jalhari granite belt.

In southern Nanga Parbat, we sampled a small (tens of cm) little-deformed granite dike which discordantly cuts orthogneiss of the Rupal-Chhichi shear zone in northern Chhichi Gah. Like the Jalhari granite, this granite dike also yielded a scatter of Th-Pb monazite ages, in this case between 9 and 17 Ma; these ages also fall along an increasing line with increasing Th/U ratios. BSE/SEM images of the monazites show a similar appearance to the monazites of

the Jalhari granite. Biotite cooling ages from the northern section of Chhichi Gah give ages of 9-10 Ma (Schneider, unpub data). As within SW NPHM, the cooling ages are concordant to the lower Th-Pb monazite age. We infer that most of the displacement along this ('outboard') portion of the RCSZ occurred prior to 9-10 Ma and, similar to the shear zone associated with the Jalhari granite, plutonism was focused within the shear zone.

Discussion

Our new results indicate a fundamental association between plutonism and the major NPHM shear zones. None of the numerous granites seen within NPMH are of large areal extent and we infer that there has not been a widespread melting event (c.f., High Himalaya leucogranites; e.g., Harrison et al., *Geology*, 1997) but numerous anatectic pulses over the last ~10 Ma (Butler et al., 1997). Magnetotelluric studies show that there is no significant partial melt zone directly beneath NPHM (Park and Mackie, *GRL*, 1997), consistent with anatexis that is restricted to small volumes and/or distinct episodes. The observed proximity of granites to shear zones suggests to us that these anatectic episodes may be related to deformation. We propose a conceptual model where crustal thickening and/or decompression melting promotes small amounts of melting and deformation enhanced melt extraction (e.g. Thompson & Connolly, *Earth-Sci. Rev.*, 1995) allows melt migration to existing (or resulting) shear zones. This process

May be strain rate sensitive, whereby local anatexic episodes are a result of higher strain rates. With deformation enhanced melt migration, sufficient increase in melt percentages are rapidly attained, initiating melt migration that likely focusses within the shear zone (e.g Brown, *Earth-Sci. Rev.*, 1994). These melt-filled shear zones are then sites of thermally weakened material that are the focus of further deformation, including when the material is cooling through the solidus. This creates a positive feedback situation whereby the presence of melt enhances deformation, and within the existing weak (shear) zone periods of granite emplacement continually reoccur.

Key words: Magmatism, deformation, tectonics, Nanga Parbat-Haramosh, Himalaya.

S/99. Schneider, D.A., Edwards, M.A., Kidd, W.S.F., Zeitler, P.K. & Coath, C.D., 1999. Early Miocene anatexis identified in the western syntaxis, Pakistan Himalaya. *Earth and Planetary Science Letters* 167, 121-129.

Evidence for typical Himalayan Early to Middle Miocene anatexis has remained elusive in the Nanga Parbat massif in the western Himalaya of Pakistan; previous work has identified only young plutonism (10-1 Ma). New U-(Th)-Pb data from the southern Chichi granite, a leucogranite in southern Nanga Parbat, reveal that crustal melting occurred during the Early Miocene. This largely undeformed, fine-grained pluton intrudes the Indian metasedimentary cover sequence adjacent to the Rupal shear, a major shear zone at Nanga Parbat. Th-Pb ion microprobe analysis of monazites from the Chichi granite yield ages between 22 Ma and 16 Ma, with majority of analysis lying at 19-18 Ma. U/Pb zircon analysis yields ages, which fall along a chord with lower intercept age of 19 Ma. The zircons also contain an ~1850 Ma inherited component. These data indicate that the Early Miocene anatexis that is ubiquitous in central portions of the Himalayan orogen, unreported anywhere in the NW Himalaya, also occurred in the western Himalayan syntaxis, and demonstrates that Nanga Parbat has a protracted melting history. A small granitic dike that cross-cuts the outer portion of the Rupal shear yields monazite ages between 22 Ma and 9 Ma, where the young ages correlate with high U concentrations. ⁴⁰Ar-³⁹Ar biotite ages from adjacent gneisses indicate cooling by 10 Ma, requiring significant displacement on this portion of the Rupal shear to be older than ~10 Ma and possibly as old as ~20 Ma.

Key words: Miocene, Nanga Parbat Massif, pluton, Himalayan Syntaxis.

S/100. Schneider, D.A., Edwards, M.A., Zeitler, P.K. & Coath, C.D., 1999. Mazeno Pass pluton and Jutial pluton, Pakistan Himalaya: age and implications for entrapment mechanisms of two granites in the Himalaya, *Contributions to Mineralogy and Petrology* 136, 273-284.

Zircon and monazite U-(Th)-Pb ion microprobe analysis were performed on the Mazeno Pass pluton and the Jutial pluton, two leucogranite bodies within the Nanga Parbat-Haramosh massif (NPHM), Pakistan Himalaya. Zircon rim ages and monazite ages indicate the Mazeno Pass pluton in southwest NPHM intruded at 1.40 ± 0.05 Ma; the Jutial pluton, to the north, similarly yields concordant zircon and monazite ages suggesting crystallization at 9.45 ± 0.06 Ma. The Jutial pluton was subsequently intruded by leucogranite dikes at 5.3 Ma, as revealed by monazite ages. Concordancy of U-Pb and Th-Pb accessory mineral ages demonstrated the robustness of the technique on young rocks. Both plutons, some of the youngest in the Himalaya, have a general association with nearby shear zones that

we interpret to have played an integral role in granite evolution and emplacement setting ('deformation enhanced ascent'). Together with new field observations, these results provide an insight on the spatial and temporal relationship between plutonism and deformation relating to the development of the massif.

Key words: Mazeno Pass, Jutial pluton, Nanga Parbat, shear zones.

S/101. Schneider, D.A., Edwards, M.A., Zeitler, P.K. & Kidd, W.S.F., 1997. Ion microprobe U-Th-Pb and $^{39}\text{Ar}/^{40}\text{Ar}$ geochronology of Nanga Parbat-Haramosh Massif (part 1). Rupal Valley, southern Nanga Parbat, and Jutial granite, Haramosh area. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 205-206.

The Nanga Parbat-Haramosh massif (NPHM), northern Pakistan-NW Himalaya syntaxial region-is a tectonic half window of partly re-worked, largely Proterozoic, Indian plate rocks that have been exhumed from beneath Mesozoic arc rocks of the Kohistan Ladakh Area. The metamorphic and thermal evolution of this anomalously hot, young massif has remained elusive.

Using UCLA's National Ion Microprobe Facility, young U-(Th)-Pb ages on accessory minerals have been obtained. Single-grain, single-spot analyses were performed on zircons and monazites from basement rock and granites. Single-grain, total-fusion $^{39}\text{Ar}/^{40}\text{Ar}$ laser experiments were performed at Lehigh University to obtain cooling data of biotites in country rocks. We report here new geochronologic data, predominantly from southern NPHM, including the first in-Pb monazite age for a large leucogranite body, the Jutial granite.

We have conducted extensive sampling along the Rupal drainage through the southern flank of Nanga Parbat in conjunction with detailed structural mapping (Edwards and Kidd, this volume). In many cases, the tectonic role identified for mapped principal structures is further supported by results of geochronologic investigations.

The Mazeno Pass pluton (5400m) is a notably undeformed, tourmaline and biotite absent, fine-grained, muscovite granite which cross-cuts foliation of local biotite gneiss. U-Pb zircon analyses record a discordant age with an upper intercept of ~1860 Ma, representing the Precambrian protolith age, typical for the NPHM; this age is consistent with those of nearby gneisses and schists. The lower intercept is defined by a cluster of concordant zircon ages at ~1.4 Ma. Moreover, monazite from the same pluton also yielded a in-Pb age of ~4.4 Ma. Accordingly, we take 1.4 Ma as the intrusion age of the Mazeno Pass pluton.

In the central portion of Upper Rupal Valley (largely between Rupal and Shigiri villages), cm-in scale dykes invading granitic augen orthogneiss are found. These predominantly muscovite rich, tourmaline-bearing pegmatites are abundant throughout the massif and typically trend ~N-S, however, in central Upper Rupal they trend ~W-E and dip N, locally reflecting gneissic fabric (Edwards and Kidd, this volume). We sampled two Rupal dykes and obtained a monazite age of ~1.2 Ma from the first, and zircon and monazite ages of ~2.2 Ma from the second. Such leucogranites within the massif have been suggested to be the result of decompression melting, allowing intrusion at shallow depths (Zeitler and Chamberlain, 1991).

A staurolite-kyanite-garnet schist sampled from Rupal valley, near the village of Tarshing gives U-Pb zircon ages clustering near or below concordia at ~1 860 Ma; furthermore, a few ages also fall along a discordia toward the origin with a lower intercept age of <5 Ma. Approximately 1-km south of Tarshing, up Chichi valley, both the biotite schist and the samples from the eastern edges of a ~SW trending, thick (kms), extensive belt of S-C fabric porphyroclastic granitic augen gneiss (the Rupal Shear Zone, see below) give a suite of total-fusion $^{39}\text{Ar}/^{40}\text{Ar}$ ages of >15 Ma. These differ sharply from the young (1.2 & 2.2 Ma) ages west and north of the Rupal shear zone, and indicate a marked contrast of exposed crustal depths, based upon the large displacements required by Rupal valley structures. An even larger age contrast is found in SW Nanga Parbat: A broad suite of total-fusion $^{39}\text{Ar}/^{40}\text{Ar}$ biotite ages mainly between 20 and 30 Ma are found for the area of Indian cover metapelites in Niat and Barai valleys (5-10 km W of Mazeno pass). Between Thia area and Mazeno / Toshe Gali, there is a steep ~NNE trending belt of faults that can be traced to both (1) the Tato shear in the Raikhot valley, and (2) the large thrust near the Indus at Raikhot/Liachar, where it locally forms the western margin of NPHM (the contact with Kohistan).

We propose that the Raikhot/Liachar southward continuation, and the Rupal shear zone, and other significant structures in the uppermost Rupal valley (Edwards and Kidd, this volume), have accommodated uplift of central Nanga Parbat on the W, S & E sides. We note that here on the Nanga Parbat southern flank, unlike the central and northern regions of NPHM, the shear zones that have accommodated "block uplift" are substantially inboard of the W & E margins (margins of India to Kohistan Ladakh Area). The area within these shear zones has enjoyed prolonged elevated temperatures sufficient to maintain open system behavior of Ar until a period coincident with plutonism and melting nearby. We regard peak metamorphism here to be contemporaneous with plutonism, and not to post-date it.

In the northwestern portion of the NPHM ("Haramosh area"), the Jutial granite is predominantly a two-mica, tourmaline granite, essentially undeformed. It intrudes and cross-cuts the surrounding quartzofeldspathic Nanga Parbat grey gneisses (termed "Jskere Gneiss", Madin et al., 1989). The approximate size of the body is difficult to determine, but our field observations suggest a diameter of at least 5 km. Observations by Butler and co-workers (1992), suggest at least two phases of intrusion can be distinguished. Two samples from the main body of the Jutial pluton were analysed: (1) a medium grained, tourmaline speckled granite and (2) a pegmatitic version of the same rock. The appearance of this second, pegmatitic rock is similar (large muscovite books, tourmaline) to the very young leucogranite pegmatites of the southern portions of the massif. Both samples yielded concordant U-Pb zircon ages of 10 ± 1 Ma. A second igneous phase was also examined. This yielded am-Pb monazite age of 5.2 ± 0.3 Ma. This phase lacks the amount of muscovite that the main body contains. Additionally in this phase, tourmaline is euhedral and roughly equal-granular (1-2 cm) and is distributed homogeneously throughout the rock. Previously reported biotite and muscovite $^{39}\text{Ar}/^{40}\text{Ar}$ cooling ages from the Jutial granite are ~5-6 Ma (George et al., 1995). It is noteworthy that our two new ages for Jutial occupy >50% of the time period occupied by the sudden and recent uplift of NPHM (i.e. since ~10 Ma). This suggests that the history of both plutonism and metamorphism is complex; that of a young, dynamically self-exposing area. The ~5Ma monazite age from Jutial granite is consistent with previous suggestions for young plutonism in both of the high massif areas (Zeitler and Chamberlain, 1991).

In addition to providing precise ages to identify thermal events and associated thermal and mechanical boundaries, our data has modified and refined the data array illustrated in Winslow et al. (1996). This now shows that within NPHM there has been differential exhumation and magmatism from north to south (younger in the south) reaching sufficiently large and well-localized displacements to involve major intra-massif shear zones, hitherto unreported for NPHM. This is a contribution from the Nanga Parbat Continental Dynamics Project

Key words: Microprobe, geochronology, Nanga Parbat, Jutial granite, Haramosh.

S/102. Schneider, D.A., Zeitler, P.K., Edwards, M. & Kidd, W.S.F., 1997. Geochronological constraints on the geometry and timing of anatexis and exhumation at Nanga Parbat: a progress report. *Eos Transaction of American Geophysical Union* 78, Spring Meeting Supplement 14, 111.

Key words: Geochronology, exhumation, Nanga Parbat, Geophysics.

S/103. Schneider, H.J., 1956. Bild und Bau des NW Karakoram. *Photograph Forsch.* 7, 80–91.

Key words: Orogeny, Karakoram.

S/104. Schneider, H.J., 1957. Tektonik und magmatismus im NW-Karakorum. *Geologische Rundschau* 46, 426-476.

The author described the geology of the North western Karakoram and showed that the rocks can be distinguished into laterally extending zones. The axial Karakoram batholith was considered to form a heterogeneous plutonic mass varying in composition from hornblende granodiorite to biotite granite with little or no hornblende. Such intrusions are considered to be synorogenic and of upper Cretaceous and early Tertiary age. Aplitic granite associated with the tectonic disruption of the region are post tectonic and post Oligocene.

Key words: Tectonics, magmatism, NW-Karakoram.

S/105. Schneider, H.J., 1959. Zur Diluvial Geschichte des NW-Karakorum. *Mitteilungen Geographia Gesellschaft München* 44, 201-216.

Key words: Orogeny, Karakoram.

S/106. Schneider, H.J., 1960. Geosynklinale entwicklung und magmatismus an der wende Paläozoikum-Mesozoikum im NW-Himalaya und Karakorum. *Geologische Rundschau* 50, 334-352.

Key words: Magmatism, Paleozoic, Mesozoic, NW-Himalaya, Karakoram.

S/107. Schneider, W., 1976. Bodenschatz im nordwestlichen Pakistan. *Aufschluss* 27(4), 147-154.

Key words: Northern Pakistan.

S/108. Schomberg, Col. R.C.F., 1935. Some glaciers of upper Chitral. *The Alpine Journal* 47, 98-102.

On the 8th, 9th and 10th there was severe wind and snow at all points above Camp V. Angtsering added that during his last two days' sojourn above Camp IV the weather was good, but a great depth of snow covered everything but steep rocks.

The valley of the Yarkhun river, which during its course is known as the Mastuj, Chitral, or Kunar, is no more than a rocky trough with many lateral streams. It rises near Wakhan, in the grassy slopes of Baroghil, but it depends for its water supply on the great glaciers that are almost wholly confined to its left side: and it is this left side, with its moraines, fans, and deposits that demonstrate the great part that glaciers have played in the present condition of the Yarkhun valley in Northern Chitral. In summer this river is a swift, turgid, black flood, while its affluents are equally unlovely.

Generally speaking, the rocky formation of the Hindu Raj and the Chitrali Hindu Kush do not lend themselves to glacier making, and in a region of great rock ranges and towering peaks, the glaciers are disappointing, for there is little chance of the snow accumulating on these perpendicular slopes, while the regular and heavy rainfall (to which I shall again refer) militates against any heavy deposits of ice and snow. The hanging glaciers are insignificant, the normal glaciers seem unusually small, and the visitor is disappointed in the somewhat non-Alpine appearance of the region. I certainly was. Perhaps I hoped for too much, but I am reluctant to think that the lack of glaciers in a country where one expects many can be wholly explained by the present era being one of glacial retreat.

At Warsum (Wassum), for instance, the fine glacier torrent flowed from a spectacularly insignificant ice and snow formation. It was only when we reached the Madod stream flowing into the left of the Yarkhun river, opposite the settlement of Shost, that I saw glaciers that would repay a visit. The stream in the early part of a July afternoon was a considerable torrent; we camped at Kand, a very small village high above the river, and some 21/2 miles from the Madod valley. Next day, with Daulat Shah of Hunza, who had a profound contempt for all Chitralis, and a local guide, we started for Madod.

We began badly. Our guide led us, although protesting and reluctant, up the side of a mountain from which he assured us we should see all: and as he was the owner of the valley, we felt he ought to know and so we gave in. My own idea was to skirt the right-hand of the valley and so ascend to the glacier, to which Daulat agreed. We followed instead the proprietor, obeying the rule of trusting the local expert. We toiled up and up to a height of 14,000 ft., and then poked our heads over and looked down on the Madod nala, to discover exactly what we expected that we were right and the expert was wrong.

We had to descend into the nala; tumbling down a steep hillside, no easy matter, but with Daulat as a guide (he had, of course, never seen the place before, but had the true Hillman's instinct) we reached the bottom of the right side of the Madod valley. The stream itself lay beyond, hidden between deep conglomerated cliffs. Above this, on the left, was some poor grazing and a little cultivation. We passed through the latter, then, climbing up the steep moraine, took an hour and a half to cross. A bitter wind blew out of a cloudless blue sky. Finally, in 5 1/2 hours we reached the top of the moraine and were rewarded with a fine view; then finding a sheltered place we were able to enjoy the spectacle in comfort.

The moraine was heaped up in the centre of the valley, but from its apex we found that it sloped away between ourselves and the glaciers in a deep trough. Although the whole valley was filled with the glacier, most of the ice, after casting up this moraine mountain (for so it was), turned aside and flowed to the left where it was piled up high on the grassy slope. It was a strange spectacle to see the ice-sheet climbing up the greensward.

On its right, the glacier had left in its wake a high knife-edge of detritus which deepened the effect of the trough. The glacier immediately below us that is, between the end of the valley and the moraine was covered with stone and rubbish, but there was no sign of any water although we expected to find a small tarn. Our attention was drawn to the head of the valley where, from a circle of abrupt and jutting peaks, fine glaciers flowed down from as many

small colors, filling the bed of the valley with a clear broken mass of glittering ice. Between these flowing glaciers were hanging ones, the entire head of the valley being thus swathed in ice or snow. I estimated the length of this clear ice in the floor of the valley as 1200 yards long. Then it grew dirty as it sank lower, flowing between the old moraine and the left side of the valley. The actual snow deposits were limited to the head of the valley. On the right, facing S.E., there was not a vestige of snow and the roads were peculiarly arid and barren. On the left was a good deal of grass and a few traces of rapidly melting snow. The lower half of the valley as well as the fields referred to above contained willow and birch trees. There were no permanent inhabitants and the barley did not look very promising, but that was due as much to neglect as to the elevation, for we saw a horse calmly devouring the ripening crop and, although the guide drove it away, there was nothing to hinder it from returning. The next glacier visited was the Vedinkot and, on the way up the Yarkhun valley, we passed two or three others after leaving the Madod, but the river was impassable. Several of these glaciers were quite short, and wholly visible from the opposite or right bank. The Vedinkot or Chattiboi (a word which means 'lake-forming') flows N., and then turning N.W. reaches the left bank of the Yarkhun river flowing at its base.

The snout of the glacier ends in perpendicular cliffs of clean white ice, with the river flowing below and lapping these ice-walls. All day and all night the crash of ice falling into the stream broke the silence: and when a large piece was detached there came a noise like thunder. The river, in consequence, was full of large blocks of ice, swirling and jostling together. A remarkable feature of the Vedinkot Glacier, which throughout its length completely filled the bed of its own valley, was that it was joined by the broad North Darkot valley with its own stream flowing in it, but the glacier of which was distant and had not advanced at all. In spite of this, on the left of this same valley, there were hanging glaciers and snow deposits of a considerable extent. The explanation of why this valley was not filled with a glacier like its fellow lies in the original shape of the Vedinkot valley. The steep icefall merged into an almost level sheet of ice, while the gradient suited the flow, continuance, and normal life of the glacier. The North Darkot, however, could not force its way down a longer and unsuitable course; the resistance and friction was greater than its momentum could overcome. The Pasu and Batura Glaciers in Hunza, the Western Aghias in the Tian Shan, and many other glaciers, which continue far down their valleys are largely indebted for their length to the gradient of the valley. Beginning with a steep icefall, but which gradually eases off, the flow of the glacier is moderated and the original momentum is diminished, while at the same time the ice stream can continue its course and preserve its identity far down into the valley.

The action of the sun is also limited to the actual surface of the glacier, of which the edges are protected by the sides of the valley. Again, the liquefaction of the steep icefall is neutralized by the gentler slope lower down. Besides the reasons given there is also, in the case of the South Darkot Glacier, a real failure in the ice of recent years. Some time ago there was a route over the Darkot Pass, down the glacier, to Vedinkot. Then for a number of years the North Darkot Glacier flows south from the Darkot Pass, and should not be confused with the glacier flowing direct into the upper Yarkhun from the same pass: this latter is the Chigar Glacier. It was closed in 1932 it was again passable, which indicates a decrease in the glacier: when crossing the Darkot Pass by the Chigar Glacier I could see that the South Darkot was easy enough. My Wakhi yak drivers, stating they would be at their homes in Vedinkot in a very short time when taking this route, disappeared contentedly down it. Near to Vedinkot was another glacier, the Pechutz or Hot Spring.

This small glacier was in a very large valley compared with its size, and suffers much from solar action on three sides, attacks from falling stones and lateral streams, and was quite a pathetic object, dwindled and shrunk in its too roomy bed. It was not wholly a case of a glacier having carved out a valley that it now fails to fill, for in this arid country a glacier is constantly exposed to outside influences which diminish it considerably. But so far as Vedinkot went, the great glacier more than compensated for the failure of its neighbours to fulfil their role and bring their ice to the river bank. It was a splendid spectacle, this long wall of ice towering over the roaring river. We heard that on one or two occasions spectators had been killed by splinters of the icewall falling across the river; we were very glad that it did not happen to us.

So far as dimensions go the principal feature of Northern Chitral is the great Chiantar Glacier, the true source of the Yarkhun river. This great glacier is, at a conservative estimate, some 20 miles long with an average width of 3-4 miles. Its bulk is most impressive, but is seen to the best advantage from 10 to 15 miles off. Otherwise, it can hardly be called a beautiful sight. Interesting, no doubt, but its flatness and regularity detract from the general effect. The surface of the glacier is singularly smooth, due to the very gentle gradient of the flow. Naturally the glacier is broken by friction near its rocky banks, but in 1933 crevasses were few, while even mere superficial cracks were not numerous, and where I wandered on it, I could have driven over much in a light motor car. The Chiantar was a wonderfully clean glacier, the surface moraine being only abundant near the snout where there were quite a number of fast collapsing tables of immense size. I judged the glacier to be divided into three distinct parts. The head and snout were smooth and regular but, owing to a change in gradient, the centre was much broken by crevasses, yet,

even so, much less than could have been expected. A feature of the glacier was its consistency in width; from a point near its snout, or indeed from any neighbouring high ground, the whole glacier was visible, except for a small part at the head. I have tried to find the meaning of the word 'Chiantar,' which many glaciers bear. In Burishashki, the language of Hunza, Nagir and Yasin, the word means 'spry, sprightly, smart,' but in rather a bad sense. What it means in Shina or in Khowar (Chitrali) I failed to discover. The glacier has one large but unnamed tributary, 6 miles long, flowing in on the left from the S., and which joins the main icestream, but preserving its own individuality, flows on the left side of the valley. Between it and the main glacier is a black band of moraine which is most conspicuous throughout its length. This tributary glacier joins the main one 5 miles from its termination in the Yarkhun river. As I have said, I found it easy to walk over the glacier; of this I did a great deal. I also crossed it with yaks about half a mile above its snout, and experienced little trouble except in getting on and off. I left slightly disappointed with the spectacular effect of this great ice river. The sides of the valley were monotonous and low, so was the smooth and tranquil sheet of ice; it was only by the effort of remembering its great bulk that I kept my interest alive. This vast ice river was, in fact, rather deadening.

The Chiantar Glacier appeared to me to be advancing very slowly. The Yarkhun river was quite unfordable anywhere, at any time, by day or night, though we watched it most carefully, since crossing the ice meant a considerable detour for all of us, and we were anxious to find a ford. All three glaciers, the Madod, Vedinkot, and Chiantar, were slowly advancing, but the other glaciers seen were small, generally static or retreating. From talking with the people it was evident that cloud-bursts are a feature of the country. I was shown tracts of territory near Wassum, for instance, where good arable land had been ruined by summer floods. In some places I saw settlements destroyed by the same cause, and the peasants attributed the damage to the heavy rain. In the Baroghil we heard alarming tales of the heavy and continuous downpours; we only escaped such a deluge by the happy accident of leaving the day before. This heavy rain must greatly affect the glaciers and especially retard vegetation; I think that this interference with the normal life of a glacier accounts for the apparent vagaries of the ones in Chitral. I do not pretend to any elaborate study of the Chitrali glaciers; but it was clear that the smaller glaciers contrasted strangely with their neighbours, and I believe that they had suffered from the effects of a recent cloud-burst, having lost an unusual quantity of their ice, which they were in the less favourable position to replace. I have often watched a sudden storm on a glacier and even a comparatively light shower achieves a great deal. The warm rain corrodes the ice, stones are brought down with a clatter, and ice, rock and much else go rattling down, causing a marked change in even a small formation. It can hardly be argued that the Chitrali glaciers of the upper Yarkhun, whether of the Hindu Kush or Hindu Raj two names for one mountain group are different from others, and yet the ice deposits exhibit a strange inconstancy and waywardness. All I suggest is that the Chitrali glaciers must be modified by these rain-storms which have so greatly altered the formation of the valley itself.

Key words: Glaciers, Chitral, Alpine.

S/109. Schomberg, Col. R.C.F., 1938. *Kafirs and glaciers: Travels in Chitral*. London, Hopkinson, Brighton. 287p, 24 plates.

The book describes exploring the mountains and villages of Chitral, including Tirich Mir.

Following a distinguished career in the British Army, Colonel Reginald Schomberg (1880-1958) became a writer, photographer and explorer travelling throughout Central Asia and the Himalayas between 1927 and 1947.

From the Himalayan Club Journal:

Kafiristan

One used to imagine a mysterious land inhabited by strange men and women, who used bows and arrows and spoke an unknown tongue. Colonel Alexander Gardner did visit the country in 1826, but then he had paid a call to almost every known portion of the earth, and unfortunately most of his records were lost. Mr. McNair, of the Indian Survey Department, carried out a most remarkable expedition in 1883, and Sir George Robertson's visits to the country in the years 1889, 1890, and 1891 were described very fully in his book *The Kafirs of the Hindu Kush*. Since then little has been written of this out-of-the-way patch of Asia.

And now that untiring traveller Colonel Schomberg has given us a book which will gladden the hearts of all lovers of the Himalaya and Hindu Kush.

From the town of Chitral itself, Schomberg went first to the Bum-boret valley, where the Black Kafirs or Kalash live. From there his wanderings took a northerly line always bearing to the east. He visited nearly all the passes over the Hindu Kush, leading from Kafiristan and Chitral into Afghanistan and Wakhan, including the Dorah, the Nuqsan, the Kotgaz, and the Shan Jinali, all of which, with their heights and approaches, are usefully described. It is

interesting to note that the Kotgaz pass, which used to be a route into Badakshan, is now a confused mass of snow and ice and impassable to an ordinary pedestrian.

Schomberg considers that almost all the major glaciers of western Chitral are in retreat, and 'with black unseemly snouts, they look shabby, seedy, and decayed'.

It is when we come to the people themselves, however, that the true value of the book is shown, their superstitions, social customs, pastimes, festivals, and general mode of living being described in detail by a highly trained observer of central Asian tribes. A touch of humour throughout takes the edge off the dreadful laziness and shortcomings of the Chitrali — and makes the book intensely readable.

The Chitrali must be the most superstitious of all mortals. Their fairies are like ordinary men and women except that their heels are in front and their toes at the rear. Surely they must have a sister who inhabits the Khyber, for the Afridis used to tell me of an evil woman whose toes pointed aft, who compelled the lonely traveller to follow her by looking at him over her shoulder, and who then led him to a deserted graveyard to be devoured by goblins and demons!

The book is very fully illustrated with excellent photographs, including a beautiful picture of the peak of Tirich Mir; there is a clear good map, and also a very handy index for reference. An appendix at the end gives a complete historical sketch of Chitral. Altogether this is a remarkable book, which, being up to date, should be of very great use to any Political Officer or traveller in Chitral or Kafiristan.

Key words: Glaciers, Chitral.

S/110. Schouppe, A. von, 1965. Die Mittel - bis Oberdenonische Korallenfauna von Kuragh (Chitral). In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), Scientific Reports IV (1), Paleontology-Zoology-Botany, 14-53. Brill, Leiden.

Key words: Oberdinonische, fauna, Kuragh, Chitral.

S/111. Schouppe, M. & Fontan, D., 1993. Geological outline of Neelum Valley (Azad Kashmir, NE Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 77-78.

More than fourteen hundred square km area is being intensively mapped at the scale 1:50.000, between the Neelum River and the watershed separating the Neelum Valley from the Kaghan Valley. New ground is broken in the sense that it is the first time that a systematic regional mapping is undertaken in a zone, which is often forbidden to foreigners due to the political instability between the Indian and the Azad Kashmir. Geological data collected since 1991 greatly improve the understanding of the Higher Himalayan Crystalline (HHC) of Neelum Valley and relatively complete previous field observations made by other authors near the Hazara Kashmir Syntaxis.

Stratigraphy

In the HHC unit of Neelum we have distinguished a basement and a cover. The basement comprises a thick sedimentary sequence intruded by leucocratic garnet-bearing granitoids of pre-Himalayan age (presumably Early Paleozoic). The sedimentary rocks consist of a monotonous alternance of psammitic to pelitic schists with minor intercalations of impure marble. The contact between the granitoids and the schist is generally tectonized. Evidence of intrusive contacts are still observable:

spotted schists with andalusite relics and skarn in the Jagram-Kaichpani area and magmatic contact in the Shardi-Surgun-Gumot area. Basaltic dykes cross-cut at low angle the regional banding of the basement. The cover has been divided into three units (from bottom to top):

unit A: a siliceous sequence made of impure quartzites associated with minor metaconglomerates, and a thick sequence of kyanite-bearing paragneisses.

unit B: an alternance of impure marble (frequently ruby-bearing), calcschist, and amphibolite.

unit C: a thick sequence made of graphite-bearing garnet micaschist. The contact between the basement and the cover is believed to be an old tectonized stratigraphic unconformity. The question remains open due to the lack of well accessible outcrops.

Metamorphism

The regional Himalayan metamorphism of the studied area has been shown to be of Barrovian type (Iron, biotite-chlorite zone to sillimanite zone) with an early eclogitic stage present only in the Shardi-Surgun-Gumot area. In the cover sequence of the Shardi-Surgun-Gumot, a typical kyanite-staurolite assemblage of high temperature amphibolitic facies, is wide-spread developed. Beside this assemblage, a few relics of previous prograde

metamorphism are present. Some chlorite crystals, discordant on the schistosity, attest for a not intensive retrometamorphism in the green schist facies.

The sedimentary sequence of the basement, well developed in the Jagram-Kalapari area, shows a metamorphic zonation consisting in a biotite-chlorite zone, a kyanite-staurolite zone and a sillimanite zone.

Rocks with biotite-chlorite assemblages were encountered near Kundaishahi. These assemblages may represent relics of a prograde phase of Barrovian metamorphism or a pro-Himalayan low-grade phase associated with the emplacement of the granitoids.

Kyanite-staurolite bearing assemblages are not common on the field. The typical assemblage consists in white mica, biotite, garnet, epidote and amphibole. Kyanite and staurolite, visible only in thin section, are associated with the spotted schists. They grow on old andalusite grains, already replaced by white mica and quartz. This suggests that the time of re-equilibration to the amphibolitic condition was relatively short.

Sillimanite appears in the sedimentary sequence with anatectic rocks (agmatites) as small needles or flakes. It is associated with the first appearance of K-feldspar.

In the granitic rocks, the old magmatic white mica is partially or totally replaced by fibrous sillimanite. In the migmatitic gneisses, sillimanite coexists with kyanite and an incipient melting appears in small (dm) shear zones. In the Shardi-Surgun-Gumot area, basaltic dykes cross-cutting the migmatitic gneisses are characterized by, eclogitic assemblages (omphacite+garnet). These eclogitic assemblages are only preserved in the centre of the dykes. Sometimes, they are partly replaced by later discordant growth of hornblende and biotite at the border zone, by green schist assemblages. Eclogites in the same metamorphic setting, have been found also outside the mapped area. They appear in the Lillan Basti area (Kaghan Valley) as strongly deformed pillow lavas and, in Kel area, as dykes cross-cutting migmatitic rocks. Eclogitic assemblages are not found in the Jogram-Kalapari area where the basaltic dykes show an amphibolitic paragenesis with relics of the magmatic texture. The fact that eclogitic assemblages have been found in the Shardi-Surgun-Gumot area and that they are absent in the Jagram-Kalapari area, suggest a different metamorphic P-T-t path for both of them.

Structure

The basement- and the cover rocks of the Higher Himalaya Crystalline of Neelum Valley illustrate the prevalent ductile nature of a complex Himalayan deformation. Four successive phases of folding have been distinguished on the field in both mapped areas ("Jagram-Kalapari" area and "Shardi-Surgun-Gumot" area).

An over spread penetrative schistosity (S1), derived from the preferred orientation of platy and acicular minerals lies subparallel to the banding. It is probably related to a large ductile shear at deep level, associated with isoclinal and intrafolial foldings (F1). This first phase (F1) developed an East oriented stretching lineation (L1) well expressed in some granites and amphibolites of the "Jagram-Kalapari" area. A second phase (F2) folded isoclinally the main schistosity and the banding. This phase brought off the transposition of the basement and cover sequence initiated by F1. Later, a third phase of tight folding crenulated the main schistosity to develop a crenulation cleavage S3, 15° to 25° oblique to the banding. The geometry of all these structures is disturbed by the fourth folding phase, which produced open folds repeated with a wavelength of several kilometres. Their axial planes are subvertical and strike NE-SW. From place to place, the fold axes are sub-horizontal, gently plunging to the NE or to SW. This suggests further gentle deformations expressed in the rocks with a very large wavelength (>20 km). We mention finally a set of small early deformations including kinking of the previous structural planes, different fracture sets and local sub-horizontal thrust planes, constantly characterized by a displacement of the roof to the SW.

Key words: Geology, stratigraphy, metamorphism, Azad Kashmir.

S/112. Schoupe, M., Fontan, D., Laduron, D. & Martinotti, G., 1995. Macro- and Mesoscopic Fold Interference Patterns in the Higher Himalayan Crystalline (HHC) and the Lesser Himalayan Crystalline (LHC) of the Kashmir Himalaya. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Recent structural analysis at Neelum valley (figure 1) has drawn a detailed picture of the major Himalayan deformation phases which have affected the rocks of the Lesser - and Higher Himalayan Crystallines (LHC and HHC) of Azad Kashmir. At least four successive phases of deformation have been recognized in both the Precambrian basement and the Tethyan metasediments of the LHC and HHC. The Kalapari rock fragment, redrawn in figure 2, illustrates the phases of deformation D1, D2a and D2b; the figure 3 illustrates the late phases D2, D3 and D4.

The earliest phase D1 of the Himalayan deformation is a penetrative ductile deformation which predates the peak of the Himalayan Barrovian metamorphism. It is characterized by intrafolial and isoclinal folds and by an axial plane

schistosity S_i , best observed in some D2a fold hinge zones (figure 2). The foliation S_i is defined by the orientation of the platy minerals. In the upper HHC of the Neelum valley, regional D_1 sheath-like folds induce a 180° re-orientation of the F_1 fold axis parallel to the N-S trend of the nappes tectonic transport.

Isoclinal folding also characterizes the early step (D2a) of the syn-metamorphic second phase of deformation (D2). Due to the focal re-orientation of the F_1 axis, the D_1 and D2a isoclinal folds show both coaxial (type 3) and not coaxial (type 2) fold interference patterns. The figure 2 illustrates an arrowhead fold interference pattern of type 2. The D2a phase of deformation has generated a fine penetrative S_{2a} foliation and a mineralogical extensional lineation L_2 , particularly visible in some amphibolites and in some orthogneisses.

A second generation of structures (D2b) has been produced during the D2 phase of deformation. Open, close to tight D2b folds are related to the shearing stress responsible for the syn-metamorphic southwestward overthrusting of the HHC over the LHC along the MCT. Close to the MCT, the crenulation of the early structures has generated a S_{2b} crenulation cleavage in the more pelitic rocks and a fracture cleavage in the more quartzitic rocks. As visible on the figure 2, D2a and D2b folds are coaxial, generating a wavy fold interference pattern (type 3).

The next phase of deformation D3 is only observable at the map scale. It consists in open flexural slip buckle folds with a more than 6,5 kilometers wavelength. The D3 fold axis trend NE-SW. The figure 3 is a synthetic map showing the macroscopic D2a and D3 folds exposed in the Neelum valley. In the lower half of the map, D2a and D3 folds are approximately perpendicular. They produce an intermediate interference pattern: arrow-head, dome and basin structures (type 1-2). On the other hand, the upper part of the map shows a considerably reduced obliquity between the D_1 -D2 and D3 structural trends. In that case, the structures generate a near-coaxial type (2)-3 interference pattern.

A last D4 phase of deformation is mostly expressed by the doming of the earlier structures to build the Hazara Kashmir Syntaxis, of which the eastern flank crosses the Neelum valley along the MBT (lower left corner of the figure 3). In the Neelum valley, the distribution of the Precambrian basement outcrops is related to large domal structures elongated in the NNW-SSE direction, such as the domes alignment of Shikar and Ganja. Tethyan metasediments outcrop inside a large synform ("basin") which trends NNW-SSE and goes through the village of Doarian. Since such large domes and basins do not occur each time D3 folds interfere with D2a folds, we believe that the D4 doming is the main factor of distribution of the basement/cover outcrops. The D4 doming has locally uplifted some previous D3-D2a domes and basins such as those of Shikar and Ganja.

Key words: Structure, deformation, ductile folds, shearing stress, Azad Kashmir.

S/113. Schrader, H.W., 1983. Contribution to the study of the distinction of natural and synthetic emeralds. *Journal of Gemmology* 18, 530-543.

Trace element contents of emeralds may be taken as a modern method to distinguish between natural and synthetic stones. It is also possible to differentiate between the localities of the natural emerald according to their chemical composition. The significant chemical characteristics of both natural and synthetic emeralds are discussed. The paper also shows that two emerald analyses from Pakistan have higher V, Sc, Ni, and lower Rb, Cr, and Mn than most other natural emeralds.

Key words: Gemology, synthetic and natural emeralds, Pakistan emeralds.

S/114. Schwan, W., 1980. Shortening structures in eastern and northwestern Himalayan rocks. Today and Tomorrow's Printers and Publishers, New Dehli, 62p.

Key words: Shortening, structure, Himalaya.

S/115. Scott, C., 1992. Glacial sediment production by the steep valley glaciers of the Nanga Parbat massif, Pakistan Himalaya. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 80.

Studies of sediments produced and transported by steep valley glacier systems in the Nanga Parbat massif, Pakistan Himalaya, raise questions -about the universal validity of present day theories of glacial sediment production, which have resulted from the study of European glaciers.

Whilst subglacial processes remain the dominant source of fine particle production, the supraglacial process of debris transport can also be seen to exhibit down-glacier fining of sediment. This view of non-passive transport of debris in the supraglacial zone is supported by Scanning Electron Microscopy of the fine sediment particles produced by these systems, which exhibit a clear down-glacier evolutionary sequence in particle morphology. Co-existing subglacial and supraglacial systems of particle comminution and fine sediment production are envisaged within the Himalayan glacier systems, where glaciers are typically high gradient with lengthy ablation/transport zones and of thick debris mantle cover. A comparison is made with a typical glacier system in the European Alps where fine sediment production is shown to be exclusive to the subglacial zone of traction. Reasons for the difference between these glacial systems are explored including glacial morphology, bedrock control of sediment input and the unique tectonic situation of the Nanga Parbat Massif within the Himalayan belt. The implications of this proposed Himalayan system for present day regional sediment output and for interpretations of Pleistocene valley glacier sediment systems are considered.

Key words: Glaciers, debris transport, sediments, Nanga Parbat.

S/116. Scott, C. & Derbyshire, E., 1990. Questions posed by a preliminary glacial landform-sedimentary map of the Nanga Parbat Himalaya. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 53.

A preliminary map of the glacial landform-sediments associations on the flanks of Nanga Parbat in the Greater Himalaya is presented. It shows the form and distribution of moraines, glaciofluvial outwash, moraine fans, debris fans, talus slopes, protalus ramparts, hummocky moraines and a variety of terrane features.

The terraces are extremely large and are made up of diamictos in some cases over 100m thick. Terrace surface relief, however, rarely exceeds 10m; the small ridges and hummocks appearing to be retreatal end moraines. The present glaciers include several high-gradient ice streams which have advanced across some trunk valleys (such as the Rupal), constraining the trunk rivers and superimposing high lateral moraines (>100m) on the flat valley-floor sediments. Some moraines impound perched proglacial lakes. There is thus marked topographical discordance between the surface of the trunk valley ice-retreat outwash sediments and the late Holocene moraines. Extrapolation of Pleistocene glacial trimlines left by the trunk glaciers and smaller ice streams from the high gradient tributary valleys prevailed at that time. However, any frontal moraine systems in the trunk valleys sedimentary burial has occurred, fills may be several hundred meters thick. The thick terraces downstream, such as those at and below the Astor junction, contain little fluvial material: they may have been emplaced by glaciers and then dissected by the rivers. The map thus poses a number of questions including the mode of deposition of coarse diamictos, the origin of the terraces and their relationships to ice limits, and the relationship of the tributary valley deposits to the lithostratigraphy trunk valley fills.

Key words: Glacial landform, Nanga Parbat, Himalaya.

S/117. Scott, D. & Rouse, A., 1983. Karakoram-Alpine style. Mountain 93, 26-33.

Key words: Geomorphology, Karakoram.

S/118. Seall, R.R., 1989. A reconnaissance study of the fluid inclusion geochemistry of the emerald deposits of Pakistan and Afghanistan. In: Kazmi, A.H. & Snee, L.W. (ed.), Emeralds of Pakistan: Geology, Gemology and Genesis, 151-164. Van Nostrand Reinhold, New York.

This study documents the geochemical characteristics of the hydrothermal fluids responsible for emerald mineralization in Swat (Mingora Mine 1 and 2, Charbagh, and Barang) and a single sample from Panjsher in Afghanistan. It is concluded that 1) salinities ranged from essentially nil to approximately 20 wt% dissolved salts, 2) the inclusions contain up to 3 mole% of a CO₂-rich component, with up to 0.22 XCH₄, 3) homogenization and decrepitation temperatures ranged from 150 to 349°C, which is equivalent to entrapment temperatures of 250 to 449°C at a confining pressure of 900 bars, and 4) boiling and fluid immiscibility were absent in all stages of hydrothermal activity recorded by these fluid inclusions.

The present data, especially those from the primary fluid inclusions suggest that mixing of a high temperature, high salinity fluid with a lower temperature, less saline fluid may have importance in mineral deposition. The only anomalous features of the fluid inclusions, observed in this reconnaissance study, are that the fluid inclusions from

Mine 2 are less saline than those from Mine 1, Charbagh and Barang, and that the fluid inclusions from Charbagh locally contain hematite daughters. All other fluid inclusion characteristics from the Swat district are indistinguishable from one mine to another. The sample from Panjsher is distinctly different from those of Swat. It contains numerous daughter minerals (including halite and sylvite) in inclusions oriented parallel to the c-axis.

Key words: Geochemistry, fluid inclusions, emerald deposits, Pakistan, Afghanistan.

S/119. Searle, M.P., 1989. Thermal model for the Baltoro-Muztagh Karakoram. *Geological Bulletin, University of Peshawar* 22, 1-9.

Following the Eocene (50 Ma.) collision of the Indian and Karakoram plates, crustal thickening and shortening in the Karakoram north of the Neo-Tethyan suture zones resulted in a widespread regional Barrovian metamorphism (M2) south of the Karakoram batholith. Pelitic lithologies are characterised by the assemblage: kyanite-staurolite-biotite-garnet-muscovite-plagioclase-quartz with sillimanite-muscovite and sillimanite-K-feldspar assemblages locally developed. Hornblende and diopside-bearing marbles and garnet-bearing amphibolites are also widespread. The age of this high pressure-high temperature metamorphism is constrained as post-50 Ma. (age of India-Asia collision) and pre-37 Ma. (age of cross-cutting, post-collisional granite plutons).

Intrusion of the 21 Ma. Baltoro batholith comprising compositions ranging from biotite monzogranite to two-mica leucogranite caused a high temperature-low pressure thermal aureole of contact metamorphism in the country rock. Andalusite-bearing hornfels along the northern contact of the batholith indicates maximum pressures of 3.5 kbars (350 MPa). A 750 increase in temperature in Kyanite sillimanite grade gneisses approaching the granite contact along the Baltoro glacier is modelled as the thermal upwarping of pre-36 Ma. Barrovian metamorphic isograds around the 21 Ma. contact aureole isotherms along the margins of the Baltoro batholith. Post-metamorphic folding of the early Barrovian metamorphic isograds is related to thrust culminations along the hanging-wall of the Main Karakoram Thrust - a reactivated breakback thrust along the older Shyok suture zone.

Key words: Thermal model, Baltoro-Muztagh, collision, Karakoram.

S/120. Searle, M.P., 1990. Baltoro-WildSide. Mountain 135, 26-31.

Key words: Baltoro, Karakoram.

S/121. Searle, M.P., 1991a. *Geology and Tectonics of the Karakoram Mountains*. John Wiley and Sons, New York, 358p.

This well produced book is a detailed compilation of the author's contribution as well as those of the earlier worker's contribution. It contains many figures, including geological maps, sketches, satellite imageries, field photographs, photomicrographs and tables. The book is divided into four parts: part 1, regional tectonic setting comprises Geological and Geophysical Constraints (Chapter1), Tectonics of Central Asia (Chapter 2), and Tectonics of the Himalaya (Chapter 3). Part 2, the greater Karakoram, comprises general statement, and Kohistan (Chapter 4), western Karakoram --Chitral-Yasin (Chapter 5), Hunza Karakoram (Chapter 6), Northern Karakoram Terrain (Chapter 7), Karakoram batholith --Baltoro, Biafo, Hushe areas (Chapter 8), Karakoram metamorphic complex (Chapter 9), and eastern Karakoram -- Siachen-Nubra-Ladakh (Chapter 10). Part 3, Physical Geography consists of Quaternary and Present Glaciations (Chapter 11), and Geomorphology, Climate and Neo-tectonics (Chapter 12). Part 4, Orogenic processes comprises chapter 13 on Pre-Collision Crustal Evolution and Chapter 14 post --Collision Crustal Structure and Evolution. There are fifteen pages of references, and index and geological map of the Central Karakoram at 1:250,000 scale. The book also contains a summary of all the radiometric ages spanning Cretaceous-Tertiary that were available by 1991.

Key words: Geology, tectonics, Karakoram.

S/122. Searle, M.P., 1991b. A new geological map of the central Karakoram at 1/250,000 scale. *Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France*, 75.

A new geological map of the central Karakoram based largely on the last five field seasons mapping is presented. The map covers the area from the Hunza Valley in the west to the Baltoro-Siachen glacier divide in the east, and

from the Shimshal valley and Skamri glacier in the north to the Nanga Parbat massif and the Deosai plains in the south. The High Himalayan terrane of the Nanga Parbat-Haramosh massif forms part of the northwestern syntaxis of the Himalaya. The Kohistan terrane to the west and the Ladakh terrane to the east of the Nanga Parbat are continuous eastwards with the Trans-Himalayan batholith in southern Tibet. These terranes are bounded along the south by the Indus Suture Zone or Main Mantle Thrust and along the north by the Shyok suture zone or Main Karakoram Thrust.

The Karakoram terrane is continuous eastwards to the Lhasa Block in south Tibet, and is made up of three domains: the Karakoram metamorphic complex in the south, the Karakoram batholith and the northern Karakoram domain composed mainly of sedimentary rocks with structural culminations of high-grade gneisses along the K2-Braod Peak Range.

Key words: Geology, Hunza Valley, Baltoro-Siachen, Shimshal Valley, Ladakh, Karakoram.

S/123. Searle, M.P., 1993. Structure, Metamorphism and Cooling History of the Central Karakoram (North Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 50.

Prior to the Eocene (ca. 50 Ma) collision of the Indian and Asian plates, the southern margin of Asia in the Karakoram region was dominated by a series of Andean-type plutonic belts (Hushe gneiss, Muztagh Tower gneiss, K2 orthogneiss) and regional low-pressure andalusite, staurolite and garnet-grade metamorphism (M1). Crustal shortening, thickening and regional metamorphism following collision occurred between 50-37 Ma and has been dated by a U-Pb zircon age from the Mango Gusar two-mica leucogranite which cross-cuts syn-metamorphic fabrics in the country rocks. Thermobarometry of kyanite and sillimanite-grade rocks indicates peak metamorphism (M2) at around 7000C and 8-9 kbars. Temperatures increase northwards along the Baltoro glacier transect towards the contact with the Baltoro granite where in situ partial melting begins in the sillimanite gneisses. Post-metamorphic folding of M2 isograds was associated with deep crustal gneiss domes and initiation of the Main Karakoram Thrust in the south. Post-M2 thermal relaxation followed from 37-25 Ma after which localized high heat concentrations at the base of the thickened crust caused widespread crustal melting and intrusion of the Baltoro granite at 25-21Ma. A high-temperature, low-pressure thermal aureole (M3) along the northern contact of the Baltoro monzogranite leucogranite is synchronous with the 21 ± 0.5 Ma U-Pb zircon crystallization age of the granite. The Mitre contact aureole contains the assemblage: andalusite + cordierite + biotite + muscovite + chlorite + plagioclase + quartz and indicates pressures less than 3.5 kbars. The increase of T along the southern contact of the Baltoro granite is interpreted as the thermal upwarping of pre-37 Ma M2 isograds by 21 Ma M3 contact metamorphic isotherms. In the southern Karakoram pressures up to 10 kbars were attained by 37 Ma ago meaning that around 37-km of overburden has been eroded since the Eocene-Oligocene boundary giving a time-averaged exhumation rate of 0.95mm/year. The 21 Ma Baltoro granite crystallized at temperatures above 750oC and pressures above 10 kbars equating to depths of burial between 26-35 km. The exhumation or unroofing rate, which includes processes of uplift and erosion is between 1.2-1.6mm/year. Subduction of Indian continental crust and mantle lithosphere northwards beneath the Karakoram and Tarim Basin continental crust southwards beneath the KunLun and the northern Karakoram has created a lithospheric-scale pop-up structure with its axis of maximum uplift aligned along the Karakoram.

Key words: Structure, metamorphism, cooling history, Karakoram.

S/124. Searle, M.P., 1996a. Geological evidence against large-scale pre-Holocene offset along the Karakoram fault: Implications for the limited extrusion of Tibetan plateau. *Tectonics*, 15, 171–186.

Two end-member models proposed to accommodate the convergence between India and Asia north of the Himalaya are (1) homogeneous crustal thickening of the Tibetan plateau and (2) continental escape, or extrusion, of Tibet and southeast Asia, away from the indenting Indian plate. Foremost among the arguments supporting the latter would be large-scale (≥ 1000 -km) offsets and high present-day slip rates along the major strike-slip faults bounding the postulated extruding crust, notably the Altyn Tagh Fault along the northern margin of Tibet and the Karakoram Fault along the SW margin. Satellite photographic interpretation and field mapping in the Karakoram mountains in Pakistan, the Nubra-Siachen area of north Ladakh, and the Pamirs in Xinjiang show that although the Karakoram Fault is extremely active today, geological offsets along the right-lateral fault are probably less than 120 km. The 21 ± 0.5 Ma Baltoro monzogranite-leucogranite batholith has been rotated clockwise about a vertical axis 35° – 40°

into NW-SE alignment, parallel with the Karakoram Fault, east of the Siachen glacier, with a maximum offset of 90 km across the fault. The Bangong-Shyok suture zone similarly has a dextral offset of 85 km. The course of the Indus River, which was antecedent to the rise of the Ladakh, Karakoram, and Himalayan ranges, has been offset dextrally by 120 km south of Pangong Lake. If present-day slip rates (approximately 32 mm/yr) (Avouac and Tapponnier, 1993) are correct, only 4 Ma are required to obtain a 120-km offset. There is no geological evidence for any larger-scale pre-Holocene offsets, and it is suggested that the Karakoram Fault cannot have accommodated major eastward lateral motion of Tibetan crust. The fault has also exerted little or no influence on surface topographic uplift, cutting obliquely across the highest peaks of the Karakoram. Dextral motion along the central part of the Karakoram Fault has been transferred in the north to the Rangkul, Murghab, and Karasu transpressional faults in the central Pamir. North of Tashkurgan, the Karakoram Fault shows mainly normal motion around the Kongur and Mustagh Ata gneiss domes (metamorphic core complexes) and the extensional Muji graben. Minor dextral displacement has occurred along the Shiquanhe Fault, but this motion cannot be linked to the Jiale Fault of east Tibet. The southern end of the Karakoram Fault merges with the Indus (Yarlung) suture zone near Mount Kailas and does not cut across the Himalaya. The lack of large-scale geological offsets along the Karakoram Fault, together with its very recent initiation (?5 or 4 Ma), suggests that it is related to the Pliocene-Quaternary northward indentation of the Pamir, and not to any long-term extrusion of Tibetan crust following the Indian collision.

Key words: Geology, Holocene, Karakoram fault, India, Asia.

S/125. Searle, M.P., 1996b. Cooling history, erosion, exhumation and kinematics of the Himalaya-Karakoram-Tibet orogenic belt. In: Yin, A. & Harrison M. (Eds.), *The Tectonic Evolution of Asia*, Cambridge University Press, 110-137.

The cooling histories of metamorphic and magmatic rocks, as determined through the use of thermochronometers and radiogenic isotope systems, combined with thermobarometers, can provide useful constraints on our determinations of depths of burial and exhumation rates. This chapter reviews the reliable geochronologic data on segments across the Himalaya-Karakoram-southern Tibet orogenic belt, and cooling histories for each zone are inferred.

Southern Tibet and the Karakoram have been sub-aerial landmasses since the mid-Cretaceous and could have been topographically high, Andean-type continental margins prior to the collision of India at 60-50 Ma. Thick continental red-bed deposition, abundant calc-alkaline volcanism, and granite magmatism suggest a thickened crust along southern Asia as far back as about 150 Ma. The collision of India with the southern margin of Asia (Kohistan-Karakoram-Lhasa terranes) may have been diachronous, occurring earlier in northern Pakistan (ca. 60 Ma) than in Ladakh-southern Tibet (ca. 50 Ma). Following the collision, crustal thickening and the timing of peak metamorphism were diachronous both along the Himalaya (pre-40 Ma northern Pakistan; pre-31 Ma Zaskar; pre-20 Ma eastern Kashmir and western Garhwal; 11-4 Ma Nanga Parbat) and across the strike of the High Himalaya, propagating southward (in Zaskar, southwestward) with time. Thrusting along the base of the High Himalayan slab (Main Central Thrust, active 21-18 Ma) was synchronous with north-south (in Zaskar, northeast-southwest) extension along the top of the slab (South Tibetan Detachment zone). Kyanite and sillimanite gneisses in the footwall formed at pressures of 8-10 Kbar and depths of burial of 28-35-km, at 30-21 Ma, whereas anchimetamorphic sediments along the hanging wall have never been buried below about 5-6-km. Exhumation rates are far greater in the High Himalayan zone (1.4-2.1 mm/a) and southern Karakoram (1.2-1.6 mm/a) than along the zone of collision or along the northern Indian plate margin. The High Himalayan leucogranites span 24-9 Ma in the central Himalaya, and anatexis occurred at 21-19 Ma in Zaskar, approximately 30 m.y. after the collision.

The Karakoram underwent high-temperature high-pressure metamorphism during the Eocene (50-37 Ma) and widespread lower-crustal melting (Baltoro monzogranite-leucogranite batholith) and upper-mantle melting (lamprophyre dikes) during the early Miocene (25-21 Ma). Uplift of the rocks and erosion, resulting in exhumation of middle- and lower-crustal rocks during the Neogene, were controlled by major thrusts and normal faults, and to a lesser extent by the increasing intensity of the monsoon at 8-6 Ma. The cooling histories show that significant crustal thickening, widespread metamorphism, erosion, and exhumation (and, therefore, probably significant topographic elevation) occurred during the Eocene-Oligocene in the Karakoram and southern Tibet, and during the early Miocene along the central and eastern Himalaya, before the onset of the monsoon, before the major changes in climate and vegetation, and before the onset of east-west extension on the Tibet Plateau.

Key words: Cooling history, erosion, exhumation, kinematics, orogenic belt.

S/126. Searle, M.P., Crawford, M.B. & Rex, A.J., 1992. Field relations, geochemistry, origin and emplacement of the Baltoro granite, Central Karakoram. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, 83, 519-538.

The Miocene Baltoro granite forms a massive plutonic unit within the Karakoram batholith, and is composed of comagmatic monzogranites and leucogranites with a mineralogy consisting of quartz-K-feldspar-plagioclase-biotite $\pm$ muscovite $\pm$ garnet, with accessory sphene, zircon, monazite and opaques. Geochemically the Baltoro granites are mildly peraluminous, and show a calc-alkaline trend on trace-element normalised diagrams with high LIL/HFS element ratios and negative Nb, P and Ti anomalies. REE are strongly fractionated with little or no Eu anomaly. Leucogranites are depleted in most elements compared to monzogranites with notable exceptions being Rb, K and the HREEs. Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are 0.7072-0.7128, considerably lower than High Himalayan leucogranites (0.74-0.79), and are indicative of a lower continental crust source. The probable petrogenesis of the Baltoro granite involves dehydration melting of a biotite-rich pelite to produce a voluminous, hot, water-undersaturated magma which could then separate from its source and intrude through an already thickened and still hot crust. Fractional crystallisation of the monzogranites produced the leucogranites and a pegmatite dyke swarm. A suite of lamprophyre dykes including amphibole-rich vogesites and biotite-rich minettes intrude the country rock, dominantly to the north, around the Baltoro granite. These calc-alkaline shoshonitic lamprophyres are volatile-rich mantle-derived melts intruded around the same time as the granite, indicating simultaneous melting of the mantle and lower crust beneath the Karakoram during the Miocene, approximately 30 Ma after the India-Asia collision which initially caused the crustal thickening. Intrusion of mantle melts provided heat to promote crustal melting and may have selectively contaminated the granite magma.

The Baltoro granite intrudes sillimanite gneisses with melt pods along the southern margin indicating temperatures above 700 °C at the time of intrusion. Locally, internal fabrics and numerous aligned xenoliths along the southern margin in the Biafo glacier region indicate steep, southward-directed thrusting during emplacement. Along the northern contact, the Baltoro granite intrudes anchimetamorphic to greenschist facies metasedimentary rocks with an andalusite-bearing contact aureole. Northward-directed culmination collapse normal faulting during Miocene emplacement is inferred, in order to explain the P-T differences either side of the pluton. This also provided an extensional stress regime in the upper crust to accommodate the rising magma.

Key words: Geochemistry, Baltoro granite, Karakoram.

S/127. Searle, M.P., Crawford, M.B., Rex, A.J. & Rex, D.C., 1990. Origin and emplacement of the Baltoro granite, central Karakoram. In *Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano*, 54.

The Miocene Baltoro granite forms a massive plutonic unit within the Karakoram batholith, and is composed of comagmatic monzogranites and leucogranites with a mineralogy consisting of quartz-K-feldspar-plagioclase-biotite muscovite garnet, with accessory sphene, zircon, monazite and opaques. Geochemically the Baltoro granites are mildly peraluminous, and show an calc-alkaline trend on trace element normalized diagrams with high LIL/HFS element ratios and negative Nb, P and Ti anomalies. REE are strongly fractionated with little or no Eu anomaly. Leucogranites are depleted in most elements compared to monzogranites with notable exceptions being Rb, K and the HREEs. Initial $^{87}\text{Sr}/^{86}\text{Sr}$, ratios are 0.7072-0.7128, considerably lower than High Himalayan leucogranites, but still indicative of a melting source in the lower continental crust.

The Baltoro granite was intruded at ca. 25-21 Ma from a lower crust-melting site into an already thickened and metamorphosed crust, approximately 30 Ma after the India-Asia collision. The Baltoro granite intrudes sillimanite gneisses with melt pods along the southern margin indicating temperatures at the times of intrusion of above 650°C. $^{40}\text{Ar}/^{39}\text{Ar}$ biotite ages of 7.9 ± 0.2 Ma combined with previous U-Pb, Rb-Sr and K-Ar dating show that the Baltoro granites was intrude into already hot country rock and maintained high temperatures for ca. 7 Ma. this was followed by very rapid Pliocene-Pleistocene uplift-erosion and exhumation rates. Active crustal shortening and thickening occurred by syn-metamorphic deformation. Numerous aligned xenoliths along the southern margin indicate southward directed thrusting during emplacement. Along the northern contact the Baltoro granite intrudes metasedimentary rocks at maximum P-T conditions of greenschist facies, with an andalusite-bearing contact aureole. Northward-directed culmination collapse normal faulting during Miocene emplacement is inferred, in order to explain the P-T differences either side of the pluton.

Key words: Geochemistry, geochronology, Baltoro granite, tectonics, Karakoram.

S/128. Searle, M.P., Fraser, J.E., Hildebrand, P.R., Parrish, R.R. & Noble, S.R., 2000. Structural and Thermal Evolution of the South Asian Continental Margin along the Karakoram and Hindu Kush Ranges, North Pakistan. Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop, (Chengdu) China, 82-83.

Prior to the Collision and accretion of the Kohistan arc terrane during the late Cretaceous and the Indian plate after the early Eocene, the southern margin of Asia along the Hindu Kush, Karakoram and Lhasa block terranes was an active Andean-type continental margin. In south Tibet this margin was dominated by the calc-alkaline Ladakh-Gangdese granite batholith, associated andesitic volcanic rocks and continental red-beds. In contrast, the southern Karakoram exposes deep crustal metamorphic rocks and crustal melt leucogranites. New U-Pb age dating from the Hunza Valley and Baltoro Glacier region has revealed four spatially and temporally distinct metamorphic episodes. M1 sillimanite grade metamorphism in Hunza was a late Cretaceous event, probably caused by the accretion of the Kohistan arc to Asia. M2 was the major kyanite and sillimanite grade event during late Eocene-Oligocene crustal thickening and shortening, following India-Asia collision. Numerous melting events resulted in the formation of crustal melt granites throughout the last 50 Ma with multiple generations of dykes and very large scale crustal melting along the Baltoro monzogranite-leucogranite batholith during the late Oligocene-early Miocene. M3 metamorphism was a high- T, low- P contact thermal metamorphism around the Baltoro granite. In Hunza, younger staurolite grade metamorphism has been dated by U-Pb monazites at 16 Ma, with the Sumayar leucogranites intruded at 9.5 Ma crosscutting the metamorphic isograds. In the Baltoro region the youngest metamorphism, M4, is the sillimanite grade Dasso gneiss core complex dated by U-Pb on monazites as late Miocene-Pliocene (5.4 ± 0.25) Ma with Precambrian protolith zircon cores (1855 ± 11) Ma. Numerous gem-bearing pegmatite dykes cross-cut these rocks and are thought to have been intruded within the last 2~3 Ma. Structural mapping, combined with U-Pb geochronology shows that major metamorphic events can be both long-lasting (up to 20 Ma) and very restrictive, both in time and space.

The Hindu Kush range also has abundant sillimanite, kyanite and staurolite grade metamorphic rocks, but in contrast to the Karakoram, U-Pb dating shows that the most metamorphism was pre-collision of both Kohistan and India. U-Pb ages of monazite, xenotime and uraninite from gneisses, migmatites and leucogranites show that this high-T low-P metamorphism spanned the Jurassic-early Cretaceous and was probably related to magmatic heat from the Andean-type granites intruded along the margin. The only evidence of post-collisional crustal melting is the 24 Ma Gharam Chasma leucogranite with its associated dykes. The Hindu Kush is however one of the most seismically active continental zones known on Earth, with a narrow zone of earthquakes extending down to 300-km depth. This reflects the active subduction of lower Indian plate continental crust beneath the Hindu Kush-Pamir range today. The Hindu Kush, Karakoram and S. Tibet all represent the southern margin of the Asian plate, yet all have entirely different geology, structural, metamorphic and magmatic histories and seismic expression.

Key words: Structure, thermal evolution, collision, Kohistan arc, Karakoram, Hindukush.

S/129. Searle, M.P., Khan, M.A., Fraser, J.E., Gough, S.J. & Jan, M.Q., 1999. The tectonic evolution of the Kohistan-Karakoram collision belt along the Karakoram Highway transect, north Pakistan. *Tectonics* 18, 929-949.

The Kohistan arc terrane comprises an intra-oceanic island arc of Cretaceous age separating the Indian plate to the south from the Karakoram (Asian) plate to the north within the Indus suture zone of north Pakistan. The intra-oceanic arc volcanics (Chalt, Dras Group) were built on a foundation of dominantly mid-ocean ridge basalt (MORB)-related amphibolites of the Kamila Group. The subarc magma chamber is represented by multiple intrusions of a huge gabbro-norite complex (Chilas complex), which includes some ultramafic assemblages of residual mantle harzburgite and dunite, layered cumulates, and hornblendites cut by late stage dikes of hornblende + plagioclase pegmatites. The Chilas complex norites intrude the Gilgit metasediments of lower amphibolite and greenschist facies in northern Kohistan, which also form xenolithic roof pendants within the top of the Chilas complex. Along the southern margin of Kohistan, Jijal and Sapat complex ultramafics (dunites, harzburgites and websterites) form remnant suprasubduction zone ophiolitic mantle rocks along the hanging wall of the Main Mantle Thrust, the Cretaceous obduction plane along which Kohistan was emplaced onto Indian plate rocks. Garnet granulites of the Jijal complex, formed at 12–14 kbars, represent original magmatic lower crustal rocks subducted to

depths of at least 45 km and metamorphosed during high-pressure and high-temperature subduction of earlier arc-related rocks. Obduction of the Sapat ophiolite and Kohistan arc occurred between $\sim$ 75 and 55 Ma.

The closure of the Shyok suture zone separating Kohistan from the Karakoram plate must have occurred prior to 75 Ma, the age of the Jutal basic dikes which crosscut the closure-related fabrics, mainly late north directed backthrusting in the lower Hunza valley. Andean-type granitoid (gabbrodiorite-granodiorite-granite) emplacement along the Kohistan-Ladakh batholith ended at the time of India-Asia collision, $\sim$ 60–50 Myr ago. Postcollisional crustal thickening along the Karakoram led to multiple episodes of metamorphism from latest Cretaceous and throughout the Tertiary. Sillimanite grade metamorphism in Hunza was actually pre-India-Asia collision and may have resulted from the earlier Kohistan collision. Localized and sporadic crustal melting episodes across northern Kohistan (Indus confluence and Parri granite sheets) and the southern Karakoram (Hunza dikes and Sumayar and Mango Gudar leucogranites) occurred from 51 to 9 Ma and culminated in the huge Baltoro monzogranite-leucogranite intrusion 25–21 Myr ago. A vast network of leucogranitic and pegmatite dikes containing gem quality aquamarine + muscovite $\pm$ tourmaline $\pm$ garnet $\pm$ biotite quartz are younger than 5 Ma and form the final phase of intrusion in the Haramosh area and parts of the southern Karakoram area.

Key words: Tectonics, collision, Kohistan arc, Shyok, Haramosh.

S/130. Searle, M.P., Khan, M.A., Jan, M.Q., DiPietro, J.A., Pogue, K.R., Pivnik, D.A., Sercombe, W.J., Izatt, C.N., Blisniuk, P.M., Treloar, P.J., Gaetani, M. & Zanchi, A., 1996. Geological Map of North Pakistan and adjacent areas of Northern Ladakh and Western Tibet (Western Himalaya, Salt Ranges, Kohistan, Karakoram, Hindu Kush), Scale: 1:650,000.

This is an updated compilation by Searle and Khan (eds.), based on the works of a number of people .

Key words: Geology, north Pakistan, Ladakh, Himalaya, Salt Range, Kohistan, Karakoram, Hindukush.

S/131. Searle, M.P. & Owen, L.A., 1999. The evolution of the Indus River in relation to topographic uplift, erosion, climate and geology of western Tibet, the Trans-Himalayan and high Himalayan Ranges. In: Meadows, A. & Meadows, P. (Eds.), *The Indus River, Biodiversity, Resources, Humankind*. Linnean Society of London, 210-230.

The Indus River is one of the major antecedent rivers of the Himalayas, its drainage course having been initiated prior to the uplift of High Himalayas. The source of the Indus is north of Mount Kailas (6,714 m) in the southern part of the Tibetan Plateau, and it collects drainage from the northern slopes of the Trans-Himalayan ranges. In the far western part of the Tibetan Plateau the course of the Indus River has been offset by about 120-km north-west along the active Karakoram Fault, a 700-km long dextral strike-slip fault which may have been active only for the last 4-5 Ma, with slip rates of 20-30 mm/year. South of the Pangong Lake the Indus river cuts westward through the Ladakh granite batholith and then follows the trace of the Indus Suture Zone (the zone of late Collision between Indian and Asia) for about 200-km in Ladakh. The late Tertiary Indus molasses sediments in Ladakh show that this section of the Indus River was initiated possibly as long ago as the middle Eocene (45 Ma). The uplift of both the Ladakh range and the High Himalayan ranges post-dated the initiation of the Indus drainage course. The steepest gradient of the Indus River is in Baltistan (north Pakistan) where it cuts right through the middle of Nanga Parbat (8,125 m)-Haramosh (7,409 m) massif, the north-western most part of the High Himalayas, eroding a deep gorge and creating some of the largest single slopes on Earth. Radiometric dating from metamorphic rocks and crustal melt granites from Nanga Parbat shows that metamorphism and melting may have occurred as recently as 2.3-1.0 Ma ago. This indicates that uplift, erosion and exhumation rates are exceptionally high. Combining petrological, thermobarometric and geochronological data, exhumation rates for Nanga Parbat are around 4.5-6 mm/year. Uplift of this region has influenced regional glaciations and dramatic climatic changes during late Tertiary and Quaternary times. The Indus Valley has been continuously modified by glacial and fluvial erosion, whilst earthquake-induced landslides have frequently caused damming and subsequent breaching of river, resulting in severe flooding, such as the great Indus flood of 1841. Erosional products are transported along the Indus River southwards to the plains of the Punjab and Sindh, and eventually into the Indus fan in the Arabian Sea.

Key words: Indus River, Karakoram fault, Nanga Parbat, glaciation, fluvial erosion, Indus fan.

S/132. Searle, M.P., Parrish, R.R., Tirrul, R. & Rex, D.C., 1990. Age of crystallization and cooling of the K2 gneiss in the Baltoro Karakoram. *Journal of Geological Society, London*, 147, 603-606.

The mountains of K2 (8611 m) and Broad Peak (8047 m) in the Baltoro Karakoram (northern Pakistan) are composed of plagioclase–hornblende and biotite–hornblende–K-feldspar orthogneisses and amphibolite–facies paragneisses, intruded by garnet–biotite–muscovite–tourmaline leucogranitic veins. A U–Pb zircon age of 115–120 Ma was obtained on an orthogneiss from the south face of K2. ^{40}Ar – ^{39}Ar analysis on hornblende yields a plateau age of 90.6 ± 1.8 Ma, consistent with a mid-Cretaceous phase of magmatism, concomitant with early subduction-related components of the Karakoram batholith (Muztagh Tower unit, Hunza plutonic unit). We interpret the K2 gneiss as representing a culmination of mid-crustal rocks along a discontinuous but wide zone north of the Karakoram batholith.

Key words: Crystallization, K2 gneiss, Baltoro, Karakoram.

S/133. Searle, M.P., Rex, A.J., Parrish, R.R., Tirrul, R. & Rex, D.C., 1988. Geology, geochemistry and geochronology of the K2 gneiss, Baltoro Karakoram. Abstracts, 4th Himalayan-Karakoram-Tibet Workshop, Lausanne, Switzerland, p.12.

Please consult the preceding account for some part of the information.

Key words: Geology, geochemistry, geochronology, K2 gneiss, Baltoro, Karakoram.

S/134. Searle, M.P., Rex, A.J., Tirrul, R., Rex, D.C., Barnicoat, A. & Windley B.F., 1989. Metamorphic, magmatic and tectonic evolution of the Central Karakoram in the Biafo-Baltoro-Hushe regions of N. Pakistan. In: Malinconico, L.L. & Lillie, R.J. (Eds.), *Tectonics of Western Himalayas*. Geological Society of America, Special Paper 232, 47-74.

The central Karakoram can be divided into three main tectonic units from north to south: a northern Karakoram terrane, the Karakoram batholith, and the Karakoram metamorphic complex. In the Baltoro Glacier region the Karakoram magmatism includes intrusive suites that predate and postdate the India-Eurasia collision. The oldest subduction-related phases include Jurassic hornblende to biotite monzogranite of the Hushe complex, and Cretaceous (ca. 82 to 75 Ma) hornblende-biotite metagranitoids of the Muztagh Tower unit, all of which were deformed during the India-Kohistan-Karakoram collision. Volumetrically dominant is a postcollisional granite, the Baltoro Plutonic Unit (BPU), which consists of biotite monzogranites to two-mica $\pm$ garnet leucogranites and pegmatite-aplites of mildly peraluminous affinity. The BPU represents the youngest magmatic phase of the composite Karakoram batholith with a U–Pb age of 21 ± 0.5 Ma and K–Ar mica cooling ages ranging from 11.7 to 5.25 Ma.

The Masherbrum migmatite complex (MMC), one of a series of such complexes along the southern margin of the batholith, immediately predates the BPU. Leucocratic dikes that cross-cut the MMC yield an Rb–Sr age of 14.1 ± 2.1 Ma and K–Ar ages of 17 to 10 Ma. The BPU is interpreted as a crustal melt ultimately derived from deep crustal levels and may not be related to leucogranite generation associated with the migmatite terrain to the south. Petrogenesis of the BPU is fundamentally different from that of the High Himalayan granites and may involve a degree of selective mantle contamination.

Four major metamorphic-deformation phases can be distinguished in the central Karakoram. The earliest, M1, is represented by low-pressure andalusite–staurolite–bearing assemblages that are spatially associated with igneous components of the Hushe complex of Jurassic age. The dominant thermal event was a widespread Barrovian-type metamorphism (M2), which was syntectonic to the main deformation and overprinted M1 assemblages. M2-related structures are cut by the 37.0 ± 0.8 Ma Mango Gusar two-mica granite pluton. M2 kyanite–garnet–plagioclase–quartz–muscovite–biotite–staurolite assemblages indicate minimum pressure temperature (P–T) conditions of 550°C and 5.5 kbar (550 MPa).

Thermal effects related to intrusion of the BPU constitute M3. Along its northern margin at Mitre Peak, the assemblage andalusite–cordierite–chlorite–biotite–muscovite–quartz–plagioclase indicates a *maximum* pressure of 3.75 kbar (375 MPa, $\approx$ 12.5-km depth). Along its southern margin at Paiyu, the presence of granitic melt pods with sillimanite, muscovite, plagioclase, and quartz indicates a minimum pressure of ca. 3.5 kbar (350 MPa) and a

temperature 75° higher than local M2 assemblages. The replacement of kyanite by sillimanite and the appearance of granitic melt pods approaching the BPU along the Baltoro Glacier transect, may be an M3 overprinting of M2. M4 (<5 Ma) is a syntectonic retrogressive metamorphism along the hanging wall of the Main Karakoram Thrust—a breakback thrust responsible for the recent uplift of the Karakoram.

Structural culminations of midcrustal rocks occur in the K2 and Broad Peak areas within Carboniferous-Lower Cretaceous sediments of the Gasherbrum Range. Metamorphism of the K2 gneiss (dominantly biotite-hornblende-K-feldspar orthogneiss) occurred during middle to Late Cretaceous time. Pegmatite dikes dated as 70 to 58 Ma (K-Ar-mica) cut the gneisses.

Key words: Metamorphism, magmatism, tectonics, Biafo, Baltoro, Central Karakoram.

S/135. Searle, M.P., Rex, A.J. Tirrul, R., Windley, B.F., Onge, M.S.T. & Hoffman, P., 1986. A geological profile across the Baltoro-Karakoram Range, N. Pakistan. *Geological Bulletin, University of Peshawar* 19, 1-12.

The Karakoram batholith along the Baltoro glacier transect separates a northern sedimentary domain with structural culminations of high-grade gneisses (K2 gneiss) from a southern high-grade metamorphic domain. The Baltoro plutonic units range in composition from biotite granodiorite to garnet bearing two-mica leucogranite; they have no mafic dyke and no volcanic component. The Baltoro granite is interpreted as being crustally derived from partial melting of deeper level rocks equivalent to the high-grade metamorphics in the south. The relationships between metamorphism, crustal-scale ductile shearing, migmatization and magmatism are discussed.

Key words: Geology, structure, K2 gneiss, metamorphism, Baltoro granite, Magmatism.

S/136. Searle, M.P. & Tirrul, R., 1990. Structural and thermal evolutions of the Karakoram crust. In: *Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano*, p.55.

Prior to the Eocene (ca. 50 Ma) collision of the Indian and Asian plates, the southern margin of Asia along the Karakoram plate was an Andean-type margin dominated by tonalitic-granodioritic magmatism of Jurassic-Lower Cretaceous age (Hushe gneiss, Muztagh Tower gneiss and K2 orthogneiss) and associated low pressure andalusite, staurolite and garnet grade metamorphism (M1). Following India-Asia collision, crustal shortening, thickening and regional Barrovian metamorphism (M2) occurred between 50-37 Ma. Thermobarometry of kyanite-grade metapelites indicate burial to depths of around 30-35 km. Simultaneous solution of the garnet-biotite geothermometer with the garnet-muscovite-biotite-plagioclase and garnet-Al₂SiO₅-quartz-plagioclase geobarometers indicates peak M2 P-T conditions of 696±20°C at 8.6kbars ±0.7kbars (860Mpa). Temperatures may have exceeded 700°C in sillimanite-grade metapelites to produce in situ partial melting and leucogranitic melt pods. Peak M2 metamorphism occurred prior to 37±0.8 Ma, the crystallization age of the Mango Gusar two mica granite pluton which crosscuts syn-metamorphic deformation fabrics.

Post M2 thermal relaxation followed from 37-23 Ma after which localized high heat concentrations at the base of the thickened crust caused widespread crustal melting and intrusion of the Baltoro granite batholith at 25-21 Ma, with compositions ranging from biotite monzogranite to garnet two-mica leucogranite. A high temperature-low pressure thermal aureole (M3) of contact metamorphism is synchronous in age with the 21±0.5 Ma zircon age of the Baltoro granite. Andalusite hornfels along the northern contact of the batholith (Mitre thermal aureole) indicates maximum pressures of 3.5 kbars (350 Mpa). A 75°C increase of temperature in kyanite-sillimanite grade gneisses approaching the granite contact along the Baltoro granite is modeled as the thermal upwarping of pre-37 Ma. Barrovian metamorphic M2 isogrades around the 21 Ma contact aureole M3 isotherms along the margins of the Baltoro batholith. A thermal model for the west Himalayan-Karakoram collision belt is presented based on a scaled crustal cross-section using all the available pressure, temperature, time and depth constraints.

Key words: Structure, thermal evolution, continental crust, Karakoram.

S/137. Searle, M.P. & Tirrul, R., 1991. Structural and thermal evolution of the Karakoram crust. *Journal Geological Society, London*, 148, 65-82.

Prior to the Eocene (c. 50 Ma) collision of the Indian and Asian plates, the southern margin of Asia along the Karakoram plate was an Andean-type margin dominated by tonalitic-granodioritic magmatism of Jurassic—Lower

Cretaceous age (Hushe gneiss, Muztagh Tower gneiss and K2 ortho-gneiss) and associated low pressure andalusite, staurolite and garnet grade metamorphism (M1). Following India-Asia collision, crustal shortening, thickening and regional Barrovian metamorphism (M2) occurred between 50–37 Ma. Thermobarometry of kyanite-grade metapelites indicate burial to depths of around 30–35 km. Simultaneous solution of the garnet-biotite geothermometer with the garnet-muscovite-biotite-plagioclase and garnet-Al₂SiO₅-quartz-plagioclase geobarometers indicates peak M2 P-T conditions of 696±20°C at 8.6±0.7kbar (860 MPa). Temperatures may have exceeded 700 °C in sillimanite-grade metapelites to produce in situ partial melting and leucogranitic melt pods. Peak M2 metamorphism occurred prior to 37 ±0.8 Ma, the crystallization age of the Mango Gusar two-mica granite pluton which cross-cuts syn-metamorphic deformation fabrics.

Post-M2 thermal relaxation followed from 37–25 Ma, after which localized high heat concentrations at the base of the thickened crust caused widespread crustal melting and intrusion of the Baltoro granite batholith at 25–21 Ma. A high temperature-low pressure thermal aureole (M3) along the northern contact is synchronous with the 21 ±0.5 Ma zircon age of the Baltoro granite. Andalusite hornfels along the northern contact of the batholith (Mitre thermal aureole) indicates maximum pressures of 3.75 Kbar (375 MPa). A 75 °C increase of temperature in kyanite-sillimanite grade gneisses approaching the southern granite contact of the Baltoro granite is interpreted as the thermal upwarping of pre-37 Ma Barrovian metamorphic M2 isograds around the 21 Ma contact aureole M3 isotherms.

Key words: Structure, thermal evolution, K2, metamorphism, Baltoro granite.

S/138. Searle, M.P., Tirrul, R., Rex, A.J. & Windley, B.F., 1985. A Geological transect across the Baltoro-Muztagh Karakoram from K2 to the Shigar valley. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The Karakoram plate north of the Shyok suture zone consists of three major domains:

a northern sedimentary domain (Carboniferous-?Cretaceous) with structural culmination of high-grade metamorphic rocks (K2 gneiss; Falchan Kangri gneiss); the Karakoram granite batholith (KGB) and a southern high-grade metamorphic domain. These Karakoram rocks crop-out along the hanging-wall of major late-stage thrust-the Main Karakoram Thrust (MKT)- that dips north and places mid- to lower crustal rocks over unmetamorphosed sediments and volcanics of the Tethyan Shyok suture zone. The Shyok suture is thought to have closed during the mid- to late Cretaceous with deformation progressing southwards across Kohistan to the Salt Range during the Tertiary.

South of the Karakoram batholith along the Baltoro glacier- Braldu River transect a high-grade metamorphic terrain consists of kyanite, sillimanite, andalusite, staurolite, garnet and cordierite-bearing paragneisses and sillimanite-K-feldspar-bearing orthogneisses. Numerous garnet-biotite + muscovite + tourmaline + beryl leucogranitic dykes and veins intrude the metamorphic sequence. Garnet, hornblende, diopside, biotite-bearing marbles and amphibolites are interbanded within the sequence. Anthophyllite and jadeite bearing metamorphosed ophiolitic rocks with rare very fresh harzburgites (olivine + orthopyroxene + chrome spinel) occur in two localities within shale and marble units. Many of the higher peaks south of the Braldu gorge consist of andalusite schists with normal downward-increasing metamorphism.

North of the MKT lineations, defined by sillimanite and hornblende needles, plunge E or SE. Foliation in the Panmah, Biafo and Braldu valleys is folded around giant doubly-plunging dome structures which may be late-stage thrust culmination related to late brittle S and SW-directed thrusting along the MKT.

Key words: Geology, structure, K2 gneiss, metamorphism, Baltoro granite, Magmatism.

S/139. Searle, M.P. & Treloar, P.J., 1992. Conference Report: 7th Himalaya-Karakoram-Tibet Workshop. Journal Geological Society, London, 149, 1045-1047.

The first Himalayan Workshop held in Leicester University was so successful that it was then agreed to hold the informal conference and workshop annually. Subsequently the Himalayan Workshops were held in Vandoevre-les-Nancy, France in 1986, London (1987), Lausanne, Switzerland (1988), Milan, Italy (1990) and Grenoble, France (1991). The upsurge in research throughout the Himalayan and Tibetan region in the last ten years has warranted these annual meetings, and the dissemination of new research throughout the Himalayan community has been invaluable. This year the meeting was held in the Department of Earth Sciences, Oxford University, under the auspices of The Geological Society, London from 6-8 April 1992. Over 120 participants from 15 countries attended.

Key words: Conference report, 7th HKT, Oxford.

S/140. Searle, M.P. & Treloar, P.J., 1993. Himalayan Tectonics-an introduction. In: Treloar, P.J. & Searle, M.P. (Eds.), Himalayan Tectonics. Geological Society London, Special Publication 74, 1-7.

This is an introduction to the book edited by the two authors. It gives brief comments on the problem and the papers grouped under the headings Karakoram and Afghanistan, North and West Pakistan, Tethyan Himalaya, High Himalaya, Main Central Thrust, and Main Boundary Thrust, Lesser Himalaya and beyond. Papers dealing with interest area of the present document are summarized in an appropriate places.

Key words: Himalayan, tectonics, Karakoram, Afghanistan, Pakistan.

S/141. Searle, M.P. & Windley, B.F., 1986. Comment on "Thrust tectonics and the deep structure of the Pakistan Himalaya". *Geology* 14, 441-442.

Key words: Thrust tectonics, structure, Himalayas, Pakistan.

S/142. Searle, M.P., Windley, B.F., Coward, M.P., Cooper, D.J.W., Rex, A.J., Rex, D.C., Tingdong, L., Xuchang, X., Jan, M.Q., Thakur, V.C. & Kumar, S., 1987. The closing of Tethys and the tectonics of the Himalaya. *Bulletin of Geological Society of America* 98, 678-701.

Recent geological and geophysical data from southern Tibet allow refinement of models for the closing of southern (Neo-) Tethys and formation of the Himalaya. Shelf sediments of the Indian passive continental margin which pass northward into deep-sea Tethyan sediments of the Indus-Tsangpo suture zone were deposited in the Late Cretaceous. An Andean-type margin with a 2,500-km-long Trans-Himalayan (Kohistan-Ladakh-Gangdese) granitoid batholith formed parallel to the southern margin of the Lhasa block, together with extensive andesites, rhyolites, and ignimbrites (Lingzizong Formation). The southern part of the Lhasa block was uplifted, deformed, and eroded between the Cenomanian and the Eocene. In the western Himalaya, the Kohistan island arc became accreted to the northern plate at this time. The northern part of the Lhasa block was affected by Jurassic metamorphism and plutonism associated with the mid-Jurassic closure of the Bangong-Nujiang suture zone to the north.

The timing of collision between the two continental plates (ca. 50-40 Ma) marking the closing of Tethys is shown by (1) the change from marine (flysch-like) to continental (molasse-like) sedimentation in the Indus-Tsangpo suture zone, (2) the end of Gangdese I-type granitoid injection, (3) Eocene S-type anatectic granites and migmatites in the Lhasa block, and (4) the start of compressional tectonics in the Tibetan-Tethys and Indus-Tsangpo suture zone (south-facing folds, south-directed thrusts).

After the Eocene closure of Tethys, deformation spread southward across the Tibetan-Tethys zone to the High Himalaya. Deep crustal thrusting, Barrovian metamorphism, migmatization, and generation of Oligocene-Miocene leucogranites were accompanied by south-verging recumbent nappes inverting metamorphic isograds and by south-directed intracontinental shear zones associated with the Main Central thrust. Continued convergence in the late Tertiary resulted in large-scale north-directed backthrusting along the Indus-Tsangpo suture zone. More than 500 km shortening is recorded in the foreland thrust zones of the Indian plate, south of the suture, and > 150 km shortening is recorded across the Indian shelf (Zaskar Range) and the Indus suture in Ladakh. There was also large-scale shortening of the Karakoram and Tibetan microplates north of the suture; as much as 1,000 km shortening occurred in Tibet. The more recent deformation, however, involved the spreading of this thickened crust and the lateral motion of the Tibetan block along major approximately east-west-trending strike-slip fault zones.

Key words: Tethys, tectonics, Himalaya.

S/143. Secord, C. & Vyvyan, M., 1939. Reconnaissance of Rakaposhi and Kunyang Glacier. *Himalayan Journal*, 11, 156p.

As this account does not have an abstract, first few paragraphs of the report are given below.

The papers published below are the record of two parts of one brief expedition which was planned to explore the basin of the upper Kunyang glacier of the Hispar Muztagh. On the way Messrs. Secord and Vyvyan succumbed to

the temptations of Rakaposhi and explored its western approaches. Mr. Secord then had to return unexpectedly to England, and Mr. Vyvyan carried out single-handed a rather less ambitious reconnaissance of the Kunyang glacier.—Ed.

Rakaposhi (Campbell Secord).

Rakaposhi towers 20,000 feet above the Hunza and Gilgit rivers which almost encircle it, and the first glimpse of it from Taliche, 40 miles away in the Indus valley, persuaded Michal Vyvyan and myself to have a closer look at it before proceeding to our intended destination up the Hispar glacier. After a day of pleasant ease at Gilgit, therefore, we set off early on the 4th July for a flying trip to the Jaglot nullah which would lead us into the recesses of the mountain's mighty western ramparts.¹

It was exciting to be skilfully ferried across the raging Hunza river on a skin raft, but the 20 miles up its arid left bank seemed interminable on—or off—the decrepit ponies supplied to us with only one saddle between them. Hospitable villagers at Matur Das compelled us to rest during the midday heat by hiding our ponies, providing shady couches and apricots galore, and talking volubly in Burushaski. It was a pleasant spot, perched high above the river, its stone-walled orchards oddly reminiscent of the Italian lake-district. The afternoon's monotony was abruptly terminated by a 600-foot climb straight up the cliffs fringing the river-bed, and we emerged on the edge of a lovely fertile hanging valley—our nullah, at last! The village of Jaglot lay nearby among well-cultivated fields, a startling contrast to the desert we had left below. We discarded the ponies and pushed on up three successive valley steps, camping, as night fell, beyond the uppermost hamlet, with morainal detritus visible in the narrowing gap beyond.

Intense curiosity roused us early next morning, and we walked rapidly upwards, following cattle-tracks along the beautifully treed moraines, as far as a high glacial mound at the junction of two affluents. A delicate cirque of 20,000-foot peaks enclosed the southern branch, but it was the view eastwards which riveted our attention. Rakaposhi soared nearly 16,000 feet directly above us, its western face a mass of tremendous ice-falls enclosed by north-western and south-western ridges of extraordinary beauty, which sprang from a large plateau lying at about 23,000 feet, and which extended at a very high level outwards almost as far as we stood. From the plateau rose the summit pyramid, about 2,500 feet high. It was a fine introduction to the high mountains of Asia.

Key words: Reconnaissance, Rakaposhi, Kunyang Glacier.

S/144. Seeber, L. & Armbruster, J., 1974. The syntaxial area between the Himalayas and the Pakistan Folded Belts. In: *Tectonic Interpretation Based on Microseismic Data*. Rep. 9. Mem. 11, 36p.

Key words: Structure, seismicity, syntaxis, folded belts, Himalayas, Pakistan.

S/145. Seeber, L. & Ambruster, J., 1979a. Seismicity of the Hazara Arc in Northern Pakistan, decollement versus basement faulting. In: Farah, A. & DeJong, K.A. (Eds.) *Geodynamics of Pakistan*. Geological Survey of Pakistan, Quetta, 131-147.

A telemetered seismic network in northern Pakistan covering most of the Hazara arc, the arcuate foreland thrust-fold belt between the Western Himalayan Syntaxis and the Sulaiman Range of Baluchistan, is producing a wealth of seismic data that give new insight into the tectonics of this area. The Indus-Kohistan Seismic Zone (IKSZ) and the Hazara Lower Seismic Zone (HLSZ) are parallel, deeply reaching faults buried under a 10 to 30 km thick layer, presumably a sedimentary or metasedimentary prism. The seismic zones appear to be straight northwestern extensions of the frontal faults of the Himalaya beyond the Western Himalayan Syntaxis where these faults bend sharply to the south at the surface. The IKSZ, by far the more active of the two seismic zones, is associated with underthrusting toward the northeast. A 12 km thick, mostly aseismic layer appears to flake off the underthrust basement and slide over the leading edge of the overthrust block. In contrast, the HLSZ defines a steeply dipping basement fault that probably merges upward and southward with a shallow dipping surface of decollement between the basement and the sedimentary rock sequence that outcrops in the Salt Range.

The eastern portion of the geologically prominent Hazara fault corresponds with a zone of low seismicity during the network operation, from 1973 to 1977. However, a magnitude mb 5.2 (USGS) earthquake that occurred near Rawalpindi on February 14, 1977, caused severe damage and some loss of life. The hypocenters of the main shock and aftershocks indicate a rupture surface between 12 and 18 km depth; if extrapolated to the surface, the trace of the rupture plane almost coincides with the Hazara fault trace. The rupture plane dips to the southeast, and

experienced a left-lateral strike slip during the earthquake. This evidence indicates either that the adjacent section of the Hazara fault cannot be considered presently active as the northwestward-dipping thrust described from surface evidence, or that the February 14 rupture occurred below a decoupling layer and the effect of this active strike slip movement is not evident at the surface.

In the southern part of the Hazara arc, the northwestern portion of the Punjab Seismic Zone and the seismicity at the Trans-Indus Salt Range are associated with a set of parallel strike-slip faults striking north-northwest. This faulting involves the entire thickness of the crust (about 35 km) and can be traced at the surface across the Trans-Indus Salt Range. The low seismicity in the Potwar Plateau and in the Bannu basin indicate that the ongoing decollement is either occurring by aseismic creep, or by rare large earthquakes

Key words: Seismicity, decollement, faulting, Hazara, Northern Pakistan.

S/146. Seeber, L. & Ambruster, J., 1979b. Seismic hazards at the Tarbela Dam site from a model of the active tectonic and earthquake magnitude distribution. WAPDA/TAMS Report 10, 55p.

Consult Seeber et al. (1980) for further details.

Key words: Seismicity, hazards, Tarbela Dam, tectonics.

S/147. Seeber, L. & Ambruster, J., 1984. Some elements of continental subduction along the Himalayan front. *Tectonophysics* 105(1-4), 263-278.

Detachment tectonics, in which the subducting basement is not internally affected by thrusting; and a steady state system, in which the pattern of deformation and topography are invariant, uplift is balanced by erosion and the material can experience subsequent “phases” of deformation by migrating through the system, are proposed to be the fundamental mechanisms of convergence at the Himalayan arc. Both surface and subsurface data are more consistent with these concepts than with more familiar concepts widely used in current models: intracrustal thrusting and evolutionary tectonics, where superimposed phases of deformation are interpreted as distinct phases. The belt of intermediate-magnitude thrust-earthquakes, the topographic front at the High Himalaya and the Main Central Thrust (MCT) are associated with the same fundamental element, the basement thrust front (BTF), which traces a small circle in the central portion of the Himalayan arc. Fault plane solutions indicate thrusting in the radial direction of this arc. This radial convergence at the BTF implies that Tibet is extending laterally at a rate similar to the rate of convergence across the BTF. This extension cannot be unidirectional and must be parallel to the BTF, if the circular shape of the BTF is invariant.

Key words: Tectonics, thrusting, topography, uplift, erosion.

S/148. Seeber, L. Ambruster, J. & Farhatullah, S., 1980. Seismic activity at the Tarbela dam site and surrounding region. *Geological Bulletin, University of Peshawar* 13, 169-191.

The earthquake activity associated with the major faults of the Himalayan front in the Hazara arc region, including Tarbela dam, is discussed in terms of the active tectonic structure of this front. Moreover, the earthquake potential at the Tarbela site arising from the Indus fault system is evaluated by extrapolating the earthquake magnitude distribution.

The active tectonics associated with plate convergence in the Hazara arc region of the Western Himalayas has been modeled primarily by using earthquake data from the seismic network centered at Tarbela. The near-surface structural trends in Hazara are distinct and separated from the trends along the Himalayan front in the Kashmir by the Hazara-Kashmir syntaxis. In contrast, the deeper structures, which are active within the basement in Hazara, are continuous with and linear extensions of the northwest trending structures of the Himalayas in Kashmir. Thus, the arcuate structures in Hazara are only thin-skin. A major detachment fault decouples the sedimentary and metasedimentary layer of the thrust-and-fold belt from the underlying basement. The relative motion on the detachment obtained from seismic data is consistent with the southward vergence of the structures in this belt.

Three families of active faults recognized as potential sources of destructive earthquakes in the Hazara arc region and, in particular; at the Tarbela dam site: the basement faults; the detachment fault; and faults within the sedimentary layers. Available intensity and instrumental data indicate that the Himalayan Basement Thrust and associated transverse or tear faults are the locus of most of the epicenters; however, the largest ($M > 8$) and most damaging earthquakes occur on the Himalayan Detachment. The Hazara arc is included in the tectonic province of

the Himalayan front, thus the Basement Thrust and the Detachment are identified with corresponding structures in Hazara, and the earthquake potential is estimated accordingly.

A layer of thick Intracambrian salt is associated with the Detachment in the Hazara arc region. The low-strength properties of this layer may cause the slip on this portion of the Detachment to occur aseismically. In this case, major Detachment earthquakes analogous to those known from the central section the Himalayan front would not be expected in the Hazara region.

The sedimentary layer in the Tarbela network region of the Hazara arc is mostly aseismic except for the Tarbela seismic zone (TSZ), centered near the Tarbela dam site. This sharply defined volume of seismicity is probably associated with anomalous rock properties rather than an isolated zone of crustal deformation. Thus, the faults active within the TSZ may slip aseismically in the sedimentary layer outside the TSZ.

The maximum credible earthquake in the TSZ is assigned a magnitude 6.5, a maximum surface acceleration of 0.5g, and is associated with the surface rupture of one of the faults in the Indus valley at the Tarbela site. From a quantitative study of earthquake-magnitude distribution a repetition time of 1200 years is obtained for the maximum credible event. This implies a probability of 1/24 that this event will occur during a 50-year lifetime of the dam. The maximum probable earthquake at the Tarbela site in 50 years is a M=5.5 event. The rate of seismicity along the Indus fault system at the Tarbela site is 50 times higher than the average seismicity for the Hazara arc region. However, the level of seismicity on the TSZ is well below the seismicity associated with some of the other seismic zones within the Hazara arc. Most prominent among these is the IKSZ.

Key words: Seismicity, Tarbela Dam, tectonics.

S/149. Seeber, L. & Armbruster, J.G., 1983. Continental subduction along the northwestern and central portion of the Himalayan arc. *Bollettino di Geofisica Teorica ed Applicata (Pamir-Himalaya Volume)* 25, 409-425.

Three prominent features, 1) the topographic front of the High Himalayas, 2) the narrow belt of thrust earthquakes and 3) the Main Central Thrust are closely interrelated and are manifestations of the Basement Thrust Front (BTF), a fundamental element of active convergence along the Himalayan arc. These features and the BTF are continuous over 2500km and are correlated with the boundary between two portions of the overriding unit: the more rigid Tethyan slab, downdip from the BTF and upthrust at this boundary (High Himalayas); and the less rigid sedimentary wedge, updip from the BTF and pervasively deformed (Lesser Himalayas and Sub Himalayas). The details of the subsurface active structures in the Hazara region, as deciphered from earthquake data from a local seismic network, are strikingly discordant to the surface structures and suggest a major subhorizontal detachment. Seismic hazard in the Hazara arc region depends largely on whether the active detachment in this region slips aseismically or by great earthquakes, as does the detachment along the rest of the Himalayan front.

For additional information, consult Seeber and Armbruster (1984).

Key words: Subduction, tectonics, Himalaya.

S/150. Seeber, L., Armbruster, J.G., Quittmeyer, R.C., Zeitler, P.K., Kidd, B., Edwards, M. & Koons, P.O., 1998. Northwest-directed shortening at Nanga Parbat: An active tectonic regime regionally controlled by strain partitioning along the Himalayan Arc and locally accelerated by topographic stress at the Indus River Gorge. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 178-180.

A very active regime of northwest-directed shortening in the Nanga Parbat area is manifested by both earthquake and geologic data, including brittle faults in crystalline rock and structures in Quaternary sedimentary rocks of the Indus and Gilgit valleys. Northwest and northeast directed shortening at Nanga Parbat and along the Himalayan front a few hundred km to the south, respectively, are at a wide angle and are thought to reflect distinct elements in the collisional regime. Northwest shortening at Nanga Parbat is interpreted as internal deformation within the Himalayan overriding block. At the scale of the Asia-India continent collision, northwest-directed shortening at the northwestern terminus of the Himalayan arc is interpreted as the result of strain partitioning along the arc. Earthquake focal mechanisms show radial convergence across the arc. Radial convergence with an undefining footwall block (India) requires arc-parallel extension in the hangingwall block (Tibet), which is indeed geologically and seismologically observed. This "intraplate" deformation in Tibet is driven by strain partitioning. Relative to the

Himalayan arc, northwest convergence at the terminus of the back arc in Nanga Parbat is along strike and in the same direction as arc-parallel extension in Tibet, the main portion of the back arc, and may balance it out, at least in part. Thus, Nanga Parbat is interpreted to be structurally the western boundary of Tibet. Many earthquakes in and near the Nanga Parbat massif were recorded by the ~60-station network we deployed on and around the massif during 1996 and from a more modest deployment in 1995. 130 single-event focal mechanisms were quality selected from the 340 accurate hypocenters located in the vicinity of the massif (100x100 km). The massif is particularly active on the northwestern flank, where topographic relief is the largest. The seismicity is very shallow, from above sea level, to a maximum depth of 6 km asl where it is sharply cut off below the axis of the massif. Focal mechanisms suggest a subhorizontal detachment at this boundary. This detachment ramps up into a thrust fault toward the northwest aiming toward the mapped surface trace of the Lichar thrust. Transport on this structure is generally to the northwest. Footwall-block seismicity is limited to the western side of the NPA. Hangingwall-block antithetic thrusting is illuminated on the southeastern side of the massif and correlates with mapped structures. While we resolved some earthquakes on thrust faults, most of the observed seismicity is from a set of subparallel shallow normal faults striking west to southwest and dipping south to southeast. These faults accommodate extension approximately in the same direction as the transport on the underlying thrust fault. Seismogenic normal faulting is concentrated in the region with highest relief on the western limb of the antiform, between the Indus River and the Nanga Parbat ridge. This faulting can be interpreted as gravity-driven collapse of the eastern wall of the Indus gorge by book-shelf-like block rotation about horizontal-axes and also as flexural slip in the overturned northwestern limb of the Nanga Parbat anticline. The superposition of shallow horizontal extension above crustal shortening at Nanga Parbat may exemplify the effect of topographic stress in regions of convergence and mountain building. The rapid uplift of the Nanga Parbat massif is associated with the northwest-verging Nanga Parbat antiform (NPA) and the southeast-dipping Lichar thrust fault, which outcrops along the northwestern flank of the massif. The Lichar fault and the NPA are interpreted to be coupled active structures (a thrust fault and a fault-propagation fold) that accommodate much of the northwest shortening, but, generally, not all of it. Previous and ongoing work by others suggest a continuous belt of northwest shortening from the western Syntaxis to the Main Karakorum Thrust, for over 200km along strike of the NPA. Furthermore, preliminary results from a survey of brittle and Quaternary tectonic structures in the Indus and Gilgit valleys show west- to northwest-directed shortening in the Kohistan terrane, suggesting that this shortening is, generally, over a belt broader than the massif. Northwest shortening in Kohistan is coupled with two prominent Quaternary transcurrent fault zones, one along the Gilgit River valley, left-lateral and striking west-northwest, the other along the Indus River valley, right-lateral and striking west-southwest. These faults are interpreted to serve as accommodation structures separating broad belts of northwest shortening south of the Indus and north of the Gilgit rivers from a much narrower portion of the belt in between. Along the portion of the belt flanked by the Indus gorge and the outcropping Lichar thrust, shortening seems to be confined to the massif, within and east of the Indus Gorge. This tectonic model is supported by the earthquake data, which show a remarkable lack of seismicity west of the Indus River, across from the very active northwestern flank of the Nanga Parbat massif. This remarkable pattern of regional shortening is thought to stem from the effect of the Indus gorge on the tectonic regime. A very large stress is derived from the combined effect of the weight of the mountain and the lack of weight along the gorge. The tectonic regime responds to this superposed topographic stress by increasing the rate of slip on the Lichar thrust in an attempt to fill the gorge from below. This attempt is futile, given the effectiveness of the river to remove material and to maintain its grade. In this hypothesis, the northwest-directed shortening is taken up completely at the gorge, where the gorge is parallel to the massif. Effectively, therefore, the southwest trending portion of Indus River between the Astor and the Diamir confluences casts a stress shadow to the northwest and shunts the shortening. Topographically driven accelerated slip on the basal thrust along this portion of the gorge may also account for the height along the corresponding portion of the Nanga Parbat massif. Once established, the drainage pattern in active mountain building orogens may have a much greater effect on the tectonics than vice versa.

Key words: Seismicity, tectonics, crustal shortening, strain distribution, Nanga Parbat.

S/151. Seeber, L., Armbruster, J.G. & Quittmeyer, R.C., 1981. Seismicity and continental subduction in the Himalayan arc. In: Gupta, H. K. & Delany, F. (Eds.), *Zagros-Hindu Kush-Himalaya Geodynamic Evolution*. American Geophysical Union, *Geodynamics Series* 3, 215-242.

Consult Seeber and Armbruster (1984) for more information.

Key words: Seismicity, subduction, Himalayan, Geodynamics.

S/152. Seeber, L. & Gornitz, V., 1983. River profiles along the Himalayan arc as indicators of active tectonics. *Tectonophysics* 92(4), 335-367.

Longitudinal profiles along sixteen major transverse Himalayan rivers add important constraints to models of active continental subduction and its evolution. These profiles are characterized by a zone of relatively high gradient that cannot be associated with differential resistance to erosion in all cases. The base of the zone of increased gradients correlates with (1) the topographic front between the Lesser and High Himalayas, (2) the narrow belt of intermediate-magnitude thrust earthquakes, (3) the Main Central Thrust zone (MCT). These features define a small circle in the central portion of the Himalayan arc. These correlations suggest that the discontinuity in the river profiles and the other features are controlled by a major tectonic boundary between the rising High Himalayas and the Lesser Himalayas. No sharp increases in gradient are observed near the Main Boundary Thrust (MBT), except on a few rivers, such as the Jhelum or Kunhar, where the MBT lies close to both the MCT and the seismic belt. Thus, it is unlikely that the MBT is a major tectonic boundary. The diversion of river courses along the MBT and around anticlines in the Sub Himalayas has probably been caused by aggradation near the erosion-deposition boundary, upstream of uplifts in the Mahabharat range and Sub Himalayas.

A parallel is drawn between the Himalayas and New Guinea based on the hypothesis that continent-arc collision, of the type occurring in northern Australia, preceded continent-continent collision in the Himalayas. The present sedimentary/tectonic phase in New Guinea resembles the Subathu (Paleocene-Eocene) phase in the Himalayas. Incipient counterparts of the major Himalayan structures, including the MCT and the MBT, are recognized in New Guinea. The drainage patterns in the Himalayas and in New Guinea bear a similar relation to major structures. This suggests that (1) the tectonic evolution of the Himalayas has been rather uniform since early stages of collision, and (2) the Himalayan drainage was also formed at these early stages and is therefore antecedent to the rise of the High Himalayas.

Key words: Subduction, topography, seismicity, river profile, Himalayan arc.

S/153. Seeber, L. & Jacob, K.H., 1977. Micro earthquake survey of northern Pakistan, Preliminary results and tectonic implications. Symposium on Himalayan Geology, Paris, 1976. *Himalayan Science de la Terre* 268, 347-348.

Key words: Seismicity, tectonics, Tarbela Dam, Hazara, Pakistan.

S/154. Seeber, L. Jacob, K.H. & Armbruster, J.G., 1974a. Tectonics, design, earthquake and seismic risk for the Tarbela Dam Project, Pakistan. Dams Monitoring Organization, Report, 55p.

Key words: Seismicity, tectonics, Tarbela Dam, Hazara, Pakistan.

S/155. Seeber, L. Jacob, K.H. & Armbruster, J.G., 1974b. Microseismic study of Tarbela Dam, Hazara, Pakistan. Dams Monitoring Organization, Archives T-33/67, 23p.

Key words: Seismicity, Tarbela Dam, Hazara, Pakistan.

S/156. Seeber, L. & Pêcher, A., 1998. Strain partitioning along the Himalayan arc and the Nanga Parbat antiform. *Geology* 26, 791-794.

Shortening along the Himalayan arc of continental convergence is approximately in the radial direction. If the underthrusting foot-wall block (India) is not deformed, the hanging-wall block (Tibet) needs to stretch along the arc, as suggested by radial grabens in southern Tibet. In contrast, the Nanga Parbat–Haramosh massif and the western Himalayan syntaxis are part of a 250-km-long antiform that strikes in the radial direction (northeast) and verges northwest. The Nanga Parbat antiform is the structural and topographic expression of arc-parallel shortening that compensates for arc-parallel extension in southern Tibet. This shortening is predicted to be as high as 12 mm/yr.

Key words: Strain partitioning, structure, topography, Nanga Parbat.

S/157. Seeber, L., Quittmeyer, R.C. & Armbruster, J., 1979. Himalayan earthquake belts: Implications from network data from the western syntaxial area. In: *Structural Geology of the Himalayas*. Saklani, P.S. (ed.). 361–392

Key words: Earthquake, structure, geology, Himalayas.

S/158. Seeber, L., Quittmeyer, R.C. & Armbruster, J., 1980. Seismotectonics of Pakistan: A review of results from Network data and implications for the Central Himalaya. *Geological Bulletin, University of Peshawar* 13, 151-168.

Microearthquakes detected by two telemetered seismic networks in northern Pakistan reveal a decollement style of tectonics for the Hazara and northwest Punjab region. The three-dimensional distribution of seismicity and sediments and metasediments is decoupled from the basement. Below the decoupling surface major faults trend northwest. These faults are recognized as basement structures that are associated with the Himalayan arc, but that extend towards the northwest beyond the Hazara-Kashmir syntaxis. During the last six years, the period of network observations, the seismicity is mostly associated with the basement faults. Seismic activity within the decollement is generally low and the decoupling surface is either aseismic or associated with very low seismicity.

The results from northern Pakistan, together with recent seismicity along the Himalayan arc and information on great Indian earthquakes, are combined to derive a general model of Himalayan tectonics. A shallow thrust of gentle dip, termed the Detachment, underlies the Indo-Gangetic plain and the Lower Himalaya. Rupture of this fault, which separates the low-strength sedimentary wedge from the basement, results in great earthquakes that cause devastation over a wide area, but occur only infrequently. Down-dip from the Detachment, beneath the higher, the thrust assumes a steeper dip and juxtaposes basement material of similar properties. Earthquakes occur more frequently on this portion of the fault, termed the Basement Thrust, but are smaller than the Detachment events. They can, however be damaging locally. The model suggests that much of the Indo-Gangetic plain underlain by the Detachment has a high seismic hazard. In the Hazara arc region of northern Pakistan the Detachment is associated with a thick layer of Infracambrian salt. In this region the Detachment may slip aseismically; however, slip by large infrequent earthquake cannot be ruled out.

Results from a seismic network centered on Quetta show that the Chaman fault, and the fault associated with the Quetta earthquake of 1935, are currently active. The segments that ruptured during the most recent large earthquakes on these faults, 1892 on the Chaman fault and 1935 on the Quetta fault, are relatively quiet at present. On both faults the current seismicity is concentrated near the ends of the ruptures associated with these earlier events, and indicates left-lateral strike-slip. In analogy with the San Andreas and Alpine fault system, in California and New Zealand, respectively, two distinct portions of the Chaman fault system are recognized. One, north of approximately 31°N, trends obliquely to the regional slip vector and is probably characterized by infrequent great earthquakes. The other, south of 31°N, has a strike subparallel to the regional slip vector and consists of a broad zone of faults that rupture in large, but not great, earthquakes.

Key words: Seismicity, tectonics, Chaman Fault, Hazara-Kashmir syntaxis..

S/159. Seilacher, A., 1983. Types of iron ores and their economic exploitation in Pakistan. 2nd National Seminar on Development of Mineral Resources, Peshawar, Proceedings.

Key words: Iron ores, economic geology, , exploitation, Pakistan.

S/160. Sverdrup, K.A., Schurter, G.J. & Cronin, V.S., 1994. Relocation analysis of earthquakes near Nanga Parbat-Haramosh massif, Northwest Himalaya, Pakistan. *Geophysical Research Letters* 21, 2331-2334.

Locations of earthquakes that have occurred between 1970 and 1988 in the northwest Himalaya of Pakistan, as computed by the ISC, were analyzed to improve knowledge of the spatial distribution of seismicity near the Nanga Parbat-Haramosh Massif (NPHM). A set of 15 earthquakes were relocated using the multiple-event relocation

technique of Jordan and Sverdrup (1981). Earthquake located using records from at least 25 to 30 stations tend to be well-located in the ISC database: smaller error ellipses and shorter distance of relocation. These analyses indicate that earthquakes with magnitudes $m(\text{sub } b)$ greater than 4.0 have occurred since 1970 along the NPHM.

Key Words: Seismology, tectonics, Nanga Parbat-Haramosh Masif, Himalaya.

S/161. Shabbir, M. & Naeem, U.Z., 1976. Process development study of uranium-bearing carbonatite-uranium ore processing. Proceedings Advance Group Meeting Washington, 67-75; IAEA Vienna.

Key words: Uranium processing, carbonatite.

S/162. Shad, A.M., 1983-85. Geotechnical studies of landslides along Murree-Kohala and Murree-Bhurban Road, District Rawal Pindi. M.Sc. Thesis, Punjab University, Lahore, 121p.

The Murree Kohala road one of the most important road of the country which provides facilities of communication between Pakistan and Azad Kashmir, crossing over the Jhelum river at Kohala. This road is also important for defence point of view. The slopes along the Murree Kohala road are very unstable, especially kassari to Phagwalai village. The condition of the Murree -Kohala road is satisfactory where a good driver can drive every type of vehicle at the speed of 40-50 kms/hour, except for the landslide areas. At Murree Kohala road three major slides were selected for study namely Kasseni (K_0, K_1, K_2, K_3), Norgali (N_1, N_2) and Eliot (A_1, A_2). These are between lower topa to Eliot which are also marked on the map. The second road which join Kohala is starting from Jhikkagali via Burban which meet the Murree Kohala road near phagwani Village. There is also a slide near Kashmiri Bazar which is shown on the map. The project area is lying in the Murree Formation which is mainly composed of Shale, mudstone and sandstone. The detailed geological mapping of the active landslides area were carried out on, the map, sandstone, mudstone and shale with specific symbol on the map. The samples were collected

Key words: Geotechnical, landslides, Murree, Kohala, Rawalpindi.

S/163. Shafeeq, A., 1972. Geochemistry and physical properties of chromites from Pakistan. Ph.D. Thesis, Punjab University, Lahore.

Key words: Geochemistry, chromites.

S/164. Shafiq, M., 1972. Geology of Bibiore Sahibabad area, Dir district, with special emphasis on Leuco-Amphibolite and Granodiorite. M.Sc. Thesis. Punjab University, Lahore, 90p.

The area is occupied by light coloured and often banded epidote amphibolites, which are intruded by granitic rocks. The geology, geomorphology and petrography of the rocks is presented.

Key words: Geomorphology, leuco-amphibolite, granodiorite, Dir.

S/165. Shah, A., 1995. Petrography and geochemistry of the rocks from the acidic volcanic belt, North of Peshawar plain, N.W.F.P., M.Phil. Thesis, University of Peshawar, 72p.

Acidic microporphyries of Late Paleozoic age are intimately associated with appreciably larger volumes of acidic plutonic rocks of alkaline igneous province of Peshawar Plain. Field evidences and their partial intercalation in the metasedimentary sequence of Jaffar Kandao and Baroach Formations suggest an Early Carboniferous age.

Very coarse to fine-grained felsic phenocryst in fine-grained to glassy felsic groundmass clearly imparts a porphyritic texture to these rocks. On the basis of modal and chemical composition, majority of these rocks are classified as rhyolites on one side and basalt (now greenschist) on the other. Variables and their ratios based on major and minor elements classify these rocks as A-type, mildly alkaline and peraluminous in character. On various tectonomagmatic discrimination diagrams, these rocks show a within plate continental rift environment, and this character is also supported by Hf/Th, Hf/Ta and concentration in Zr and Ta. Sensitivity of Th, Hf and Ta due to crustal contamination is seen in tectonomagmatic discrimination triangular diagrams based on these three elements.

Eu-anomaly displays fluid-solid rock interaction confirming soda metasomatism due to late magmatic phases in these rocks.

Key words: Petrography, geochemistry, volcanic belt, Peshawar.

S/166. Shah, H., 1990. Stream sediment study of Ushu and Gabral rivers for heavy minerals, north of Kalam, Swat District, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 451.

Key words: Stream sediments, heavy minerals, Ushu, Gabral, Kalam, Swat District.

S/167. Shah, H., 1994. Stream sediments of Ushu and Gabral rivers for heavy minerals, North of Kalam, Swat district, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release, 451.

Hand-panning survey in an area of about 1083 square miles in the lower part of Kohistan bordering Swat district was carried out to study the distribution of heavy minerals in the alluvial of Ushu and Gabral rivers.

The area under examination is underlain by various types of plutonic, volcanic and metasedimentary rocks. The plutons are represented by norites, diorites and the associated rocks of the Kohistan Basic Complex. Metasedimentary suite is represented by quartzite, various types of schists, phyllites and semi crystalline limestone of the Kalam Group. Whereas volcanics are represented by rhyolite and dacite of the Utror Group.

Microscopic examination of heavy suite reveals hornblende, opaque minerals, garnet, biotite, hypersthene and augite. These constitute bulk of the detrital heavy minerals. Whereas sphene, silliminite, cassiterite, leucosena and tourmaline are present in some slides. Among the opaque minerals magnetite, titanomagnetite, pyrite, chalcopyrite, arsenopyrite, limonite and ilmenite were tentatively diagnosed. Radiometric analysis of the hand-panned concentrates reveals presence of no radioactive mineral. Search for valuable fluorescent minerals has also been carried out and except zircon no other mineral has been detected under UV-lamp of short waves lamp.

Key words: Heavy minerals, Ushu, Gabral, Swat.

S/168. Shah, H. & Said, M., 1990. Geology of Thana quadrangle, Swat district, NWFP., Pakistan., Geological Survey of Pakistan, Information Release, 476.

This area occurs to the south of the MMT and its northern part is drained by the Swat River. It is occupied by metamorphosed pelitic and calcareous rocks which contain granitic intrusions. Field features, structure and lithology of the rocks is presented, along with a geological map.

Key words: Geology, geomorphology, Thana quadrangle, Malakand Agency, Swat.

S/169. Shah, J., 1992. Some observations on the regeneration of vegetation and stabilization of scree slopes in Hunza Valley. Proceedings, National Seminar on Progress of Geography in Pakistan, University of Peshawar, 84-85.

A brief account of the type of debris and talus is given, with mention of those near Pasu, Aliabad, Gulmet, Khanabad and Chapperson. This is followed by data on the existing flora and species, together with some recommendation for stabilization of scree slopes.

Key words: Vegetation, scree slope, stabilization, Pasu, Chapperson, Hunza.

S/170. Shah, K., Shahabuddin, Hassan, B. & Ahmed, M.S.A., 1967. Studies on Resin from Makerwal Coal. Pakistan Journal of Scientific & Industrial Research, 10(3), 212-215.

Makerwal coal is known to contain a high percentage of resins which are recoverable by solvent extraction. Alternative methods of recovery reported earlier show a wide degree of variation in the yield of resins and the quality of coal residue. An attempt has been made to evaluate these methods, by studying separately the behaviour

of original coal, solvent extracted resins and the coal residue from solvent extraction, on superheated steam treatment and carbonisation.

It was found that on superheated steam treatment at 300-330°C these resins were only partially recoverable while on carbonisation extensive cracking of the resins was observed. The experimental data from the present work and critical review of the earlier work in this direction has clarified some of the hitherto reported anomalies of the behaviour of Makerwal coal.

Key words: Coal, Resins, Makerwal, Trans-Indus Salt Range.

S/171. Shah, M.A., 1991-92. The geology and mapping of Muzaffarabad area from Yadgar to Chattar Kalas with special emphasis on geotechnical properties of rock aggregates in the investigated area. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 53p.

The geological and mineralogical characteristic of Rara limestone has been investigated to evaluate the properties of limestone as concrete aggregate. The Crushing Value, Impact Value, Loss Angle 'S', Specific gravity, water absorption and shape of the particles are comparable to recommended B. S standards with few exceptions. At places rocks are highly crushed and deleterious material in the rock aggregate is very high. Mineralogically the iron content (25%), muscovite (7%) and dolomite (2%) are unacceptable. The alkali concrete aggregate reaction involves argillaceous dolomitic limestones, clays, argillites and very far in south expansive cherts were found. It is common in the gravel derived from various limestone formations in the area. Siliceous limestones are investigated from lower plain and Majuhan and in some instances, appear to be a major factor in concrete deterioration. The classical areas of alkali carbonate reaction occur in lower plain and Darwana Nalah. The iron content in the presence of water, argillites and clays associated with alkali expansive reactions in concrete have been described.

Key words: Geology, geotechnical, aggregates, Muzaffarabad, Azad Kashmir.

S/172. Shah, M.A. & Anwar, J., 1981. Regional geology of Chili Bagh west of Kohat, N.W.F.P., M.Sc. Thesis, Department of Geology, University of Peshawar, 41p.

The rocks of the area range in age from Eocene (represented by the Panoba Shale, Kuldana Formation, and Kohat Formation) to Miocene (represented by the Murree Formation) with a disconformity between them. The Panoba Shale has a varied lithology of clay, shale, and marl and was deposited in deltaic environments.

The Kohat Formation is divisible in a lower Kaladhand Limestone Member, a middle Sadkal Shale Member and an Upper Habih Rahi Limestone Member. These were deposited in moderately deep to shallow marine environments. The Murree Formation is represented by clay and sandstone in the area, and was deposited in the lacustrine environments.

The area exhibits remarkable deformational structural features the study of which revealed a series of symmetrical and asymmetrical, cylindrical and non-cylindrical folds. A fault with major strike slip components, joints and other major structural features, were also observed, studied, and marked on the map. The cross bedding is characteristic of Murree Formation.

The rocks of the area have been subjected to intense chemical weathering and rapid rate of erosion in the geological past. Deep erosional work of the various agencies in the past have cut most of the intensely folded anticlines, the cores of which are now exposed.

Key words: Geology, Chili Bagh, Kohat.

S/173. Shah, M.A. & Din, W., 1976. Study of water logged and saline land of Kafoor Dheri area, Peshawar. M.Sc. Thesis, Peshawar University.

Key words: Water logging, salinity, Kafoor Dheri, Peshawar.

S/174. Shah, M.A., Hashmatullah, & Khan, R.A., 2000. Structure and stratigraphy of Chichali Nala, Surghar Range, Pakistan. M.Sc. Thesis, University of Peshawar, 62p.

Key words: Structure, stratigraphy, Chichali Nala, Surghar Range, Trans-Indus Salt Range..

S/175. Shah, M.A. & Ihsanullah, 1969. Geology of the southern part of Warsak area. M.Sc. Thesis Peshawar University, 80p.

This is a geological and petrographic account of the area. The rocks comprise schists, metagabbro sheets and alkaline granite. They seem to form a synclinal structure.

Key words: Geology, Warsak Area.

S/176. Shah, M.M. & Ahmad, Z., 1998. Style of deformation and petroleum prospects of Jhatta area, Talagang, Potwar Plateau, Pakistan. M.Sc. Thesis, University of Peshawar, 110p.

Key words: Deformation, petroleum prospects, Talagang, Potwar Plateau.

S/177. Shah, M.R., 2001. Paleoenvironment, sedimentology & economic aspects of the Hangu Formation in Kohat-Potwar & Hazara area. Ph.D. thesis. NCE Geology, University of Peshawar.

The Hangu Formation of early Paleocene age is widely distributed in the hill ranges of Kohat-Samana, Surghar, Attock-Cherat, Hazara and Salt Range areas of north Pakistan. The formation is comprised of thin to thick-bedded sandstone, siltstone with thin interbeds of limestone and shale. The rocks are characterized by horizontal lamination, graded bedding, cross stratification and bioturbation.

The formation occupies a significant stratigraphic position as it marks the Cretaceous-Tertiary (K-T) boundary. This stratigraphic boundary is in the form of a major unconformity at the base of the Paleocene in north central Pakistan and adjacent north western India, defined by laterite, ferruginous pisolites, and bauxite or local erosional unconformities. The lower contact of the formation marks varied erosional phases in different parts of the north Pakistan. Stratigraphically it overlies the Cretaceous Kawagarh Formation at Samana, Kalachitta and Hazara, whereas in Surghar Range it overlies the Lumshiwal Formation. The hiatus is even more pronounced in the Salt Range area, where it overlies the Lumshiwal, Samanasuk, Datta, Mianwali, Chhidru, Wargal, Amb, Sardhai formations and Warchha Sandstone of Cretaceous, Jurassic, Triassic and Permian ages respectively. In Cherat and Balakot area the formation rests over the Dakhner Formation of Precambrian and Abbottabad Formation of Cambrian age. This indicates a major unconformity in these areas progressively increasing eastward.

From the study of different stratigraphic sections the formation can be subdivided into a number of lithostratigraphic units and lithofacies based on the lithological variations and sedimentary structures. The important lithofacies recognized in these areas are; 1) Lateritic/Bauxitic lithofacies. 2) Cross-bedded sandstone lithofacies. 3) Bioclastic limestone lithofacies. 4) Coal, carbonaceous shale lithofacies. 5) Bioturbated quartzose sandstone lithofacies. Lithofacies analysis and petrographic studies of the Hangu Formation indicate that transgressive shoreline environments deposited the formation, which is partly represented by terrestrial to coastal swampy conditions and partly by shoreface to offshore (shelf) environments of deposition.

The upper and basal parts of the formation contain economic minerals like coal, laterite, bauxite, silica sand and fairly good source rock potential for hydrocarbon generation. The coal is found in the Samana Range, Surghar Range and Attock-Cherat Range but is missing in Salt Range, Kalachitta and Hazara areas. The coal is dull to shining black in colour, grades from high volatile B to C bituminous in rank and is in the form of lenses, stringers and lenticular beds. The laterite and bauxite developed at the base of the formation in the study area is found as discontinuous beds, lenses, sheets and pockets. The laterite is found in Samana Range, Surghar Range, Attock-Cherat, Kalachitta, Salt Range and Hazara while bauxite is confined to Salt Range area. The silica sand, which is present in the upper, middle and lower parts of the formation, is well developed in the Samana Range, moderately developed in the Surghar Range and is poorly developed in the western Salt Range. Source rock potential for hydrocarbon generation is developed in Surghar, Salt Range and Attock-Cherat Ranges.

Key words: Stratigraphy, paleoenvironments, lithofacies, Hangu, Kohat-Potwar, Hazara.

S/178. Shah, M.R., Abbasi, I.A. & Haneef, M., 1999. Lithostratigraphy of the K-T boundary in north Pakistan. Additional abstracts, IGCP 421, North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics, Peshawar Meeting, 1p.

Key words: Lithostratigraphy, biogeography, K-T boundary, North Pakistan.

S/179. Shah, M.R., Abbasi I.A. & Haneef, M., 2000. Stratigraphy and lithofacies architecture of the Early Paleocene rocks of the Northern Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, p.52.

Key words: Stratigraphy, lithofacies, Paleocene, Northern Pakistan.

S/180. Shah, M.R., Abbasi I.A. & Haneef, M., 2001. Facies and paleoenvironment of the Hangu Formation (Paleocene), N. Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, 29-30.

The Hangu Formation of Early Paleocene age is widely distributed in N. Pakistan. It is comprised of thin to thick-bedded sandstone, siltstone with thin limestone/shale interbeds and thin coal seams, containing a wide variety of sedimentary structures (Shah et al., 1993). The thickness of the formation varies from 97m at the stratotype to 1m in the Eastern Salt Range.

As a part of this study, 19 stratigraphic sections of the formation were studied and described along the entire belt of the outcrop in the Salt Range, Attock-Cherat Range, Kohat-Potwar and Hazara areas. The purpose of this study is to establish the stratigraphic relationships, identify lithofacies and interpret the depositional environments. Five lithofacies of the formation are recognized on the basis of lithological variations and distinct depositional fabric (Shah et al., 1999). These lithofacies include; FILF-1 (Laterite/Bauxite Lithofacies): This lithofacies marks the base of the formation and is comprised of laterite, lateritic clay, shale, bauxite and bauxitic clay, as discontinuous bodies, pockets and lenses. The laterite is well developed through out, while bauxite is confined to the Central Salt Range.

HLF-2 (Cross-bedded Sandstone Lithofacies): This lithofacies is dominantly comprised of sandstone in Kohat-Samana area and sandstone, siltstone, clay and limestone in Surghar Range and Salt Range. The lithofacies is cross-bedded. HLF-3 (Bioclastic Limestone Lithofacies): This lithofacies is represented by skeletal wacke packstone and is only present in the Surghar Range and Salt Range. It is interbedded in siltstone and shale. FLLF-4 (Coal/Carbonaceous Shale Lithofacies): Coal, carbonaceous shale and sandstone lithofacies is restricted to Hangu, Makarwal and Cherat areas. This lithofacies is found in the upper part at the Hangu section, while at Makarwal and Cherat it is found in the lower and middle parts.

HLF-5 (Bioturbated Quartzose Sandstone Lithofacies): This is the topmost lithofacies of the formation and is comprised of highly bioturbated sandstone, siltstone and clays. The lithofacie occurs widely in the study area.

The lithofacies interpretation of the Hangu Formation reveals that the formation represent deposition in near-shore, beach-barrier environments. HILF-1 represents non-marine terrestrial (sub-aerial exposures) environments. HLF-2 represents beach/foreshore environments deposition. HLF-3 is deposited in paralic (back-barrier) environments. HLF-4 is interpreted to deposited in shallow marine/lagoonal environments, while HLF-5 represents shoreface environments of deposition.

Key words: Lithofacies, paleoenvironment, sandstone, stratigraphy, coal, Hangu Formation.

S/181. Shah, M.R., Abbasi I.A., Haneef, M. & Hussain, A., 1997. Lithofacies and depositional environment of the Hangu Formation (Paleocene) in northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.58.

Consult the preceding account.

Key words: Lithofacies, paleoenvironment, sandstone, coal, Hangu Formation.

S/182. Shah, M.R., Abbasi I.A., Haneef, M. & Khan, A., 1993. Nature, origin and mode of occurrence of Hangu-Kachai area coal, district Kohat, NWFP, Pakistan: A preliminary study. Geological Bulletin, University of Peshawar 26, 87-94.

Coal showings are known from the Hangu Formation of Paleocene age in the Hangu-Kachai area, northwest of Kohat. The Hangu Formation is well developed in this area and is comprised of quartzitic sandstone with minor intercalations of shale. The coal seam is developed near the upper contact of the Hangu Formation with the overlying lockhart limestone. Preliminary exploratory drilling of the Hangu Formation in the area have revealed the presence of coal. The coal is dull to shining black and ranges from high volatile B to C bituminous in rank. The Hangu area coal occurs in the form of discontinuous stringers and lenses and is less than 2 meters thick.

The average analytical results on as received basis indicate, the coal bed contains 0.52 % moisture, 14.2 % ash, 4.2% sulphur, 53 % fixed carbon and 32.64 % volatile matter. Based on the average BTU/lb and fixed carbon content of the Hangu-Kachai coal samples collected from the field, with minor exception of variation in color, the Hangu coal is analogous to the known coals of the Balochistan and the Salt Range areas. On the basis of its stratigraphic position, mode of origin and structure, the Hangu-Kachai coal is comparable with the Makarwal coal of the Surghar Range. Detailed exploratory studies are proposed to evaluate the nature and extent of the Hangu-Kachai area coal.

Key words: Coal, sandstone, Hangu Formation, Kachai, Hangu.

S/183. Shah, M.T., 1986. Petrochemistry of the rocks from Shergarh Sar area, Allai Kohistan, Northern Pakistan. M.Phil. Thesis, University of Peshawar, 221p.

The Shergarh Sar area in Allai Kohistan is located at the junction between the Indo-Pakistan plate and the Kohistan island arc block. Rocks of the area are distinguished into three petro-tectonic units: (1) The Kohistan island arc sequence, (2) The Indus suture mélange zone, and (3) The Indo-Pakistan subcontinent sequence.

Amphibolites are the most abundant rocks in the Kohistan island arc sequence. These are distinguished into epidote-amphibolites and garnet epidote-amphibolites. The Indus suture mélange zone mainly comprises ultramafics (clinopyroxenite, peridotite and serpentinite), pillow lavas, greenschist rocks, and blueschist facies metagraywacke. The Indo-Pakistan subcontinent sequence includes granite gneiss, thin bedded crystalline limestone, and schists. In the present work, the field features, petrography, and chemistry of the constituent rock units are discussed in detail.

The potential usefulness of the observed petrochemical indices from the constituent rocks in the studied suite is elucidated as tectonic finger prints and genetic indicators in this thesis. The major and trace element constraints of amphibolites, suggest their derivation from a basic igneous parent of tholeiitic character developed in an island arc type environment. The intimately associated igneous and metamorphic rocks within the Indus suture mélange zone owe their development to different processes in varied tectonic environments. The chemistry of the ultramafics suggests the comagmatic nature of the constituent rocks, and their development by the partial melting of mantle of peridotitic composition. Lavas in the Indus suture mélange zone are compact, mostly glassy or very fine grained. These are characterized by pillow structures, and frequently show incorporation of angular to rounded fragments and blocks of carbonate rock. Their major and trace element analyses closely correspond to tholeiitic rocks produced by partial melting process in an island arc type environment. Chemistry of greenschist rocks, occurring in north western part of the studied area, suggests their derivation from a basic parent through metamorphism. Assessment of the chemical data in related chemico-tectonic systems favour origination of their parent material in typical oceanic environments.

Petrography and mineral chemistry of the blueschist facies metagraywacke from the studied area are compared with that of the equivalent rocks occurring in Shangla (Swat) and Ladakh. P-T conditions of metamorphism are calculated. Details of thin section and chemical study oppose oscillatory transition in metamorphic conditions, as noted in Shangla, or retrogression as found in similar rocks from eastern Ladakh.

Key words: Petrography, geochemistry, suture zone, Shergarh Sar area, Allai, Kohistan.

S/184. Shah, M.T., 1991. Geochemistry, mineralogy and petrology of sulfide mineralization and associated rocks around Besham and Dir, Northern Pakistan. Ph.D. dissertation, University of South Carolina, Columbia.

Key words: Geochemistry, mineralogy, petrology, Besham, Dir.

S/185. Shah, M.T., 1992a. Validity of sphalerite geobarometry and garnet-biotite geothermometry to estimate P-T conditions of metamorphism for the sediments-hosted base

metal deposits in Besham area, northern Pakistan. Geological Bulletin, University of Peshawar 25, 67-71.

Regionally metamorphosed sediment-hosted stratiform exhalative type base metal deposits are exposed in the Lahore and Pazang properties of Besham area at the northern margin of the Indian plate. Sphalerite geobarometer and garnet-biotite geothermometer were used calculate the P-T conditions of metamorphism. These geothermobarometer yielded most convincing results for the studied deposits. These deposits and the host meta-sediments were subjected to amphibolite facies metamorphism with a metamorphic temperature of $585 \pm 250^\circ\text{C}$ and a pressure of 8 ± 2 kb.

Key words: Sphalerite, geobarometry, geothermometry, metamorphism, metasediments, Besham, Kohistan.

S/186. Shah, M.T., 1992b. Tourmaline as an evidence of exhalative origin for Besham base metal deposits in northern Pakistan. Geological Bulletin, University of Peshawar 25, 123-126.

Tourmaline occurs as an accessory phase in the metaquartzite/meta-arkose unit of the Pazang group in Besham area. The chemistry of different tourmaline grains varies within the same sample but there is no change in composition within a single grain. These tourmalines have an intermediate composition between schorl and dravite. This composition along with FeO/FeO+MgO ratio for the studied tourmaline grains is unlike those of granitic terrain and can be comparable to that of the tourmaline found in association with submarine exhalative massive sulfide deposits.

Key words: Tourmaline, base metal, mineralization, Besham, Kohistan.

S/187. Shah, M.T., 1993a. A note on the chalcopyrite disease in sphalerite in the volcanic-hosted copper mineralization in Dir area, Northern Pakistan. Acta Mineralogica Pakistanica 7, 82-84.

Key words: Chalcopyrite, sphalerite, copper, mineralization, Dir, Pakistan.

S/188. Shah, M.T., 1993b. Skarnization of the massive sulfide ores and associated rocks of the Pazang group in Besham area at the northern margin of Indo-Pakistan plate. Acta Mineralogica Pakistanica 7, 68-78.

Proterozoic sediment-hosted massive sulfide ores occur in the highly deformed and metamorphosed rocks of the Pazang group in the Besham area, District Kohistan. The massive sulfide ores and associated rocks of the Pazang group were subjected to skarnization after their deposition. Both magnesian and calcic skarns were formed. As a result, the Mn-rich skarn minerals (i.e. clinopyroxenes, pyroxenoids, garnet, olivine and serpentine) have been developed within these rocks. The chemistry of these minerals suggest that the protoliths for both calcic and magnesian skarn were probably impure limestone and dolomite respective with intercalations of umber, chert and clays.

Key words: Proterozoic, massive sulfide, pazang group, chemistry, Besham, Kohistan.

S/189. Shah, M.T., 1994. A note on the bornite-chalcopyrite intergrowth texture in the volcanic-hosted copper mineralization in the Dir area, northern Pakistan. Geological Bulletin, University of Peshawar 27, 125-126.

Various experimental studies have been carried out to understand the possible bornite-chalcopyrite intergrowth texture. The bladed and lenticular shape intergrowth of chalcopyrite in the studied bornite can be termed as widmstätten texture of Schwartz (1931) and Durazzo and Taylor (1982). This type of intergrowth texture can possibly be the product of either: 1. Replacement of bornite by chalcopyrite or 2. Exsolution from anomalous bornite during heating in a temperature range c. $200-2500^\circ\text{C}$. In this case the chalcopyrite exsolution lamellae in the bornite matrix of the studied rocks may have probably been produced due to the rapid growth of chalcopyrite in a highly supersaturated bornite matrix with chalcopyrite $> 25\%$.

Key words: Texture, chalcopyrite, exsolution, matrix, copper mineralization, Dir.

S/190. Shah, M.T., 1995a. Metallic mineral deposits of northern part of Pakistan "Souvenir, International symposium and field workshop on phosphorites and other industrial minerals; SEGMITE-UNESCO joint organization, Abbottabad, Pakistan.

Key words: Metallic mineral, phosphorite,.

S/191. Shah, M. T., 1995b. Mineralogy, texture and geochemistry of the volcanic-hosted hydrothermal copper mineralization in the Dir area, northern Pakistan. In: Abst., vol. Dissanayake, C. B., Almond, D. C., and Cooray, P. G., (Eds.), Second South Asia Geol. Cong., Colombo, Sri Lanka, p.176.

Consult the following for further information.

Key words: Mineralogy, texture, geochemistry, hydrothermal, copper mineralization, Dir.

S/192. Shah, M.T., 1997a. Mineralogy, texture and geochemistry of the volcanic-hosted hydrothermal copper mineralization in Dir area, Kohistan arc terrane, northern Pakistan. In: Wijayananda, N.P., Cooray, P.G. & Mosley, P. (Eds), Geology in South Asia-II, Geological Survey and Mines Bureau, Sri Lanka, Professional Paper 7, 263-280.

Copper mineralization in the Dir area is related to a hydrothermal activity, which is mainly confined to the metavolcanic sequence within the Kohistan island arc in Pakistan. The sequence is composed predominantly of basaltic-andesite and andesite with subordinate basalt, dacite, rhyolite and pyroclastic breccia. Chalcopyrite is the main copper-bearing phase. Subordinate Cu-phases are bornite, chalcocite and covellite. Electron microprobe analysis indicates the pure nature of these ore phases. Malachite and azurite showings are conspicuous along the shear zones. A variable gain and loss of MnO, Na₂O, K₂O and P₂O₅ are noticed in the mineralized metavolcanics, which show an enrichment of Cu, Zn, Mo, Cd, Ag and Au. Both mineralized metavolcanics and mineralized quartz veins have a high $\delta^{18}\text{O}$ signature. This suggests the involvement of isotopically heavy or-forming fluid in the alteration and copper mineralization in these volcanics. This fluid has an estimated $\delta^{18}\text{O}$ isotopic composition of 5.1 per mil, which could be the magmatic water introduced by the granodiorite or diorite intrusion below the metavolcanic sequence.

Key words: Mineralogy, texture, geochemistry, hydrothermal, copper mineralization, Dir.

S/193. Shah, M.T., 1997b. Mineralogy, chemistry and genesis of the Proterozoic base metal deposits at the northern margin of the Indian plate in Besham area, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

Consult the following account.

Key words: Mineralogy, chemistry, genesis, base metals, Proterozoic, Indian plate, Besham, Kohistan.

S/194. Shah, M.T., 1997c. Mineralogy, chemistry and genesis of the Proterozoic base metal deposits at the northern margin of the Indian plate in Besham area, Himalaya, Northern Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), Proceedings, National Symposium on Economic Geology of Pakistan, 1997, Islamabad, 11-57.

The Himalayan mountain range is a geological manifestation of the collision of northward moving Indian plate with the Asiatic plate. Kohistan arc terrane is sandwiched between these two plates and is bounded by two major thrust faults. Rocks of the northern margin of the Indian plate have a complex tectono-metamorphic history with poly-phase deformation and metamorphism. These are mainly composed of the Proterozoic basement gneisses and schists, which are overlain by several sequences of metasediments of Phanerozoic age. These rocks have been

divided into Besham, Pazang and Karora groups. The first two groups are a part of the basement complex and the third one is composed of a cover of metasediments that unconformably overlie the basement complex.

Base metal mineralization in the rocks of the Indian Plate occurs along its northern margin in the footwall of Main Mantle Thrust (MMT) around Besham and is confined to the Pazang group. The rocks of the Pazang group are distinguished into Pelitic formation, Sulphide formation and Meta-quartzite/Meta-arkose formation from bottom to top. The Sulphide formation having Zn-Pb mineralization constitutes the distinct portion of the Pazang group and is the subject of present research.

Mn-rich clinopyroxenes, pyroxenoids and Mn-rich garnets are the common skarn minerals. Quartz, feldspars, biotite, muscovite, hornblende, phlogopite, epidote and carbonates are present in variable amount in each rock unit. Tourmaline, zircon, apatite, sphene and pyrophanite occur as accessories. Olivine, serpentine and phlogopite are commonly developed in the magnetite-rich carbonates. Among the ores, sphalerite, pyrrhotite, pyrite and galena are the main sulphides with minor amount of chalcopyrite and melnikovite. Magnetite is the major oxide present in these rocks. Mineralogy and chemistry of various silicates and sulphides and the whole rock major and trace elements geochemistry provided some clues regarding the paragenesis of massive sulphide ores.

Lead isotopic gave model ages of 2120-2199 Ma (Proterozoic) for both the Pazang and Lahor deposits. These deposits are more primitive in terms of ages and have lower μ values relative to the well-known sediment-hosted deposits elsewhere in the world. The non-radiogenic isotopic composition and the homogeneity of the ore lead in both Pazang and Lahor ores suggest a well-mixed common source and similar processes for the formation of these ores.

Zn-Pb stratiform mineralization in Besham area occurs in a highly deformed and metamorphosed terrane. Most of the textural features suggest that the mineralization predate the deformation and metamorphism. Both deformation and metamorphism have caused remobilization and crystallization of various ore phases to the present situation. Igneous metasomatic skarn has played an important role in the formation of Mn-rich clinopyroxenes, garnet and pyroxenoids along with Cu, Mo and W mineralization, within the rocks of the Pazang group. Massive sulphide ores and the host rocks are subjected to the upper amphibolite facies metamorphism with a metamorphic temperature of $583 \pm 35^\circ\text{C}$ and pressure of 8 ± 2 Kbars.

The mineralogy, petrology and geochemistry of various ore bodies and their lead isotopic ratios, lack of volcanic rocks and lack of footwall hydrothermal alteration favor a distal submarine exhalative origin for the Besham Zn-Pb ore bodies. These deposits can be classified as sedimentary exhalative stratiform zinc-lead.

Key words: Mineralogy, chemistry, genesis, base metals, Proterozoic, Indian plate, Besham, Kohistan

S/195. Shah, M.T., 1997d. The geological setting of the metamorphosed Proterozoic massive sulfide deposits at the northern margin of the Indian plate in Besham area, northern Pakistan. Franks M. Vokes 70 years anniv. Symposium on Formation and Metamorphism of massive sulfides, Norway. (Abstract).

Consult the preceding account.

Key words: Mineralogy, chemistry, genesis, base metals, Proterozoic, Indian plate, Besham, Kohistan

S/196. Shah, M.T. & Danishwar, S., 1997. High fluoride content and its source of contamination in the drinking water of Kheski (District Nowshera) and Narangi (District Swabi) area of N.W.F.P., Pakistan. Colloquium on Geology and Human Life, (Abstract) p.44.

Key words: Fluoride contamination, drinking water, Nowshera, Swabi.

S/197. Shah, M.T. & Gohar, A., 2000. Feasibility study of Eocene limestone of Kohat Formation (District Kohat, N.W.F.P., Pakistan) for its use as concrete aggregates. Abstracts, Third South Asia Geological Congress, Lahore, p.51.

Key words: Concrete aggregate, Eocene, limestone, Kohat.

S/198. Shah, M.T. & Hamidullah, S., 1994. Field and mineralogical constraints of the Dir metavolcanic sequence, Kohistan arc terrane, northern Pakistan. *Geological Bulletin, University of Peshawar* 27, 43-55.

The Dir metavolcanic sequence, a part of the Dir group, constitutes a NE-SW trending belt within the northwestern portion of the Kohistan island arc in the western Himalaya of northern Pakistan. This sequence is dominantly composed of basaltic-andesite and andesite with subordinate basalt, dacite, rhyolite, and pyroclastic breccia. These rocks are foliated and sheared along local faults and also have small intrusions at places.

Porphyritic textures are dominant, with less common aphyric and seriate textures. Plagioclase (An 10-42) is ubiquitous in all the members of the sequence and occurs as phenocrysts and in groundmass. K-feldspar and quartz predominate both as phenocrysts of the dacites and rhyolite. Chlorite, epidote, and actinolite are the most common metamorphic phases; hornblende, muscovite, biotite, kaolinite, sericite, carbonate, and opaques occur rarely. Phase assemblages and chemistry suggest predominant greenschist facies metamorphism with epidote-amphibolite facies conditions attained locally.

Key words: Metavolcanic, geochemistry, metamorphism, Dir group, Kohistan arc.

S/199. Shah, M.T., Haq, I. & Hamidullah, S., 2000. Geology and geochemistry of the rocks of Yushiri valley, District Dir, Northern Pakistan. *Geological Bulletin, University of Peshawar* 33, 53-78.

The study area is lying in the north-western portion of the Kohistan arc terrane. This terrane is bounded by two suture zones of regional extent at its northern and southern sides, believed to be formed by obliteration of ancient oceanic basin. This arc experienced its first collision at its northern margin with the Karakorum plate at 90-80 Ma, and its second collision at the southern margin during Early Eocene with the Indian plate. Rocks of the study area are distinguished into two main lithological units: (1) Amphibolites and (2) Metadiorites/metagranodiorites. The amphibolites occupy the southern part of the studied area while metadiorite/metagranodiorites are exposed in the northern part of the study area. Both these rock units have intrusive contacts and exhibit local faulting and shearing. The amphibolites also host small patches of slightly metamorphosed gabbro-norites. The amphibolites are generally massive but also exhibit banding at places. They are intruded by quartz and quartzo-feldspathic veins especially in areas where shearing and faulting are intense. They are also intruded by the metadiorite / metagranodiorite in the form of small plugs. The metadiorites / granodiorites are medium to coarse-grained, massive in character and have xenoliths of amphibolites. Copper mineralization in the form of disseminated grains of tetrahydrite and chalcopyrite and supergene enrichment in the form of malachite and azurite occur within quartz veins in limited areas. Amphibolites are mainly composed of hornblende and plagioclase with subordinate amount of quartz and alkali feldspar. Biotite, muscovite, chlorite, epidote, apatite, sphene, rutile, calcite and opaque occur as accessories. The metagabbro-norites contain plagioclase, orthopyroxene and clinopyroxene as the dominant mineral constituents. The metadiorite, quartz-diorite and metagranodiorite are dominantly composed of plagioclase with variable proportion of quartz and alkali feldspar. The other minor constituents include biotite, hornblende, muscovite, apatite, sphene, zircon, garnet and opaque.

Chemically the amphibolites and metagabbro-norites are comagmatic. Their chemical characteristics favor the igneous parentage (i. e., host gabbro-norite) for the studied amphibolites. The major and trace elements study of these rocks suggests that these are of calc-alkaline nature and are formed by the arc magma within the subduction related environment. The chemical characteristics of the granitoid rocks (metadiorite/metagranodiorite) suggest that these are comagmatic and have close affinity towards the calcalkaline rocks, developed in island arc type of set up. Both the amphibolites and gabbro-norites could be related to either Kamila amphibolites belt or Chilas Complex. The studied granitoids are, however, correlated with the stage II pluton of the Kohistan batholith.

Key words: Geochemistry, amphibolites, diorites, Yusheri Valley, Dir.

S/200. Shah, M.T., Ikramuddin, M. & Shervais, J.W., 1991. Thallium in copper-bearing quartz veins and associated metavolcanics from the Dir area, northern Pakistan. GAC-MAC-SEG meeting, Toronto, Canada.

Key words: Thallium, quartz veins, metavolcanics, Dir.

S/201. Shah, M.T., Ikramuddin, M. & Shervais, J.W., 1994. Behaviour of Tl relative to K, Rb, Sr and Ba in mineralized and unmineralized metavolcanics from the Dir area, northern Pakistan. *Mineralium Deposita* 29(5), 422-426.

Copper mineralization in the Dir area of northern Pakistan is confined to the quartz veins and associated with hydrothermally altered metavolcanics. Chalcopyrite is the main copper-bearing phase with subordinate amounts of bornite, chalcocite, covellite, malachite and azurite. Both mineralized quartz veins and associated unmineralized (least altered) and mineralized (strongly altered) metavolcanics have been analyzed for Cu, Au, Ag, Tl, K, Rb, Ba and Sr. An increase of Cu, Au, Ag, Rb/Sr and Tl/Sr, and a decrease of Sr and K/Rb is observed in both mineralized metavolcanics and mineralized quartz veins. Thallium shows lithophile behaviour in the Dir metavolcanics and no chalcophile behaviour was observed. The Tl/Sr ratio might be an indirect guide for the exploration of volcanic-hosted hydrothermal copper deposits.

Key words: Copper mineralization, thallium, geochemistry, metavolcanics, Dir.

S/202. Shah, M.T. & Jan, M.Q., 1993. Mineralogical constraints of the Shergarh Sar amphibolites, Allai Kohistan, northern Pakistan. *Geological Bulletin, University of Peshawar* 26, 59-73.

Shergarh Sar amphibolites, a part of the southern amphibolite belt, widely exposed in the area around Bana in Allai Kohistan. Epidote-amphibolite is the main unit with scattered patches of garnet-bearing variety. Amphibole, epidote and, in some, garnet are the main phases with minor amount of quartz, plagioclase, clinopyroxene, opaque oxides and rutile. Amphiboles range in composition from tchermakitic-hornblende to actinolite with magnesio-hornblende as an intermediate phase. This transition is marked by decrease in Al/Ti, alkalies and Fe^{2+}/Mg ratio and increase in Si. Epidote occurs as large crystals (both zoned and unzoned) with low Ps contents (9-15) and as small granular aggregates with high Ps contents (17-27). Garnet occurs sporadically in the form of porphyroblasts and is found in association with leucocratic veins. It is chemically unzoned and is predominantly made up of almandine-grossular-pyrope solid solution. Plagioclase ranges from An₂₇ to pure albite and clinopyroxene is chemically homogenous diopside.

Petrographic observations and thermobarometry suggest that the rocks were initially equilibrated under amphibolite facies with overprinting of greenschist facies assemblage. This retrogression may have been facilitated by shearing during the obduction (uplift-cooling) of the rocks along the Indus suture following their Eocene collision with the Indian plate.

Key words: Mineralogy, amphibolites, petrography, metamorphism, Allai, Kohistan.

S/203. Shah, M.T. & Khan, A., 1997. Mineralogy, geochemistry and genesis of the Mn-deposits and associated metacherts of Sadgai and Shuidar area, North Waziristan, N.W.F.P., Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.59.

For further information, consult the following account.

Key words: Geochemistry, Mn-deposits, North Waziristan.

S/204. Shah, M.T. & Khan, A., 1999. Geochemistry and origin of Mn-deposits in the Waziristan ophiolite complex, North Waziristan, Pakistan. *Mineralium Deposita* 34, 697-704.

The Waziristan ophiolite complex is located along the western margin of the Indian plate in northwestern Pakistan. The Mn-deposits in the Saidgi and Shuidar areas are part of this ophiolite complex. These deposits, both banded and massive in nature, are hosted by metachert and are generally overlying metavolcanics. Braunitz and cryptocrystalline quartz are the main constituents of the manganese ores in both areas. Hematite occurs in the Shuidar deposits as a minor phase. Metacherts are microcrystalline quartz, chalcedony, and lesser hematite. Chemically, the studied Mn-deposits and associated metacherts are very similar to those formed by submarine

hydrothermal effusive processes. The deposits originated along sea-floor spreading centers (mid-ocean ridges) within the Neo-Tethys Ocean and were later obducted as part of the Waziristan ophiolite complex.

Key words: Geochemistry, ophiolite, Mn-deposits, chalcedony, North Waziristan.

S/205. Shah, M.T., Latif, A. & Aurangzed, 1980. Major element abundances in volcanic rocks from Kalam volcanic zone, Swat. M.Sc. Thesis, University of Peshawar, 56p.

Andesite and salic eruptives of calc-alkaline affinity in the Kalam volcanic zone constitute the upper part of the Kohistan sequence (Tahirkheli et al., 1970) developed in the western branch of the Himalayan syntaxis between 71°E and 75° E. The sequence is interpreted as a complete cross section of a mature island arc formed by subduction during Mesozoic in the southern part of the Neotethys and obducted onto the Indian plate in Upper Cretaceous time (Bard et al., 1980). The Kohistan sequence includes a thick complex of amphibolites, hypersthene gabbros, pyroxene diorites, hornblende diorites, granodiorites, metasediments and volcanic rocks.

The potential usefulness of the geochemical parameters of the extrusive rocks from the Kalam area, Swat as tectonic fingerprints and genetic indicators is discussed in this paper. There is a close correspondence between the available petrochemical indices of genetic significance of the studied suite to the calc-alkaline volcanics in western and southwestern Pacific regions, which substantiates earlier workers' designation of an island arc environment in the Kohistan Himalaya during Mesozoic time.

Key words: Geochemistry, volcanic rocks, Kalam, Swat.

S/206. Shah, M.T. & Lechler, P.J., 2001. Stream sediment exploration for base and precious metal in the Dir and Swat Kohistan, northern Pakistan. *Journal of Asian Earth Sciences* 19, p.60.

Key words: Stream sediments, precious metal, exploration, Dir, Swat.

S/207. Shah, M.T. & Lechler, P.J., 2002. Gold anomalies in the Dir and Swat Kohistan, northern Pakistan. *Journal of Science & Technology, University of Peshawar*, 26, 1-6.

The major portion of the study area is comprised of rocks of the Kohistan Island arc while the rest of the area is composed of the rocks of the Indo-Pakistan plate. Both these terrains are separated by the Indus suture mélange zone, which represents the collision suture between the Indo-Pakistan and Eurasian plates.

Geochemical exploration for gold has been carried out by collecting heavy mineral panned- concentrates and stream sediment samples from various drainage basins of the study area. Mineralogical studies of the panned-concentrates suggest the presence of gold in the form of piece, speck and color in certain drainage basins, however, no nugget of gold has been found. The characteristics of these gold particles suggest that these have been transported from nearby source. The concentration of gold, obtained in various drainage basins, has been processed through geo- statistical map analysis technique, which has delineated anomalous areas of most interest for further

Key words: Geochemistry, gold, Kohistan, Dir, Swat.

S/208. Shah, M.T. & Majid, M., 1985. Major and trace element variations in the lavas of Shergarh Sar area and their significance with respect to the Kohistan tectonic anomaly. *Geological Bulletin University of Peshawar*, 18, 163-188.

A belt of dark-green volcanics along with serpentinite, peridotite, pyroxenite and greenschist marks the spatial disposition of the Indus suture zone in Allai Kohistan of Hazara division. Major and trace element analyses of selected lava samples are used to investigate geochemical variations in the Shergarh Sar Pashtu village section of the volcanic belt. The lavas are mostly glassy but occasionally show phenocrysts of plagioclase, clinopyroxene and, very rarely, brown hornblende. On the basis of normative mineralogy, two compositional groups, e.g. olivine tholeiite and quartz tholeiite, are identified. Fractionation control of the observed phenocrysts over the major and trace element distribution in the lavas is established through the solutions of chemical data in the C.M.A.S. model and conventional two-dimensional plots.

The major and trace element constraints of the studied lavas are corresponding more closely to tholeiites developed in the island arc type environments and substantiate, through a chemical comparison, the assumed prevalence of

such structure(s) in the Tethys ocean before the complete closure as proposed in the tectonic models of the Himalayan development.

Key words: Geochemistry, volcanics, tectonic, Shergarh Sar, Kohistan.

S/209. Shah, M.T. & Majid, M., 1992. Petrology and chemistry of the ultramafic rocks from the Allai Kohistan section of the Indus suture zone in Hazara, Northern, Pakistan. *Acta Mineralogica Pakistanica* 6, 73-84.

Rocks of the Shergarh Sar area, a part of the Allai Kohistan are divisible into three petroectone units: (1) Kohistan Island Arc sequence, (2) Indus Suture Zone, (3) Indo-Pakistan subcontinent sequence. The Indus Suture Zone in this area comprises an elongated belt of ultramafic rocks, pillow lavas, greenschists, blueschists and metasediments that have been obducted onto the Indo-Pakistan plate. Ultramafics (clinopyroxene, peridotite and serpentinite) exhibit strong shearing or cataclasis. Clinopyroxene and olivine are the dominant primary phases and are partially or completely altered to serpentine, fibrous amphibole, chlorite, magnetite and chromite. Among serpentine, both antigorite and chrysotile of syntectonic and post tectonic behavior have been distinguished. The effects of serpentinization on the whole-rock chemistry is indicated by the release and introduction of certain elements during the process. The constituent rocks are comagmatic and probably represent a dismembered ophiolite suite.

Key words: Petrology, geochemistry, ultramafic rocks, ophiolite, Indus Suture, Allai, Kohistan.

S/210. Shah, M.T., Majid, M. & Hamidullah, S., 1992. Petrochemistry of amphibolites from the Shergarh Sar area, Allai Kohistan, N. Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.37.

Consult the following account for further information.

Key words: Petrography, amphibolites, tectonics, geochemistry, Allai Kohistan

S/211. Shah, M.T., Majid, M., Hamidullah, S. & Shervais, J.W., 1992. Petrochemistry of amphibolites from the Shergarh Sar area, Allai Kohistan, N. Pakistan. *Kashmir Journal of Geology* 10, 123-139.

Shergarh Sar Area, a part of the Allai Kohistan is located at the closure of the Indo-Pakistan and Kohistan island arc block. Rocks of the area are distinguished into three petroectonic units. 1-the Kohistan island arc sequence 2-the Indus mélangé zone and 3-the Indo-Pakistan subcontinent sequence. Amphibolites are the most abundant rocks exposed in the area and are considered to be a part of the southern amphibolite attributed to the metamorphic segregation processes. Mineralogically these rocks are distinguished as epidote amphibolite and garnet epidote-amphibolites. Amphibole + epidote + clinopyroxene + actinolite + chlorite+ quartz + opaque is the main mineral assemblage. Garnet occurs sporadically in these rocks. The textural features are indicative of retrogression from epidote-amphibolite to green schist facies conditions. The major and trace element constraints of these amphibolites, suggest their derivation from basic igneous parent of tholeiitic character developed in the island arc type of environment.

Key words: Petrography, amphibolites, tectonics, geochemistry, Allai Kohistan.

S/212. Shah, M.T. & Sarwar, A., 1998. Litho and stream sediments survey for gold and base metals in areas around Timargara and Samarbagh, District Dir , northern Pakistan. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 180-181.

The area of study (about 900-km²) is lying within the Kohistan arc terrane in the northern part of Pakistan. It is located immediately north of the Main Mantle Thrust (MMT) in Dir district. It has a complex geology and is mainly composed of amphibolites, metadiorites, metagabbro-norites, metagranodiorites, metagranites and metavolcanics with subordinate amount of hornblendites, ultramafites and tonalites. The area has already been investigated for preliminary geology, however, no detail geochemical investigation has been carried out for precious and base metals

mineralization. This study is mainly based on rocks and stream sediments (both pan-concentrates and -80 mesh fine fraction) geochemical survey for gold and base metals in order to delineate areas likely to contain mineralization and be worthy of follow-up work.

The area has been divided into 56 drainage cells ranging from 2-50 km² with an average density of about one site per 15 km². From each cell a pan concentrate and -80 mesh fine fraction were collected for mineralogical and geochemical studies. The visible gold as piece (>0.5mm), speck (0.5-0.3mm) and color (<0.3mm) was identified in the pan concentrates of certain streams, mainly in the north eastern and north western portion of the study area. However, no nugget of gold has been noticed in the pan-concentrates. The specks and colors are generally angular to subangular, sometime irregular to rectangular in shape and bright yellow in color. The pan concentrates are dominantly composed of magnetite whereas zircon, quartz, pyroxene, garnet, hornblende, feldspar, tourmaline, chromite and rock fragments occur as minor constituents. The floats were also examined for alteration and other geological phenomenon at each site.

Samples of Rocks and stream sediments (both pan concentrates and fine fraction) have been analyzed for Au, Ag, Cu, Zn, Pb, Co, Ni, and Cr. The geochemical data have been displayed and evaluated by considering various geostatistical methods. Geochemical maps have also been prepared on the basis of single and multi-elements consideration in order to pin point areas of most interest. These studies show that pan-concentrates have higher concentration of base metals as compared to that of fine fraction and are, therefore, silicate-bound rather than sulfide-bound in stream sediments. The higher concentration of Cu, Pb, Zn, Ni, Cr, Co and Ag could be related to the bed rock rather than to specific mineralization in the area. The anomalous gold, however, could not be directly related to the bed rock but it could possibly be related to the existence of gold-bearing mineralization, most probably in the form of quartz veins, in the north and north-eastern part of Samarbagh. Further detail geochemical survey is, therefore, recommended for follow-up in the region.

Key words: Stream sediments, geochemistry, base metals, gold, Dir.

S/213. Shah, M.T., Sarwar, A. & Ahmad, W., 1999. Geochemical exploration for gold and base metals in part of Dir area, Kohistan arc terrane, northern Pakistan. Geological Society of America. Abstracts with Programs, Annual Meeting, p.46.

Consult the preceding and following accounts for further information.

Key words: Geochemistry, exploration, gold, base metal, Dir, Northern Pakistan.

S/214. Shah, M.T., Sarwar, A., Ahmad, W. & Siddiqui, S.A., 1998. Litho and stream sediment's geochemical studies for gold and base metals in area around Timaragara and Samarbagh, District Dir, Northern Pakistan. *Acta Mineralogica Pakistanica* 9, 37-54.

The area of study (about 900-km²) lies within the Kohistan arc terrane in the northern part of Pakistan. It is located immediately north of the Main Mantel Thrust (MMT) in Dir district. It has a complex geology and is mainly composed of amphibolites, metadiorites, metagabbro-norites, metagranodiorites, metagranites and metavolcanics with subordinate amount of hornblendites, ultramafites and tonalites. The area has already been investigated for preliminary geology; however, no detail geochemical investigation has been carried out for precious and base metals mineralization. This study has main emphasis on the rocks and stream sediments (both pan-concentrate and -80 mesh fine fraction) geochemical survey for gold and base metals in order to delineate areas likely to contain mineralization and be worthy of follow-up work.

The area has been divided into 56 drainage cells ranging from 2-50 km² with an average density of about one site per 15 km². From each cell a pan-concentrate and -80mesh fine fraction were collected for mineralogical and geochemical studies. The visible gold as piece (>0.5mm), speck (0.53mm) and color (<0.3mm) was identified in the pan-concentrates of certain streams, mainly in the north eastern and northwestern portion of the study area. However, no nugget of gold has been noticed in the pan-concentrates. The specks and colors are generally angular to sub-angular, sometime irregular to rectangular in shape and bright yellow in color. The pan-concentrates are dominantly composed of magnetite whereas zircon, quartz, pyroxene, garnet, hornblende, feldspar, tourmaline, chromite and rock fragments occur as minor constituents. The floats were also examined for alteration and other geological phenomenon at each site.

Samples of Rocks and stream sediments (both pan-concentrates and fine fraction) have been analyzed for Au, Ag, Cu, Zn, Pb, Co, Ni, and Cr. The geochemical data have been displayed and evaluated by considering various

geostatistical methods. Geochemical maps have also been prepared on the basis of single and multi-elements consideration in order to pin point areas of most interest. These studies show that pan-concentrates have higher concentration of base metals as compared to that of fine fraction and are, therefore, silicate-bounded rather than sulfide-bound in stream sediments. The higher concentration of Cu, Pb, Zn, Ni, Cr, Co and Ag could be related to the bedrock rather than to specific mineralization in the area. The anomalous gold, however, could not be directly related to the bedrock but it could possibly be related to the existence of gold-bearing mineralization, most probably in the form of quartz veins, in the north and north-eastern part of Samarbagh area. Further detail geochemical survey is, therefore, recommended for follow-up in the region.

Key words: Stream sediments, base metal, gold, Dir.

S/215. Shah, M.T. & Shervais, J.W., 1990. Petrochemical evolution of the Dir metavolcanic sequence, Kohistan island arc, northern Pakistan. Geological Society of America Abstracts with programs, Annual Meeting Dallas, Texas.

Key words: Metavolcanics, petrochemistry, Kohistan island arc, Dir.

S/216. Shah, M.T. & Shervais, J.W., 1996. Mafic volcanism and the petrologic evolution of the Dir-Utror metavolcanic sequence, Kohistan arc Terrane, Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 133.

The Dir-Utror volcanic series forms a NE-SW trending belt within the northwestern portion of the Kohistan island arc terrane in the western Himalayas of northern Pakistan. The Kohistan arc terrane comprises a diverse suite of volcanic, plutonic and subordinate sedimentary rocks of Late Mesozoic to Tertiary age, developed prior to and after suturing of the Indo-Pakistan and Asiatic continental blocks. The Dir-Utror volcanic series near Dir is dominated by basaltic-andesite and andesite, with subordinate basalt, high-Mg basalt, dacite, and rhyolite. Porphyritic textures are dominant in the lavas, with less common aphyric and seriate textures. Pyroclastic breccias are common locally and may represent near vent facies. Plagioclase is the dominant phenocryst in mafic to intermediate rocks, K-feldspar and quartz phenocrysts predominate in the dacites and rhyolites. Chlorite, epidote, albite and actinolite are the most common metamorphic phases; blue-green amphibole, andesine, muscovite, biotite, kaolinite, sericite, carbonate, and opaques are widespread but less abundant. Phase assemblages and chemistry suggest predominant greenschist facies metamorphism with epidote-amphibolite facies conditions attained locally.

Whole rock major element compositions define a calc-alkaline trend: CaO, FeO, MgO, TiO₂, Al₂O₃, V, Cr, Ni and Sc all decrease with increasing silica, whereas alkalis, Rb, Ba, and Y increase (Figure 1). MORB-normalized trace element concentrations show enrichment of the low-field strength incompatible elements (Ce, La, Ba, Rb, K) and deep negative Nb, P, and Ti anomalies – patterns typical of subduction related magmas. Mafic volcanic rocks plot in fields for calc-alkaline volcanics on trace element discrimination diagrams, showing that pre-existing oceanic crust is not preserved here. All rocks are LREE-enriched, with La=16-112*chondrite, La/Lu=2.6 to 9.8*chondrite, and Eu/Eu*=0.5 to 0.9 (Figure 2). Dacite and rhyolites have the lowest La/Lu ratios and highest Eu/Eu* ratios, reflecting the dominant role of plagioclase fractionation of the more mafic lavas; chondrite-normalized REE patterns for these andesites cross those of the basaltic andesites, indicating that these lavas cannot be related to a common parent.

The high proportion of mafic lavas is similar to that observed in the Aleutian arc and rules out involvement of older continental crust. The scarcity of more evolved felsic volcanics (dacite, rhyolite) can be explained by the nature of underlying crust, which consists of accreted intra-oceanic arc volcanic and plutonic rocks, and is mafic relative to normal continental margins. Andesites with high La, La/Lu, K₂O, and Rb may be crustal melts. The REE pattern for some andesites cross the chondrite-normalized patterns of dacites and rhyolites, showing that these rocks cannot be related by fractional crystallization, assimilation, or magma-mixing. The REE systematics of these andesites are compatible with an origin by crustal anatexis, leaving a refractory residue mineralogically similar to high pressure mafic and ultramafic granulites of the Jijal Complex. We suggest that the garnet-rich granulites of the Jijal Complex represent the restites formed during this crustal melting.

Key words: Mafic volcanics, petrology, Jijal Complex, Utror volcanic, Kohistan arc.

S/217. Shah, M.T. & Shervais, J.W., 1997. Oxygen isotope geochemistry of the Dir metavolcanic sequence and associated copper mineralization in Kohistan arc terrane, northern Pakistan. *The Nucleus* 34, 49-55.

Dir metavolcanic sequence constitutes a northeast southwest trending belt within the northwestern portion of the Kohistan arc terrane. This sequence is dominantly composed of basaltic-andesite and andesite with subordinate basalts, dacite, rhyolite and pyroclastic breccia. Copper mineralization in the Dir area is mainly confined to the quartz veins and associated hydrothermally altered metavolcanics. Chalcopyrite is the main copper-bearing phase with subordinate amount of bornite, chalcocite, covellite, malachite and azurite in both mineralized quartz veins and associated mineralized metavolcanics.

Both mineralized metavolcanics and mineralized quartz veins have high $\delta^{18}\text{O}$ signature. This suggest the involvement of isotopically heavy ore forming fluid in the zonation and copper mineralization in these volcanics. This fluid has the estimated $\delta^{18}\text{O}$ isotopic composition of 5.1 per million which could be the magmatic water introduced by the granodiorite or diorite intrusion below the metavolcanic sequence.

Key words: Geochemistry, oxygen isotope, metavolcanics, copper mineralization, Kohistan arc.

S/218. Shah, M.T. & Shervais, J.W., 1999. The Dir-Utror metavolcanic sequence, Kohistan arc terrane, northern Pakistan. *Journal of Asian Earth Sciences* 17, 459-475.

The Dir-Utror volcanic series forms a NE-SW trending belt within the northwestern portion of the Kohistan island arc terrane in the western Himalayas of northern Pakistan. The Kohistan arc terrane comprises a diverse suite of volcanic, plutonic, and subordinate sedimentary rocks of late Mesozoic to Tertiary age, developed prior to and after suturing of the Indo-Pakistan and Asiatic continental blocks. The Dir-Utror volcanic series near Dir is dominated by basaltic-andesite and andesite, with subordinate basalt, high-MgO basalt, dacite and rhyolite. Porphyritic textures are dominant, with less common aphyric and seriate textures. Plagioclase is the dominant phenocryst in mafic to intermediate rocks, K-feldspar and quartz phenocrysts predominate in the dacites and rhyolites. Chlorite, epidote, albite, and actinolite are the most common metamorphic phases; blue-green amphibole, andesine, muscovite, biotite, kaolinite, sericite, carbonate, and opaques are widespread but less abundant. Phase assemblages and chemistry suggest predominant greenschist facies metamorphism with epidote-amphibolite facies conditions attained locally.

Whole rock major element composition define a calc-alkaline trend: CaO, FeO, MgO, TiO_2 , Al_2O_3 , V, Cr, Ni, and Sc all decrease with increasing silica, whereas alkalis, Rb, Ba, and Y increase. MORB-normalized trace element concentrations show enrichment of the low-field strength incompatible elements (Ce, La, Ba, Rb, K) and deep negative Nb, P, and Ti anomalies-patterns typical of subduction related magmas. Mafic volcanic rocks plot in fields for calc-alkaline volcanics on trace element discrimination diagrams, showing that pre-existing oceanic crust is not preserved here. All rocks are LREE-enriched, with $\text{La}=16\text{-}112 \times \text{chondrite}$, $\text{La/Lu}=2.6\text{-}9.8 \times \text{chondrite}$, $\text{Eu/Eu}^*=0.5\text{-}0.9$. Dacites and rhyolites have the lowest La/Lu and Eu/Eu* ratios, reflecting the dominant role of plagioclase fractionation in their formation. Some andesites have La/Lu ratios which are too high to result from fractionation of the more mafic lavas; chondrite-normalized REE patterns for these andesites cross those of the basaltic andesites, indication that these lavas cannot be related to a common parent.

The high proportion of mafic lavas rules out older continental crust as the main source of the volcanic rocks. The scarcity of more evolved felsic volcanics (dacite, rhyolite) can be explained by the nature of the underlying crust, which consist of accreted inter-oceanic arc volcanic and plutonic rocks, and is mafic relative to normal continental margins. Andesites with high La, La/Lu, K_2O , and Rb may be crustal melts; we suggest that garnet-rich high-pressure granulites similar to those exposed in the Jijal complex may be restites formed during partial melting of the crust.

Key words: Geochemistry, basalt, andesite, Jijal complex, Utror volcanics, Dir.

S/219. Shah, M.T., Shervais, J.W. & Ikramuddin, M., 1991. Geochemistry of metavolcanics and associated Cu-mineralization in the Dir area of the Kohistan island arc, N. Pakistan. *Geological Society America, Abstract with Programs, Annual Meeting, Sanfransico, California.*

Key words: Mineralogy, metavolcanics, geochemistry, copper mineralization, Kohistan island arc, Dir.

S/220. Shah, M.T., Shervais, J.W. & Ikramuddin, M., 1994. The Dir meta-volcanic sequence: Calcalkaline magmatism in the Kohistan arc terrane, northern Pakistan. Geological Bulletin, University of Peshawar 27, 9-27.

A variably deformed and metamorphosed NE-SW trending belt of Dir metavolcanic sequence is exposed within the north-western portion of the Kohistan arc terrane. The sequence is mainly composed of massive and sheared volcanics and pyroclastic breccia. The petrochemical indices suggest that they are dominantly basaltic-andesite and andesite with subordinate basalt, dacite and rhyolite in composition.

Whole rock major element compositions define a calc-alkaline trend: CaO, FeO, MgO, TiO₂, Al₂O₃, V, Cr, Ni and Sc all decrease with increasing silica, whereas alkalis Rb, Ba, and Y increase. Mafic to intermediate volcanic rocks show calc-alkaline affinities on petrochemical diagrams. Chondrite-normalized REE patterns are LREE-enriched. Dacites and rhyolites have the lowest La/Lu ratios and highest Eu /Eu* ratios, reflecting the dominant role of plagioclase fractionation in their formation. MORB-normalized spider diagrams show progressive enrichment of the low-field strength incompatible elements (Ce, La, Ba, Rb, K) and a distinct negative Nb anomaly; patterns typical of subduction related magmas.

It is suggested that the high-Mg basalt of the Dir area is primitive in nature and could be the representative of the primary magnesian liquid formed by the partial melting of mantle wedge at the base of the Kohistan arc terrane. This liquid may have fractionated the other members of the sequence especially low magnesia basalt and basaltic-andesite.

Key words: Calcalkaline magmatism, Kohistan island arc, Dir.

S/221. Shah, M.T., Thorpe, R.I. & Siddique, S.A., 1992. Lead isotope signature of the Proterozoic sediment-hosted base metal deposits at the margin of the Indian plate in Besham area, northern Pakistan. Geological Bulletin, University of Peshawar 25, 59-65.

Proterozoic base metal deposits in the rocks of the Indian plate occur along its northern margin at the Pazang and Lahor properties near Besham. These are stratiform exhalative type deposits, which are highly deformed and regionally metamorphosed. Lead isotope studies were carried out on these deposits. Lead isotope ratio yield model ages of 2120-2199 Ma (Proterozoic) for both the Pazang and Lahor deposits. The assumed minimum age of mineralization is 2077 Ma, as suggested by the secondary isochron. These deposits are more primitive in terms of age and have lower μ values relative to the well-known sediment-hosted deposits elsewhere in the world. The non-radiogenic isotopic composition and the homogeneity of the ore lead in both Pazang and Lahor ores suggest a well-mixed common source and similar processes for the formation of these ores.

Key words: Pb isotope, base metal deposits, Pazang, Besham, Kohistan.

S/222. Shah, M.Y., 1997. Gold-silver and base metal prospect south of Skardu and part of northern Deosai Plateau, District Skardu, Northern Pakistan. Abstracts, National Symposium on Economic Geology of Pakistan, Islamabad, 1p.

A cost effective geochemical exploration methodology based on panned concentrate and minus 80 mesh samples from contiguous measured drainage cells in south of Skardu. Northern Pakistan have established an area of 613 sq. kms as highly potential target for occurrence of precious and base metals. Based on visual gold counts in the panned concentrate samples and supported by a range of chemical analyses of pan con. and minus 80 mesh samples. a total of 64 anomalous values for gold, silver, copper, lead, zinc, cobalt, bismuth and nickel has been evolved above the threshold values already set for Northern Areas, in individual drainage cell areas ranging from 6-54 sq. kms. Field observations of the alteration types, prevailing mineralization pattern and chemical analyses of a few outcrop chip samples in the prospect area also provide terra firma for detailed exploration to locate source rock/s for precious and base metals.

Key words: Geochemistry, gold, silver, base metals, Skardu, Deosai.

S/223. Shah, M.Y. & Shah, H., 1973. Heavy minerals in the alluvials of Ushu and Gabral Rivers and their tributaries, Swat Kohistan, North West Frontier Province. M.Sc. Thesis, Peshawar University.

Key words: Heavy minerals, alluvial, Ushu, Gabral, Swat Kohistan.

S/224. Shah, R.A., Akhtar, S.M. & Amin, M., 1974. Studies on the effect of particle size on the upgradation of chromite from Dargai area, Pakistan. Pakistan Journal of Scientific and Industrial Research 17, 152-153.

Key words: Chromite processing, Dargai, Malakand Agency.

S/225. Shah, R.A. & Khan, A.H., 1979. Occurrence utilization and potential of gypsum in Pakistan. Pakistan Council of Scientific and Industrial Research, Monograph, 46p.

Key words: Gypsum, economic geology, Pakistan.

S/226. Shah, R.A., Khan, A.H. & Qazi, M.A., 1979. Prospects of steel making from indigenous iron ore. International Seminar Exploitation Technology, Peshawar, 123p.

Key words: Steel, technology, iron ore.

S/227. Shah, R.A., Naz, M.A., Naqvi, A.A. & Safdar, M., 1964. A study of Swat kaolinite. Pakistan Journal of Scientific and Industrial Research 7, 183-187.

Key words: Kaolinite, Swat.

S/228. Shah, S. & Khan, M.S., 2000. Structure, stratigraphy and statistical studies of the Siwalik group of an area between Kotli and Mirpur, Azad Kashmir. M.Sc. Thesis, University of Peshawar, 148p.

A thick sequence of molasse sediments of the Siwalik group, exposed in part of the area between Mirpur and Kotli district of Azad Kashmir are objective of this report. Amongst the major geological aspects, stratigraphy structure, petrography and statistical analysis have been dealt in detail.

Stratigraphically these sediments, ranging in age from late Miocene to Pleistocene are divided into

I Upper Siwalik - Soan Formation (Late Pliocene to early Pleistocene).

II Middle Siwalik

(a) Dhok Pathan Formation (early to middle Pliocene)

(b) Nagri Formation (Early Pliocene)

III lower Siwalik - Chinji Formation, (Late Miocene).

The Siwalik group comprises sandstone, shale, and conglomerate. The Chinji Formation is composed of reddish shale and subordinate sandstone beds. In the Nagri Formation Sandstone is predominant with occasional shale beds. The Dhok Pathan Formation is marked by alternating sandstone and clay bed.

Structurally the area is folded into six anticlines and synclines with same trend of fold axis. These folds are of open type. Brief petrographic study show that sandstone comprises of quartz, feldspar, mica, calcite, hornblend, rock fragments, and minor amounts of apatite garnet, zircon, chlorite, sphene and ore. Kyanite and staurolite are other rare mineral. Sieve analyses of sixteen samples Indicates that dominant clastic fraction in medium to fine moderately sorted, positively skewed and steeply peaked. Average values of various statistical measures obtained are:

Sorting	Skewness	Kurtosis	Mean
0.968	0.246	1.076	2.437

There is no systematic horizontal or vertical variation in different statistical measures but present a rather zigzag pattern which indicates that the material of variable size was brought to the basin between each cycle.

Key words: Structure, stratigraphy, siwalik, Kotli-Mirpur, Azad Kashmir.

S/229. Shah, S.A.R., 1976. Petrology of Harnoi-Khwar valley area, Swat. M.Sc. Thesis, Peshawar University, 83p.

Key words: Petrography, geology, Harnoi Khwar, Swat.

S/230. Shah, S.H., 1980. Lead investigation Thelichi area, Gilgit District. Geological Survey of Pakistan, Information Release 114, 20p.

Two principal mineralized zones exist along the Thalichi Gah, where small scale mining has been done, as small adits. The mine located in the Thalichi Gah named “nala Mine” consists of small and thin veins of lead-zinc ore; while the other mine located at the top of a hill between Thalichi Gah and its northern tributary named “Davide Mine”, consists of small and thin veins of lead-copper ore. In general, the veins in both mines, measure less than 5 cms. In thickness and not more than 9.5 meters exposed length; with steep dip. In Shukisoh area lead-copper has been mined from the phyllitic gauge zone, where mineralization occurs as very small veinlets and disseminated grains.

Key words: Lead mineralization, Thelichi, Gilgit.

S/231. Shah, S.H., Khan, K.S. & Shah, S., 1982. Cement raw materials in Gilgit Agency. Geological Survey of Pakistan, Information Release 168, 38p. 2 figurs. 9 plates.

Key words: Cement, raw material, Gilgit.

S/232. Shah, S.H., Khan, K.S.A., Khan, N.A. & Khan, M.S.Z., 1987. Geology and mineral investigation of the Thor quadrangle (Topographic Map, 43-E/15; Scale, 1:50,000), Diamir district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release No. 289, 21p.

The Thor quadrangle lies within the southern portion of the Kohistan island arc sequence, which is bounded by the two megashears, the Main Mantle Thrust (MMT) towards the south and the Main Karakoram Thrust (MKT) towards north. The MMT zone, lies a few kilometres south of this quadrangle (out of map). The major lithological zones within the quadrangle include the southern amphibolite belt (Kamila amphibolites), the pyroxene granulites, the Thurlu ultramafics and Kohistan granodiorite. The Kamila amphibolites, with both banded and massive varieties, trending almost east-west: with southward dips, have sporadic granitoid intrusions related to the Kohistan granodiorite. These granitoid intrusions of both massive and gneissic texture, range in size from small pockets to that of stocks. The pyroxene granulite belt of noritic composition, degranulitized in its southern portion at its contact with the Kamila amphibolites, is believed to have been crystallized from a tholeiitic magma in a continental margin or island arc location, metamorphosed at a depth of more than 40 kms and finally tectonically emplaced in its present position as remobilized crystalline material. The degranulitized portion consists of plagioclase, hornblende, biotite and quartz, formed as a result of the retrograde metamorphism of the previous noritic complex. A small oval - shaped ultramafic body, mainly composed of dunite, troctolite and peridotite with basic dykes, has been tectonically emplaced within the pyroxene granulites after the main metamorphism during the collision of the Indian - Asian landmasses, but before the two uplifted to their present positions. This ultramafic suite is believed to represent a portion of oceanic crust and upper mantle. A syncline trending NE-SW, is present within the pyroxenite granulite. Small exposures of buff coloured micaceous and silty clay are locally present on both banks of the Indus River.

The ultramafic suites although favourable for crystallization and segregation of metallic minerals, because of composition and localized stratiform nature, are almost devoid of any significant mineralization.

Key words: Geology, minerals, Thor quadrangle, Diamir.

S/233. Shah, S.H. & Khan, N.A., 1999. Geochemistry of sulphide bearing zones in Shigar-Skardu area, Skardu District, Baltistan. Geological Survey of Pakistan, Information Release 691.

Key words: Geochemistry, sulphide, Shigar-Skardu.

S/234. Shah, S.H., Khan, N.A., & Khan, M.S.Z., 1987. Geology, geochemistry and mineral investigation of the Skardu quadrangle (43 M/11), Baltistan district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 290.

Regional geological mapping at the scale of 1:50000, of the Skardu - Shigar area was carried out during the field season 1983-84 as a part of the geological Survey of Pakistan's continuing programme of regional geological mapping of Pakistan, and particularly of the Northern Areas.

The Skardu - Shiga area, covered by topographic sheet 43-M/11 is underlain by the rocks of the Katzarh Formation, the Greenstone complex, the Yasin group, the Burj-La Formation, basic complex, the Deosai volcanics, the Ladakh intrusives, and the unconsolidated deposits of moraines, terrace and recent alluvium & sand dunes.

The Katzarh Formation of Early Cretaceous age consists of various grade schists, phyllites, slates and shale. The greenstone complex of Early Cretaceous age consists mainly of gneiss, marble schist and green tuffaceous slate, intruded by various mafic and intermediate igneous rocks. The Yasin group of Early Cretaceous age consist of massive, dolomitic limestone, limestone, quartzite, and carbonate schists and shale. The Burj-La formation of Late Cretaceous age consist of black slate, phyllites, tuffaceousu slate, argillaceous breccia. The Basic complex of Cretaceous – Eocene age consists of amphibolite, hornblendite, pyroxenite, uralite gabbro, diorite and schists. The Deosai volcanics of Late Cretaceous age consist of green andesite and andesite porphyry, dacite and dacite porphyry, rhyolite porphyry, and tuffaceousu slate. Most of the rocks are metamorphosed in low grades. The Ladakh Intrusives of Early Eocene to Miocene – Pliocene age consists of quartz diorite, diorite, granodiorite, muscovite granite, two mica granite, pegmatite and aplites. Some gabbroic and ultramafic rocks in the form of dykes are also present in places. The unconsolidated rocks in Skardu-Shigar area consists of unsorted glacial morains, river alluvium, and eolian sand deposits in the form of dunes.

The Greenstone complex has faulted contacts both with the underlying Katzarh formation and the overlying Yasin group. The Deosai volcanics are faulted against the underlying Burj-La formation. Folds and faults of varying scales of magnitude are common in the mapped area.

Copper showings in the form of crack fillings and disseminated grains are present in the Deosai volcanics, located in the Shagari Kalan Lung, Shagari Bala Lung and Irgilun Lugma. Marble bands are exposed at the base of the Greenstone complex on both banks of the Shigar River, and continued eastwards beyond the Shigar Lungma. A bed of quartzite within the yasin group is present on both banks of the Mustafabad Lungma.

Key words: Mapping, stratigraphy, Cretaceous, Miocene, Skardu quadrangle.

S/235. Shah, S.H., Khan, N.A. & Latif, M., 1986. Geology and pegmatites of the Gilgit-Jaglot-Hanuchal area, Gilgit District, Northern Areas. Geological Survey of Pakistan, Information Release 273.

A large number of pegmatites were checked physically in the field. In most cases grab, samples were taken, but channel samples of some zoned pegmatites were also collected.

The pegmatites are generally scattered but there is a large concentration of them from Parri upto Shuta along the Skardu road. In the investigated area about 1200 pegmatites have been observed, which range in dimensions from mere one centimetre stringers and veinlets to about 9 metres in thickness and from a few metres to about 175 metres in length. Pegmatites run both along and across host rocks but they mostly occur as dykes. Their general trend is east-west. The host rocks for the pegmatites are meta tuff, diorite, granodiorite, para- amphibolite, ortho-amphibolite and the meta-sedimentary schistose rocks

Most of the pegmatites are simple but some are zoned. The zoned pegmatites mostly consist of wall zone, intermediate zone and core. In some pegmatites, intermediate zone can be further subdivided into two subzones. The zones are not essentially symmetrical with each other, some heterogeneous pegmatites were also found, viz. hornblende pegmatites in Shuta area.

Most of the pegmatites are intrusive in nature whereas around Parri the recrystallized pegmatites are also developed from the acidic intrusive rocks mostly from granodiorite and aplite under the action of volatiles. Most of the pegmatites are barren, except a few in which some economically important minerals are noted, viz, microcline, biotite, beryl, radioactive mineral and amazonite. Beryl has been found in the biotite-bearing pegmatites only. Such economically important minerals are found only as surface traces in pegmatites which seem to be uneconomical except the beryl-bearing pegmatites at Konadas, Station (Sn, 13), Jalalabad (Sn.37) and amazonite-bearing pegmatites at Jaglot (Sn. 46) which are worth further exploration. Low radioactivity in some samples from Parri, Skardu road, and Jaglot area was noted which measures from 434 to 2,774 counts per hour.

Key words: Geology, pegmatites, Jaglot, Gilgit.

S/236. Shah, S.H. & Khan, R., 1998. Geology and mineral investigations of the Jaglot–Bunji quadrangle (43 I/10), Gilgit- Diamir – Skardu Districts, Northern Areas, Pakistan, Geological Survey of Pakistan, Information Release 547, 39p.

The investigated area lies towards SE corner of the Kohistan Island Arc sequence, which is bordered by the Nanga-Parbat Haramosh massif of the Indian mass, having remobilized cataclastic metamorphosed and granitized gneisses. Direct collision of the Indian mass occurred with the Eurasian mass, along the Nanga Parbat-Haramosh massif spur, thus dividing the Kohistan-Ladakh island arc in two parts -the Kohistan island arc and the Ladakh island arc. In the investigated area, the rocks of the Indian mass started subducting under the rocks of the Kohistan Island arc, during the Early Eocene, along a megashear the Main Mantle Thrust (MMT). The MMT zone, in the investigated area, generally measures 200 m -300 m in width, while in the Lichar surroundings it is truncated and disturbed by the Raikot fault and also concealed under scree. The subduction of the Indian mass under the island arc, resulted in severe tectonism, thrusting, folding, formation of a cordillera type folded mountain chain, along with profuse intrusion of subduction related granitoids in the island arc sequence.

The Cretaceous island arc volcanogenic rocks were intermixed with the Jurassic to Cretaceous flysch type intra arc metasediments with subsequent multi-phase and diversified type magmatism of granitoids in the Kohistan island arc. The first phase of this magmatism commenced in Late Cretaceous (Albian) while its third and final stage, representing a swarm of acidic dykes and pegmatites, in the Indus-Gilgit confluence area, occurred during Oligocene and even Miocene (Patterson and Windley, 1985). The earlier acidic intrusions were metamorphosed to orthogneisses. Three Himalayan orogenic episodes from Late Paleocene to Pliocene/Pleistocene caused strong diastrophism, resulting in the formation of different sets of foliation and lineation and metamorphism. Large deposit of white, saccharoidal marble is present in Thelichi area. Some metalliferous hornblendites and volcanics, mineralized pegmatites, scattered multi coloured sulphide deposits and placer gold showings, all make the investigated area economically significant.

Key words: Kohistan Island Arc, MMT, Gilgit, Diamir, Skardu.

S/237. Shah, S.H. & Khan, R., 1999a. Geology of Mehdi Abad quadrangle (43 M/16), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 686.

Key words: Geology, Mehdi Abad, Skardu.

S/238. Shah, S.H. & Khan, R., 1999b. Geology of Baghicha quadrangle (43 M/6), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 688.

Key words: Geology, Baghicha quadrangle, Skardu.

S/239. Shah, S.H., Khan, R., Khan, N.A. & Latif, M., 1999. Geology of the Satpara quadrangle (43 M/12), Skardu District, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 689, 15p.

The Satpara quadrangle covers the Survey of Pakistan topographic sheet No. 43-M/12 and lies in the Ladakh island arc. The mapped area covers the eastern portion of the gigantic Deosai Plateau having average elevation of about 4,000m above the sea level.

The investigated area is underlain by the flysch type metasediments, the metavolcanics and the plutonics. The calcareous metasediments are exposed as small outcrops within the pelitic metasediments, and supposed to have originated as a result of isolated depositional basin environments. The unconsolidated sediments cover the valley slopes, as well as, have vast exposures over the Deosai Plateau. The intra-arc metasediments and metavolcanics, were subsequently subjected to magmatism of calc-alkaline nature. This magmatism occurred in three phases during Late Cretaceous to Miocene (Petterson and Windley, 1985). The granitoids of the investigated area, cover mostly the second phase magmatism which are subduction related and Andean type in origin.

Three Himalayan orogenic episodes from Late Paleocene to Pliocene/Pleistocene caused diastrophism and tectonism, resulting the formation of different set of foliation, and lineation. Local folding and faulting within metasediments and metavolcanics occurred, but the mapped area lacks any regional controlled megastructure. Ferruginous fault breccia, exposed at the shahtung baihk, resulted the weak zone along which iron rich solutions impregnated the countryrock volcanics. However, iron (Fe_2O_3) content is surprisingly low, from 5.75% to 7.75%.

The sulphide showing at the Shikar Nala mouth, contain stringers, small pods and thin veinlets having mineralization of pyrite, chalcopyrite and manganese dendrites, Such sulphide mineralization is sparse, scattered and as low percentage by volume in the Deosai volcanics, These factors make it uneconomical. Small marble exposures are located in the remote and unapproachable areas, which make it uneconomical due to transportation problems.

Key words: Geology, Satpara quadrangle, Skardu.

S/240. Shah, S.H. & Khan, S., 1980. Geology and geochemistry of part of Hunza area, Gilgit Agency. Geological Survey of Pakistan, Information Release 115, 44p.

Reconnaissance geological mapping and geochemical investigations were carried at 1:250000 scale during September and October, 1975 from Bulchi das to Khunjerab in the Upper Hunza Valley, lying in topographic sheets 42 L and 42 P. during this field season, the reconnaissance mapping was done mostly along the Karakoram Highway.

Two mountain ranges running approximately east-west Karakoram in the south and Hinduraj in the north. These mountain ranges consist of acidic igneous rocks viz. granite/granodiorite. The region between these ranges consists of sedimentary and metasedimentary rocks including limestone, slate, gneiss, schist and quartzite of probably Upper Carboniferous to Jurassic age. Fossils in the limestone and the slate are not common. Folding within sedimentary and metasedimentary rocks can be seen at some localities.

The contact of the Karakoram granodiorite with the Pasu slate is faulted, but with the metamorphic rocks of the Baltit group it is intrusive. The high grade metamorphic rocks garnet-mica schist, and coarsely crystalline marble, probably indicate thermodynamic regional metamorphism caused by the intrusion of the two huge silicic batholith (Karakoram & Hinduraj) composed mainly of biotite-granodiorite.

Key words: Geology, geochemistry, Hunza, Karakoram, Hinduraj.

S/241. Shah, S.H. & Shah, S.S., 1984. Geology and mineral investigation of Parri quadrangle (43 I/9), Gilgit district, Northern Areas, Pakistan. Geological Survey of Pakistan, Information Release 224.

The investigated area lies within the Kohistan island arc sequence, bordered by two megashears viz. the Main Mantle Thrust (MMT) on southern side and the Main Karakorum Thrust (MKT) on northern side. Towards eastern extremity of the quadrangle, the bedded variety of Kamila amphibolite is exposed, which was considered a part of the Salkhalas, by previous workers. The rocks of the Greenstone complex are developed on the northern periphery of the Kohistan island arc; while the Kamila amphibolite, which form the base of the arc is the product of an intraoceanic subduction in the fore-arc basin. The Nanga Parbat-Haramosh massif which lies towards southeast of the quadrangle, is largely composed of more or less intensely metamorphosed metasediments of the Salkhala formation.

The area around the Gilgit-Indus Rivers confluence is composed of hornblende granodiorite, melanocratic diorite, inclusions and xenoliths of amphibolite, hornblende para gneiss and ortho-amphibolite bodies of various dimensions. These rocks are perhaps the result of assimilation and hybridization processes occurring along the

marginal zones of the Kailas granodiorite batholith. The effects of dynamothermal metamorphism are more pronounced along the marginal zone of the batholith and resulted the formation of paragneiss and granite gneiss. Such rock types are common in the neighbouring Nanga Parbat. Tectonically, the area has been greatly disturbed which resulted a number of anticlines and synclines associated with faults. Due to proximity with the Main Mantle Thrust (MMT), the Hurban area has been severely affected by tight folding and faulting.

The intrusions of pegmatites along with the granitic and aplitic dykes and sills are quite profuse from Jalalabad along Gilgit River, and Shuta along Indus River, down streamwards upto Jaglot (out of the quadrangle). The pegmatites are mostly uneconomical, with the exception of some showings of beryl near Jalalabad alkali feldspar near Aftab camp, which may prove to be of economic significance by later detailed exploration. Significant stratified sulphide zones alongwith a gossan, have been observed in the Bilchhar and Cinnakar areas, which need further prospecting. Workable marble deposit is present in the Hurban -Shahbatot area, within the metasedimentary rocks of the Kamila amphibolite. The reserve estimation has been calculated with the following formula (Mc Kinsty, 1968, p.60). Reserves (in metric tons) = Volume in m³ x Sp. Gravity. (The specific gravity for marble taken to be 2.7).

Key words: Geology, mineralogy, Parri quadrangle, Gilgit.

S/242. Shah, S.H., Zaidi, M.M. & Shafique, M., 1986. Reconnaissance geology of Tangir–Darel–Khanbari area, Diamir district, Northern Area, Pakistan. Geological Survey of Pakistan, Records, 78.

This is a detailed mapping of some the most inaccessible area in the Kohistan terrane, namely, the valleys of Tangir, Darel and Khanbari. Theses valleys cross the boundary between the Chilas Complex and the Kohistan Batholith. The map shows that screens of metamorphosed volcaosedimentary rocks, biotite-feldspar gneisses and schists occur in a terrain mainly occupied by gabbro, olivine gabbro (minor), varieties of quartz diorites and monzonite. Field features and petrographic characteristics for the rocks are given.

Key words: Geological mapping, norite, diorite, granite, Central Kohistan, Diamir.

S/243. Shah, S.H., Zaidi, M.M. & Shafique, M., 1987. Geology of Tangir-Darel Khanbari area, Diamir District, Northern Areas, Pakistan. Geological Survey of Pakistan, Record 78.

The area contains metamorphosed volcano-sedimentary rocks and norite. The former comprise migmatized amphibolite, gneiss, schist and quartzite derived from argillaceous/ tuffaceous material. These have been intruded by mafic to felsic rocks, olivine gabbro (oldest), the diorite, quartz diorite, quartz monzonite, granodiorite dykes and felsic pegmatites. Pyroxene-quartz diorite seems to be a product of hybridization of meta-norite by quartz diorite magma. The pegmatites contain radioactive and tungsten minerals in trace amounts. There are eight tables, three maps and three cross sections.

Key words: Metavolcanics, paragneisses, Tangir, Darel, Khanbari, Chilas complex, Kohistan arc.

S/244. Shah, S.H.A., 1976. A brief note on the metamorphism and pre-existing structures of the section between Thakot and Shatial Bridge. Geological Bulletin, Punjab University 12, 105-107.

Key words: Metamorphism, structures, Thakot, Shatial.

S/245. Shah, S.H.A., 1984a. Stratigraphic observations of laterites in Pakistan and oscillation and movement of the Eurasian and Indian Blocks. Geological Bulletin, University of Peshawar 17, 101-108.

The laterite beds in Pakistan are found in isolated zones of outcrops but are spread a wide area in the country. They can be divided stratigraphically into four age groups: Upper Devonian of Chitral district; Jurassic of Punjab and Baluchistan; Cretaceous –Paleocene of Punjab, Baluchistan and Sind; and Oligocene of Sibi. Laterites are also found as thin layers or ferrogenous coating in the Siwalik group of rocks.

The mode of formation of the laterites indicates conditions of sub-aerial weathering or oxidation. It has been observed that rocks rich in ferromagnesian minerals on oxidation gave rise to thicker beds of laterites having higher percentage of iron. Some interesting information regarding the movement of plates have been provided by these laterite layers when studied on regional scale.

Key words: Stratigraphy, Eurasia, Indian block.

S/246. Shah, S.H.A., 1984b. The ophiolite belt and suture traces in Pakistan. Geological Bulletin, University of Peshawar 17, 113-117.

The paper deals with the four ophiolite belt as indicated by the occurrences of ultramafic rocks, pillow lavas, greenschists, pyroclasts and basaltic flows. Of these four belts, three are indicative of suture zones while one is related with a deep fracture through which ultramafic magma along with other types has intruded.

Key words: Ophiolite, ultramafic, suture zones, Fracture.

S/247. Shah, S.H.A. & Abdullah, S.K.M., 1961. Raw material for ceramic in Swat, West Pakistan. Natural Resources (University of Karachi) 1(2), 41-44.

Key words: Ceramic, Raw material, Swat.

S/248. Shah, S.H.A. & Afridi, M.R., 1970-71. The petrographic studies of dolerite intrusions in the Palaeozoic Formation of Attock-Cherat Range and Nowshera reef, W. Pakistan. M.Sc. Thesis, University of Peshawar, 40p.

The authors have described the petrography of the dolerite intrusions in the Palaeozoic formations of the Attock slate series, and the Nowshera Reef Complex.

The intrusions are in the form of lensoid sills except a few dykes in the Nowshera Reef complex. They measure from a few feet to as much as 10 feet in thickness. Mineralogically they are composed of plagioclase, pyroxene, ilmenite and Magnetite. The constant accessories are quartz, calcite, chlorite, epidote. The rare accessories are hornblende and apatite. From this study the authors have concluded that the rocks crystallised from a tholeiitic magma. Mineralogically they are the same and may be correlated to the Cretaceous ultrabasic intrusions.

Key words: Petrography, dolerite, Paleozoic, Attock-Cherat, Nowshera Reef.

S/249. Shah, S.H.A., Arbab, M.S.H. & Siddiqi, R.A., 1977. Preliminary observation of ERTS imagery for the geological studies of northern and northwestern areas of Pakistan. CENOT Workshop on Applications of Remote Sensing Data and Methods, Lahore, 1975. US Geological Survey, (IR) CEN-10, 150-153.

Key words: Geology, ERTS imagery, Northern Pakistan.

S/250. Shah, S.H.A., Malik, M.A. & Ahmed, S., 1997. Neogen molasses sediments of Potwar Plateau, Pakistan their implications for petroleum generation and exploration. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. Geological Survey of Pakistan, Records 109, 42-47.

The Potwar Plateau lies in the northern Pakistan and is confined by the Kala Chitta and Margalla Hills to the north and the Salt Range to the south. It is bounded by the Jhelum River to the east and the Indus River and Kohat Plateau to the west.

The Potwar Plateau is part of the Himalayan foreland fold- and thrust-belt system formed due to the ongoing collision between the Eurasian and Indian Plates that started in Early to Middle Eocene time (Stoneley, 1974). This is the principal oil producing province of Pakistan. Oil is produced from pre-Neogene carbonates and sandstones.

The Neogene molasse sediments which are the focus of this study are represented by the Miocene Rawalpindi Group and Pliocene-Pleistocene Siwalik Group. The Neogene rocks are as thick as 6400 m (Fatmi et al., 1984). The stratigraphy of the Neogene molasse sediments has been studied extensively (Burbank and Reynolds, 1988; and Johnson et al., 1986). These sediments which comprise conglomerate, sandstone, siltstone and shale were derived from the southward advancing upthrust Himalayan mountain ranges and were deposited in a network of fluvio-deltaic system in the adjoining foredeep area. Rapid rates of sedimentation ranging from 20 to 50 cm/ 1,000 years have been established (Reynolds and Johnson, 1985).

Drilling in the Potwar Plateau has revealed abnormally high formation pressures in the Neogene molasse sediments. These abnormal pressures in the Neogene rocks are in cases as high as lithostatic. Pressure gradients above lithostatic have been reported in the Adhi area (Malick, 1979). Undercompaction and tectonic stresses have been considered the main causes of these abnormal pressures in the Potwar Plateau (Malick, 1979; Sahay and Fertl, 1988; and Kadri, 1991). But the possibility of structural deformation as being one of the causes cannot be ruled out as well. Based on the mudweight and drilling exponent data, formation pressures in the Neogene sediments increase from the north to south. In the north Potwar drilling has revealed pressure gradients in the range of 0.5 to 0.65 psi/ft. (Fig 2), whereas pressure gradients approaching lithostatic have been found in the central and eastern Potwar regions (Fig.3). These overpressured zones seem to be widely distributed in the Potwar area. They constitute severe drilling and safety hazards thereby significantly increasing drilling costs and in some cases they also have resulted in the abandonment of the wells prior to reaching the target reservoirs.

On the contrary, the Neogene molasses sediments have played a vital role in the hydrocarbon generation in the Potwar region. Maturity modeling (Fig. 4) suggest that the Neogene molasse deposits have provided the required depth of burial to bring about the maturation of the source rock to generate and expel hydrocarbon to the traps. These overpressured Neogene molasses sediments have also provided effective sealing mechanism for the entrapment of oil in the Potwar region. A major part of the Potwar oil is sealed below the Neogene molasses deposits.

Key words: Neogene molasse, conglomerate, petroleum, Potwar Plateau.

S/251. Shah, S.M.A., 1966. Thesis on geology and petrology of Thakot–Shang area (Swat, Hazara) with special emphasis on Schistose Rocks. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Key words: Geology, petrology, schist, Thakot-Shang, Swat, Hazara.

S/252. Shah, S.M.A. & Wahabudin, M., 1976. Study of the waterlogged and saline land of Kafur Dehri area, N.W.F.P., M.Sc. Thesis, University of Peshawar, 41p.

This report covers field work, and comparison of data obtained by the authors with data achieved by the WAPDA during session 1974-1975. It has been established from lithologic-log of the test wells drilled in the Kafurdheri area that the sub-surface geology of this area is very complex and great variation can be expected from place to place. But generally the area is underlain by unconsolidated deposits of Quaternary age comprising of gravels, sand with silts, and clay.

The analysis of shallow-water and soil samples show that the shallow-groundwater of the area is generally of calcium-magnesium-bicarbonate type and cover about 70 percent of the total area (30,031 acres). The soils in the thesis area are mainly developed from the material contributed by the adjoining hills of Khyber Agency and are medium to fine texture with very weak to moderate

Structure. The soil salinity is localised and mainly confined to the area around Palam-dhari, Kafurdheri and Shahi Bala villages. The affected area is non-alkali-saline soil and are not supposed to present any difficulties in reclamation.

The main objective of the present work of WAPDA is to remove the constraint of water-logged and salinity, for this purpose it is proposed to remodel the present drainage system and to install about 73 tube - wells of capacity 1 - 2 cubics to the Kafur-Dheri area, so that the water table would be established at 15 feet below natural surface.

Key words: Waterlogging, salinity, Peshawar.

S/253. Shah, S.M.I., 1962. Bentonite deposits of Pakistan. CENTO Symposium on Industrial Rocks and Minerals, Lahore,

Key words: Bentonite deposits, Pakistan.

S/254. Shah, S.M.I., 1969. Discovery of Palaeozoic rocks in the Khyber Agency. Geological Survey Pakistan, Geonews 1(3), 31-34.

Key words: Paleozoic, Khyber Agency.

S/255. Shah, S.M.I., 1977a. Precambrian and Palaeozoic. In: Shah, S.M.I. (ed.), Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 1-29.

Key words: Precambrian, Paleozoic, stratigraphy.

S/256. Shah, S.M.I. (ed.), 1977b. Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoirs 12, 138p.

This monograph gives information on Precambrian to Quaternary stratigraphy and mineral deposits (including gemstones of Pakistan) by seven contributors lithological description has been given for various formations together with other pertinent data and a large number of important references. Grade, tonnage and localities for the mineral deposits have been given. Folder consists of correlation charts, maps and a table of major mineral deposits.

Key words: Stratigraphy, mineral deposits, gemstones.

S/257. Shah, S.M.I., 1977c. Precambrian. In: Shah, S.M.I. (ed.), Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 1-5.

Key words: Stratigraphy, Precambrian.

S/258. Shah, S.M.I., 1977d. Palaeozoic. In: Shah, S.M.I. (ed.), Stratigraphy of Pakistan. Geological Survey of Pakistan, Memoir 12, 5-28.

Key words: Stratigraphy, Paleozoic.

S/259. Shah, S.M.I., 1978a. Recent discovery of Palaeozoic rocks in the northern parts of Pakistan. UN Publications MRDS, 42(IV), 6p.

Key words: Stratigraphy, Paleozoic, Pakistan.

S/260. Shah, S.M.I., 1978b. Current status of stratigraphic correlation in Pakistan. UN Publications MRDS, 42(IV).

Key words: Stratigraphy, correlation, Pakistan.

S/261. Shah, S.M.I., 1980. Progress of geodynamics in Pakistan. Geological Bulletin, University of Peshawar 13, 1-4.

Key words: Geodynamics, Pakistan.

S/262. Shah, S.M.I., 1984. Siwaliks: An introduction. In: Shah, S.M.I. & Pilbeam, D. (Eds.), Contributions to the Geology of Siwaliks of Pakistan. Geological Survey of Pakistan, Memoir 11, I-IV.

Key words: Geology, siwaliks, Pakistan.

S/263. Shah, S.M.I., 1978. Geology of Pakistan. In: Fairbridge, R.W. (Chief ed.), Encyclopedia of World Regional Geology. Volume 2, Eastern Hemisphere.

The part I includes Western Hemisphere (including Antarctica and Australia), which is out of the area of this publication, thus is excluded. The volume 2 includes the geology of Pakistan. No further information was available to the authors of this book.

Key words: Geology, Pakistan.

S/264. Shah, S.M.I. & Bhutta, A.I., 1988. Geology of coal occurrences of Kotli District, Azad Jammu and Kashmir. Geological Survey of Pakistan, Information Release, 310, 29p.

Key words: Coal, Kotli, Azad Kashmir.

S/265. Shah, S.M.I. & Pilbeam, D. (Eds.), 1984. Contributions to the Geology of Siwaliks of Pakistan. Geological Survey of Pakistan, , Memoir 11, 77p.

Key words: Siwaliks, Pakistan.

S/266. Shah, S.M.I., Raza, S.M. & Sheikh, K.A., 1985. Field Guide to the Siwalik Hominoid Sites, Potwar Plateau. Geological Survey of Pakistan, Information Release 248.

The uplift and erosion of the Himalayas during the Neogene has resulted in an extensive apron of freshwater sediments deposited in the sublatitudinal foredeep developed at the margins of the mountain front. These clastic sediments of fairly homogenous composition are generally known as the Siwalik Group. The area where they are defined and are best known is the Potwar Plateau of Pakistan.

The Siwalik rocks of the Potwar Plateau and the adjoining regions of Jammu and Himachal Pradesh have remained the focus of intensive studies for the last more than 100 years. Because of the continuity of sedimentation spanning over much of the Neogene time and for the reasons that these rock units contain diverse and important assemblage of fossil vertebrates, the Siwaliks of Pakistan are ideally suited for the collection of late Tertiary vertebrate fauna. During the past hundred years these deposits have attracted most of the celebrated vertebrate Paleontologists of the world. Although large and small mammal taxa recorded in the Siwaliks are also found in the Neogene of Africa, Europe, Central Asia and North America, but the Siwaliks are unique to provide fossiliferous strata forming long and continuous stratigraphic sequences and offer clear superposition of the fossil localities. The Siwaliks, therefore are key to the land-mammal stages of Southern Asia and subsequently the recent studies are proving to be critically important for refining the Neogene vertebrate chronology of the Old World.

Since 1973, various aspects of the geology, paleontology and paleoanthropology of the Siwaliks of Potwar Plateau have been studied by research groups from the Geological Survey of Pakistan, Peshawar University, Harvard University, Dartmouth College, Lamont-Doherty Geological Observatories, and the University of Arizona. The studies have been done in three separate areas - the Chinji-Nagri area, the Hasnot -Tatrot area, and the Khaur area. Each area contains the type-section of one or more of the classic Siwalik formations.

Material collected in Pakistan from 14 to 8 Ma B.P., greatly expanded our knowledge of this group; previously unknown parts are now represented, in particular post cranial remains which are so important in the post cranial anatomical studies and even for precise taxonomical emplacement of these species. New finds of hominoids from other parts of the world have greatly enhanced the phyletic knowledge and understanding of the stages of hominoid evolution after about 5 million years ago, prior to that time, an enormous gap still exists; i. e. the time between 8 to 4 m.y. spans this gap. Fortunately a large area in Pakistan is occupied by the continental sediments of this age.

Provided the said stock did not extinct after 8 m. y. in Pakistan; it is believed, that a thorough search in the Siwaliks, where so many reasons combine to indicate greater probability of success, will hopefully yield material so crucial to the understanding of the critical phases of hominoid evolution.

Key words: Hominoids, Potwar Plateau, siwaliks.

S/267. Shah, S.M.I., Siddiqui, R.A. & Talent, J.A., 1980. Geology of the eastern Khyber Agency, North Western Frontier Province. Geological Survey of Pakistan, Records 44, 31p.

Geological investigation of the eastern part of the Khyber Agency has shown that four major stratigraphic units can be identified and mapped. The youngest, the Khyber Limestone of Carboniferous to Permian age, overlies the Ali Masjid Formation of Late Devonian age. Shagai Limestone of Silurian Devonian age underlies the Ali Masjid Formation and the oldest unit is the Landi Kotal Formation of ? Ordovician-Silurian age.

All the formations have wide spread exposures in the eastern part of the map area, Detailed search for fauna indicated that sections of these formations along the Khyber highway proved barren while those of the western part of the map area are fossiliferous. This being the case the upper two formations are richly fossiliferous while the lower formations are rarely fossiliferous. Structurally the area is very complex, frequent folding followed by faulting complicates stratigraphic interpretation of the area.

Key words: Khyber Agency, stratigraphy.

S/268. Shah, S.M.I. et al., 1985. Paleoanthropology. Geological Survey of Pakistan, Information Release 248.

Key words: Paleoanthropology, siwaliks.

S/269. Shah, S.R.A., 1990-92. Geological mapping and evaluation geotechnical properties of decorative stones of Nauseri-Muzaffarabad and Garhi Habibullah area Neelum valley, Azad Kashmir. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 1-116.

The geotechnical properties, dynamic and static test results are presented for three types of rocks ranging in age from pre-Cambrian to Permian. Attention was drawn to the different geotechnical properties of these rocks and hence, the variation in their stability as decorative stones. Comparison was made between a number of the static properties of the rocks and the geotechnical performance. The study emphasizes the importance of those properties relevant to particular application as building or decorative stones. An indication is given of the suitability of these rocks to the main construction geomaterial uses, building stones, riprap, decorative, stone, roadstone, aggregate dressing and concrete. The geotechnical properties like compressive strength, crushing strength, water absorption, water content, soundness, Abrasion resistance, Porosity and specific gravity evaluation suggest that the rocks are suitable for decorative purposes.

Key words: Mapping, geotechnical properties, decorative stones, Garhi Habibullah, Neelum Valley, Mansehra, Azad Kashmir.

S/270. Shah, S.S. & Khan, S., 1970. Geology of part of Swat between Khwaza Khela and Lillunai. M.Sc. Thesis, Peshawar University.

This is a report of the geological, work, covering about 20 sq.m of Khwaza Khela area. The purpose of this work is to study the nature of the contact between the Upper Swat Hornblendic Group and the lower Swat-Buner Schistose Group of Martin et al (1962), and to study the Hornblendic Group in some detail. Most of the area is covered by the Hornblendic Group, which is classified into: -

- 1) Banded Gneisse
- 2) Amphibolite
- 3) Diorite
- 4) Minor alpine ultramafics and pegmatites

The rocks are regionally metamorphosed, hornblende and Epidote are very common minerals (along with feldspar). The schistose group is represented by:-

- 1) Green Schist
- 2) Phyllite schists
- 3) Garnet-mica schist

The Hornblende Group strikes North-East and dips North-West, whereas the Schistose Group strikes North-South. Close to the contact, variations are common in the dip and strike due to thrusting. The area is a continuation of the western part of the Himalayan mountain. Age of the Hornblende Group is so far not certain but mostly agreed upon Precambrian, while the Schistose Group is proposed to be Silluro-Devonian age.

Key words: Geology, Khawaza Khela, Swat.

S/271. Shah, S.Z., Muhammad, T., Shafiq, M. & Wais, M., 1997. Structure and stratigraphy of a part of Kohat Plateau, northeast of Mittha-Khel, District Karak, N.W.F.P., Pakistan. M.Sc. Thesis, Department of Geology, University of Peshawar, 53p.

The exposed rocks of the area under study range in age from Eocene to Pliocene and belong to the Chharat, Rawalpindi and Siwalik groups. The Chharat Group is represented by the Jatta Gypsum, Kuldana and Kohat formations. The Kohat Formation is unconformably overlain by the Kamli Formation of Rawalpindi Group which is in turn overlain by the Chinji and Nagri Formations of the Siwalik Group. The proposed structural model which is based on detailed field traverses shows large scale south-verging folds and a series of hinterland dipping fore thrusts and foreland dipping back thrusts, emerging from a basal decollement located within the Jatta Gypsum. The structural geometry of all these faults have resulted in the development of imbricate structure in the eastern part of the mapped area and a pop-up structure in the western part. The imbricate structure comprises of two fault-bounded horses which repeat the stratigraphic units of the area. The pop-up structure is bounded by a fore and back thrust with opposing vergence directions. The structural geometry of the area is typical of the foreland fold and thrust belt and the sequence of faulting is from interior to exterior i.e. break forward sequence of faulting.

Key words: Stratigraphy, structure, Kohat Plateau, Karak, Pakistan.

S/272. Shah, Z., 1978. Mineralogy and petrology of the Loe-Shilman carbonatite complex, Khyber Agency. M.Sc. Thesis, University of Peshawar, 35p.

Key words: Mineralogy, petrology, carbonatite complex, Loe-Shilman, Khyber Agency.

S/273. Shahid, M., 1995. Depositional environments of the Misri Banda and Panjpir Formation, Peshawar Basin, NWFP. M.Phil. Thesis, University of Peshawar, 44p.

The Early to Late Ordovician Misri Banda Formation of Peshawar basin is an approximately 280 meters thick siliciclastic sequence of interbedded fine to medium grained quartz arenites and shales. On the basis of sandstone to shale ratios, bed thickness and characteristics, sedimentary structures, five lithofacies are recognised. These are lithofacies MB1, basal conglomerate and sandstone lithofacies; MB2 cross laminated sandstone lithofacies; MB3 medium grained quartz arenite lithofacies MB4 laminated shale lithofacies and MB5, sandstone interbedded with shale lithofacies. These lithofacies are interpreted to have been deposited in foreshore (intertidal) to shelf below the storm wave base. Lithofacies MB1 was essentially deposited on beach to foreshore environments. The lithofacies MB2 was deposited in a shoreface set up and lithofacies MB3 on foreshore. Lithofacies MB4 and MB5 were deposited in shelf environment. The forinerone in deeper and below storm wave base while the last one in a comparatively shallow set up. The deposition of these lithofacies when viewed in a chronological order indicates transgressive regressive trends of the sea at the time of their deposition.

Similarly five lithofacies were identified in about a 800 meters thick Panjpir Formation of Silurian age. These are lithofacies PF7, argillite; PF2, papery laminated shale with sandstone lensoid bodies; PF3, argillite with interbeds to sandstone; PF4, bioturbated quartz arenite and PF5, calcareous sandstone and sandy limestone with dark grey shale. These lithofacies are interpreted to have been deposited in shelf to foreshore set up. Lithofacies PFJ was deposited in shelf with partially restricted environments which prevailed up to the deposition of lithofacies PF2. However, the

environments became open and shallower during the deposition of lithofacies PF3 and PF4 which were deposited in shallow shelf and foreshore set up respectively. The deposition of lithofacies PF5, as interpreted, in restricted shelf indicates another deepening episode. The overall stratigraphic arrangements of the lithofacies of Misri Banda Formation and Panjpir Formation with MB1 the oldest and PF5 the youngest lithofacies, suggest several transgressive and regressive episodes and therefore several parasequence boundaries are identified within these formations.

Key words: Depositional environment, Misri Banda Formation, Panjpir Formation, Peshawar Basin.

S/274. Shahid, M., Tanoli, S.K., Haneef, M. & Jaswal, T.M., 1997. Lithofacies and depositional environments of Misri Banda Formation (Ordovician), Peshawar Basin, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.60.

The Early to Late Ordovician Misri Banda Formation of Peshawar basin is an approximately 280 meters thick siliciclastic sequence of interbedded, fine to medium grained, quartz arenites and shales. On the basis of sandstone to shale ratios, bed thickness/geometry and sedimentary structures, five lithofacies are recognised. These are lithofacies MBI, basal conglomerate and sandstone; MB2, cross laminated sandstone; MB3, medium grained quartz arenite; MB4, laminated shale and; MB5, sandstone interbedded with shale. These lithofacies are interpreted to have been deposited in from foreshore (intertidal) to shelf environments. Lithofacies MB 1 was essentially deposited on beach to foreshore environments. The MB2 was deposited in a shoreface set up and MB3 on foreshore. Lithofacies MB4 and MB5 were deposited in shelf environment. The former one in deeper and below storm wave base while the last one in a comparatively shallow set up. Lithofacies MB2 and MB3 are repeated several times in Misri Banda Formation. The deposition and repetitions of these lithofacies, when viewed in a chronological order, indicates several transgressive/regressive trends of the sea at the time of their deposition.

Key words: Depositional environment, Misri Banda Formation, Panjpir Formation, Peshawar Basin.

S/275. Shahid, M., Tanoli, S.K., Haneef, M. & Rehman, K., 1997. Lithofacies and depositional environments of Panjpir Formation (Silurian), Peshawar Basin, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.61.

About 800 meters thick Panjpir Formation (Silurian) of Peshawar basin is dominantly argillite and shale with crinoidal limestone and arenite. Five lithofacies are identified on the basis of lithology, bed thickness/geometry and sedimentary structures. These are lithofacies PFI, argillite; PF2, papery laminated shale with sandstone lensoid bodies; PF3, argillite with interbeds of sandstone; PF4, bioturbated quartz arenite and PF5, calcareous sandstone and sandy limestone with dark grey shale. These lithofacies are interpreted to have been deposited in shelf to foreshore set up. Lithofacies PFI was deposited in shelf with partially restricted environments which prevailed up to the deposition of lithofacies PF2. However, the environments became open and shallower during the deposition of lithofacies PF3 and PF4 which were deposited in shallow shelf and foreshore set up, respectively. The deposition of lithofacies PF5, as interpreted in restricted shelf, indicates another deepening episode.

Key words: Depositional environment, Misri Banda Formation, Panjpir Formation, Peshawar Basin.

S/276. Shahid, N.K., 1964. Geology of Rajdhawari pegmatites, Oghi subdivision, Hazara District, West Pakistan. Geological Survey of Pakistan, Information Release 19, 188p.

Key words: Geology, petrography, pegmatites, Mansehra, Hazara.

S/277. Shahid, S., 1986-88. Stratigraphic studies of Jabri Area southern Hazara. M.Sc. Thesis, Punjab University, Lahore, 129p.

Key words: Stratigraphy, Hazara.

S/278. Shahnawaz, R., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1993. Reconnaissance microfacies studies of Margala Hill Limestone, Jabri Area, Southern Hazara, Pakistan. *Pakistan Journal of Hydrocarbon Research*, 5 (1&2), 53-62, 2pls.

Key words: Reconnaissance, microfacies, Margala Hill Limestone, Hazara.

S/279. Shahnawaz, R.K., Chaudhry, M.N., Ghazanfar, M. & Sameeni, S.J., 1992. A reconnaissance microfacies studies of Margalla Hill limestone, Jabri area, southern Hazara, Pakistan. Abstracts, 1st South Asia Geological Congress, Islamabad, p.54.

Key words: Reconnaissance, microfacies, Margalla Hill limestone, Hazara.

S/280. Shahzad, M.S., 1992-94. Sedimentary petrology/sedimentology of early Paleocene Lockhart limestone of Changla Gali and lithostructural mapping of Barian area Hazara, North West Himalaya, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 96p.

A comprehensive study of Geology and Structure of Barian area (Distt. Abbotabad) is presented with special emphasis on the sedimentology of Lockhart Limestone of Early Paleocene age. Large scale (1:21120) geological mapping of a small segment (50 square km) of Attock Hazara fold and Thrust Belt (AHFTB) of Lesser Himalaya in Barian area within the geographic coordinates: longitudes, 73° 21' 45" to 73° 25' 15": Latitude, 33° 55' to 33° 59' 30" has carried out. The project area comprises nearly 50 sq. km on both sides of the Murree-Khaira Gali road. The Murree Ayubia road passes through the area. The lithostratigraphic units range in age from Middle Jurassic Samanasuk formation to the Murree Formation of Early Miocene age. Structurally, the area is comprised of a number of major fold structures and faults. The core of the Chhumbi Anticlinorium in the extreme north west of the area comprises of M. folds with near vertical tight synclinal in folds of Lumshiwal Sandstone. At Darya Gali, there is an opposing vergence of folds across MBT (Darya Gali fault). A number of closely spaced faults together constitute the Khaira Gali Fault zone in the southeast in the core region of Chhumbi Anticlinorium. A detailed study of sedimentary petrology of Lockhart Limestone of Early Paleocene has been carried out to unravel the environment of deposition and diagenesis of the Lockhart Limestone was deposited on open shelf. It has been divided into lower wackstone and an upper packstone facies which in turn contains sixteen microfacies. However, the lower wackstone indicates lower nutrient supply due to which the biological activity was relatively at lower level. The upper packstone facies marks an increase in the supply of nutrients proliferation of biological activity.

Key words: Sedimentary petrology, sedimentology, Paleocene, Lockhart limestone, mapping, Abbottabad.

S/281. Shahzad, T., 1994-96. Geotechnical studies along Pakistan Motorway project Kallar Kahar and Chakri Area & Geological mapping of Khanpur Dam area Haripur, Hazara District, Pakistan. M.Sc. Thesis, Punjab University, Lahore, 98p.

Key words: Geotechnical, mapping, Kallar Kahar, Khanpur Dam, Haripur.

S/282. Shaikh, P.I., 1976. Geology and petrology of Dainyor–Hini area, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore.

Key words: Petrology, Dainyor, Gilgit.

S/283. Shakoor, A., 1976a. The geology of Muzaffarabad–Nauseri area, Azad Kashmir, with comments of the engineering behavior of the rocks exposed. *Geological Bulletin*, University of Punjab 12, 78-89.

Detailed geological mapping of about 200 sq. miles of Muzaffarabad – Nauseri area has been done on a scale of 1": 0.263miles. In all, seven rock units have been differentiated. Location, contact relationships, lithology, structure, and engineering behavior of each of these rocks are described briefly. Nauseri Granite gneiss has been mapped and described for the first time. The regional structure of the area has been described.

Key words: Engineering geology, granite gneiss, maps, Azad Kashmir.

S/284. Shakoor, A., 1976b. A preliminary study of landslides and bridge failures along Muzaffarabad-Nauseri-Tithwal road of Azad-Kashmir. Geological Bulletin, University of Punjab 13, 99-106.

A 35 miles long stretch of Nilum valley road, from Muzaffarabad to Jargi, has been investigated to study landslides, bridge failures, and other problems associated with this important but badly maintained road. A map showing geology on both sides of the road has been prepared and the areas, which are most susceptible to slope failure, are delineated along the road. Also the portions where retaining walls are needed have been marked. Suggestions for improving the present condition of the road are also made at the end of the paper.

Key words: Engineering geology, granite gneiss, Azad Kashmir.

S/285. Shakoor, A., 1986-88. Geology and petrology of the Eastern Chilas calc-alkaline complex in the vicinity of Chilas (District Diamar) with special emphasis on petrogenesis of the rock units. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan 105p.

A geological map of 301 sq. km. between Pain Ges Gah Helor Gah in the north of the Indus River and Thuly Gah in the south in Chilas area is presented at the scale of 1:25,000 on toposheet No's 43 E/15, 43 I/9 and 43 I/7 issued by the survey of Pakistan. Most of the project area lies in the vicinity of the north side of the eastern Chilas Complex. The exposed sequence of rocks in the project area is a part of the northern limb of the Chilas Complex, where ultramafic rocks occur in the core of the anticline and is overlain by norite, gabbro-norite and diorites. This is capped by metadiorites of Early Jurassic age which is a part of Kamila Amphibolite. Field and petrographic study show that the rocks of the Chilas Complex are formed within a separate magma chamber and igneous in nature. There is a younger silt like leuco dioritic pluton emplaced in metadiorite. The leuco diorite hosts a small ultramafic body which has probably been formed by a magmatic protrusion of ultramafic composition and is not related to ultramafic rocks in core of the Chilas Complex.

Key words: Petrology, petrography, petrogenesis, Chilas complex, Kohistan arc.

S/286. Shakoor, A., 1987. A preliminary survey of landslide hazards along the Karakorum Highway, northern Pakistan. Annual Meeting, Association of Engineering Geologists 30, p.50. Consult Shakoor (1994) for additional information.

Key words: Landslides, KKH.

S/287. Shakoor, A., 1992. A Preliminary evaluation of landslide hazard along the Karakoram Highway, Northeastern Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.37.

Consult the following account for further details.

Key words: Landslides, KKH.

S/288. Shakoor, A., 1994. A Preliminary evaluation of landslide hazard along the Karakoram Highway, Northeastern Pakistan. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia-- I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 347-353.

The Karakoram Highway, known as the world's highest and the most difficult road ever built, is a 500 mile (800 km) long road that links Islamabad, the capital of Pakistan, to the Xinjiang Province in China. It took 25,000 workers nearly 20 years to construct the Karakoram Highway which first runs along the Indus River from Thakot to Gilgit, and then along the Hunza River to the Chinese boarder. Twenty-nine million cubic yards of rock had to be moved during the construction stage. The highway cuts across three major ranges including some other world's highest mountains, and ascends from an elevation of 5,000 ft (1,515 m) near Thakot to over 16,000 ft (4,800 m) near Khunjerab Pass at the Chinese boarder.

Landslides and other forms of slope failure have been the most serious problem along the Karakoram Highway both during and after its construction. Over 1,000 people died during the construction of this road, mostly due to landslides and rock falls. Since its opening to heavy traffic in 1979, it has seldom been free from, obstruction caused by landslides, many of which resulted in fatal accidents. The presence of a large variety of highly jointed rock types, loosely deposited glacial sediments, extremely high and steep slopes, melt and occasional occurrence of large earthquakes are the important factors that contribute to slope failures along the Karakoram Highway. Rock falls, plane failures, wedge failures, toppling slumps, debris slides, debris flows and mudflows are common along the Highway. The largest and the most devastating failures occur in the glacial deposits. Examples of these various types of slope movement are presented.

Key words: Landslides, KKH.

S/289. Shakoor, A. & Chaudhry, M.N., 1965. Geology of Khaki area, Hazara. M.Sc. Thesis, Punjab University, Lahore.

Key words: Maps, geology, Hazara.

S/290. Shams, 1979-81. Lithostructural mapping of Kalapani, Kathwal, Kakul Area, District Abbottabad. M.Sc. Thesis, Punjab University, Lahore, 235p.

The project area (Kakul, Kathwal and Kalapani) lies on the western flank of the Hazara Kashmir syntaxial bend of erosional cycle is of youth stage. The weathering of chemical nature mainly aided by mechanical action of water ice in winters. The valleys are mostly 'V' shaped. On the basis of climatic conditions and other physiographic features, it is concluded that the mapped area is in 'Maritime' morphogenetic region.

The rocks of the area were deposited in the Himalayan part of Tethys geosyncline and range in age from Mesozoic to Tertiary, along with Hazara Formation of Precambrian Era. All the rocks of the project area are sedimentary in origin. The Hazara Formation however, is affectedly metamorphism. The area is interrupted by two disconformities marked by laterite, one between Samana Suk Formation and Chichali Formation and others between Kawagarh Formation and Hangu Formation.

An attempt is made to reconstruct the depositional environments of the formation in detail. For the ancient environmental analysis different factors are brought under consideration.

Petrographic analysis of the rock samples has been made to construct the ancient geological environments of deposition and is also used to determine the economic value of the rocks. The geological history of the area is constructed on the basis of detailed study of structure, tectonics, depositional environments, fossils and sedimentary structures.

The structure of the area is complex. The folds are asymmetric recumbent and overturned with their axis in NE-SW directions. The general strike of the formation is NE-SW, but may change locally. Faults are of reverse and pseudonormal type. A brief description of tectonic behaviour of each rock unit also described. The structure of the area under consideration is the result of Himalayan Orogeny.

Key words: Geomorphology, weathering, metamorphism, Hazara Formation, Kakul, Abbottabad.

S/291. Shams, F.A., 1956a. Some of the recently discovered mineral species. Pakistan Journal of Science 8, 38-40.

Key words: Minerals, new discovery.

S/292. Shams, F.A., 1956b. Dunite occurrence near Chilas, Gilgit Agency. Abstract volume, 8th All Pakistan, Science Conference, Lahore.

Key words: Ultramafics, dunite, Chilas.

S/293. Shams, F.A., 1961. A preliminary account of the geology of the Mansehra area, District Hazara, West Pakistan. Geological Bulletin, Punjab University 1, 57-63.

A preliminary map and a short account of the geology and the regional structures of the Mansehra area are presented. The area consists mainly of regionally metamorphosed arenaceous schists and quartzites; and granites and granite gneiss of varying age. Dolerite intrusions are common; and much of the area is covered by alluvium. Preliminary studies indicate that the older granites were emplaced as sheets and the younger granite intruded as a small cross-cutting plug-like body.

Key words: Maps, structure, metamorphism, granite, dolerites, Mansehra.

S/294. Shams, F.A., 1963a. Reaction in and around a calcareous xenolith lying within the granite-gneiss of Manglaur, Swat state West Pakistan. Geological Bulletin, Punjab University 3, 7-18.

The results of mineralogical and petrographic studies of an inclusion, lying within the Swat granite-gneiss and now composed mainly of skarns, are described in relation to the geological environment. The probable reactions that took place under the influence of the granite are discussed. It is concluded that combined thermal and metasomatic contact action must be assumed to have occurred if the present mineralogy of the xenolith with its skarns is to be accounted for.

Key words: Mineralogy, petrography, skarn, granite, Swat.

S/295. Shams, F.A., 1963b. The effect of thermal metamorphism upon calcareous nodules in the quartz-mica schists of the Mansehra area, Hazara District, West Pakistan. Geological Bulletin, Punjab University 3, 25-27.

The results of a petrographic study of a band of calcareous nodules, situated within the quartz-rich mica schists near the southern contact of the Mansehra granite, are described. Under the thermal influence of the granite, reactions and recrystallizations took place, which are further discussed.

Key words: Petrography, metamorphism, granites, Mansehra.

S/296. Shams, F.A., 1963c. An inky blue beryl from Swat State. Geological Bulletin, Punjab University 3. p31.

Some time ago, three crystals of an inky-blue mineral were sent from Swat State to the writer for identification. The mineral was quickly identified as a species of beryl but its unusual colour suggested further study. Megascopically, all the three fragments of crystal show perfect hexagonal symmetry with occasional unequal development of prism faces. The terminal faces are not present, having been broken off during extraction from the rock. The fresh interiors show traces of a whitish material, identified microscopically as quartz, zonally distributed and extinguishing simultaneously. In plane-polarised light, the beryl is markedly pleochroic from colourless to bluish. Under crossed polars a very fine cross-hatched twinning of the microcline type is seen. Also seen is a haphazard, non-uniform and patchy extinction; the areas with weaker illumination yield perfect uniaxial interference figures while the others show a distinct biaxial nature with a 2V of 10° to 15°; this feature was also noted in the green beryl (emerald) of Swat by Davies (1962). In the present example, the dual optical character may mean, either that the hexagonal symmetry is simulated by means of a fine polysynthetic twinning of aragonite type (Winchell, 1951), or that the higher symmetry originated at a higher temperature and broke down on cooling. Refractive index measurements on these crystals, in white light, gave; $w=1.607$ and $\epsilon = 1.599$ (both ± 0.001), while the majority of beryls have w values within the range 1.568 to 1.602 (Winchell, 1951). This inky-blue beryl is similar to one described by Schaller et al.

(1962), from Arizona, U. S. A., which was reported to contain an unusually high cesium content and to be low in lithium. The mineral is being further studied.

Key words: Gems, beryl, Swat.

S/297. Shams, F.A., 1963d. Lead mineralization in Abbottabad area, Hazara District, West Pakistan. *Economic Geology* 58, 605-608.

Description is given of thin veins containing lead in Hazara slates of Abbottabad area.

Key words: Mineralization, Hazara slates, Abbottabad,

S/298. Shams, F.A., 1964. Kyanite pseudomorphing andalusite in hornfelsed pelitic schists of Amb State, West Pakistan. *Geological Bulletin, Punjab University* 4, 23-28.

Kyanite pseudomorphs after andalusite have been discovered in certain contact metamorphic rocks of the Amb State area. These show no evidence of the action of shearing stress and appear to have developed under conditions of strong hydrostatic pressure, following thermal metamorphism of the pelitic rocks. Theoretical implications are discussed.

Key words: Pseudomorphs, metamorphic rocks, Kyanite, Amb state, Hazara.

S/299. Shams, F.A., 1965a. Mineral differentiation in crenulated schists. *Geological Bulletin, Punjab University* 5, 48-50.

A kind of metamorphic differentiation of quartz and mica in crenulated schists has recently been explained by Rast (1965 p. 89-90) on the basis of migration of mica minerals towards areas of maximum flexure. On the other hand, Nicholson (1966) p. 209-210 has attributed mobility of silica towards less strained areas of the fold hinges, thus leaving behind a mica enrichment in the flanks. In addition to these minerals, silicates containing iron, magnesium and aluminium also show noteworthy behaviour. Rast (loc. cit. p. 90) has commented that "The siting of porphyroblasts containing iron, magnesium and aluminium is strongly influenced by phyllonitic minerals. The common over-growth of garnet on the limbs of flexures suggests a common nucleation on the biotite (or muscovite) of the flexures". Thus it is suggested that the crystallization of garnet, and presumably of other such basic silicates, is determined only by the pre-location of biotite etc. and that they themselves do not show any particular behaviour while the rock is suffering crenulation folding. The writer's observations are based on work in the Mansehra-Amb State areas of northern West Pakistan, do not lend support to this idea. The present note is intended to draw attention to certain interesting pieces of evidence which have a bearing on the problem. In the Mansehra-Amb State areas, regionally metamorphosed pelitic to psammitic schists had suffered refolding during a tectonic phase connected with the Himalayan orogeny; syntectonic growth and neocrystallization of garnet, staurolite and chlorite being common. Due to their somewhat equidimensional porphyroblastic nature, the pre-existing garnet crystals appear to have suffered rotation with continued growth and are mostly located near or in the crestal regions of the folds, as if the old schistosity had flowed around them. The garnet crystallization that took place during crenulation led to the growth of distinct shells around the pre-existing crystals; the shells enclose inclusions of groundmass minerals in the helicitic fashion. In addition a new generation of garnets arose within similar regions of the folds.

Key words: Schists, metamorphic rocks, differentiations.

S/300. Shams, F.A., 1965b. An occurrence of kyanite pseudomorphs after andalusite from Amb State, West Pakistan. *Mineralogical Magazine* 35, 669-670.

The Amb State area makes part of the western limb of a regional syntaxial arc of the north-western Himalayas. It consists of pelitic and psammitic schists and quartzites, intruded by granitic gneiss, while the whole area is cut sporadically by doleritic minor bodies. The highest grade of metamorphism reached by the schists is marked by almandine garnet while andalusite and cordierite-bearing hornfels are developed at the granite contact. Nothing has yet been published on this area although a preliminary account on the adjoining Mansehra area has been published (Shams, 1961). Recently, during field investigation of the aureole rocks near Choian (grid 896394 1" topographic sheet No. 43B/15, Survey of Pakistan), certain hornfels were found in which the andalusite had

suffered transformation into kyanite in such a manner that the original shape and twinning of the andalusite are remarkably well preserved. These rocks are heavy, tough and dark coloured and, in addition to pseudomorphs, consist of quartz, muscovite, biotite, garnet, and tourmaline etc. The pseudomorphs lie preferably within weak foliation planes of the rock and show rough parallelism of their longer dimensions, although all orientations are present (fig. 1). Their size varies from very tiny to as big as 2"X ~"X a., and rarely even bigger individuals are present. Their surface is generally coated with a brownish micaceous material while the freshly broken surfaces show the typical bluish colour of kyanite. Inside the pseudomorphs the kyanite blades are arranged in completely haphazard manner, minor amounts of quartz and muscovite are also present, the latter being at, least partly of alteration origin. The kyanite gave: a 1"713, 3 1"720, F 1"725 (all • measured in filtered white light), 2Va -- ~ 82 ~ sp. gr. = 3"43. The shape and the interpenetration twinning of the andalusite is so well preserved (fig. 2) that shearing stress, in the sense of Harker (1939), does not appear to have played any significant role during pseudomorphism. On the basis of field observations, it is concluded that the inversion took place when the hornfelsed meta-sediments were acted upon by confined hydrostatic pressure that had developed during the FIGS. 1 and 2 : fig. 1 (left). Sketch of a rock bearing kyanite pseudomorphs after andalusite. Note a broken crystal at the top. FIG. 2 (right). Photograph of kyanite pseudomorph after twinned and Musite expansion of the granite body. This mode of formation compares well with that of the Southern Rhodesian pseudomorphs (Workman and Cowperthwaite, 1963) and proves that Harker's theory of stress dependence of the transformation, andalusite to kyanite, is not of universal application. This inversion can take place under the influence of pure hydrostatic pressure as well.

Key words: Pseudomorphs, metamorphic rocks, kyanite, Amb state, Hazara.

S/301. Shams, F.A., 1965c. Uranium prospecting in Pakistan. Science Chronical 3, 23-24.

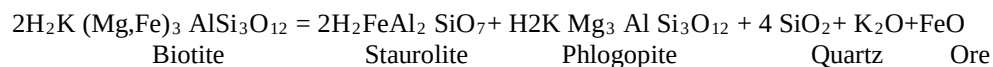
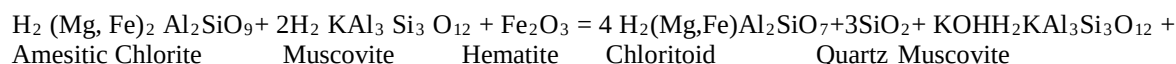
Key words: Radioactive minerals, uranium.

S/302. Shams, F.A., 1965d. Magmatic granitization of batholithic dimensions as exemplified in the Mansehra area, Hazara district, West Pakistan. Abstracts, 17th All Pakistan, Science Conference, Karachi.

Key words: Magmatism, granitization, Mansehra.

S/303. Shams, F.A., 1967a. The petrology of some chloritoid and staurolite-bearing schists from the Mansehra-Amb State-area, Northern West Pakistan. Geological Bulletin, Punjab University 6, 1-9.

Petrographic description is given of some chloritoid and staurolite-bearing pelitic schists from the Mansehra-Amb State area, Northern West Pakistan. Textural evidence suggests possibility of the following reactions:



Petrochemistry of the rocks is discussed. The ratio FeO+MnO/FeO+MgO for the co-existing chloritoid and staurolite is 0.89 and 0.87 respectively, which suggests that there can be only a very narrow P – T range of co-existence of these minerals.

Key words: Petrology, chloritoid, schists, Amb state, Mansehra.

S/304. Shams, F.A., 1967b. A note on radiometric ages of the micas from granites of Mansehra-Amb State area, northern West Pakistan. Geological Bulletin, Punjab University 6, 89-90.

One of the controversial aspects of Himalayan geology is age of the granitic intrusions that form voluminous outcrops along almost all the Himalayan belt. Right from the beginning of geological work in the Himalayas, it was generally felt that these intrusives bodies could be grouped into two types (Pascoe, 1963:

(i) dominantly foliated calc-alkaline granites, with essential biotite and/or hornblende and subordinate muscovite, and accessory ore, garnet, apatite, tourmaline and zircon. This was called the Central Gneiss or the Himalayan Gneiss. It occurs as sheet-like bodies which form continuous outcrops over long areas and show remarkable parallelism between their strike and dip and that of the foliation of the enclosing strata, and (ii) dominantly unfoliated sodalite granites with essential muscovite, tourmaline and some-time hornblende, and subordinate biotite and accessory garnet, epidote and ore minerals. In the field, they occur as small plutons or sheet-like bodies that are rather sporadically distributed and frequently intrude the Central Gneiss.

Perusal of the literature shows that there has never been any major difference of opinion about the age of second group of granites; assuming their essentially unfoliated nature, they are believed to have been emplaced during the period of waning Himalayan orogeny, and are loosely called Tertiary granites, although as Pascoe (loc cit.) writes "the actual evidence- of such so far found is not as widespread as it was at first supposed" (p. 420). The controversy turned upon the question of the-age of the Central Gneiss. The proposed ages range from Palaeozoic (Carboniferous, Auden (1932); Infra-Triassic, Middlemiss (1896) to Tertiary (Tertiary, Hayden (1907); early Miocene, MacMahon (1833). These ideas were based on the general concepts of the writers rather than direct evidence. On record, however, is an important discovery, made by Auden (op.cit.) of a granitic pebble in the breccia at the base of the "Purple Series" of Garhwal.

Lithologically, this pebble was found to be identical to the Arwa granite, a member of the Central Gneiss, and therefore Auden claimed that the Central Gneiss cannot be younger than Carboniferous. According to Wadia (1939) there are three types of granites in Kashmir Himalayas : (i) A biotite granite, most widespread from Kashmir to Assam, (ii) A hornblende granite, less common than (i) but similar in structure and composition. It is thought to be post-Cretaceous, as it was found to be intrusive into an orbitolina limestone at the head of the Burzil valley.

No age is suggested for the biotite granite, but it is considered to be earlier than the hornblende granite; it will be pre-Cretaceous anyway, and (iii) Tourmaline granite, more recent than (i) and (ii) as it intrudes them. Misch (1949) has been concerned with the Nanga Parbat granites. He claims that the various types, as described by him and earlier recognized by Wadia (1939), have so close affinities that no real age sequence can be found. According to him the granite of Nanga Parbat is a product of syntectonic granitization while the tourmaline granites are the product of the continuation of this process in the post-tectonic period. It follows from this that the main granite is post-Cretaceous and the tourmaline granites are much younger.

Key words: Chronology, radiometric ages, granites, Mansehra.

S/305. Shams, F.A., 1967c. The granites of Mansehra-Amb State area and the associated metamorphic rocks West Pakistan. Ph.D. Thesis, Punjab University, Lahore.

This is a detailed study of the granitic rocks of the Mansehra-Amb State area, and the regionally metamorphosed rocks through which the granites are emplaced. Several varieties of granite have been identified and described. The work is a good example of field and petrographic studies. Many of the papers by the author are either the outcome of, or contributed to this work.

Key words: Granites, metamorphic rocks, Amb state, Mansehra.

S/306. Shams, F.A., 1967d. Chess-board albite in the Mansehra-Amb State area, northern West Pakistan. Pakistan Journal of Scientific Research (Punjab Univ.) 19, 79-82.

Key words: Granites, chess-board albite, Amb state, Mansehra.

S/307. Shams, F.A., 1968. The role of granitic bodies in the syntaxis of the Northwest Himalayas. Abstracts, 22nd All Pakistan Science Conference, Dacca.

Key words: Granites, Himalayan syntaxis..

S/308. Shams, F.A., 1969. The geology of the Mansehra-Amb state area, northern West Pakistan. Geological Bulletin, Punjab University 8, 1-32.

About 600 square miles of area, covering large part of Mansehra sub-division of the Hazara District and the adjoining Amb State, in northern part of the West Pakistan, has been mapped and an original geological map, on the scale of 1 inch to 1 mile has been prepared.

The area constitutes the hard crystalline core of a major syntaxial loop of the northwest Himalayas and is composed of semi-pelitic to psammitic schists and quartzites that have suffered regional metamorphism up to kyanite grade of the Barrovian type. These schists bound a large granitic complex composed of an older group of gneissic (the Susalgali gneiss) to granitoid rocks (The Mansehra granite and the andalusite-bearing granites), ranging from granite to granodiorite, and a younger group of sodic granites (The Hakale granite, Karkala granite etc.). In addition, there are a large number of aplites and pegmatites, and a few porphyry dykes are met with. Dolerites cut the entire plutonic complex and are met with as ophitic dolerites, epidiorites and amphibolites, depending upon their age of emplacement. Details of field observations and laboratory studies are given as far as the general geological aspects of the area are concerned.

Key words: Geological map, granites, gneiss, metamorphic rocks, Amb state, Mansehra.

S/309. Shams, F.A., 1972. Glaucophane-bearing rocks from near Topsin, Swat-First record from Pakistan. Pakistan Journal of Scientific Research 24, 343-345.

Brief description is given of the first-ever discovery of glaucophane bearing rocks from Pakistan. Chemical analyses of two rocks with different mineral assemblages are given, alongwith optical data of the mineral.

Key words: Glaucophane schists, high-p metamorphism, Indus Suture, Swat.

S/310. Shams, F.A., 1975. The petrology of Thak valley, Gilgit Agency, northern Pakistan. Accademia Nazionale dei Lincei Rendiconti 59(8), 453-464.

The geology and petrography of the Thak valley between tarla Babusar and Indus river is described. Major element analyses are given for 13 rocks. The area is occupied, from south to north by, diorite group, veined diorite, and norite with bodies of dunite and ultramafic breccia. The rocks have been considered to be tholiitic in nature.

Key words: Diorite, norite, ultramafic rocks, petrography, geochemistry, Thak valley, Chilas.

S/311. Shams, F.A., 1978a. A note on the obliquities of some potash feldspars from the Hazara granitic complex, NW Himalaya, Pakistan. Geological Bulletin, Punjab University 15, 70-72.

Obliquities of some potash feldspars, extracted from major members of Hazara granitic complex, were estimated with the help of X-ray diffractometry. The results are in harmony with the conclusions drawn from extensive field and laboratory investigations as to the permeation – granitization origin of the granitic complex.

Key words: Obliquities, K-feldspar, granitic complex, Hazara.

S/312. Shams, F.A., 1978b. Mechanical analysis of the so-called “clay” near Ahl, District Hazara, North West Frontier Province, Pakistan. Pakistan Journal of Scientific Research (Punjab University) 7, 87-93.

Key words: Clay, mechanical analyses, Mansehra, Hazara.

S/313. Shams, F.A., 1980a. Origin of the Shangla blueschists, Swat Himalaya, Pakistan. Geological Bulletin, University of Peshawar 13, 67-70.

Chemical analyses of two metasedimentary and one meta-igneous type blueschist rocks from Swat suggest that the former type is hypersodic as compared with many of the world occurrences. The blue amphibole is crossite of

appropriate chemical composition. The rocks are believed to be of metasomatic origin, having suffered soda activity of pore fluids. A yet younger phase of soda activity originated from serpentinization of the Alpurai ultramafic mass and was responsible for growth of the albite prophyroblasts that contain helicytic trails of the blue amphibole.

The blueschist zone is taken to make a typical fossil trenchplate subduction suture in terms of theories of global tectonics. Radiometric age of muscovite from a metasedimentary blueschist type is 84 ± 1.7 m.y. or upper Coniacian, which compares suitably with other ages obtained from the region. The presence of this early Alpine subduction zone of the Swat Himalaya is taken to represent the continuation of the Indus Suture Line.

Key words: Metasediments, blueschists, Shangla, Swat, Himalaya.

S/314. Shams, F.A., 1980b. Geological evolution of the Himalayan “Central Gneiss” and its implications. Abstracts, 26th International Geological Congress, Paris, 1, p.89.

Key words: Gneiss, Mansehra, Himalaya.

S/315. Shams, F.A., 1980c. Ready Reckoner for Mineral industry in Pakistan. Oriental Enterprise Publications, Lahore, 90p.

This is a useful book. It gives all the relevant information about economic minerals of Pakistan and their industrial uses.

Key words: Minerals, uses, industry, Pakistan.

S/316. Shams, F.A., 1980d. An anatectic liquid of granitic composition from Hazara Himalayas, Pakistan and its petrogenetic importance. *Accademia Nazionale dei Lincei* 68, 207-215.

Three sills of granitic porphyry near Mansehra are considered to be anatectic in origin. Six chemical analyses are given.

Key words: Petrogenesis, geochemistry, anatexis, Mansehra granites, Himalaya.

S/317. Shams, F.A., 1981. Some phenomena within contact zones of the Hazara granitic complex, NW Himalayas, Pakistan. *Geological Bulletin, Punjab University* 16, 146-162.

Concise description is given of some important phenomena observed within contact zones between various outcrops of the Hazara granitic complex and the associated metamorphic formations. Briefly, these are recorded as thermal, structural metamorphic and hydrothermal effects, which have important bearing on origin and evolution of the granitic complex with regional implications to other parts of the Himalayas.

Key words: Hazara granitic complex, metamorphic, hydrothermal, Himalaya.

S/318. Shams, F.A. (ed.), 1983a. Granites of Himalayas, Karakorum and Hindukush. Institute of Geology, Punjab University, Lahore, Pakistan, 427p.

This is a major compilation of papers from international authors on granitic magmatism in the Himalaya, Karakoram and Hindukush region. Individual papers relevant to the present work are annotated at appropriate places.

Key words: Books, granites, Karakoram, Himalaya, Hindukush.

S/319. Shams, F.A., 1983b. Granites of N.W. Himalayas in Pakistan. In: Shams, F.A. (ed.), *Granites of Himalayas, Karakoram and Hindukush*. Institute of Geology, Punjab University, Lahore, 75-121.

A general review is given of the mode of occurrence, lithological subdivision, mineralogical and geochemical compositions of major granitic complexes of the NW Himalayas in Pakistan. Variation and comparative studies are utilized to interpret origin and mutual relationship among the granites. It is concluded that regional granitization

leading to anatexis had been a repeated cycle in the evolution of the granitic complexes starting with the Caledonian upheaval. Dominant are the pre-Himalayan granites while true Himalayan granites are subordinate. Pegmatitic phases are important elements in correlative petrology and shows regional application of the petrogenetic scheme proposed herewith. The process of granitisation and tectonic mobilization had been active within zones of decreased pressures due to up-warping produced as a result of northwards drift of the Indo-Pak plate. Besides internal homogenization, pre-existing rock formations suffered addition and exchange of material with the environments and the mantle-derived fluids. A special lineage of this process lead to the formation of alkaline complexes. The phenomena of reversed metamorphism is explained and the status of granitic areas as thermal highs and capable of originating tectonics is presented. Comments are made on mineral potential of granitic complexes of the Himalayas. Absolute age data are utilized in support.

Key words: Granites, NW Himalaya, Pakistan.

S/320. Shams, F.A., 1983c. Workshop on Stratigraphy of Pakistan. Age relations of granitic bodies of the Himalayas and Karakorum. Geological Bulletin, Punjab University Special Issue 18, Lahore.

Key words: Geochronology, granites, Himalaya, Karakorum, Hindu Kush.

S/321. Shams, F.A., 1983d. Plate tectonic model for the Himalayas and uranium mineralization. In: Shams, F.A. (ed.), Granites of Himalayas, Karakoram and Hindukush. Institute of Geology, Punjab University, Lahore, 299-307.

On the basis of plate tectonic model for the Himalayas and information drawn from regional geophysical surveys, speculations have been attempted regarding regions and rock formations that may have inherent potential for Uranium mineralization. Attention has been given particularly to granitic complexes on the basis of their nature of origin and mode of emplacement in relation to geotectonic episodes. Available data on some of the known Uranium occurrences have been utilized in support and suggestions are made.

Key words: Plate tectonics, uranium, mineralization, Karakoram, Himalaya, Hindukush.

S/322. Shams, F.A., 1984a. Granites of the northwest Himalayas in Pakistan. Abstracts, First Geological Congress, Lahore, 56-57.

For further information, consult Shams (1983b).

Key words: Granites, Karakoram, Himalaya, Hindukush.

S/323. Shams, F.A., 1984b. Do the Dir-Swat volcanic zones indicates split in Indo-Pak plates? Abstracts, First Geological Congress, Lahore, p.72.

In the western part of the so called Kohistan Zone in Dir and Swat, there are the belts of volcanics that do not extend eastwards over the entire length of the Kohistan Zone, although most of the other lithologies do so, such as amphibolites, norites-gabbros, diorites etc. The origin of the volcanics in Western sub-zone indicates great depths reached by the subducting Indo-Pak plate, leading to fusion of rocks and generation of magma. The eastern sub-zone no such occurrence of volcanic rocks in may indicate that eastern portion of the subducting plate reached shallower depths. If true, then the Indo-Pak plate is considered to have split, with western portion reaching greater depths as compared with the eastern portion that attained shallower depths on subduction. The line of split may coincide with the Indus re-entrant and this may also explain the restricted occurrence of blueschists and the nature of obducted Jijal block. Implications are commented upon.

Key words: Plate tectonics, volcanics, Dir, Swat, Kohistan.

S/324. Shams, F.A., 1986a. The Indus-Kohistan suture zone and blueschist metamorphism in N.W. Pakistan and its implications. Abstracts, Symposium/Workshop on Plate Tectonics and Crust of Pakistan. Institute of Geology, Punjab University, Lahore, 24-25.

Blueschist metamorphism along the Indus-Kohistan Zone was discovered in 1971 (Shams, 1972) from Swat Himalayas, while many more occurrences are now known from other parts of IKS-IS-ITS zone of the Himalayas. This unique phenomenon is believed to confirm the activity of a subduction zone. Although many plate tectonic models have been proposed regarding the origin of the Himalayas and many sutures have been suggested in northern Pakistan yet petro-structural importance of the blueschists have not been well recognized so far. It is noteworthy that such rocks have not been discovered from the Karakorum (or Northern) Thrust zone or from the Main Boundary Thrust (MBT) which has been claimed as a Palaeozoic suture recently (Nawaz and Ghazanfar, Abs. 24). This may mean that blueschist metamorphic conditions were not prevalent along these tectonic zones. On the other hand, Permian absolute ages from Chilas and Dras (in Kashmir) basics hint towards rift status of the IKS-IS, comparable in age to the Panjal rift that is referred generally to Hercynian epirogenic movements.

On the basis of field, petrochemical and age data, it is tempting to propose that northern Pakistan (and its geologic-tectonic extensions) represents a region of tectonic piling up of rifted longitudinal slices of Indo-Pak plate. It was only along the IS that subduction occurred while other narrow zones of longitudinal seas closed by compressional movements. The 1KB (and IS~ITS) appears to have been reactivated during Jurassic-Cretaceous, like the MBT which is now claimed being reactivated. Although the sequence of closure of various sutures is disputed and views differ even diametrically yet the subduction-zone status of the 1KB-IS-ITS is accepted by all. Therefore, the principle of pregradation of tectonic sutures southwards is not violated even in view of complex history of evolution of orogens North of the Indo-Pak plate. Various evidence and views are critically reviewed.

Key words: Metamorphism, blueschist, Indus suture, Indus Kohistan.

S/325. Shams, F.A., 1986b. Plate tectonics and crustal geology of northern Pakistan. Episodes 9, p.184.

This is a report of a conference, the abstracts of which are presented elsewhere in this work. The geotectonic map of northern Pakistan is given.

Key words: Plate tectonics, Northern Pakistan.

S/326. Shams, F.A., 1987a. Geology of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resources Potential of Mountainous Regions of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 20-26.

Key words: Pakistan geology.

S/327. Shams, F.A., 1987b. Mineral resources of mountainous regions of Pakistan. In: Shams, F.A. & Khan, K. (Eds.), Resources Potential of Mountainous Regions of Pakistan. Centre for Integrated Mountain Research, Punjab University, Lahore, 39-44.

Key words: Mineral resources, mountainous region.

S/328. Shams, F.A., 1991a. Plate tectonics, granite emplacement and mineralization. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, p.5.

Key words: Plate tectonics, mineralization, granites.

S/329. Shams, F.A., 1991b. Erosion in the Yasin valley, Northern Areas. Culture Area Karakorum, Newsletter 1, p.9. Tubingen.

Key words: Erosion, Yasin valley, Gilgit.

S/330. Shams, F.A., 1991c. Erosion in the Yasin valley, Northern Areas. Mountnews 5, p.31, Lahore.

Key words: Erosion, Yasin valley, Gilgit.

S/331. Shams, F.A., 1992a. Granites and granitization in Himalayas and Karakoram. Abstracts, First South Asia Geological Congress, Islamabad, p.38.

Key words: Granites, Himalaya, Karakoram.

S/332. Shams, F.A., 1992b. Granites, granitic gneisses and granitization in the NW Himalayas. Mountnews 5, 49-51.

Key words: Granites, gneisses, Himalaya.

S/333. Shams, F.A., 1992c. Tectonic factor in mass erosion, Northern Areas, Pakistan. In: Shams, F.A. (ed.), Culture Area Karakorum Research Project in the Northern Areas, Pakistan. Proceedings of the Pak-German joint Workshop, December 1991, Lahore. 219-226.

Key words: Tectonics, mass erosion, Himalaya.

S/334. Shams, F.A., 1992-93. Plate tectonics and origin of NW Himalayas. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 17-22.

The origin of the NW Himalaya is briefly described in the light of Plate tectonics. Short comments are given on Indo – Pakistan plate, Karakoram block, the Main Mantle Thrust zone, Chalt ophiolitic mélange and major groups of rocks in the Kohistan arc. Included in the latter are the amphibolite belt, Jijal complex, Chilas complex, Kohistan batholith, Rakaposhi volcanics, and Yasin group.

Key words: Plate tectonics, Himalaya.

S/335. Shams, F.A., 1995a. Metallic raw materials. In: Bender, F.K. & Raza, H.A. (Eds.), Geology of Pakistan, Gebruder Borntraeger, 234-257.

The metallic mineral resources of Pakistan are described in this paper.

Key words: Metallic mineral, raw material.

S/336. Shams, F.A., 1995b. Natural hazards on the Karakorum Highway, northern Pakistan. In: Stellrecht, I. (ed.), Pak-German Workshop on Problems of Comparative High Mountain Research with regard to the Karakorum, Tubingen October 1992. Culture Area Karakorum, Occasional Paper 2, 22-32.

Karakoram Highway has been frequently affected by natural hazards. These include surges of glaciers and snow avalanches in the north, land slides and rock failure, rain-affected slopes, floods, and active faults.

Key words: Hazards, KKH.

S/337. Shams, F.A. & Ahmad, S., 1979a. Petrochemistry of some granitic rocks from the Nanga Parbat massif, NW Himalaya, Pakistan. *Geological Bulletin, University of Peshawar* 11, 181-187.

Petrographic notes and chemical analyses are given for ten granitic rocks from the Nanga Parbat massif, northwestern Himalayas. Chemical and normative variation diagrams are used to show that the granitic rocks originated through alkali metasomatism of metasediments, a specific chemical change being controlled by original composition of the particular lithologic facies. Scanty previous data are included for comparison.

Key words: Petrography, geochemistry, granites, Nanga Parbat massif, Himalaya.

S/338. Shams, F.A. & Ahmad, S., 1979b. The petrochemistry of the Thak valley igneous complex, District Diamir, northern area, Pakistan. *Pakistan Journal of Scientific Research Punjab University*, 31, 145-150.

Consult Shams, 1975 above.

Key words: Diorite, norite, ultramafic rocks, petrography, geochemistry, Thak valley, Chilas.

S/339. Shams, F.A. & Ahmed, Z., 1968. Petrology of the basic minor intrusives of the Mansehra-Amb State area, northern West Pakistan. Part 1—The Dolerites. *Geological Bulletin, Punjab University* 7, 45-56.

The dolerite members of the basic minor intrusives, of the Mansehra-Amb State Area, have been subjected to detailed petrographic and mineralogical investigations. In addition to modal variation of various constituent minerals, pyroxene minerals have been studied to understand their relationship in co-existence. The chemical nature of the dolerites and their trend in mineralogical phase variations are comparable to those of the well known tholeiitic provinces of the world. An outstanding feature of pyroxenes of these dolerites is that their maximum magnesian content is higher than most of the known cases of similar origin.

This is the first detailed study of dolerites of the Mansehra-Amb State Area.

Key words: Petrology, dolerites, Amb state, Mansehra.

S/340. Shams, F.A., Chaudhry, M.N., Ahmad, N., Shaikh, R.A. Saleemi, A.A., Ahmad, S., Dean, A.Z., Sarwar, M. & Hyderi, I.H., 1984. The Punjab University expedition to Baltistan, NE Pakistan. *Geological Bulletin, Punjab University* 19, 1-68.

Report is given of geology and petrology of the northeastern part of the Shigar valley, Baltistan, including structural and geomorphologic information. An original geological map on 1:12,500 scale is presented on the basis of an expedition carried out during the summer, 1982. Significant achievements are briefly stated including economic mineral resources of the area. The program was part of the University Centenary Celebration planned by the Institution. The project will continue for a few years.

Key words: Petrology, structure, geomorphology, mineral resources, Baltistan.

S/341. Shams, F.A., Jones, G.C. & Kempe, D.R.C., 1980. Blueschists from Topsin, Swat District, NW Pakistan. *Mineralogical Magazine* 43, 941-942.

BLUESCHIST rocks, the first to be found in Pakistan, were reported by Shams (1972) from near Topsin (34° 53.5' N.; 72° 34-5' E.) and also by Desio (1977) from Shangla, a nearby locality also in Swat District, northern Pakistan. Recently, further occurrences were reported from the area by Tahirkheli (1979). The rocks form part of the so-called Lower Swat-Buner Schistose Group of Palaeozoic age (Martin *et al.*, 1962). To the north the blueschists are bounded by an amphibolite zone which is succeeded by a basic complex, considered to have suffered regional metamorphism up to the granulite facies (Jan and Kempe, 1973; Jan, 1979a, b). On the north-east is an alpine-type serpentinite mass thought to be a tectonically emplaced block (Jan, 1979c). Phyllite and quartzose mica schists outcrop to the east and

west, also belonging to the Lower Swat-Buner Schistose Group. To the southwest, the blueschist rock body thins out and disappears under alluvial cover. A major regional thrust immediately to the north of the Schistose Group, the so-called Patan Line, has been accepted as marking the edge of the subduction zone related to the suturing of the colliding Indian and Eurasian lithospheric plates (Desio, 1977). This thrust has since been renamed the Main Mantle Thrust by Tahirkheli *et al.* (1979), who regard it as the zone of obduction of the basic complex (the Kohistan Sequence) on to the Indian plate. This has increased the importance of the discovery of the blueschists and warrants an account of their petrology. One type of rock (14348; Table I) is schistose, greenish grey in colour, and strongly foliated with shiny, slickensided surfaces. The blue amphibole is associated with micaceous folia, along with quartz, albite, muscovite, garnet, chlorite, epidote and traces of tourmaline, rutile, sphene and apatite. A younger phase of albite (0.03% CaO) forms porphyroblasts which contain trails of matrix minerals as well as of the blue amphibole. The other type of rock (14363) is a heterogeneous, dark bluish black metadolerite, variously composed of a granular aggregate of epidote, chlorite, garnet, quartz, and minor sphene and rutile, with blue amphibole forming clusters of large crystals. The chemical compositions of the two rock types are given in Table I, along with their amphibole compositions and structural formulae. Plotting of the amphibole compositions in the $Mg/(Mg + Fe^{2+})$ versus $Fe^{3+}/(Fe^{3+} + Al^{VI})$ diagram (fig. 1) for the glaucophane-riebeckite group shows them to be crossites comparing closely with four compositions from Deer *et al.* (1963). Thus, the blueschist rocks from Topsis illustrate typical assemblages such as are taken to mark plate subduction or obduction zones in fold mountain belts (Ernst, ~1975), as in the Himalayas (cf. Farah and DeJong, 1979). Their discovery shows that the anomalous status attributed to the Himalayas as collision-type mountains lacking blueschist metamorphism (Powell and Conaghan, 1973) is no longer applicable.

Key words: Blueschists, geochemistry, mineral chemistry, Swat. .

S/342. Shams, F.A. & Mahmood, A., 1984. Plate-tectonic model for northern Pakistan and mineralization regims. Abstracts First Pakistan Geological Congress, Lahore, p.73.

Key words: Plate tectonics, mineralization.

S/343. Shams, F.A., Mahmood, A., Mirza, K.J., Mirza, Z.A., Ahmad, Z.A. & Siddiqui, M.A., 1983. Petrology of Shamozaï area, District Dir and Swat NW Pakistan. *Kashmir Journal of Geology* 1, 55-60.

The first detailed description of the Shamozaï area, districts Dir and Swat is given on the basis of 1: 10,000 mapping of about 206 km² North of the River Swat and including Southern edges of the Hornblende Complex, Kohistan Zone. Petrographic and mineralogical details of various units are given. The structural features of the area and problems of metamorphism are briefly discussed.

Key words: Petrography, metamorphism, Shamozaï, Swat.

S/344. Shams, F.A. & Rehman F., 1966. The petrochemistry of the granitic complex of the Mansehra-Amb state area, northern West Pakistan. *Pakistan Journal of Scientific Research* (Punjab University) 1, 47-55. 68- p.150.

The granitic complex of the Mansehra-Amb State area is composed of an older group of granitic gneisses and granitoid granites, and a younger group of tourmaline-bearing granites; in addition, a large number of aplitic and porphyry bodies are also associated. Representative specimens of each rock type have been analysed chemically and the petrochemical data is interpreted in conjunction with the results of field and petrographic investigations.

Key words: Petrography, chemistry, granites, Amb, Mansehra.

S/345. Shams, F.A. & Rehman, F., 1966-67. Tungsten molybdenum mineralization north of Oghi, Hazara District, West Pakistan. *Pakistan Journal of Scientific Research* (Punjab University) 2, 41-46.

Key words: Mineralization, Tungsten, Molybdenum, Mansehra.

S/346. Shams, F.A. & Rehman, F., 1967. An estimation of temperatures of formation of some granitic rocks of the Mansehra-Amb state area, Northern West Pakistan, and its bearing on their petrogenesis. *Geological Bulletin, Punjab University* 6, 39-43.

Temperatures of formation of some granitic rock of the Mansehra-Amb State area have been estimated on the basis of mineralogical reactions and transformations, and by Barth's method of two-feldspar geothermometry. The estimated temperatures range from 580°C to 670°C and therefore, are in the range of granitic magmas both as products of differentiation as well as that of anataxis.

Key words: Temperature estimation, chemistry, granites, Amb, Mansehra.

S/347. Shams, F.A. & Rehman, F., 1969. Study of metasomatism across a granite contact near lower Batrasi Tehsil Mansehra, District Hazara, Pakistan. *Pakistan Journal of Scientific Research (Punjab University)* 5, 1-12.

Field evidence of metasomatism of the metamorphic rocks had the contact with a facies of the Mansehra granite has been followed with laboratory investigations and the results are discussed.

Key words: Metasomatism, Mansehra granites.

S/348. Shams, F.A. & Rehman, F., 1973. A note on copper mineralization near Baldher, Haripur, District Hazara, North West Frontier Province, Pakistan. *Geological Bulletin, Punjab University* 10, 95-96.

Rare copper staining of the Hazara Slates has been known for some time but only in 1971 worth- while zone of mineralization was located near Baldher (Long. 73°6'; Lat. 33°59') about 9 miles N-E of Haripur (Fig. 1). The place was visited by authors in April, 1972. The mineralized zone represents a belt of fault breccia in the Hazara Slate Formation of Palaeozoic age. The latter are represented by khaki to steel grey coloured fine-grained slates that texturally show a status near to phyllites. Thin bands of greenish and purplish slates are sporadically present. Mineralogically, these are composed of varying proportions of quartz, muscovite, bleached biotite, chlorite, feldspar, tourmaline and ore grains etc. No detailed account of petrography of these rocks is available in literature, nevertheless, it is of no direct bearing to present problem in its restricted sense.

The fault breccia zones are recognisable due to the presence of rock rubble and conspicuous ochery colour of limonite. The angular rock fragments are strongly fractured and stained by limonite while the central portion of the breccia zone is occupied by greyish white, coarse quartz-rich material; copper mineralization is generally associated with the latter rocks. In thin section, the quartz rich breccia-zone rocks show strong cataclastic texture, composed of large strained quartz grains bordered by fine-grained strain free quartz. Wherever fractures run through the rock, quartz shows growth outward from its margins; the fractures themselves are generally healed by limonite. In addition to dominant quartz, irregularly distributed angular fragments of slate are present, which show a weak preferred orientation in specimens sampled near walls of the breccia zones. General coarsening of the rock fragments along fractures running through them is frequently seen. Such fractures, both in quartz-rich areas as well as in rock fragments, are quartz grains; occasionally intergranular spaces occasionally filled by bright green malachite, lined as well carry malachite. 111 frequent cases, galena outwardly by limonite is associated although it shows tendency to occur separately from copper mineralized areas of the breccia zone rocks.

The elemental copper content of 5 representative specimens ranges from 0.34% to 2.35% (determined by dithizone method). The primary copper mineral is chalcopyrite which alters to cuprite to malachite. Pyrrhotite is generally associated and makes veins and bands that contains tiny chalcopyrite grains. The chalcopyrite areas show boxwork alteration to reddish limonite with a thin marginal zone of pyrrhotite around chalcopyrite.

The malachite is associated with ore minerals in such a manner that its thin veins appear issuing from alteration zones and penetrating the host material. The malachite preferably fills openings in slate fragments parallel to foliation and fractures in large It appears that chalcopyrite is the primary ore and its content will increase with depth, as has been supported by exploratory digging to a vertical depth of about 10 feet. Further work is in progress.

Key words: Mineralization, copper, Haripur, Hazara.

S/349. Shamsi, K.A., 1964. Geology and structure of Khanpur-Kirala, area. M.Sc. Thesis. Geology Department, Punjab University, Lahore.

Key words: Structure, geology, Khanpur.

S/350. Sharma K.K., 1983. Transhimalayan granitoids of Ladakh and Karakorum range, Ladakh Himalaya. In *Granites of Himalayas, Karakorum and Hindu-Kush*, F.A. Shams ed., Punjab University, Lahore, Pakistan, 341–354.

Key words: Granitoids, Karakoram, Ladakh, Himalaya.

S/351. Sharma, K.K., 1991. Geology and geodynamic evolution of the Himalayan collision zone: a synthesis. *Physics and Chemistry of the Earth* 18, 431-439.

The great mountain ranges of the Himalaya and the Karakoram and the highest plateau of Tibet are the earth's unique features which according to general consensus came into being due to the successive accretions of various isolated continental and arc terranes with the converging Indian and Eurasian land masses during Late Mesozoic-Early Tertiary. The regions which were terracognita till seventies aroused global interest to generate field and laboratory data for the better understanding the geological history and the geodynamic evolution of these spectacular features. The data generated in the past two decades suggest that four major terranes Kun-lun, Qiangtang, Lhasa and Himalaya have accreted successively with one another along Litian-Jinsha suture, Banggong-Nujiang suture and Indus-Zangbo suture, respectively (see Inset Map-1 of the compiled geological map). More detailed studies of these collision zones are likely to provide information to reconstruct the chronology of various events, as has been possible to some extent in the case of the Himalayan collision zone. A number of micro-terranes, such as the Kohistan island arc, the Ladakh island arc and the Gangdise continental arc, evolved and sutured in different stages and at different times, resulting in the Himalayan collision zone. The information on other collision zones occurring to the north of this zone is also increasing and a multi-disciplinary effort by Chinese (Academia Sinica) and British (Royal Society London) scientists during June, 1985 (Chang Chengfa et al., 1988) has further added to our knowledge of these collision zones. This attempt followed the successful endeavour of the Chinese and French scientists who carried out joint studies during 1981 in the southern Tibetan region of the Lhasa sector of the Himalayan collision zone. In the classical concept of the plate tectonics and orogeny, the rifting of the continental lithosphere initiates under a hot convecting column which ultimately drives the rifted continent blocks apart with opening of the sea and creation of the oceanic crust in-between the separated blocks. At some stage of its growth, the oceanic crust starts subducting to give rise to an island arc or a continental arc depending upon Mariana or Chilean type subduction.

Key words: Geodynamics, India, Eurasia, Mesozoic, Tertiary.

S/352. Sharma, K.K., 1994. Geological map of the Himalayan collision zone. 101 (H.L.O.) Printing Group of Survey of India.

This map covers the area of the greater Himalayan region from the eastern syntaxis upto Kabul and show all the major lithologies. There are also five inset maps showing tectonic features, distribution of metamorphic belts, granitoids and volcanic rocks.

Key words: Geological map, Karakoram, Himalaya.

S/353. Sharma, K.K. & Gupta, K.R., 1978. Some observations on the geology of the Indus and Shyok Valley, Ladakh: In: *Recent Researches in Geology 7*, Hindustan Publications Corporation, Delhi, 133-143.

Key words: Geology, sutures zones, Indus, Shyoke.

S/354. Sharma, K.K., Sharma, O.P., Choubey, V.M. & Nagpaul, K.K., 1981. Age of Ladakh-Deosai granite batholith, Trans-Himalaya. *Current Science* 50, 819-821.

Key words: Granitic batholith, Ladakh, Deosai, Trans Himalaya.

S/355. Sharma, K.K. & Viridi, N.S., 1997. Extensions and analogues of Lesser and Higher Himalaya vis-à-vis the status of the Main Central Thrust in the NW Himalaya - comparative study in the Indian and Pakistan segments. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.62.

Key words: MCT, Lesser Himalaya, Higher Himalaya, India, Pakistan.

S/356. Shaukat, M. & Sattar, A., 1986. Geology and structure of the central part of Attock-Cherat Range. M. Sc. Thesis, Peshawar University.

Key words: Structure, petrology, Attock-Cherat range, NWFP.

S/357. Sheikh, A.A., 1988-90. Geological mapping and economic geology of the metamorphic rocks (Gokdarra-Ghaligai), Swat District. M.Sc. Thesis, Punjab University, Lahore, 84p.

The detailed geological map of the project area has been prepared. The project area has been mapped on a scale 1" = 12500' = 12,500'. This thesis consists of two sections. Section No.1 deals with the general geology of the project area. Introduction, Physiography, Structural Geology & Tectonics and the lithologic units of the project area have been discussed in this part. In Section No.2, Petrography, Chemical analysis, Petrogenesis, Discussion on Petrogenesis, Economic Geology and SOME THING, NEW ONE (Dolomite/Wollastonite Skarn) in the project area is discussed. The project area is consisting upon the metasedimentary and metamorphic rocks which lie in the Higher Himalaya Crystallines of the MMT Zone. The rock units belong to Lower Swat Buner Schistose Group and are of Lower Palaeozoic age.

Key words: Mapping, metamorphic rocks, economic geology, Swat.

S/358. Sheikh, A.M., 1983-85. Litho-structural studies of Fitni-Bhirina-Paniali and Haddo Bandi Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 162p.

There is a specific relationship between the geological structures, landforms and the climate. This relationship can be worked out by qualitative as well as quantitative analysis of the topographic map. The most commonly exposed lithologies in the project area are schists from chlorite to garnet grade, Susalgali granite gneiss, Mansehra granite, quartzites and hornfels. The rocks of the project area have been classified into nine lithologic units for the sake of mapping purposes at a scale of 9.2 Cm. to a kilometer on 5.8 inch to a mile. The area is deformed by different deformation phases, among which three are recognized on mesoscopic as well as microscopic scale and area is characterized by heterogeneous deformation. The rocks have been folded isoclinally and later being refolded into open folds. The area lies in the zone of brittle deformation and show extensive fracturing instead of folding. Mesoscopic and microscopic deformational features are well developed in the area. The rocks exhibit effects of polymetamorphism. The thermal metamorphism is superimposed on the regional metamorphism.

Key words: Lithology, structure, Mansehra, Hazara.

S/359. Sheikh, I.A., 1973-74. Engineering geology of Muzaffarabad-Tithwal, Azad Kashmir. M.Sc. Thesis, Punjab University, Lahore.

Field mapping of about 200 miles² of the Neelum Valley area from Muzaffarabad area to Jari have been done on a scale of 1"=0.263 miles. Nauseri granite gneiss has been identified and mapped for the first time. A description of

the location, aerial extent, contact relationships, lithology and petrography, structural features and engineering behavior of each of the rock types shown on the map is given. This is followed by separate chapter on the structure of the area.

A detailed study of the existing Muzaffarabad-Tithwal road has been made with respect to its alignment and the problems associated with it such as those of landsliding, bridge instability and poor drainage. The rocks exposed at the proposed Nurseri bridge site have been studied and engineering tests have been performed on the samples taken. A careful study of the slopes at this site was also made. On this basis the proposed site has been evaluated and its feasibility is worked out. In the end a summary of the whole study recommendations is given.

Key words: Engineering geology, structure, petrography, granite gneiss, Neelum valley, Muzaffarabad.

S/360. Sheikh, K.A., 1996. Use of magnetic reversal timelines in ancient fluvial systems: A case study of Miocene Chinji Formation, Potwar Plateau, Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, Geological Survey of Pakistan, Islamabad, p.78.

Key words: Geodynamics, India, Eurasia, Mesozoic, Tertiary.

S/361. Sheikh, K.A., 1997. Use of magnetic reversal timelines in ancient fluvial systems: A case study of Miocene Chinji Formation, Potwar Plateau, Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (Eds.), Paleomagnetism of Collision Belts. Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, 129-141.

Magnetic polarity stratigraphy and sedimentology of the lower part of the Middle Miocene Chinji Formation at its stratotype is discussed. The area lies on the southern flank of the Soan Synclinorium, south of Chinji village between Chittaparwala section in the east, to Huch Nala section in the west, some 16 km apart along the strike. The Chinji Formation is composed dominantly of red to reddish brown siltstone and mudstone with subordinate light grayish green to gray sandstone. Two laterally continuous sand body units, namely the Rainbow Sandstone and the Obstacle Sandstone were traced in the lower part of Chinji Formation to correlate Chittapanwala section to Huch Nala section. In order to check the isochroneity of these trace units, seven short lithostratigraphic sections each 150 m thick on average, spanning over the interval bracketed by the two sandstone bodies were measured and paleomagnetic sites were chosen at an average of 7 m in each section. Magnetic reversal timelines and polarity zones in each section were established and correlated with the Chittaparwala magnetic polarity section. Reversal timelines (named T1 through T7) were traced between the Chittaparwala and Huch Nala section, i.e., 13.88 to 12.33 Ma. The Rainbow Sandstone throughout its lateral extent in the area remains within the reversal timelines T2 and T3 (13.88 to 13.46 Ma). The upper sandbody, the Obstacle Sandstone, lying about 120 m above the Rainbow Sandstone, gives a much complex history of fluvial system spanning between T4 to T7 (13.21-12.33 Ma). The sedimentary details and isochron of the Rainbow and Obstacle sandbodies indicate different channel belts and floodplain mosaic. It can be postulated that the fluvial system represented by the Rainbow sandbody was dominated by coexistence of more than one major river draining the area. The Obstacle sandbody suggests perhaps switching of the same river system westward through time. The mean sedimentation rate for the Lower Chinji Formation is 0.13 d y r . The mean rate of lateral migration of the river system w k h deposited the Obstacle sandstone is 1.7 cm/yr approximately.

Key words: Paleomagnetism, Chinji Formation, Miocene, fluvial system, siwaliks, Potwar Plateau.

S/362. Sheikh, K.A., Friend, P.F., Raza, M.S. & Shah, S.M.I., 1992. Magnetic polarity stratigraphy of type Chinji Formation and its implications on sedimentation. Abstracts, First South Asia Geological Congress, Islamabad, p.67.

Key words: Magnetic polarity, sedimentation, Chinji Formation, siwaliks, Potwar Plateau.

S/363. Sheikh, K.A. & Shah, S.M.I., 1984. Paleocurrent directions of Chinji Formation in Pakistan. In: Shah, S.M.I. & Pilbeam, D., (Eds.), Geological Survey of Pakistan, Memoir 11, 75-77.

Key words: Paleocurrent, Chinji Formation, siwaliks, Potwar Plateau.

S/364. Sheikh, K.M., 1985-87. Geology of Dunga Gali-Barian Area, District Abbottabda. M.Sc. Thesis, Punjab University, Lahore, 103p.

This report incorporates a comprehensive geological study of nearly 25-km² area between Dunga Gali and Barian on the Murree-Abbottabad road. The study includes stratigraphically the rock units range from Upper Jurassic to Eocene and represent the sequence of the Hazara Province of the Kohat-Potwar Basin. It is primarily a limestone-shale sequence reflecting a stable shelf facies. Structurally, the area shows the development of a few synclinoria and anticlinoria, within which a generally tight parallel to similar asymmetric to overturn style of folding predominates. A number of dip-slip-strike faults both of the normal and reverse type is present. A petrographic study of all rock units, based on fairly representative field sampling, is also present.

Key words: Stratigraphy, Jurassic, Eocene, Abbottabad.

S/365. Sheikh, N., Qureshi, M.Y. & Rahman, R., 1967. A study of the indigenous manganese ores. Pakistan Journal of Scientific Research 19, 61-66.

Key words: Manganese ore.

S/366. Sheikh, R.A., 1973. Lithostructural mapping of Darra Adam Khel area, District Kohat with special emphasis on stratigraphic studies and depositional environments. Field Report/Thesis, Punjab University, 80p.

Key words: Stratigraphy, depositional environment, mapping, structure, Darra Adam Khel, Kohat.

S/367. Sheikh, R.A., 1984. Stratigraphy and tectonic style of Darra Adam Khel area, District Kohat. Abstracts, First Pakistan Geological Congress, Lahore, p.51.

Key words: Stratigraphy, tectonics, structure, Darra Adam Khel, Kohat.

S/368. Sheikh, R.A., Butt, A.A. & Qureshi, M.K.A., 1997a. Microfacies analysis and diagenesis of the Kingriali Formation, Kala Chitta Range, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.62.

Key words: Microfacies, diagenesis, Kingriali Formation, Kala Chitta Range.

S/369. Sheikh, R.A., Butt, A.A. & Qureshi, M.K.A., 1997b. Microfacies analysis and diagenesis of the Jurassic Samana Suk Formation from Sangar Gali and Thai areas, Abbottabad District, northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.63.

Key words: Microfacies, diagenesis, Samana Suk Formation, Jurassic, Abbottabad.

S/370. Sheikh, W.A., 1985-87. Geological studies of Khanspur Dewal Area with special emphasis on mineralogy and petrology. M.Sc. Thesis, Punjab University, Lahore, 94p.

This report gives an account of geological studies of Khanspur and Dewal Area with emphasis on mineralogy and petrology. The prescribed area lies to the north of Murree in extreme east of Abbottabad and southeast of Muzaffarabad. The area is approximately 56 sq. km. for which geological mapping was done on lithostratigraphic basis, at the scale of 1:10,000. The stratigraphic succession ranges from Datta Formation to Murree Formation (From Jurassic to Miocene). The lithology is mainly limestones, shales, and sandstone with intercalations of marl and clay. Extensive sampling of the rocks was done and studied afterwards in laboratory. In the Chapter of Petrography, the microscopic and megascopic studies of each formation are given. The percentage of each mineral content is also given. Sedimentary structures, tectonics and economical mineral deposits of project area have been discussed in separate chapters.

Key words: Geology, stratigraphy, Khanaspur.

S/371. Sheldon, R.P., 1966. Reconnaissance evaluation of West Pakistan for phosphate rocks. US Geological Survey/Geological Survey of Pakistan, Information Release PK-32, 20p.

Key words: Reconnaissance, phosphate, West Pakistan.

S/372. Shi, Y. & Wang, W., 1980. Research on snow cover in China and the avalanche phenomena of Batura glacier in Pakistan. *Journal of Glaciology* 26, 25-30.

This paper summarizes the state of research in China on snow cover, snow-drift control, and avalanche defences, and also reports the results of observations of avalanching above Batura Glacier, Pakistan, during two expeditions.

Key words: Glaciers, snow cover, avalanche, Batura, Karakoram.

S/373. Shi, Y., Wang, W. & Zhang, X., 1980. Forecasting the change of the Batura glacier this and the next centuries. In: *Professional Papers on the Batura Glacier, Karakoram Mountains*, 191-207. Beijing. Science Press.

Key words: Glaciers, Batura, Karakoram.

S/374. Shi, Y. & Zhang, X. 1981. Batura Glacier of Karakorum Mountain, an example of the complex type glacier. In: *Proceedings of the Symposium on Qinghai-Xizang (Tibet) Plateau, Geological and Ecological Studies of Qinghai-Xizang*, 2: 1619-1624.

Key words: Glaciers, Batura, Karakoram.

S/375. Shi, Y. & Zhang, X., 1984. Some studies of the Batura glacier in the Karakoram Mountains. In: Miller, K.J., (ed.). *The International Karakoram Project*, I, 51-63. Cambridge University Press: Great Britain.

Key words: Glaciers, Batura, Karakoram.

S/376. Shi, Y. & Zhang, X., 1978. Historical variations in the advance and retreat of the Batura glacier in the Karakoram Shan. *Acta Geographica Sinica*, 33(1): 7-13.

Key words: Glaciers, Batura, Karakoram.

S/377. Shipton, E., 1939. Map of Hispar-Biafo glacier regions (Karakoram Himalaya). Royal Geographical Society, London.

Key words: Glaciers, maps, Hispar, Biafo, Karakoram.

S/378. Shipton, E., 1940. Karakoram, 1939. *The Geographical Journal* 95, 409-427.

Key words: Karakoram.

S/379. Shipton, E. & Yeates, E.W., 1950. Hispar-Biafo Glacial Regions (Karakoram Himalaya). Royal Geographic Society, London.

Key words: Map, Hispar, Biafo, Karakoram.

S/380. Shroder, J.F., 1984. Batura glacier terminus, 1984, Karakorum Himalaya. *Geological Bulletin, University of Peshawar* 17, 119-126.

Batura Glacier in northwest Karakorum Himalaya has received considerable attention in the past decade because of some unusual characteristics and its effects on the Karakorum Highway between China and Pakistan. Chinese glaciologists found evidence that the Batura terminus would advance in the present decades and retreat in the 1990's. The predicted advance has not begun and instead the frontal ice cliff has downwasted and the cliff above the main meltwater channel has backwasted.

Key words: Glaciers, Batura, Karakoram.

S/381. Shroder, J.F., 1989a. Geomorphic development of the western Himalayas. *Geological Bulletin, University of Peshawar* 22, 127-151.

Evolution of the drainage system of the western Himalayas was controlled by antecedence, superposition, capture, ponding, avulsion, and faulting following collision and suturing of the Kohistan-Ladakh island arc between the Indian and Eurasian Terranes. The Indus River arose sometime in the middle Tertiary from an area of eroded volcanics near Mt. Kailas in Tibet and established a course to a ancestral "Sindh estuarine" embayment about 300 km north of the present delta. Neither the old idea of a northwest-flowing "Indobrahm" river in the Himalayan foredeep, nor the newer postulate of an east-flowing ancestral diverse drainage directions. Instead the Indus River seems to have established itself along the axis of the island arc system, and in the Haramosh-Nanga Parbat area is was deflected south in an apparent sinistral sense along the Main Mantle Thrust. Subsequent reversal of motion produced a later dextral offset along the Raikot fault. The river was deflected similarly as it crosses the Kalabagh fault through the Salt Range.

Consideration of relations between uplift rates and erosion shows that the Himalayas are at least six times lower than the theoretical maximum, indicating that balance is achieved by discontinuous pulses of rapid uplift alternating with longer periods of quiescence, as well as by variable rates of channel incision and slope processes of erosion. Calculation of long-term sediment deposition in the Indian Ocean equates to a denudation rate of 0.2 mm/yr. Short-term present day rates are 1-1.8 mm/yr. Present uplift of Nanga Parbat is about 5 mm/yr. and is nearly balanced by denudation at Raikot Glacier of 4 mm/yr.

In Pleistocene at least three episodes of glacial advance left thick valley-fill sections that allow definition of Quaternary events. The early stage is indurated lower Jalipur tillites that lack clasts from Nanga Parbat and show that uplift had not yet exposed the massif. Overlying heterogeneous upper Jalipur valley-fill sedimentary rock is younger than 1-2 mm/yr and is overturned or overridden by basement faulting in places. The middle stage is two or more tills intercalated within variable sediments, including thick lacustrine deposits at Gilgit and Skardu. The last stage consists of three or more separate advances that retain moraine topography. At Nanga Parbat and several other places, transverse glaciers at this time blocked the Indus to produce prominent lake deposits. Some of these ice dams failed and produced catastrophic floods and emplacement of the Punjab erratics at the mountain front. In Holocene time numerous glacial fluctuations and surges have occurred and are being monitored. Both glacial advances and major slope failures across rivers have occurred throughout the western Himalaya in historic time and have produced large impoundments, the dams of which failed subsequently and produced catastrophic floods.

Key words: Geomorphology, drainage, Indus river, Pleistocene, Quaternary, Himalaya.

S/382. Shroder, J.F., 1989b. Hazards of the Himalaya. *American Scientist* 77, 564-573.

Key words: Hazards, Himalaya.

S/383. Shroder, J.F., 1992a. Himalaya to the Sea: Geomorphology and the Quaternary of Pakistan in the regional context. In: Shroder, J.F. (ed.), *Himalaya to the Sea: Geology, geomorphology and the Quaternary*. Routledge, London, 1-42.

Pakistan is characterized by a highly varied geomorphological landscape. Caught up in continental collision both in the north and west, the area of Pakistan consists of 1. the Karakoram, Hindukush and Himalayan ranges in the North, 2. Suleman and Kirthar mountain range in the west and southwest, 3. Makran coastal ranges in the south along the Arabian sea, 4. Indus plain in the East, and 5. Thar desert in the southeast. Much of the plane area of the country belongs to the Indus river drainage system. This paper describes geomorphology and Quaternary sediments of the country.

Key words: Geomorphology, Quaternary, Himalaya.

S/384. Shroder, J.F. (ed.), 1992b. *Himalaya to the Sea: Geology, geomorphology and the Quaternary*. Routledge, London.

This is a compilation of a number of articles on the late Tertiary and Quaternary tectonic evolution and geomorphology of the Himalayan mountain ranges.

Key words: Books, geomorphology, Quaternary, Himalaya.

S/385. Shroder, J.F., 2002. Satellite-image analysis of glaciers of Northern Pakistan. In: Williams, R.S. Jr. & Ferrigno, J.R. (Eds.), *Satellite Image Atlas of Glaciers of the World*. US Geological Survey, Professional Paper 1386.

Key words: Glaciers, remote sensing, North Pakistan.

S/386. Shroder, J.F., Bishop, M.P., Copland, L. & Sloan, V.F., 2002. Debris - covered glaciers and rock glaciers in the Nanga Parbat, Himalaya. *Geografiska Annaler*, 82 A (1): 17-31.

Key words: Glaciers, debris, Nanga Parbat, Himalaya.

S/387. Shroder, J.F. Jr., 1984a. Comparison of tectonic and metallogenic provinces of Afghanistan to Pakistan. Abstracts, First Geological Congress, Lahore, p.20.

Different ideas of tectonic and metallogenic zonation, and difficulties in communication between geologists working in Pakistan and Afghanistan over the last twenty years have limited exchange of information. Detailed work in Afghanistan shows 21 metallogenic zones with 37 associated ore districts. Also recorded are 1432 mineral resource locations classified as: (1) large and medium deposits; (2) small deposits; (3) occurrences; (4) showings; as well as 306 broadly defined mechanical mineralogical haloes. This comprehensive resource analysis was organized around the geosynclinal concepts of Russian work with metallogenesis but is herein adjusted to a plate-tectonic framework and compared to the new tectonic zonation of Pakistan. Cross-border correlation of tectonic zones and metallogenic provinces could be useful in exploration strategy in Pakistan.

Key words: Tectonics, metallogeny, Afghanistan, Pakistan.

S/388. Shroder, J.F. Jr., 1984b. Comparison of tectonic and metallogenic provinces of Afghanistan to Pakistan. *Geological Bulletin, University of Peshawar* 17, 87-100.

Consult the preceding account.

Key words: Tectonics, metallogeny, Afghanistan, Pakistan.

S/389. Shroder, J.F., Jr., 1998. Slope failure and denudation in the western Himalaya. *Geomorphology* 26, 81-105.

Slope failures, glaciers, and rivers constitute the three main agents of denudation in the Himalaya. Failure of slopes is strongly controlled by bedrock geology, especially at plate terrane boundaries, although climatic and seismic controls of failure also occur. Slope-failure complexes in the western Himalaya studied for this report include the Pakhar, Kaghan, Nanga Parbat, and Atabad Hunza areas, with 23 different slope failures reported within all the complexes. Quantification of denudation by mass movement requires measurement of volumes and determination of timing of sediment emplacement and removal where possible, to obtain better data on recurrence intervals and total geomorphic work performed in formation of the landscape. The relation of mass movement to overall denudation by glaciers and rivers, and its role in catastrophic floods and debris entrainment is assessed.

Key words: Slope failure, denudation, Himalaya.

S/390. Shroder, J.F., Jr. & Bishop, M.P., 1995. Denudation of Nanga Parbat Himalaya, Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, ETH Zurich, Switzerland.

Conflicting ideas about cause and effect of uplift and erosion of the Himalaya require careful assessment of a variety of tectonic and isostatic uplift mechanisms, coupled with detailed studies of associated denudation. Thermobarometric and geochronologic work by others shows that uplift and unroofing of the Nanga Parbat massif along peripheral faults have accelerated through the Quaternary to over 5 mm yr⁻¹, perhaps even to twice that rate. Climate fluctuations and rapid denudation have also been suggested as a cause of decompression melting, high grade metamorphism and injection of young leucogranites. Erosion of Raikot, Buldar, Astor, Sachen, Rupal, Tarshing, Diamir, and Patro valleys is being assessed by us to determine present-day and past denudation rates. Mass movement, glacier and river erosion are regarded as the chief denudation agents, but catastrophic flood-flushing of sediments from behind multiple glacier and slope-failure dams is thought to have been an efficient and major contributing factor in several valleys as well. Erosion of the Raikot valley (8125 - 1125 m altitude; 128 km² area) on the immense north face of Nanga Parbat is being analyzed most extensively using: (1) erosion surfaces reconstructed from several surviving remnants; (2) most probable durations of erosion; (3) geomorphologic mapping of landforms, sediment transfers, and sediment stores, and (4) measurement of modern process rates. Glacial erosion in middle altitudes dominated in later Pleistocene, but perhaps less so in earlier Pleistocene, possibly before the mountain had achieved its present altitude. The Silver Saddle ice cap on an erosion surface at upper altitudes (~7500 m), and basal ice several thousand meters downslope, are cold based and relatively nonerosive. During Pleistocene colder periods this zone of reduced erosion may have extended to lower elevations than today, but the Raikot Glacier also then extended down into the Indus valley, either as a glacier out of phase with other ice expansions, or as a tributary to trunk valley ice. At present the Raikot Glacier terminus ends at ~3200 m, and little terminal moraine exists there, which suggests efficient transfer of glacial debris load to riverine transport. Below the active Raikot River has eroded a deep gorge across the Raikot Fault and into the Indus River. Present-day denudation rates of warm-based ice at the modern Raikot glacier terminus have been measured by others at ~4.6-6.9 mm yr⁻¹. Also, cosmogenic isotope exposure ages by others on nearby Indus strath terraces show incision rates of 6-8 mm yr⁻¹. Erosion-rate variation in the Raikot and other basins in late Quaternary was most probably episodic, but our time-averaged hypsometric analyses give varying average rates of 3-7 mm yr⁻¹, with an overall rate of 4-5 mm yr⁻¹ as the most consistent with the evidence. Ongoing comprehensive field measurements are expected to produce more detailed and robust measure of denudation for the entire massif.

Key words: Tectonics, denudation, Himalaya.

S/391. Shorder, J.F.Jr. & Bishop, M.P., 1998. Mass movement in the Himalaya: new insights and research directions. *Geomorphology* 26, 13-35.

Ongoing studies that relate tectonics to the processes at the surface of Earth show that many more sources of information about agents of shallow denudation, such as mass movement, are required to comprehend the long term erosion that leads to deep denudation over geologic time. Mass movement in the Himalaya is scale-dependent, from

the massive extension of whole mountain ranges (gravity tectonics), through the sacking failure of single peaks, to the smallest slope failures. Generally, denudation of the Himalayan orogen begins with slope failure onto glaciers and into river valleys and continues by glacial and fluvial transport. The maximum size of stable slopes and mean angles of slope that are produced by these failures are complex and controlled by a variety of factors, including mass strength of the rocks, stress fields, angles of internal friction controlled by rock type, cohesion that includes the control of rock temperature, bulk unit weight of rock, and discontinuities. The processes of mass movement in the Himalaya have been described many times for the past two centuries. Recently, developments in a variety of fields have been introduced to assess the character of mass movement. Geomorphometry, remote sensing, digital elevation models, and geographic information system technology are revolutionizing the study of mass movement in the Himalaya.

Keywords: Mass movement, tectonics, denudation, Himalaya.

S/392. Shroder, J.F.Jr. & Bishop, M.P., 1999. Indus to the sea: evolution of the system and Himalayan Geomorphology. In: Meadows, A. & Meadows, P. (Eds.), *The Indus River, Biodiversity, Resources Humankind*, Linnean Society of London, 231-248.

The Indus River originated more than thirty million years ago, shortly after the collision of the Indian and Eurasian plates, on the slopes of the Mt. Kailas massif, itself a remnant of debris eroded from igneous rocks produced by the collision. Thereafter the river was caught and entrained across the Ladakh and Kohistan island arcs between the rising edges of the colliding plates. Lateral motions on faults formed along the plate boundaries later caused the river to be offset significantly at several locations. As the plates continued to converge, the ancestral Indus eventually broke out to the south at the Nanga Parbat-Haramosh syntaxis. Large quantities of sediment were deposited by the river in foreland basins in front of the range; a vast braidplain was spread out between the Indus and its five tributaries in the Punjab, and the river extended its delta progressively south into the ocean. During the world-wide glacier increases of the Pleistocene, lower sea levels led to entrenchment of the lower Indus into its delta and braidplain. Resedimentation of these entrenchments after the Pleistocene allowed numerous lateral channel migrations, one of which apparently isolated Mohenjo Daro. Water withdrawals upstream now reduce sediment carried to the river mouth so much that the delta is being degraded through erosion.

The Indus sediment cascade, produced by extreme erosion rates that are among the world's highest, has progressively unroofed the range since collision and uplift. This deep exhumation was caused mainly by long term mass wasting, glaciation, and river erosion which mobilized and removed sediment from the Himalayas via the Indus River. The high mountain geomorphology, produced by fluctuating earth surface processes throughout the many climate changes of Quaternary time, is being studied actively to further our understanding of the upper and middle Indus watershed. The Batura Glacier area of Hunza, the Raikot Glacier area of Nanga Parbat, and the Baltoro Glacier area of K2 mountain are the special focus of our ongoing denudation research.

Key words: Indus River, collision, Kohistan.

S/393. Shroder, J.F. Jr. & Bishop, M.P., 2000. Unroofing of the Nanga Parbat Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 163-179.

The rapid erosional unroofing of the Nanga Parbat Himalaya in late Cenozoic time is thought to have initiated when the Indus River, initially flowing somewhat north and well to the west of its present location, was captured and diverted south close to the massif of today extensional structures and downfaulted topography across the Kohistan-Ladakh island arc terrane. It is hypothesized that the Nanga Parbat pop-up structure was initiated at c. 12-10 Ma, as tectonic aneurysm caused by rapid incision by the Indus River and other surface processes. Because of this subsequent rapid unroofing of the region, however, the oldest sediments to record erosion in the immediate region of Nanga Parbat are <200 ka old: most sediments and our cosmogenic and ISRL exposure dates are more than five times younger. Diverse field measurements of rate of local incision and areal denudation for mass movement, glacial, river and catastrophic floods for the past c. 55 ka are highly differential but internally replicative and externally consistent with research indicating long-term, severe denudation. Averaged rates of maximum incision at more than 15 points around the massif are $22 \text{ mm} \pm 11 \text{ mm a}^{-1}$. Late Pleistocene surface processes at Nanga Parbat were capable of erosional unroofing of the massif sufficiently vigorous to produce the pronounced relief of today.

Key words: Indus River, tectonics, Nanga Parbat, Himalaya.

S/394. Shroder, J.F. Jr., Bishop, M.P. & Schepp, R., 1998. Catastrophic flood flushing of sediment, western Himalaya, Pakistan. In: Kalvoda, J. and Rosenfeld, C.L. (Eds.), *Geomorphological Hazards in High Mountain Areas*. Kluwer Academic Publishers, Dordrecht, 27–48.

Key words: Sediments, floods, Himalaya.

S/395. Shroder, J.F. Jr., Bishop, M.P., Quade, J., Phillips, W. & Maston, R., 1995. Denudation of Nanga Parbat Himalaya. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, p.15.

Recognition of rapid uplift of Nanga Parbat (8125m) has led to new understandings of associated casual mechanics of deep crustal processes in fact, it has even been suggested that denudation processes have produced rapid unroofing, decompression melting at depth, injection of Lecucogranites, and metamorphism. Thus high frequency – high magnitude earth surface processes of slope failure, glaciation, river flow, and catastrophic flooding active for only about a million years in middle to late Quaternary time may have caused these lithologic and structural effects. An international group of scholars, headed by Peter Zeitler, original discoverer of rapid uplift of Nanga Parbat, will analyse the mountain range over the next three years. The denudation research group expects to continue to use standard techniques of geomorphologic mapping, remote sensing, geographic information system, quaternary stratigraphy, and new methods of cosmogenic radionuclides dating to analyse the amounts, rates and chronology of denudation of the Nanga Parbat Himalaya through the quaternary.

Key words: Denudation, Nanga Parbat, Himalaya.

S/396. Shroder, J.F., Jr., Bishop, M.P., Quade, J., Phillips, W., Nieland, P.H. & Schmidt, A.M., 1996. Dendrogeomorphology and denudation efficiency, Nanga Parbat Himalaya. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 135-136.

Denudation of the Nanga Parbat Himalaya throughout the Quaternary period has been extremely rapid, perhaps enough to produce decompression melting, injection of leucogranites and high-grade metamorphism. Elucidation of magnitude and timing of denudation provides constraints upon these bedrock processes. Denudation processes of many kinds occur on Nanga Parbat but those of chief interest here are mass movement, glaciation, rivers, and catastrophic flood flushing of sediment from ice- and slope-failure-dammed lakes. Remote sensing and geographic information system mapping and analysis of modern process distributions and measurement of rates enable establishment of contemporary sediment fluxes from which to better estimate past denudation quantities. Assessment of these past denudation amounts is constrained temporally through cosmogenic radionuclide dating, carbon-14 dating, soil development, and the principles of dendrogeomorphology. Nanga Parbat is well suited to the use of tree ring dating, mainly in its middle elevations (200-4000m), where geomorphic processes are most diverse and most active, and there coniferous and birch forests can provide standard process-event-response chronologies. Mass movement and glacial processes have affected hundreds of trees on the mountain, particularly in the Diamir, Patro, Raikot, Buldar, Astor, and Sachen valleys.

We report here our results from the Sachen and Raikot valleys where we have analyzed the distribution, timing, and volume of debris flows, several kinds of catastrophic breakout floods, glacier downwasting events, the backwasting of glacier termini, and glacial advances. These data enable better understanding of the transfer of sediment of one process-mechanics regime to another; especially the transfer efficiency of sediment from glaciers to rivers. Depending upon various topographic and geomorphic conditions, the glaciers of Nanga Parbat are moderately to highly efficient in transferring their sediment load to rivers. Raikot glacier is highly efficient, whereas Sachen glacier has a lower efficiency. Other things being equal, more efficient transfer occurs in those glacier valleys where: (1) there is a high ratio between plentiful cold-based, protective ice, and limited warm-based, erosive ice so there is not as much sediment; (2) firn-field glacier nourishment is dominant, which provides maximum ice flux; (3) debris sources and feed limited; (4) supraglacial loads are thinner; (5) outburst floods that remove sediment are more common; (6) the steep terminus zone increases sediment transfer energetics; (7) ice velocity and glacier sediment

discharge are relatively lower at the terminus; (8) there is a laterally migratory subglacial drainage portal at the terminus; (9) high meltwater discharge occurs; (10) a narrow valley occurs in the glacier terminus zone which restricts the moraine and enables its removal. Less efficient sediment transfer occurs: (1) where a low ratio occurs between the more limited cold-based, protective ice, and the more plentiful warm-based, erosive ice so that there is a significant increase in debris; (2) where ice- and snow-avalanche glacier supply predominates so that not as much total glacier ice forms; (3) where debris supply is so enhanced by ice- and snow-avalanches that fluvial regimes are overwhelmed; (4) where plentiful source slopes of mass movement and avalanche rock debris exist; (5) where there is a thicker supraglacial debris load; (6) where outburst floods are restricted; (7) in valleys with a gentler gradient, hence with less potential process-systems energetics; (8) with a fixed drainage portal at the terminus so that material accumulates in other areas; (9) with generally low meltwater discharge; and (10) in wide valleys at the glacier terminus where the ice can spread out moraine. In some cases, dendrogeomorphology in those areas of different transfer efficiencies enables determination of relative and absolute magnitudes of denudation quantities.

Dendrogeomorphology was used to study denudation in the Raikot basin in the north and south Biale debris flow basin, as well as on both sides of the terminus of highly transfer efficient Raikot glacier. The Biale basins on the West Side of the Raikot glacier have experienced catastrophic precipitation events on a ~67-year return cycle, with major tree-corroding events in 1923 and 1990. In the approximately 5000 years since the Neoglacial moraines were emplaced at the base of these basins, some 75 of these events can reasonably be expected to have occurred; less when the monsoon was restricted, more when it was dominant. It can be seen in these cases that although the debris does not leave the mountain directly because it tends to be trapped in the ablation valleys behind the lateral moraines, still it is initially mobilized into these temporary storages that are more easily removed by ice and water late. Recessional moraines of the Raikot glacier occur as thin loops of rocky debris around the front and sides of the terminus. The timing of emplacement of these landforms is defined by tree-ring succession dates and historical records. Our data on glacier velocity and supraglacial debris load proved estimates of the total volume of debris that should have been imported in the time allotted into the open space between the recessional moraine and the present terminus. That total amount of debris, less that of the remaining moraine constitutes missing debris transferred into the Raikot River and generally entirely off the mountain.

In late 1993 or early 1994, the subglacial drainage system of the Raikot glacier became blocked and stopped the Raikot river. After a number of months of restricted water discharge, a catastrophic breakout flood burst from four new portal; three on the west side and one on top of the ice near the terminus, before returning to the original portal on the west side of the terminus. This event mobilized considerable supraglacial debris at the terminus, as well as debris form along the west side of the glacier, the ablation valley, the Neoglacial (NG) and Little Ice Age (LIA) moraines, and a small portion of the most distal of the Biale debris flow sediment. All this sediment was transported into, and flushed from the mountain in, the main Raikot River that became re-established close to its original position. In aggregate our data from the Raikot basin on the huge and active north face of Nanga Parbat suggest that denudation on this portion of the mountain is highly active now and has been even more so in the past. For example, we see from our preliminary cosmogenic dates on the high older moraines of >125,000 years age, that the ancestral Raikot glacier was eight times wider and thicker than it is now. Although we are as yet uncertain about the fluctuating altitude of the cold-based/warm-based transition zone that would have controlled the cold, protective ice zone above the warmer, erosive ice zone underneath, still we can see that with the high ice activity of the recent past, a proportional scaling upwards of denudation values in the past is reasonable.

Sachen glacier on the east side of Nanga Parbat has no firm accumulation zone in direct contact with the terminus, unlike that of the huge Raikot system on the north side of Nanga Parbat, and instead is almost entirely fed by ice avalanches from high up the mountain. The lower efficiency of Sachen glacier is exemplified by the huge lateral and recessional NG and LIA moraine storages and the last glacier is maximum (LGM) in its valley. These moraines are tree-covered and deal for dendrogeomorphologic work. For example, event-response chronology shows that a minor ice advance and catastrophic breakout flood are known to have occurred on the north frontal lobe in the late 1920's but the volume of sediment moved was small. The data suggest that significant denudation from this area could only be accomplished in times of major glaciation and through major catastrophic flood flushing at those times. Otherwise sediment tends to accumulate in long term storages. In terms of the overall denudation of the Astor valley to which the Sachen valley is tributary, more efficient removal of sediment would have occurred when LGM ice was in the Astor valley below Sachen, or when large breakout floods occurred from a Sachen ice dam across the Astor river valley. In sum, facilitated by dendrogeomorphology as a part of the full analytical package being applied to this interesting problem.

Key words: Geomorphology, denudation, Nanga Parbat, Himalaya.

S/397. Shroder, J.F., Jr. & Khan, M.S., 1990. Quaternary glaciation of Karakoram and Nanga Parbat, Himalaya. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 17-18.

Controversy and agreement between Pakistani, American and British workers on the extent and timing of Pleistocene glaciation in the western Himalaya are highlighted or resolved in our work through recognition of three main glacial stages, and several glacial stages. The early glaciation, or Shanoz stage, includes glaciated high-level erosion surfaces, the Bunthang till in Skardu and perhaps other tillites. The Jalipur tillite is glacially and tectonically indurated and deformed. We judge it evidence of an oldest glaciation and equivalent to Shanoz and Bunthang, but British workers consider it to be youngest only. The middle glaciation, or Yunz stage, includes a number of tills, perhaps had two major stages, and extended the farthest down the Indus of any glaciation. The last glaciation is subdivided into several stages, the most important of which is the Borit Jheel. We consider it to have terminated in the Dak Chautk or Dianyor moraine at Gilgit, whereas the British workers think it terminated near Chilas and to be equivalent to the Jalipur. A problem has been their lack of acknowledgment of our prior work to which they have had access directly from us. Proper reinterpretation of these contentious issues is critical because of the importance of ongoing studies of absolute uplift rates. In as much as uplift rates are commonly calculated as a function of cooling rates as minerals pass through annealing isotherms at depth, the paleo-configuration of the isothermal surfaces of this region is required for assessment. With present-day relief in the Karakoram and Nanga Parbat Himalaya on the order of 6-7 km, the descending cool waters in fractured and faulted glacial valleys; the rising thermal waters along the Raikot and other faults; the paleotopography, and the glacial and non-glacial histories all have controlled the paleo-isothermometry which is the focus of our present research.

Key words: Glaciation, Nanga Parbat, Quaternary, Karakoram, Himalaya.

S/398. Shroder, J.F. Jr., Khan, M.S., Lawrence, R.D., Madin, I.P. & Higgins, S.M., 1989. Quaternary glacial chronology and neotectonics in the Himalaya of north Pakistan. In: Malinconico L. & Lillie, R.J. (Eds.), *Geology and Tectonics of the Western Himalayas*. Geological Society of America, Special Paper 232, 275-294.

Thick deposits preserved in deep valleys in the Indus, Gilgit, and Hunza River Basins, and a variety of dates, allow new definition of Quaternary events in the Karakoram and Nanga Parbat Himalaya. An unusually long record for an actively eroding high mountain area is recognized in three major episodes of glaciation during Pleistocene time. An early glaciation is represented by the indurated lower Jalipur tillites and heterogeneous upper Jalipur valley-fill sedimentary rock younger than 1 to 2 Ma, which are folded, overturned, or overridden by rapid movement on the dextral-reverse Raikot fault. This is associated with high overall uplift rates of the Nanga Parbat-Haramosh massif during late Cenozoic time. The middle glaciation is represented by two tills intercalated within variable sediments, including thick lacustrine units dipping as much as 43° along the fault. The Indus -Shatial till of the early middle glaciation records the farthest advance of Pleistocene glaciers down the Indus River valley. The last glaciation apparently occurred after about 140,000 yr ago and consists of three to four or more separate advances, as recorded by moraine topography. The most prominent of these is the Dianyor moraine near Gilgit, which was produced by a major longitudinal glacier. Near Haramosh and downstream at Nanga Parbat, Shatial, and elsewhere, transverse glaciers blocked the Indus River to produce lake deposits now dipping as much as 6° near the fault. Catastrophic floods from failure of the ice dams, and possibly landslide dams as well, emplaced some Punjab erratics and sediments that may have been re-worked into loesses and other sediments at the mountain front.

Key words: Glaciation, chronology, Nanga Parbat, Quaternary, Himalaya.

S/399. Shroder, J.F.Jr., Owen, L. & Derbyshire, E., 1993. Quaternary glaciation of the Karakoram Mountains and Nanga Parbat Himalaya. In: Shroder, J.F.Jr. (Eds.), *Himalaya to the Sea: Geology, Geomorphology, and the Quaternary*. Routledge, London, 132-158.

The Karakoram mountain ranges and the adjacent Nanga Parbat of the Northwest Himalaya to its south constitute one of the most glaciated areas in the world. This area is drained by the Indus river system, much of which is fed by the glaciers. The geomorphology of the area is essentially controlled by exhumation, rapid erosion and glaciation. This has resulted in large quantities of Quaternary sedimentary deposits, the subject of this paper.

Key words: Glaciation, Nanga Parbat, Quaternary, Karakoram, Himalaya.

S/400. Shroder, J.F.Jr., Scheppy, R. & Bishop, M.P., 1999. Denudation of small alpine basins, Nanga Parbat Himalaya. *Arctic, Antarctic and Alpine Research* 31, 99-105.

Key words: Denudation, Alpine basins, Nanga Parbat, Himalaya.

S/401. Shu, P.Y. & Lin, B.Z., 1984. Stress field and plate motion in the Karakoram and surrounding regions. In: Miller, K. J. (ed.). *The International Karakoram Project* 2, 185-199. Cambridge University Press.

The spatial distribution of earthquakes in the Karakoram and surrounding regions is studied, along with focal mechanisms, macroseismic evidence and faulting patterns. From these data stress field in the region is inferred. Finally, relations with plate motions are discussed.

Key words: Earthquakes, seismicity, Karakoram.

S/402. Shuaib, S.M., 1973. Subsurface petrographic study of joints in variegated siltstone-sandstone and Khairabad limestone, Pakistan. *American Association of Petroleum Geologists Bulletin* 57 (9), 1775-1778.

Petrographic methods for the determination of joint parameters such as volume density of joints, and joint porosity and permeability have been applied to selected core samples from the Nuryal 1 well drilled in the Potwar region of West Pakistan.

Joint porosity and permeability data from Jurassic variegated siltstone-sandstone and Paleocene Khairabad Limestone from selected core sections of the Nuryal 1 well at depths between 4,662 and 4,751 m indicate the presence of fairly effective reservoir potential in Jurassic variegated siltstone-sandstone and effective reservoir beds in the Paleocene Khairabad Limestone.

Key words: Petrography, siltstone, sandstone, limestone, Khairabad, NWFP.

S/403. Shuaib, S.M., 1978. Correlation of Permian, Triassic, Jurassic sandstone formations in Potwar region on the basis of nonopaque heavy minerals. *National Seminar on Development of Mineral Resources*, Lahore March 6-9, 1978, 56-66.

Key words: Heavy minerals, Permian, Triassic, Jurassic, Potwar.

S/404. Shuaib, S.M., 1981. Investigation of prospecting areas and horizons of Oil and Gas in Pakistan. *Geological Bulletin*, Punjab University 16, 37-42.

Belt, of Potwar-Sulaiman-Kirthar foredeeps along with adjoining uplifts and highs in Punjab Sind plains and Mekran Coastal areas are considered important for the exploration and prospecting oil and Gas reservoirs in Protoquartzite to orthoquartzite sandstones and fractured limestones belonging to Paleozoic, Mesozoic and Paleogene ages. These contain all the geological features which are characteristic for oil and gas bearing regions namely thick sedimentary sequences; presence of regional and local traps for hydrocarbons; almost all the oil and gas seepages including mud-volcanoes, and so for all the discovered off and gas fields. Prospecting areas are discussed in the light of the wells drilled and tectonic movements.

Key words: Hydrocarbons, prospecting, Potwar, Kirthar.

S/405. Shuja, T.A., 1966. Geology of Hazara area. *Field Report/Thesis*, Punjab University, 67p.

Key words: Stratigraphy, Hazara.

S/406. Shuja, T.A., 1983a. A study of thermal springs of northern Pakistan. Geological Survey of Pakistan, Information Release 179.

Key words: Thermal springs, Northern Pakistan.

S/407. Shuja, T.A., 1983b. Geothermal resources and possibility of their development in Pakistan. Geological Bulletin, Punjab University 18, 22-23.

The paper discusses exploitation potential of geothermal sources of energy. Describing various types of sources, comments are made on Pakistan's status in this connection.

Key words: Geothermal resources.

S/408. Shuja, T.A., 1984. Role of geothermal energy in Pakistan. Abstracts, First Geological Congress, Lahore, p.6.

Keeping in view the limited reserves of fossil fuels and soaring energy demands, the need has been felt to develop alternate energy resources. Among alternate resources, geothermal energy occupies an important place. Geothermal energy has been developed in 30 countries mainly for generation of electricity. This is cheap and renewable energy resource located in remote areas where poor accessibility hampers development.

Evidence of geothermal activity in the form of hot springs is found in Northern areas, Chagai District (Baluchistan), Dadu District (Sind) and in Azad Kashmir. Geothermal resource studies in Gilgit and Hunza Agencies indicate the presence of high temperature geothermal fluids (1200C— 2000C). Similarly sub-surface temperatures in Chagai have been estimated to range from (1500C - 1750C). Temperature as high as 1600C has been found at Lakhra during drilling. Large concentration of thermal springs in Dadu also Merits attention.

Key words: Geothermal energy.

S/409. Shuja, T.A., 1986. Geothermal areas in Pakistan. Geothermics 15, 719-723.

In this paper an attempt has been made to correlate the tectonic and geologic features with surface manifestations of geothermal activity in Pakistan to delineate prospective areas for exploration and development of geothermal energy. Underthrusting of the Arabian plate beneath the Eurasian plate has resulted in the formation of Chagai volcanic arc which extends into Iran. Quaternary volcanics in this environment, along with the presence of thermal springs, is an important geotectonic feature revealing the possible existence of geothermal fields. Geothermal activity in the northern areas of Pakistan, as evidenced by thermal springs, is the likely result of collision and underthrusting of the Indian plate beneath the Eurasian plate. Numerous hot springs are found along the Main Mantle thrust and the Main Karakorum thrust in Chilas and Hunza areas respectively. The concentration of hot springs in Sind Province is also indicative of geothermal activity. A string of thermal seepages and springs following the alignment of the Syntaxial Bend in Punjab Province is also noteworthy from the geothermal viewpoint. In Baluchistan Province (southwest Pakistan), Hamun-e-Mushkel, a graben structure, also shows geothermal prospects on the basis of aeromagnetic studies.

Key words: Geothermal energy.

S/410. Shuja, T.A., 1999. Engineering geological studies along the Chakdara Dir road, NWFP, Pakistan. Geological Survey of Pakistan, Information Release 702.

Key words: Engineering geology, Chakdara-Dir road.

S/411. Shuja, T.A., Asrarullah, & Khan, A.L., 1984. Prospect of geothermal energy in Pakistan. Geological Survey of Pakistan, Information Release 242.

Consult Shuja, T.A. (1984, 1986) for further informations.

Key words: Geothermal energy.

S/412. Shirahase, T., 1996. Outline of joint studies on the Chilas complex. Proceedings of Geoscience Colloquium (Geoscience Lab, Geological Survey of Pakistan, Islamabad) Geological Survey of Pakistan Islamabad 14, 35-38.

This paper gives an outline of joint studies and earlier publications on the Chilas complex.

Key words: Chilas complex, Kohistan.

S/413. Shirahase, T., Kubo, K. & Kausar, A.B., 1996. Outline of joint cooperative studies on the Kohistan area, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 15, 3-14.

Key words: Kohistan.

S/414. Siddiqi, F.A., Abbas, S.A. & Amin, M., 1967. Talc deposits of Jamrud, Khyber Agency. Pakistan Journal of Scientific and Industrial Research 10, 300-303.

Key words: Talc deposits, Jamrud, Khyber Agency.

S/415. Siddiqi, F.A., Ahmad, N., Qaiser, M. A. & Amin, M., 1988. Lead-zinc ore of Kohistan, Hazara, Pakistan. Pakistan Journal of Scientific and Industrial Research 31, 487-490.

The Kohistan Pb-Zn mineralization occurs as veins and disseminations of sphalerite, galena and pyrite in Besham at a distance of about 150 km from Abbottabad. Igneous and metamorphic rocks are the main rocks exposed in this geologically complex area. The petrology, chemical and X-ray studies reveal that the major minerals are quartz, galena and sphalerite with minor chalcopyrite.

Key words: Mineral deposits, Lead-Zinc, Kohistan.

S/416. Siddiqi, F.A. & Akhter, S.M., 1965. Mineralogy of the alluvial sand of the Kabul River, near Charsadda. Pakistan Journal of Scientific and Industrial Research 8, 245-248.

Heavy minerals from washed alluvial sand of the Kabul river in the Doab area near Charsadda are described. The main minerals present are magnetite, garnet and ilmenite but hypersthene, clinopyroxene hornblende are also present. Radioactive minerals are either absent or present in very insignificant amount.

Key words: Mineralogy, heavy minerals, alluvial sand, Charsadda.

S/417. Siddiqi, F.A., Alauddin, M., Khan, H., Nasreen, S. & Hussain, A., 1986. Studies on quartzite deposits of Nowshera and Swabi area, Peshawar Division, Pakistan. Pakistan Journal of Scientific and Industrial Research 29, 327-331.

Key words: Quartzite deposits, Misri Banda, Nowshera, Swabi.

S/418. Siddiqi, M.I., 1984. Geology of Tarlidomal Shonthar area, Neelum valley, Azad Kashmir. Kashmir Journal of Geology 2, 116- on ward.

The area studied is about 80 km². It lies NNE of Muzaffarabad at a distances of 173 km. The mapped area lies between 74° 24' 50"-74° 32' 50" longitudes and 34° 54' 40"- 35° latitudes it covers parts of Survey of Pakistan toposheet No.43 j/5 & 43 j/9. The rocks of the area are of Salkhala Formation. The Salkhala Formation is a metamorphic complex of variegated lithology comprising of schist (chlorite-garnet grade), amphibolites, quartzite

and marble. Granite gneiss is emplaced in Salkhala Formation and is in turn intruded by pegmatites and quartz veins. Regional metamorphism and accompany penetrative deformation, post-date the granite intrusion, because the granite itself is involved in the deformation. Field evidences and Laboratory studies favor magmatic origin for granite bodies.

The area is tectonically disturbed being involved in Himalayan orogeny. The major faults are the Shonthar Nar fault and Daliwala fault. The Shonthar Nar fault trends NE-SE. Shonthar Nar Valley runs more or less along the trace of this fault. Daliwala fault may be considered a dip-slip-strike fault along the eastern margin of Uti Domel granite body. Regional metamorphism and tectonic effect has imparted well-developed secondary foliations and gneissosity in the rocks of the area. Minor folds are numerous. These are close and tight folds and reflect the intensity of forces involved in their formation. Jointing is abundant in the rocks. Tension and shear joints are encountered in granite gneiss, marble and schists. The mineral occurrences in the area under review include Graphite, marble gemstone (Ruby, Topaz, Aquamarine, Quartz etc.) and mica etc.

Key words: Mapping, structure, Salkhalas, Azad Kashmir.

S/419. Siddiqi, R.A., 1973a. A note on silica sand deposits of Khisore and Marwat Ranges, D. I. Khan Division, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 57, 18p.

Large deposits of silica sand are found in the basal Part of Datta Formation (Jurassic) in Khisore and Marwat Ranges, D.I. Khan Division, N.W.F.P. The total length of the outcrop is 10.5 (4miles in Khisore range and 6.5 miles. Marwat Range). Its thickness vaies from 50 feet to 70 feet. The total reserves upto a workable dip depth of 100 feet are estimated to be 20 million tons.

Silica sand is medium to fine grained. Sieve analysis of grain size from two channels indicate that grains between 20 and 100 mesh, which are necessary for glass making, constitute 57.34% and 75.55% of the two samples respectively.

Chemical analysis of ten channel samples from two sections each from Marwat and Khisore range show that SiO₂ content ranges from 76.61 to 96.99% and Fe₂O₃ from .67% to 4.5%. This shows that silica content and iron, alumina impurities vary a great deal and that quality zoning of the outcrop is unavoidable.

The deposits are easily approachable and at present are being queried near Chunda, 5 miles south of Pezu. The silica sand is being supplied to glass manufacturers of Sind.

The deposit appears capable of meeting the requirements of a modest scale glass industry in N.W.F.P. for the production of ambar and green glass. However, it is recommended that large scale mapping and close interval channel sampling may be carried out for detailed chemical analyses and study of the deposit for possible variation in its quality.

Key words: Silica sand, Khisore Range, Marwat Range, DI Khan

S/420. Siddiqi, R.A., 1973b. Limestone resources of Kohat area, N.W.F.P., Pakistan. Geological Survey of Pakistan, Information Release 58, 21p.

Huge limestone deposits are found in Kohat area. They range in age from Jurassic to Eocene. Chemical analyses show that the most suitable limestone for Cement Industry and for sugar refining is of Kohat Formation, (Eocene). Reserve estimate of Eocene limestone, within a radius of 20 miles from Kohat town is 7000 million tons upto 200 feet above surface. The Outcrops are very close to the communication lines. Plenty of water, power and labour is available. Other raw materials for cement industry, such as gypsum and clay are also available abundantly. Most of the limestone is high grade- and has more than 50% CaO and less than 3% of MgO. Babri Banda, about 5 miles from Kohat on Kohat-Rawalpindi Road, is suggested for setting up a cement factory.

Key words: Limestone, Kohat.

S/421. Siddiqi, R.A. & Saleem, M., 1976. Preliminary report on the discovery of sulphide mineralization in Sawar area, Kotli District, Azad Kashmir. Geological Survey of Pakistan, Information Release 93.

Sulphide mineralization of possible replacement lode type has been found in a shear zone in the Muzaffarabad formation of Permian-Carboniferous age, near Sawar, Kotli District, Azad Kashmir. The metal content of a channel rock sample from the oxidized zone (table-1) is as under:-

Pb	Ag	Zn	Cu	Ni	Au
3.76%	5 gms/ton	0.24%	0.15%	0.003%	5 centigram/ton

An area of 4900 sq. meters was studied and the geochemical anomalies of 224 soil samples, have indicated mineralization covering about 350 sq. meters. The high anomalous areas indicating mineralization are aligned in north west south east direction.

Geochemical values between the median and the threshold, covering an area of about 3000 sq. meters, are also of interest with regard to further work. Further geochemical investigations of a regional nature are in progress and their results would be presented in a final report.

Key words: Sulphide mineralization, Kotli, Azad Kashmir.

S/422. Siddiqui, A.F.K., 1970. Petrology of Timurgara area, Dir. M.Sc. Thesis. Geology Department, Punjab University, Lahore, 80p.

Key words: Petrology, Timargara, Dir.

S/423. Siddiqui, F., Khan, H., Ahmad, N. & Khan, R.W., 1992. Mineralogical and chemical studies of feldspars from Swat and Hazara in NWFP, Pakistan. Pakistan Journal of Scientific and Industrial Research 35, 14-00.

Petrological, X-ray diffraction and chemical studies of feldspar samples from the Hazara and Swat in NWFP established the presence of soda-spars and potash-spars. Moreover, these two types of feldspar are amenable to commercial exploitation for use in glass and ceramic industries.

Key words: Mineralogy, chemistry, feldspar, Swat, Hazara.

S/424. Siddiqui, F.A., 1967. Note on the discovery of carbonatite rocks in the Chamla area, Swat State, West Pakistan. Geological Bulletin, Punjab University 6, 85-88.

Following the discovery of an alkaline rock complex in Swat (Siddiqui, 1965), detailed mapping of the area was undertaken and presence of some "calcite" veins in the syenite was noticed by A. Shakoor and two M.Sc. students of the Geology Department, Panjab University. This information was passed on to the author who visited the area during August 1966, and found that the veins, mentioned above, contained pyroxene and feldspar in addition to carbonate minerals. Subsequent petrographic work showed that the pyroxene was aegiritic in nature and that apatite was also present in abundance. The field relations and mineralogy of the rock was thus found to have features similar to some known carbonatite rocks. For further confirmation, two samples were submitted to Dr. T. Deans of the Institute of Geological Sciences, Great Britain, who arranged their X-ray fluorescence analysis at his laboratory (Special Report No. 252, 1967). The results showed heavy traces of Ba, Sr and the rare earths Ce and Y, with minor traces of La (See Table No.1). On the basis of these investigations it was concluded that these rocks are in fact carbonatite and an announcement to the effect was made in the Commonwealth Liaison Office Newsletter for October and November 1967. The present note is intended to report further progress on the work being conducted by the author. The rocks have been named as the "Naranji Kandao Carbonatite" in reference to the place where the occurrence was first noticed.

Key words: Mapping, alkaline rocks, carbonatite, Swat.

S/425. Siddiqui, F.A., 1973. Alkaline rocks of ijolatic affinity from Tarbela Dam area, Hazara District. Geological Survey of Pakistan, Geonews 3, p.17.

Key words: Alkaline rocks, Tarbela, Hazara.

S/426. Siddiqui, F.A., 1977. Ore microscopy of pyrrhotite-pyrite-chalcocopyrite vein from Pattan, Indus Kohistan, Pakistan. Geological Bulletin, Punjab University 14, 95-96.

During an investigation of the geology of the lower part of Indus Kohistan, "a fifteen feet thick brecciated zone" located in a road cut about 2 -miles north of Pattan (Long: 730 1' ; Lat : 35° 12') and containing "quartz feldspar and arsenopyrite" was noted by Jan & Tahirkheili (1969). At the author's request Jan kindly provided -specimens of the vein for ore microscopic studies. A brief account of the mineralogy and ore petrography of the specimens is given in this paper.

Key words: Ore microscopy, pyrite, Pattan, Indus Kohistan.

S/427. Siddiqui, F.A., Chaudhry, M.N. & Shakoor, A., 1970. Geology and petrology of the feldspathoidal syenites and pegmatites of the Koga area, Chamla valley, Swat, West Pakistan. Geological Bulletin, Punjab University 7, 1-29.

The feldspathoidal syenites and associated rocks of the Koga area, first reported by Siddiqui (1965), are described in detail. The area lies in the west central portion of a large intrusion of the so-called Ambela Granitic Complex, which occupies much of the Buner, Chamla and Khudukhel areas of the southern Swat.

In the Koga area, three main petrologic types have been distinguished. 1. A calc-alkaline body named Chingalai granodiorite gneiss. 2. Per-alkaline syenites and granites called Babaji Syenites and characterized by granitoid texture and abundance of basic xenoliths. 3. Feldspathoidal syenites called Koga syenites. The contact of type 1 and 2 is occupied by a fault zone. The Koga syenites are intrusive in both 1 and 2 and are similar to Babaji syenites in that both have aegirine, abundance ilmenite, sphene and apatite as common constituents. These minerals occur only as accessories in the Chingalai granodiorite gneiss. Babaji syenites appear to be co-magmatic with the Koga syenites. The Koga syenites occupy a roughly oval shape area with irregular outlines. Field, petrographic and chemical investigations indicate the following sequence of formation: Per-alkaline syenites (with or without quartz)-nepheline syenites-nepheline sodalite syenite- carbonatite. Thus the trend is one of progressive desilication with differentiation. Flow structure is common indication that the under-saturated magma was emplaced as a viscous mush with alkali feldspar crystals suspended in a liquid capable of crystallizing nepheline.

Key words: Petrology, petrography, alkali syenite, Koga, Swat.

S/428. Siddiqui, N.K., 2000. Remote sensing for prediction of floods in Jhelum River and the significance of Kashmir valley-the Pir Panjal depression. Abstracts, Third South Asia Geological Congress, Lahore, p.74.

Key words: Remote sensing, flood prediction, Kashmir, Punjab.

S/429. Siddiqui, R.A., 1992. Pakistan main dhati maadni imkanat. Geological Survey of Pakistan, Mineral Information Release 10.

Key words: Metallic minerals (in Urdu)

S/430. Siddiqui, R.A. & Shah, S.M.I., 1995. Mineral occurrences in the Eastern Khyber Agency, NWFP. Geological Survey of Pakistan, Mineral Information series 18, 28p.

Preliminary investigation for economic minerals was conducted in the Khyber Agency. Samples were collected and analysed in the Geological Survey of Pakistan. The results obtained are encouraging. Radioactive minerals have been detected in some of the rocks having a considerable extension. Iron mineralization at Misrikhel, good quality dolomite of western LoeShilman, and large quantities of black mica in the eastern Loe Shilman are some among other potential prospects, recommended for detailed exploration. The formations in the Khyber Agency change

facies, some of them rapidly in a short distance. (Change of environment and source, coupled with the episode of metamorphism, makes the entire Khyber Agency worthwhile for detailed mineral exploration.)

Key words: Minerals, Khyber Agency, NWFP.

S/431. Siddiqui, R.H., 1996. Mineralogy of late quaternary Haro river Loess-paleosol deposits, Attock district, Punjab, Pakistan. Proceedings of geoscience colloquium, geoscience lab, GSP, Islamabad, 14, 107-115.

XRD analyses of 24 samples show the presence of quartz, calcite, albite, vermiculite, dickite, with hornblende, gypsum and halite in some samples. The presence of the latter two minerals suggest deposition in hot and arid climate.

Key words: Late quaternary, loess-paleosol deposits, mineralogy, Attock.

S/432. Siddiqui, S.F.A., 1965. Alkaline rocks of Swat, Chamlā. Geological Bulletin, Punjab University 5, 52.

Our field investigations into the origin of certain zircon pegmatites, originally reported in Martin et al. (1962, p. 9) have brought to light the presence of rocks of nepheline syenite and related composition, which may be connected with this occurrence; some of the rocks bear sodalite, aegirite, and other alkaline minerals. This is probably the first recorded occurrence of these rocks in Pakistan. Work is now going on with a view to mapping the area of interest to determine the nature, form and extent of the alkaline bodies and to ascertain whether there is any genetic connection with the riebeckite porphyries of Shewa, Mardan District. The occurrences are located near Ambela, Swat State.

Key words: Mapping, alkaline rocks, Swat.

S/433. Sigogneau, R.D. & Russel, D.E., 1983. A new dichobunid artiodactyl (mammalia) from the Eocene of north-west Pakistan; III, reconstitution du moulage endocranin. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B: Palaeontology, Geology, Physics and Chemistry 86, 319-330.

Key words: Palaeontology, mammals, Eocene.

S/434. Sikhani, S.N., 1990-92. Geological mapping and evaluation of geotechnical properties of Cambrian to Eocene rocks of Nauseri area, Muzaffarabad Azad Kashmir and Garhi Habibullah, Mansehra, Pakistan. Institute of Applied Geology, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, M.Sc. Thesis, 1-78.

The geotechnical, Petrographical, Chemical and lithological characteristics and dynamic and static test results are presented for Cambrian to Eocene Rocks. Comparison is made between a number of static properties of the rocks and their geotechnical performance, particularly during evaluation of different geotechnical properties with changing mechanical, chemical, mineralogical and environmental conditions. The samples (Cambrian) were taken from dolomite quarries near yadgar, Panjal Volcanics (Permian) from Nauseri area and limestone (Eocene) from Yadgar quarries. The Test results presented suggest that the Panjal Volcanics and limestones are suitable as construction raw material for riprap, aggregates, subbase and concrete. The dolomite is fine to medium grained with high magnesium Contents and is useful for industry. The use of dolomite as construction raw material. The Panjal volcanics have high iron content and is harmful to be used as construction raw material in tropical region.

Key words: Mapping, geotechnical properties, Cambrian-Eocene, Mansehra, Azad Kashmir.

S/435. Sillitoe, R.H., 1976. Metallogenic evolution of a collisional mountain belt in Pakistan (A preliminary analysis). Geological Survey of Pakistan, Record 34, 16p.

Consult the following account.

Key words: Metallogeny, collisional mountain belts.

S/436. Sillitoe, R.H., 1978. Metallogenic evolution of a collisional mountain belt in Pakistan: A preliminary analysis. *Journal of the Geological Society, London* 135, 377-387.

Five post-Palaeozoic metallogenic environments are recognized in Pakistan and adjoining regions: 1. Mississippi Valley-type fluorite, barite and barite-galena deposits generated in Jurassic limestones on the northern miogeoclinal margin of the Indian Shield, perhaps during incipient rifting heralding India's separation from Gondwanaland; 2. chromite deposits in serpentinized dunite, manganese-oxide deposits in layer-1 sediments and a cupriferous massive sulphide occurrence in layer-2 basalts generated within an ophiolite complex at a Tethyan oceanic spreading centre; 3. porphyry copper-molybdenum, manto-type copper, Kuroko-type massive sulphide, vein copper, contact-metasomatic copper and iron, and volcanogenic iron deposits generated in Cretaceous-Cenozoic times by intrusive and extrusive calc-alkaline magmatism along the southern edge of the Iran-Afghanistan microcontinental plate during northward subduction; 4. stibnite occurrences emplaced in the intracontinental Chaman transform fault system during post-early Miocene times; and 5. sandstone-type uranium deposits in Siwalik molasse-type sediments shed during post-early Miocene uplift of the Himalaya. Juxtaposition of the miogeoclinal, ophiolitic and Cretaceous calc-alkaline metallogenic provinces resulted from suturing of the Indian plate with the southeastern margin of the Iran-Afghanistan microcontinent, representing final closure of eastern Tethys. Subsequent renewed northward motion of the Indian plate, causing crustal shortening and uplift along its northern edge, produced the transform-fault and molasse-basin provinces and, along the Makran segment of the plate boundary unaffected by continental collision, the post-early Miocene calc-alkaline province.

Key words: Metallogeny, collisional mountain belts.

S/437. Sillitoe, R.H., 1979. Speculations on Himalayan metallogeny based on evidence from Pakistan. In: Farah, A. & DeJong, K.A. (Eds.), *Geodynamics of Pakistan: Geological Survey of Pakistan*, 167-179.

Sillitoe (1978) recognized five discrete metallogenic environments in Pakistani Baluchistan. They are related to a shelf-carbonate succession, an ophiolite suite, a subduction-related calc-alkaline magmatic arc, an intracontinental transform fault zone, and a molasse basin. None of these environments is well represented further to the northeast, in the Himalayan region. However, minor ophiolitic chromite in the Indus suture zone, molasse-contained uranium in the Subhimalaya, and contact-metasomatic magnetite of probable subduction origin in the north-west Himalaya are recorded. Potential would seem to exist for discovery of other ophiolitic ore types and, in the Lower and Tibetan Himalaya shelf carbonates, of Mississippi valley-type deposits. Subduction-related base and precious-metal mineralization is not likely to be widespread. In much of the Himalaya but may be encountered in the Transhimalaya and, north of the southern branch of the Indus suture zone in the northwest Himalayan region.

Based largely on evidence from the northwest part, post-Palaeozoic mineralization in the Himalaya, including regions immediately north of the Indus suture, is believed to be dominated by minor polymetallic occurrences of Neogene age carrying mainly copper, lead, barite, gold, and antimony of metamorphic origin, and by gemstones, along with some fluorite and possibly rare-earths and minor base metals, generated by anatectic leucogranites. Metamorphic mineralization is attributed to precipitation in dilatant sites by fluids expelled from sedimentary rocks undergoing regional metamorphism, either during thrusting and/or during uplift. The anatectic leucogranites are believed to be poorly mineralized compared with subduction-related intrusives because their source 'magmas, generated by partial melting of basement rocks during continental underthrusting, were water-saturated and therefore consolidated at depths of perhaps 10 km without possessing subvolcanic or volcanic equivalents; the magmas also may have been intrinsically poor in metals. Both these Neogene metallogenic environments were imposed by the process of thrust progradation whereby renewed post-Eocene northward motion of the Indian plate was taken up on a series of major, low-angle thrusts within its leading edge, with activity migrating progressively with time (prograding) southwards from the Indus collisional suture. In Baluchistan, post-collisional northward motion of India was taken up on the Chaman transform fault zone so that thrust propagation was relatively unimportant.

It would appear that the metallogeny accompanying continental collision and its related later effect is on a small scale and that the major ore types, such as porphyry copper, epithermal precious metal and Kuroko-type massive sulphide deposits, found in Cordilleran or island-arc settings above subduction zones, are unlikely to be found.

Exploration programmes should take account of these speculative conclusions and should therefore perhaps concentrate on pre-Mesozoic ore types fortuitously incorporated in the mountain belt, relatively important examples of which are found at Rangpo, Sikkim and Asker, Uttar Pradesh.

Key words: Metallogeny, Himalaya.

S/438. Silvestri, A., 1934a. De petris, saxis et foxilibus paleozoici superioris a Missione Italica Geografica in Caracorum inventis. *Scientiarum Nuncius Radiophonicus* 30, 28 Mart, 1934.

Key words: Paleozoic, geography, Italian mission, Karakoram.

S/439. Silvestri, A., 1934b. Rocce e fossili del Paleozoico superiore raccolti della Spedizione Geografica Italiana nel Caracorum (1929): P.I, Le Rocce. *Memorie della Pontificia Accademia Romana di Novi Lincei*, Series 3(1), 33-48.

Key words: Paleozoic, geography, Italian Expedition, Karakoram.

S/440. Silvestri, A., 1935. Rocce e fossili del Paleozoico superiore raccolti della Spedizione Italiana Geografica nel Caracorum (1929): P.II, I fossili. *Memorie della Pontificia Accademia Romana di Novi Lincei*, Series 3(2), 79-117.

Key words: Paleozoic, geography, Italian Expedition, Karakoram.

S/441. Sinha, A.K., 1997. Subduction tectonics of plates and accretion of Karakoram terrane in the northern high mountain region of Indian Sub-Continent. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.65.

Key words: Tectonics, plate movement, orogeny, accretion, Karakoram.

S/442. Smith, F.H., 1895. On the geology of the Tochi valley. *Records of the Geological Survey of India* 28(3), 106-110.

This may be amongst the earliest accounts of this part of the tribal Area of present day Pakistan. Following are a few paragraphs from the records.

Bannu District.-One of the four trans-Indus Districts of the North-West Frontier Province, lying between 32° 16' and 33° 5' N. and 70° 23' and 71° 16' E., with an area of 1,670 square miles. The District forms a basin drained by two rivers from the hills of Waziristan, the Kurram and the Gambila or Tochi, which unite at Lakki and flow into the Indus south of Kalabagh. It is shut in on every side by mountains: on the north by those in the Teri tahsil Physical aspects. of Kohat District; on the east by the southern extremity of the Maidani Pahar or Khattak Niazi range and the northern spur of the Marwat range, which separate the District from the Isa Khel tahsil of Mianwali District in the Punjab; on the south-east and south the Marwat and Bhattanni ranges divide it from Dera Ismail Khan; and on the west and north-west lie Waziristan and independent territory inhabited by the Bhattanni tribe. These hills nowhere attain any great height. The highest point of the Maidani range at its centre, near the hamlet and valley of Maidan, has an altitude of only 4,256 feet. The Marwat range culminates in Sheikh Budin, the hill which rises abruptly from its south-west end to a height of 4,516 feet, and forms the summer retreat for this District and Dera Ismail Khan. From these ranges numerous spurs jut out into the Bannu plains, but no other hills break their level expanse. Of the rivers the larger is the Kurram, which, entering the District at its north-western corner close to Bannu town, runs at first south-east, then south, and finally winds eastward through the Darra Tang or 'narrow gorge' which lies between the extremities of the Maidani Pahar and Marwat ranges. The Tochi river enters the District about 6 miles south of the Kurram and flows in the same direction, gradually drawing closer to it until their streams unite about 6 or 7 miles west of the Darra Tang. Between these rivers, and on the left bank of the Kurram in

the upper portion of its course, lie the only tracts which are perennially irrigated. For the first 10 miles of its passage through the District the Kurram runs between banks of stiff clay which rise abruptly to a height of 10 to 30 feet, and its bed is full of stones and boulders; but lower down it spreads over long stretches of marsh land. Its flow is rapid, but it is highly charged with a rich silt which renders it most valuable for irrigation. At the south-east edge the western flanks of the hills bounding Mianwali and Dera Ismail Khan Districts expose Tertiary lower Siwalik soft sandstone and upper Siwalik conglomerates, a thickness of which dips regularly under the alluvium and gravels forming the greater part of the great Bannu plain. On its western side the border area has been examined along one line of route only, namely, the Tochi valley. Here long ridges striking north and south expose upper and lower Siwaliks, Nummulitic limestone, sandstone and shales, some Mesozoic limestone in the ridge east of Miram Shah, and a great mass of Tertiary igneous rocks (diorites, gabbros, and serpentines) west of Muhammad Khel. In the irrigated portions of the District trees abound of the same species as are common in Peshawar; elsewhere there is little but thorny shrubs of the same kinds as are found in Kohat. The more common plants are *Reptonia buxifolia*, *Dodonaea viscosa*, *Capparis aphylla*, *Flacourtia sapida*, *F. sepiaria*, several species of *Grewia*, *Zizyphus nummularia*, *Acacia Jacquemontii*, *Alhagi camelorum*, *Crotalaria Burhia*, *Prosopis spicigera*, several species of *Tamarix*, *Nerium odorum*, *Rhazya stricta*, *Calotropis procera*, *Penriplaca aphylla*, *Tecoma undulata*, *Lycium europaeum*, *Vithania coagulans*, *V. somnifera*, *Nannorhops Ritchieana*, *Fagonia*, *Tribulus*, *Peganum Harmala*, *Calligonum poligonoides*, *Polygonum aviculare*, *P. plebejum*, *Rumex vesicarius*, *Chrozophora plicata*, and species of *Aristida*, *Anthistiria*, *Cenchrus*, and *Permnisetum*.

Bears occasionally come from Waziristan and leopards still frequent the hills, while hyenas are sometimes found where there are ravines. Wolves are common, rewards having been paid for destroying 168 from 1900 to 1904. The Sulaimani markhor is found on all the higher hills, including Sheikh Budin. Uridl are also to be found on the hills, and 'ravine deer' (gazelle) in the neighbourhood of Jani Khel. The general elevation of the plains is about 1,000 feet, and the temperature would be much the same all over the District did not special local causes affect it. Trees, excessive irrigation round the town, and the closeness of the hills combine to make Bannu moist and close in the hot season, and to equalize the temperature throughout the twenty-four hours. The sandy plain of Marwat is hotter by day and cooler by night, and far more healthy in spite of the intense heat. Fevers are common from September to November, and respiratory diseases cause considerable mortality. The annual rainfall averages 12 inches, rarely rising above 16, but at Bannu in 1891-2 less than 5 inches fell in the year. The fall is frequently unseasonable. The population of Bannu is, and has been for many centuries, essentially Afghan. There are, however, remains which tell of an older Hindu population, and afford proof that the District came within the pale of the Ancient Graeco-Bactrian civilization of the Punjab.

Key words: Geology, Tochi, Waziristan.

S/443. Smith, H.A., 1993. Characterization and timing of metamorphism within the Indo-Asian suture zone, Himalayas, Northern Pakistan. Ph.D. Thesis, Dartmouth College, Hanover, 196p.

Key words: Metamorphism, India-Asian suture zone, Himalaya.

S/444. Smith, H.A. & Chamberlain, C.P., 1992. Evidence for late Eocene anatexis within the Indian plate as a result of Eocene Himalayan orogeny. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 84.

Our geologic mapping in the upper Kaghan Valley of northwestern Pakistan has focused on the Indian plate rocks defining the footwall of the Main Mantle Thrust. These rocks exhibit structural and mineralogic changes related to the south-directed obduction of the Kohistan Island Arc onto the Indian plate, thought to originate with the onset of continental collision at approximately 50 Myr (Patriat and Achache, *Nature*, 311:615-621, 1984). As a first step to answering some of the petrologic questions relating to this tectonic event, we sought emplacement ages for a narrow band of leucogranites near the village of Naran that extend for 4-km, cutting across lithologic boundaries within the Indian basement.

Because of the likelihood of xenocrystic components in these melts, we made use of the capabilities of the SHRIMP facility at Australia National University. With the ability to analyze a 20-30 micron spot on an individual grain, SHRIMP U-Pb zircon analyses can avoid obvious inherited cores and instead provide ages for rims presumably grown as a result of the most recent igneous event. We analysed a number of zircons from each of 4 leucogranite

samples in the Kaghan Valley. The youngest ages for each of these 4 samples cluster at 40–45 Myr. These ages are notably older than any leucogranite ages from the greater Himalaya.

Both the structural setting and the mineralogy of leucogranite in the Kaghan Valley are similar to other Himalayan leucogranites. Our leucogranites outcrop in the hanging wall of a pronounced shear zone (the Oghi Shear) which thrust amphibolite-grade basement rocks over low grade, graphitic metasediments of the Salkhala Formation. This structure is thought to be correlative with the MCT, the hanging wall of which hosts other Himalayan leucogranites. However, each of the previous studies of Himalayan leucogranites has used the occurrence of undeformed leucogranites that crosscut the foliation to constrain the minimum age of deformation. In the Kaghan Valley, we find that the leucogranites are deformed.

Thus our relatively old leucogranite ages obviously do not constrain the minimum age of deformation. What they do illustrate is unexpectedly early igneous activity in the Indian plate. That this igneous activity is not simply an isolated, local phenomena is shown by zircon U-Pb ages of 43 Myr, similarly obtained using SHRIMP, from the Malakand Granite near Swat, 300 km to the west.

Taken together, our ages of 40–45 Myr from leucogranites and the Malakand Granite require that igneous activity began within 10 Myr following the onset of Eocene collision between the Indian subcontinent and Asia. While the generation of melts this soon after collision may seem unusual, numerical modeling suggests that water-saturated melts can be expected 0–20 Myr following initial tectonic thickening, given appropriate fluid fluxes.

Key words: Himalayan metamorphism, magmatism, Indian plate, Kaghan valley.

S/445. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1990a. Young monazite ages from schists: Dating metamorphism in the Nanga Parbat Syntaxis, Himalayas, Northwestern Pakistan. Abstracts, International Conference on Geochronology, Cosmochronology, and Isotope Geochemistry. September 25, 1990, Canberra.

Key words: Metamorphism, geochronology, Nanga Parbat syntaxis, Himalaya.

S/446. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1990b. Young monazite U-Pb ages from schists in the Nanga Parbat Syntaxis, Himalayas, Northwestern Pakistan. Geological Society of America, Abstracts with Programs 22, p.27.

Key words: Metamorphism, geochronology, U-Pb, Nanga Parbat syntaxis, Himalaya.

S/447. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1992. Documentation of Neogene regional metamorphism in the Himalayas of Pakistan using U-Pb monazite. *Earth and Planetary Science Letters* 133, 93–105.

In the Himalayas, investigators have constrained the timing of metamorphism associated with the Eocene orogeny through the use of cooling ages on a number of minerals. The majority of such studies give minimum metamorphic ages of ~ 30–40 Ma, largely confirming theoretical studies predicting peak metamorphic conditions occurring tens of millions of years after large-scale collision. In northwestern Pakistan, however, the Nanga Parbat-Haramosh Massif (NPHM) exhibits much more recent activity, with rapid and accelerating cooling over the past 10 Ma. The NPHM also exhibits unexpectedly recent igneous activity: three leucogranite dikes give minimum zircon U-Pb ages of 7, 5 and 2.3 Ma. The problem we address in this paper is whether the thermal structure suggested by recent leucogranite production at depth is discernible in the shallower metamorphic rocks of the NPHM. To date metamorphism, we have used the U-(Th)-Pb system in monazite, a common accessory mineral in high-grade metamorphic rocks which can be a viable metamorphic geochronometer, dating the formation of the mineral under moderate metamorphic conditions. Monazite separated from schists and gneisses of the NPHM gives U-Pb ages of 4–11 Ma. We interpret these young ages as evidence for Neogene metamorphism affecting the NPHM, an event heretofore unsuspected in the greater Himalaya and only intimated in the NPHM. This recent metamorphism roughly coincided with leucogranite production at depth and with the onset of high denudation rates. As such, our conclusions offer important constraints on further modeling of similarly anomalous behavior within tectonically active regions, suggesting that any reasonable model should strive to explain the relationship between recent, rapid uplift and coincident recent metamorphism.

Key words: Metamorphism, geochronology, U-Pb, Himalaya.

S/448. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1993. Relationship between deformation and monazite ages-two counter examples in the Himalaya. EOS 74(16), p.123.

Monazite has found use as a geochronometer for metamorphic processes, processes intimately coupled with deformation in developing orogens. While the role deformation might play in initially forming monazite is unknown, the prograde metamorphism of pelites has been shown to result in the genesis of metamorphic monazite. The U-Pb system in such monazite then gives a direct age for onset of metamorphism, as well as offering constraints on the timing of deformation.

In Pakistan, we have used such ideas in two separate regions: the Nanga Parbat-Haramosh massif (NPHM) of the Indian plate and in the Karakorum range of the Asian plate. Although it has been shown that the NPHM is a region of rapid, accelerating uplift and denudation over the past 10 Ma, expectations were that the timing of Himalayan metamorphism would be broadly similar to that shown for the central Himalayas: mineral cooling ages there give younger bounds on the age of metamorphism of ~30-40 Ma. However, metamorphic rocks of the NPHM gives much younger monazite U- Pb ages of 4-11 Ma. We have been able to confirm none of the known scenarios for resetting the U-Pb system in monazite. Instead, we find independent corroborating evidence of Neogene metamorphism: young zircon U-Pb ages from leucogranite dikes and from the metasediments, as well as consistently younger fission-track ages.

Such is not the case for the Karakorum. Undeformed, post-metamorphic igneous units constrain deformation and metamorphism to being older than ~35 Ma, while 2 upper amphibolite facies metamorphic samples give concordant U-Pb monazite ages of 6-7 Ma. Although other geochronologic data are scarce, such young ages are enigmatic. We will use these two counter-examples to speculate on the viability of the U-Pb system in monazite as influenced by thermal and deformational perturbations.

Key words: Deformation, geochronology, orogeny, metamorphism, Nanga Parbat syntaxis.

S/449. Smith, H.A., Chamberlain, C.P. & Zeitler, P.K., 1994. Timing and duration of Himalayan metamorphism within the Indian Plate, Northwestern Himalaya, Pakistan. Journal of Geology 103, 493-508.

Key words: Metamorphism, geochronology, Indian plate, Himalaya.

S/450. Snee, L.W. & Rosenberg, P.S., 1985. Nappe structure in a crustal scale duplex in Swat, Pakistan. Geological Society of America, Bulletin, Abstract with Program, 17, p.640.

Key words: Structure, nappes, duplex, Swat, NWFP.

S/451. Snee, L.W., Foord, E.E., Hill, B. & Carter, S.J., 1989. Regional chemical differences among emeralds and host rocks of Pakistan and Afghanistan: implications for the origin of emerald. In: Kazmi, A.H. & Snee, L.W. (Eds.), Emeralds of Pakistan: Geology, Gemology and Genesis, 93-123. Van Nostrand Reinhold, New York.

This account has no abstract. It gives a brief of chemical differences between emeralds of Pakistan and Afghanistan. Emphasis is given on chemistry of the emeralds found in these areas. The authors have concluded that the emeralds of Pakistan, like the other emeralds of the world, are green in color due to the substitution of chromium to aluminum in the beryl structure. Pakistan emeralds are unique as they contain large amount of iron, megnisium and sodium. Emeralds from different areas in Pakistan and Afghanistan are chemically different. Swat, Mohmand, Khaltaro, and panjsher emeralds show small but distinct differences in aluminum, magnesium, sodium, chromium, vanadium, and scandium. Emeralds are clearly a reflection of the chemistry of both host rocks and mineralizing fluid.

Key words: Gemology, emerald, chemistry, Afghanistan, Pakistan.

S/452. Snee, L.W. & Kazmi, A.H., 1989. Origin and classification of Pakistani and world emeralds deposits. In: Kazmi, A.H. & Snee, L.W. (Eds.), *Emeralds of Pakistan: Geology, Gemology and Genesis*, 229-236. Van Nostrand Reinhold, New York.

Emerald, the result of the substitution of a small amount of chromium for aluminum in the beryl crystal structure (Deer and others, 1986), is the product of special geological conditions.

Even though beryl is the most common mineral that has beryllium as a major constituent, it is itself rare and is generally found in significant abundance only in late-stage igneous rocks, such as pegmatites. Beryl is rare because beryllium (with an ionic charge of +2) has both a small atomic radius (0.3 Å; Shannon and Prewitt, 1969; hence it is excluded from the crystal structure of most minerals) and a small crustal abundance (less than 5 ppm as estimated by Wedcpohl, 1978, or less than 3.5 ppm according to Beus, 1965). Emerald is even scarcer because chromium, the coloring agent of emerald, and beryllium are geochemically incompatible. Chromium is found only in significant amounts in "primitive" rocks such as ultramafic igneous rocks; in these, beryllium is absent. Thus, special circumstances are necessary to bring chromium and beryllium together and therefore, emerald is one of the rarest and most precious gemstones.

In Pakistan, a series of special geological events resulted in the formation of emerald. In the first three chapters of this book, we summarize the large-scale events. In chapters four through seven, we discuss additional clues on the origin of the emeralds; these clues are revealed in physical and chemical characteristics of the emeralds as well as in the morphology and physicochemical conditions of the formation of tiny inclusions within the crystals. In chapter 8, we review the geology of other known world emerald deposits. In all, an intriguing picture about the general geologic setting and the origin of not only Pakistani, but world emeralds is unfolding. In this final chapter, the characteristics of Pakistani emeralds are summarized and are used to formulate a theory on their origin. Next, a classification scheme based on the general geologic setting of world emeralds is proposed and discussed and is developed into an hypothesis for the origin of all emeralds. Finally, we propose some additional studies that would shed new light on the origin of emeralds.

Key words: Gemology, emerald, chemistry, Pakistan.

S/453. Snelgrove, A.K., 1979. Migrations of the Indus River, Pakistan, in response to plate tectonic motions. *Journal of the Geological Society of India* 20, 392-403.

Key words: Plate tectonics, Indus River, Pakistan.

S/454. Sohail, A., 1987-89. Geotechnical studies for landslide problems along the Murree Kohala Road. M.Sc. Thesis, Punjab University, Lahore, 111p.

Landslides are widespread in many countries and cause great economic losses especially when engineering constructions are designed and erected without knowing the stability conditions of the slopes.

The greater frequency of landslides provoked by construction works, as compared with the past is probably due to several reasons:

- The interference with natural slopes is more intensive because of the rising boldness and extent of structures.
- The mechanization of earthworks accelerates excavation but excludes the possibility of sorting the rock material.
- The selection of building sites is generally restricted to the less favourable ones which were avoided by previous builders etc.

Landslides are closely connected with the geological conditions of the area. Generally speaking Pakistan has a very intricate geological history with active tectonic zones. Frequently occurring landslides, in different parts of the country create problems for government and local people. The area between Murree and Kohala is the site of very diverse sliding Phenomena. (especially along the road). Landslides endanger settlements, high roads, public utilities etc. The Murree Kohala Road has great national importance from strategic and regular communications view point. This shortest possible route between Pakistan and Azad Kashmir is promoting the facilities of communications for development of the linked areas and the supply of basic needs. The Murree -Kohala Road crosses the Jhelum River at Kohala through Kohala Bridge and a stretch of about six kilometers is along the Jhelum River from Basian to Kohala. This road is also important from defence point of view. There is another road which starts from Jhikagali via Bhurban and joins the Murree -Kohala Road near Basian via Bush Road is named as Khaquan Abbasi Road (due

to late Khaquan Abbasi). The entire area through which road passes is the rugged mountainous terrain having sub humid to semi arid climate conditions. As far as the slopes of the project area are concerned, the major part of the road is on the escarpment face and variety of slope conditions exist in the area. The condition of the Murree -Kohala road is satisfactory where a good driver can drive every type of vehicle at the speed of 40-50 kms/hour, except for the landslide areas.

Key words: Hazards, landslides, geotechnical, Azad Kashmir.

S/455. Sohail, M., 1981-83. Lithostructural mapping and biostratigraphic study of Burikhel Bandakha Area (western Salt Range), District Mianwali. Institute of Geology, Punjab University, Lahore, M.Sc. Thesis, 1-100.

Detailed Lithostructural Mapping and Biostratigraphic study of Barikhel- Bandakha Area (Western Salt Range) District Mianwali, has been done at 1:10,000. Area is exclusively a sedimentary terrain. Stratigraphy along with micropaleontology of certain formations is described. In addition to this macrofauna have been described. Lateral extension of liminic permeable coal is noted. Tectonic style of the area is described with the help of structural details i.e. study of folds, faults and joints etc.

Key words: Lithostructure, biostratigraphy, Salt Range, Mianwali.

S/456. Sohan, I.G., 1959a. Early Tertiary ostracodes from West Pakistan. Geological Survey of Pakistan, Memoirs 3(1), 91p.

Key words: Palaeontology, ostracode, Tertiary.

S/457. Sohan, I.G., 1959b. Lower Tertiary ostracodes from Pakistan. Geological Survey of Pakistan, Memoir 3(2).

Key words: Palaeontology, ostracode, Tertiary.

S/458. Sohn, I.G., 1970. Early Triassic marine ostracodes from the Salt Range and Surghar Range, West Pakistan. In: Kummel, B. & Teichert, C. (Eds.), Stratigraphy Boundary Problems, Permian and Triassic of Pakistan. University of Kansas, Geology Department, Special Publication 4, 193-206.

Key words: Palaeontology, ostracode, Triassic, Surghar Range, Salt Range.

S/459. Sokolov, B.A. & Shah, S.H.A., 1966. Major tectonic features of Pakistan. Part 1, West Pakistan. Pakistan Journal of Scientific and Industrial Research 4, 175-199.

The junction of the foredeep with border folds of Attock-Hazara are in along the whole southern rim of the Himalayan folded system. Morphologically, the Kohat part of the Rawalpindi zone west of Indus River represents a system of narrow fractured anticlines and relatively wide synclines.

The Karakoram median mass "is made of Pre-Palaeozoic granites of various types, gneisses, crystalline schists and other highly metamorphosed rocks. Along the northern and southern margins of the median mass the narrow, limited by faults, strings of outcrops of Upper Palaeozoic, Mesozoic and even younger rocks appear outside the boundaries of Pakistan.

The igneous activity is of considerable extent in the Cretaceous period, and is expressed as a wide spread intrusions of granitic and granodioritic and is expressed as widespread intrusions of granitic and granodioritic rocks as less of more basic diorite, gabbro and ultrabasic rocks.

Key words: Tectonics, Attock-Hazara.

S/460. Spadea R.P., 1975. Description of the specimen of metamorphic and plutonic rocks from the Lake Shiwa area. In: Desio, A. (ed.), Italian Expeditions to the Karakorum and Hindu Kush. Petrographic Appendix, 582-596. Brill, Leiden.

Key words: Metamorphic rocks, plutonic rocks, Karakoram.

S/461. Spath, L.F., 1930. The fossil fauna of Samana Range and some neighbouring areas; Part-5, the Lower Cretaceous Ammonoidea; with notes on Albian Cephalopoda from Hazara. Geological Survey of India, Memoirs, Palaeontologica Indica (New Series) 15(5), 50-66.

Key words: Cretaceous, ammonioidea, fauna, cephalopoda, Hazara, Samana Range, Hangu.

S/462. Spath, L.F., 1934. The Jurassic and Cretaceous ammonites and belemnites of Attock district. Geological Survey of India, Memoirs, Palaeontologica Indica (New Series) 20(4), 1-39.

The ammonites and belemnites described in this paper come from a number of localities in the Attock district, in the extreme north-west of the Punjab, on the borders of the North-West Frontier Province. They were sent to me marked partly Basal Giumal beds (the Jurassic and Spiti shales species), partly Upper Giumal beds (the Albiau forms and some indeterminable belmenites). These cephalopods were accompanied by a number of brachiopods, also pelecipods and gastropods, which are being described by Miss H. M. Muir-Wood and by Mr. L. R. Cox 'respectively. The fauna has already been referred to in my Revision of the Jurassic Cephalopoda of Kachh, hut the publication, in the meantime, of other works, especially on Upper Jurassic successions, makes it desirable to discuss the stratigraphic results afresh and in more detail in a final chapter.

I have to record my grateful acknowledgments to the past and present Directors of the Geological Survey of India in Calcutta (Sir Edwin Pascoe and Dr. L. L. Fermor) for entrusting me with the description of these interesting forms ; also to the Keeper of the Geology Department of the British museum (Natural History), Dr. MT. D. Lang, for giving me all facilities in connection with the study of the collections. I should like similarly to acknowledge the help and continually receiving from colleagues all over the world by consignments of new material, literature or information, even if it may not seem to be directly concerned with the area here discussed. The measurements of ammonites are given in the usual order :--(1) diameter in millimetres, (2) whole-height, (3) whole-thickness, (4) width of umbilicus in percentages of the diameter. The localities are referred to under numbers 1-12 in the specific descriptions to avoid lengthy repetitions, but they are given in full in Chapter 111. Since a number of the species here recorded have been

described from Kachh, the synonymies are also generally condensed. A full list of literature on the subject is given in the last part of my Revision of the Jurassic Cephalopoda of Kachh.

Key words: Ammonites, belemnites, Jurassic, Cretaceous, Attock.

S/463. Spath, L.F., 1939. The Cephalopoda of the neocomian belemnite beds of the Salt Range. Geological Survey of India, Memoirs, Palaeontologica Indica, New Series, 25, Memoir 1, 1-154, 25 pls.

Key words: Cephalopoda, belemnite, Salt Range.

S/464. Spencer-Cervato, C. & Spencer, D.A., 1991. Stable isotope analysis of the carbonates in the Higher and Lesser Tethyan Himalayan, North Pakistan. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 87.

The Upper Kaghan nappe in the NW Himalaya of Pakistan consists of a lower granitoid basement with two cover units: first, a metagraywacke unit of Lower Paleozoic age and second, a Tethyan sedimentary sequence which has at its base the Permian Panjal Traps, which are continental tholeiitic to mildly alkaline basaltic lavas that evolved in the passive continental margin of neo-Tethys. Syn-depositional limestone (new-marble) intercalations occur between

the lava flows. These marbles show extensive extensional structures, associated with the rifting and subsequent extrusion of the lavas themselves. Due to the high grade of metamorphism under which the whole nappe has undergone (eclogite-amphibolite facies metamorphism) only a few fossils were found to indicate the age of the unit. Previous geochemical correlations between the Higher Himalayan-Tethyan Panjal volcanics with known Lesser Himalayan-Tethyan Panjal volcanics in Kaghan Valley revealed that a correlation between the two units could be made. Carbon and oxygen isotope analyses on the marbles between the lavas, as well as those above the analytical groups consist of the Higher Himalayan Panjal Traps (HHPT), Lesser Himalayan Panjal Traps (LHPT), Higher Himalayan Tethyan Triassic series (HHTSS) and the Lesser Himalayan Triassic Rara Formation (LHTRF).

Preliminary analyses show that the marbles from the Panjal Trap units give a marine carbon isotope signature whilst the younger sedimentary series gave a different result. Such stable isotopic correlation is only possible because of the well-defined nature of the units being studied, and that the actual stratigraphic correlations with other documented sections are available. It is therefore considered as a powerful tool in the analysis and reconstruction of similar sedimentary environments that have subsequently undergone different tectonic histories.

Key words: Isotopes, carbonates, Himalaya.

S/465. Spencer-Cervato, C. & Spencer, D.A., 1992. Petrographic and isotopic study of the marbles from upper Kaghan valley, NW Himalaya, Pakistan. Proceedings of the Symposium on the Himalayan Geology, Shimane University, Japan, 56-58.

Key words: Isotopes, petrography, marbles, Himalaya.

S/466. Spencer, C.H., 1996. Gypsum plaster in Pakistan: Past, present and future. Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994, p.199.

Key words: Mineral resources, gypsum plaster.

S/467. Spencer, D.A., 1988. Deformation of the Main Mantle Thrust zone at Babusar Pass, Karakorum, Himalaya, Pakistan. M.Sc. thesis, Imperial College, University of London.

Key words: Deformation, MMT, Babusar, Karakoram, Himalaya.

S/468. Spencer, D.A., 1991a. Different shortening histories between the 'syntaxial' and 'non-syntaxial' areas of the Himalayan belt. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 79-80.

Recent plate tectonic models of Himalayan deformation (e.g. Dewey et al., 1989) are, as yet, the most advanced suggested for the understanding of the collision zone. North of the Indus Suture, they show that shortening accommodation is not homogenous along the length of the mountain chain but varies: crustal thickening and uplift of the Tibetan plateau essentially occurring in north of the Central parts of the Himalaya and indentation with strike-slip faulting occurring in the Karakoram and Pamir region. Similarly, south of the suture, different amounts of shortening by thrusting are suggested to have occurred, although this does not explain how the structurally anomalous syntaxes are formed, their different structural, metamorphic and tectonic histories nor why they are confined to certain area of the Himalaya.

It is suggested that the deformational history south of the suture is primarily influenced by the shape of the Indian plate promontory in the NW Himalaya and the lack of the promontory in the Central Himalaya. The effect of this promontory resulted in the initiation of subduction in the NW parts of the Himalayan belt and reaches the greatest depths for the Indian plate, as evidenced by high pressure eclogite and blueschist facies metamorphism, which are conspicuously lacking in the Central Himalaya. Also, the occurrence of extensional tectonics in the Central Himalaya and its absence in the NW Himalaya probably also attests to differential uplift histories.

The effect of the initial collision of the promontory caused in the Indian plate to rotate anticlockwise in a force field adjustment. This rotation produced a change of tectonic transport shortening direction within the promontory and

subsequently led to large scale superimposed folding which explains syntaxial formation. By contrast, the central Himalayas were more of a 'head-on' collision with shortening easier north of the suture by plateau uplift and then by thrusting south of the suture.

Of fundamental importance in this interpretation is basically the argument about whether the Indian plate promontory actually exists and, if so, its shape. Indentation tectonics in the Pamirs with sinistral faulting on the western boundary and dextral faulting on the eastern boundary, deflection of Asian sutures older than Himalayan age, anticlockwise rotation of the Indian plate, the outline of the Higher Himalayan Crystalline, occurrence of syntaxes and differential rates of collision rates from NW to NE along the belt all attest to presence of a promontory and the subsequent progressive eastward closure of the suture. A 'triangular' shape for the promontory is thought to be the most appropriate.

It is obvious that the promontory did not act as a rigid indenter as thrusting occurred south of the suture. Similarly, during the uplift of the nappes, folding played a major part in the shortening history, in some cases producing a 'Panini' sheet-like deformation in the more internal units. Examples of fold interference are presented from the Hazara-Kashmir, Kaghan and Nanga Parbat-Haramosh Syntaxes, as well as basin and dome patterns in the Upper Kaghan area and are mainly due to a horizontal, anticlockwise translation of deformation, comparable and probably coeval with the movements of the Indian plate. Small-scale structures, as well as the metamorphic and geochronological considerations (Poignant, this volume) correlate well these modifications.

It is therefore suggested that folding is a crucial accommodation feature south of the suture in the syntaxial areas of the Himalaya and has been mainly neglected in shortening history models of the mountain belt. Slight modifications are therefore applicable to explain the deformational features south of the suture, where folding, as well as thrusting, are thought to be of great importance in the understanding of the different shortening histories between the 'syntaxial' and 'non-syntaxial' areas of the Himalayan belt.

Key words: Deformation, syntaxis, Himalaya.

S/469. Spencer, D.A., 1991b. Wie hoch können sich die Gipfel des Himalaya-Gebirges heben? Erdwissenschaften Heute. ETH (Zurich) Bulletin 232, p.40.

Key words: Orogeny, Himalaya.

S/470. Spencer, D.A., 1991c. Evidence for the deepest and earliest derived nappe of the Indian plate, NW Himalaya, Pakistan. Proceedings of the Symposium on Himalayan Geology, Shimane University, Japan, 51-55.

Key words: Indian Plate, Himalaya.

S/471. Spencer, D.A., 1992a. Geochemistry of the peraluminous Higher Himalayan Crystalline Granite Basement, Upper Kaghan, Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 126.

The Higher Himalayan Crystalline Basement of Upper Kaghan Valley consists of granites of possible Precambrian (?) age. It is well represented in all parts of the Upper Kaghan nappe due to superposed folding that exposes different structural levels of the unit in both amphibolite and eclogite facies conditions. Major and trace element analysis of a variety of granite types show fairly consistent geochemical analysis, but with a differentiation trend.

Analyses are presented in three chemical mineralogical diagrams (Debon and Le Fort, 1983). In a Q-P diagram, the samples plot on the granite to adamellite sector. Characteristic mineral (A/B) plots show a distinctive trend from granite to granodiorite in the distribution line attitude of the representative points from the association. The slope (ie. the direction of its major evolutionary trend) is negative and in contrast to that seen in the Leucogranite of Upper Kaghan and Zaskar which are vertical (parallel to $A = Al - (K + Na + 2Ca)$, although with a negative trend when plotted together). The Higher Himalayan Crystalline Granites broadly correspond to the 'Cafemic' type of association. Quartz-rich and quartz-poor associations occur with samples plotting above and below the critical line and the colour index ranges from leuco- to mesocratic. Most samples plot in the peraluminous domain and outside the leucocratic field ($B > 38.8$). In the Q-B-F diagram, none of the samples plot in the leucocratic field but occur

between the $Q/Q + F$ of 20-45%. A negative correlation between Na₂O and K₂O occurs with (Na₂O + K₂O) varying from 6.12-9.52.

Major and trace element spider diagrams, with normalizations according to Thompson et al. (1984) and, for comparison, to the Bhutan Leucogranite Mean Standard Deviations, were made. Thompson normalisations show distinctive depletion in Sr, P and Ti with a general negative trend. Bhutan normalisations show rather constant depletion and enrichment amongst the samples themselves, compared to the standard deviation. Distinctive enrichment occurs for Ba, Sr, Sc, Y, Zr, Ti and Zn, whilst depletion occurs for Na, K, Ca, Rb, P, Pb and Co. These patterns may reflect a highly evolved source for the protolith and to generate these concentrations, evolved continental material is needed.

An interesting comparison to the leucogranites of Kaghan can be made. Whilst the characteristic mineral diagrams show distinct differences between the basement and the leucogranite, there are some similarities in peaks between them on the spider diagram. The leucogranites were obviously derived from the basement rocks in Kaghan. A-F-M plots are certainly differentiated ($F/A = 0.12-0.69$) and follow the calc-alkaline differentiation trend, as seen for example in the granitoid rocks of the Trans-Himalayan Batholith. All trace element variation diagrams (Zr, Y, Ba and Rb) with increasing SiO₂ show a magmatic differentiation trend. On the A-C-F diagram, all points plot in the Type 1 field (Al rich) with the most distinguishable feature of these granites being the Al Content Number (Al₂O₃ / Na₂O + K₂O + CaO) all being greater than one (Al content ranges = 1.33 - 1.77). All the granites are therefore peraluminous. By contrast, a Ca-K-Na plot shows a distinctive trend with most having a poor Ca content (Ca < 1.5: range 0.16 - 1.38). Other variation diagrams (Pb/SiO₂: Pb/Ba; Y/Fe₂O₃ and Zr/P₂O₅) also show a distinctive grouping but differentiation of the Higher Himalayan Crystalline Granites compared to the Leucogranite. Further discrimination diagrams (Nb/SiO₂ Nb/Y; Rb/(Y + Nb); Y/SiO₂ and Rb/SiO₂) all put the granites very distinctly into the field of within-plate granites.

The Higher Himalayan Crystalline Granites therefore appear to show very clear geochemical major and trace element characteristics. They were the obvious source of anatectic melting for the Himalayan-aged leucogranite by movement along the Main Central Thrust. Their aluminous content is distinctive and suggests a S-type origin forming in a within-plate environment.

Key words: Geochemistry, Higher Himalayan crystallines, Kaghan valley, Himalaya.

S/472. Spencer, D.A., 1992b. Himalayan eclogite exhumation by fold superposition. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 127.

Superposed folds are common features in orogenic belts that can occur on a variety of scales ranging from micro- to megascopic (e.g. Loch Monar in the Caledonian orogenic belt and the syntaxes of the Appalachians and Himalaya orogenic belt). Their formation is usually accentuated by the occurrence of competence differences between different lithologies, as well as between different units, such as a basement and cover. When the scale of these differences is regional rather than local (as for example in the Higher Himalayan Crystalline of Northern Pakistan and the Lepontine Alps of Central Switzerland), it is possible that the differential local amplitudes of the superposed folds may play an important role in its exhumation history. This is especially so where the interference patterns are thought to be related to formation in an environment of primary origin (such as plate motion) rather than of secondary origin (accommodation features or changes in principal stress directions due to strain localization).

The Upper Kaghan Nappe of the NW Himalaya is of crucial importance for the understanding of the deep-seated orogenic processes associated with the Himalayan collision. Bounded by the Main Central Thrust to the south and the Indus Suture to the north, this Higher Himalayan and Tethyan tectonic unit thus represents exposures of the deepest part of the Indian plate. Evidence of the deep subduction and subsequent differential exhumation of the nappe by thrusting along the MCT, erosion, isostasy and fold superposition is shown by the presence within the nappe of an oval shaped area of eclogite facies metamorphism of some 150 km². Surrounding this high-pressure zone, with decreasing pressure isobar contours, but constant temperature conditions, are found rocks with amphibolite facies. Pressure-temperature estimations, based on microprobe analysis of mineral composition in the eclogites, gives $T = 650 \pm 500^\circ\text{C}$ at pressures of $P = 15$ kbar. This equates to depths of formation of around 55-60 km at Eo-Himalayan times. In contrast, at the southwest front of the nappe, amphibolite facies assemblages of staurolite-almandine with kyanite-sillimanite suggest $T = 550-650^\circ\text{C}$ at $P = 8$ kbar equating to a depth of formation at 30-km. Within the nappe itself, therefore, there seems to exist a relative horizontal pressure gradient that must have formed at different vertical depths in the order of 25 km. taking the minimum possible difference of differential exhumation. Thus, not only was the nappe subducted to different levels, it must have been exhumed at different rates as well. No

internal imbrications (uplift faults), shear zones or major discontinuities. nor extensional structures surrounding the eclogite-amphibolite facies transition have been found within the nappe. An alternative mechanism of exhumation is therefore proposed. The structural evolution of the High Himalayan and Tethyan units in Pakistan show a remarkable similarity to the Pennine style of nappe formation and deformation In the Alps: be. an initial development of large scale recumbent folds followed by complex large scale refolding subsequent to nappe emplacement. In the Higher Himalaya of Kaghan, where ductile deformation was the main process of deformation, evidence suggests that a polyphase ductile - penetrative overprinting occurred after the original nappe forming movement. This led to the development of a system of major post-nappe folds, which were superposed on, and deformed structures related to an earlier Himalayan history of deformation. As with the Pennine nappes of the European Alps, the post-nappe folds can be subdivided into two groups: main Himalayan folds and late Himalayan folds. The late folds are superimposed on the main Himalayan folds with type 1 or 3 interference patterns giving very large scale domes, which are found In the syntaxes, as well as basins and domes In the areas between the syntaxes. such as that in Upper Kaghan. The formation of the second phase basin and domes on the original nappe forming structure is a form of buckling anisotropy, as the earlier formed nappe-style recumbent sheet folds influence the subsequent preferred axes of buckling of the later superposed folds. The refolding is perpendicular to the nappe forming stretching lineation direction and the tectonic shortening direction is parallel to the first main phase Himalayan fold axial planes. The amplitudes of the folds of the latter structures are smaller than those of the recumbent style folds, emphasising that the nappe movements contribute to the overall uplift. However, subsequent horizontal compression on the nappe appears to have been a far more effective uplift mechanism, albeit localised to the amplification of the refolded isobars, than the differential shear accompanying the nappe forming movements. The dimensions of the late stage folds can be derived from their wavelength (W) and amplitude (A). Wavelength determinations between two Inflection points from a cross section parallel to the tectonic shortening direction responsible for their formation, gives a wavelength approximation of 10-km. The tightness of the folds, derived from tangents to the fold surface through the inflection points, gives an average interlimb angle within the close range (70o-30o) of 40o. By using Fourier coefficient analysis, the amplitude of the fold can be derived at 14-km. When the basins and domes are considered together (eclogites are also found in some basin depressions) this figure of 28 km (2 x Amplitude) is certainly within the ballpark of differential uplift within the nappe. Amplification rates of the folds in such an environment were probably not constant and may have been slow during the early continental collision tectonic history. Rather, the eclogite exhumation would be at a maximum during the latter part of the tectonic history. Overall, it may account for some 20-30% of the total vertical uplift, especially in the case of the Upper Kaghan Nappe in the Himalayas where the first confirmed high-pressure metamorphism was found within the Indian Plate of the Himalayan Belt.

Key words: Eclogite, exhumation, Kaghan valley, Himalaya.

S/473. Spencer, D.A., 1992c. Fold superposition as a mechanism of Himalayan rock exhumation. Abstracts, First South Asia Geological Congress, Islamabad, 65-66.

Key words: Exhumation, tectonics, Himalaya.

S/474. Spencer, D.A., 1992d. Continental collision in the Northwest Himalayan Tethyan Region. Abstracts, First South Asia Geological Congress, Islamabad, p.42.

Consult the following account and Spencer (1994a).

Key words: Continental collision, Himalaya.

S/475. Spencer, D.A., 1993a. What was the timing of the Himalayan continent-continent collision (45, 50, 55, 60 OR 65 Ma.)? Constraints from eclogites. Abstract with Programmes, Geological Society of America, p.A-121.

The Himalayan collision may have been diachronous from west to east. A promontory collision may have caused the earlier and deeper subduction in the northwest Himalaya and account for variation in initial Collision timing. Earliest collision may have occurred at the KT boundary.

Key words: Continental collision, eclogite, Kaghan valley, Himalaya.

S/476. Spencer, D.A., 1993b. Tectonics of the Higher-and Tethyan Himalaya, upper Kaghan valley, Northwestern Himalaya, Pakistan: implications of an early collisional, high pressure (eclogite facies) metamorphism to the Himalayan belt. Doctoral Dissertation ETH nr.10194.

Key words: Continental collision, eclogite, Kaghan valley, Himalaya.

S/477. Spencer, D.A., 1994a. Continental collision in the Northwest Himalayan Tethyan Region. In: Ahmed, R. & Sheikh, A.M. (Eds.), *Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992*. Hydrocarbon Development Institute of Pakistan, Islamabad, 185-202.

The plate motion that is associated with the formation of the Himalayan Orogenic belts has been studied from many different aspects. In general, the collision of the Indian and Asian plates has essentially been described as a “head-on”, north-south collision of India into Asia with virtually no significant component of compression parallel to the plate boundaries. This is generally accepted by many workers to have occurred in Eocene times (55-40 Ma) and very few have argued that collision was significantly earlier by up to 10-25 Ma. Interpretations of strain partitioning in the Himalayan collisional belt have been made by numerous authors who emphasized that the Himalayas themselves only took up some one-third of the shortening, the other two thirds being accommodated in the Asian Plate itself. There are five main methods by which the collision of the Indian into the Asian Plate has been accommodated (extrusion (strike-slip) tectonics, uplift and crustal thickening, thrusting, extension and folding). The structural evidence from a simple “head-on”, south-north collision in the Northwest Himalayan region is not apparently convincing when many of the localized tectonic variations are considered. In view of the localized exhumation anomalies that are now found in the Northwest Himalayan region (Upper Kaghan eclogites, Nanga Parbat granulite facies metamorphism, Shang La blueschists etc.) and their associated basinal depressions (Kashmir Basin, Peshawar Basin, Skardu in intermontane Basin). It is interpreted that this may all attest to differential exhumation and subsidence for different localities in the Himalayas. These occurrences may be localized in space yet they should be explained, on a broader scale, to regional variations in the plate movements. Numerous variations along strike of the Himalayan belt can be documented in the Asian and Indian Plates. These observations, combined with the fact of the remarkable linearity of the units of Himalayan Orogen, suggest that they were diachronous. The diachroneity is suggested to be due to the rather gradual changes along strike of the major Himalayan units. Much evidence suggests a promontory collision in the Northwest Himalayan has occurred. The indentation promontory of the Indian block may have had a “triangular” shape. The promontory would be the first part of the crust to subduct and effectively go to the deepest level and attain the highest pressure for any part of the collision zone. The recognition of the eclogite facies metamorphism is suggested to be an important factor in the understanding of the timing of the Himalayan collision. Upper Kaghan may be the “tip of the iceberg” in terms of the extent of the eclogite facies metamorphism.

Key words: Continental collision, eclogite, Kaghan valley, Himalaya.

S/478. Spencer, D.A., 1994b. Volatile alteration and metamorphic facies: Release of H₂O and CO₂ in the Panjal traps of the NW Himalaya. *Journal of Nepal Geological Society* 10 (Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu), 12-129.

Whilst the bulk rock geochemistry of a basalt, subjected to progressively increasing metamorphic grade, may remain on the whole isochemical, it has been long known that volatiles would have to be released and cannot remain constant. Three volatiles which should change through an increase in metamorphic grade are H₂O, CO₂ and O₂. The various metamorphic grades of the Panjal Traps in the NW Himalayas (unmetamorphosed, greenschist, amphibolite and eclogite facies) provide an ideal opportunity to test these ideas and possibly act as chemical indicators of the state of alteration of the rock. Direct and indirect determination of CO₂ and H₂O were made on numerous samples.

Direct determination of CO₂ content in a rock sample has been made by coulometric titration for five main groups: Zaskar Tethyan Shelf - Panjal Trap basalts (Ba); Lesser Himalaya - Panjal Trap Basalts (PJ); Higher Himalaya Second Cover: a -Panjal Trap amphibolites (A); Higher Himalaya Second Cover: a - Panjal Trap Dolerites (D) and

Higher Himalaya Second Cover: a - Panjal Trap eclogites (E). The main observation on the occurrence of % CO₂ in the Panjal Traps with increasing metamorphic grade is that there is a decrease in % CO₂ content that appears to be fairly gradual. This therefore suggests that with increasing metamorphism, CO₂ is being driven off by decarbonation reactions.

Estimation of the volatile content in a sample can be made by the simple weight loss on ignition, and used as a method of indirect determination of H₂O. The loss on ignition and the H₂O(+FeO) in the Panjal Traps show that with an increase in metamorphic grade there is a decrease in the L.O.I and H₂O(+FeO) content that appears to be fairly gradual. This therefore suggests that with increasing metamorphism, volatiles are being driven off by dehydration reactions.

Comparison of the results of this work with the results of some published theoretical calculations are made for the wt. % H₂O of a subducting, and therefore dehydrating, oceanic crust or tholeiitic basalt. Here, predictions were made by combining calculated pressure- temperature paths with a model of metabasalt phase equilibria, where a progression (for the upper parts of the oceanic crust) pass through greenschist to amphibolite to eclogite facies. The agreement between these two independently produced sets of data is clearly apparent.

Key words: Metamorphism, geochemistry, Panjal traps, Himalaya.

S/479. Spencer, D.A., 1994c. Where is (Is there a?) Main Central Thrust in the NW Himalayas of Pakistan? Journal of Nepal Geological Society 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, 129-130.

The term "Main Central Thrust" was first introduced into Himalayan terminology by Heim and Gansser in 1939. They described the detachment as a tectonic contact surface between a terrigenous-carbonate autochthon and an overlying metamorphic complex of mica schists and gneisses. It generally dips towards the north and is not a single tectonic discontinuity, but rather a thick shear zone, in places ranging from 5-20 km. It is associated with a strong stretching lineation, strong foliation, and high strains. Still today, much discussion occurs about whether the Main Central Thrust is actually one or two or three thrust surfaces, especially in the Central Himalaya of India and Nepal. As the Main Central Thrust is widely accepted as the intracontinental thrust that separates the Higher and Lesser Himalaya, its recognition is therefore implicit in using these unit names in the Pakistan Himalaya. Any description of the Main Central Thrust must be associated with accompanying structural, metamorphic, stratigraphic and tectonic considerations, which have been well defined in other parts of the Himalayas. For any location of the Main Central Thrust to therefore be accepted, it must comply with all, if not most, of these considerations and not just part of it. Therefore, a description or location of a possible Main Central Thrust cannot be considered without comparing on a regional scale what the implications of this definition mean.

The location of any "Main Central Thrust" in the Pakistan area of the Northwest Himalayan region is likely to remain controversial for some time. This is simply because the area where the Main Central Thrust was last seen, to the south of the Kashmir Basin, was some 100-km away from the next suggested location in Neelum and Kaghan Valleys. This intervening area between the last known location and any new suggested location is only scantily mapped in part. This is due to a border dispute between the countries of Pakistan and India regarding the Kashmir region.

The first occurrence of the Main Central Thrust at Batal, Kaghan Valley, was described by Chaudhry and Ghazanfar in 1986. Since then, ten other suggestions of locations of the "Main Central Thrust" have been made in Pakistan. Whilst it is obvious that not all of these interpretations can be correct, a review of their indicative features is given for discussion. It is also important to note that other workers in the NW Himalayas suggest that the terminology of the "Main Central Thrust" and the associated " Higher- and Lesser Himalaya" be discontinued completely in this region.

Suggested "Main Central Thrust" locations in Pakistan are:

A Main Central Thrust on the western side of the Nanga Parbat Syntaxis

The Shontargali Thrust is an analogue of the Main Central Thrust

The Panjal Fault is, in part, the equivalent of the Main Central Thrust

The Mansehra and Panjal Thrusts are coeval to the Main Central Thrust

The Balakot Shear Zone is the equivalent of the Main Central Thrust

The Oghi Thrust is the equivalent of the Main Central Thrust

The Luat Fault is the equivalent of the Main Central Thrust

Main Central Thrust is located in the lower part of Neelum Valley

Main Central Thrust is the northward continuation of the Batal Fault

Main Central Thrust is folded to form the Kaghan Syntaxis

Only one position of the Main Central Thrust, at Batal in the Kaghan Valley which was the one first recognized by Chaudhry and Ghazanfar in 1986, is generally accepted by the majority of northwest Himalayan workers (who do believe in a continuation of the MCT) as the correct location for a major tectonic contact which might correlate with the Main Central Thrust.

Key words: Tectonics, MCT, Himalaya.

S/480. Spencer, D.A., 1994d. Tectonics of the Higher and Tethyan Himalayan, Upper Kaghan Valley, NW Himalaya, Pakistan. *Journal of Nepal Geological Society* 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, 132-134.

This presentation will aim to summarize the work that has been done in Upper Kaghan over the last few years, to outline existing problems and to attempt to categorise this area in a Himalayan framework (Spencer, 1993). The Upper Kaghan Nappe is tectonically situated in the western syntaxis area of the Northwest Himalaya, NE Pakistan. It belongs to the Higher Himalaya and, as such, it is here delimited by the Main Central Thrust at its base and the Indus Suture at its structurally highest position. The nappe is suggested to be unusual from the generally accepted concepts of other known regions of the Higher Himalaya. Stratigraphically, the Higher Himalaya basement (granite intruding into minor, older metasediments) is overlain by two Tethyan lithological covers (Lower Palaeozoic to Triassic?), which were also metamorphosed during the Himalayan orogeny. Structurally, numerous macrostructural measurements (planar, planar-linear, folds, faults etc.) define at least two major phases of deformation - the first associated with the nappe forming event and the latter deforming the recumbent folds to form a superposed type 1 or 3 interference pattern. Very high strain can be recorded associated with the early ductile deformation. The Indus suture shows only evidence of a late-stage "top-to-the-south" thrust sense of shear, although this is suggested to overprint an earlier extensional movement along the suture zone. This, and the late-stage interference folds (suggested to act as a mechanism for increased erosion by advancing relative uplift), act as the exhumation processes for one of the most unusual features that have been found in Upper Kaghan: the eclogites.

The eclogites of Upper Kaghan show X_{jd} contents of omphacite of up to 0.431, which retrogress to diopside. All garnets are almandine-rich ($X_{\text{alm}} = 0.460 - 0.592$) and coexist with sodic calcic and alkalis amphiboles, phengite and rutile. Garnet-clinopyroxene Fe²⁺-Mg exchange thermometry calculates a mean temperature of formation of $650^{\circ}\text{C} \pm 50^{\circ}\text{C}$. Garnet-phengite (Fe²⁺-Mg) exchange thermometry suggests $658^{\circ}\text{C} \pm 17^{\circ}\text{C} - 676^{\circ}\text{C} \pm 38^{\circ}\text{C}$. The jadeite + quartz and the phengite Si⁴⁺ barometer indicates pressures up to 17.5 kbar, suggesting depths of formation of some 60-km, the deepest known rocks yet to be found that were exhumed by the Himalayan orogenesis. Retrogressive exhumation took place at decreasing temperatures. Three stages of metamorphism are suggested: M1 - rapid increase of pressure and temperature associated with the subducting Indian plate; M2 a decompressional event with decreasing pressure and temperature associated with a stable geotherm; M3 a retrogressive phase associated with overprinted greenschist facies metamorphism. The metamorphic conditions in the nappe are not constant with evidence of isothermic but non-isobaric gradient from the core to the outer sheets of the nappe.

Cathodoluminescence observations on the carbonates of the second Tethyan cover show that at least part of the calcite is not the product of dolomite decarbonation but that tremolite and diopside are closely related to the existing calcite composition. Sedimentary structures only seen in cathodoluminescence suggests a shallow shelf sea environment of formation for the Panjal trap carbonates. XRD calculations of the mineralogical content of the carbonates distinguish between the stratigraphic lower calcite-rich carbonates and the stratigraphic higher dolomite-rich samples, although, the "Permian Carbonates" contain minor calcian dolomite ($\text{Mg}_{39}\text{Ca}_{61}\text{CO}_3$).

Geochemically, the basement feeder and cover flow eclogites and amphibolites (as well as the Lesser Himalaya and the unmetamorphosed Panjal Traps) show remarkable similar element abundances and discriminate to tholeiitic (to sub-alkalic), within plate, continental flood basalts. The Higher Himalayan basement is a peraluminous, "S"-type granite forming in a within-plate environment with signatures that closely correlate to the Mansehra granite. The peraluminous Higher Himalayan leucogranites show many similarities with the Higher Himalayan basement and appear to be derived from the basement granites. $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ isotopes on the carbonates of the Higher Himalaya second cover of upper Kaghan show a distinctive chemo-stratigraphical trend between the known and suggested Permian/Triassic sequences, suggesting stratigraphic affiliation. With increase of the grade in metamorphism, both show a regular successive depletion in the means from a $\delta^{13}\text{C}$ of +2.3‰ to -1.5‰ PDB and $\delta^{18}\text{O}$ of +20.3‰ to +16.7‰ SMOW. Isotope depletion ratios essentially depend on carbonate mineralogical content. Negative shifts of carbon isotopes at the assumed Permian - Triassic boundary of Zaskar are also found. Radioactive isotope ages of

samples from the Upper Kaghan nappe are: $^{147}\text{Sm}/^{143}\text{Nd}$ analysis of garnet and clinopyroxene in eclogite gives an age of 49 ± 6 Ma ($\epsilon_{\text{Nd}} = +2.6$); $^{87}\text{Rb}/^{87}\text{Sr}$ analysis of phengite, garnet and clinopyroxene in eclogite gives an age of 43 ± 1 (initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.70900 ± 0.00004); $^{238}\text{U}/^{206}\text{Pb}$ analysis of rutile in eclogite gives ages of 39 - 40 +1 $^{40}\text{K}/^{40}\text{Ar}$ analysis of hornblende and biotite in amphibolite and eclogite range from 35.2 ± 1.4 Ma to 42.7 ± 1.4 Ma for hornblende and 26.3 ± 0.7 Ma for biotite. $^{39}\text{Ar}/^{40}\text{Ar}$ analysis of phengite and amphibole in eclogite suggests that excess argon was incorporated as they define ages of >106 Ma for amphibole and 81 Ma for phengite. Caution is suggested when using the $^{39}\text{Ar}/^{40}\text{Ar}$ method for high-pressure samples. $^{147}\text{Sm}/^{143}\text{Nd}$ whole rock analysis of basalts, metabasalts, amphibolite, amphibolite-eclogites and eclogites, which pertain to give the extrusion age of the Panjal Traps, are 337 Ma ($\epsilon_{\text{Nd}} = +3.2$) although the M.S.W.D. is high. Whole rock $^{143}\text{Nd}/^{144}\text{Nd}$ analyses of the amphibolites and eclogites of Upper Kaghan (and the Panjal Traps of the Lesser Himalaya and Zaskar) identify them as tholeiitic continental flood basalts. $\epsilon_{\text{Nd}} t = 270$ varies between -9.9 to +4.9 with the more positive values occurring at the higher metamorphic grades. Minor continental crust contamination is present with a mixing curve evolution. Whole rock initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios range from 0.70559 ± 3 to 0.71643 ± 4 (with one exceptionally high 0.73829 ± 3) again suggesting signatures that evolved through the continental crust as tholeiitic, continental flood basalts. Using this new data and published literature data, the cooling history of the Upper Kaghan nappe is determined at $13^\circ - 14^\circ\text{C}/\text{Ma}$. Structural subdivisions of the nappe by core and outer sheet indicate a “rapid - slow - rapid” cooling history rather than a constant cooling history as determined for the nappe as a whole. The cooling history of Upper Kaghan is very different to that of the Nanga Parbat and Besham areas. It is also very different to the East Central Kohistan Island arc.

Fluid inclusion studies on the eclogites and quartzites in upper Kaghan show the presence of three systems of secondary inclusions: $\text{H}_2\text{O}-\text{CO}_2-\text{NaCl}$, $\text{H}_2\text{O}-\text{CO}_2-\text{CH}_4$ and CO_2 . Isochore calculations show that they were all the product of late stage metamorphic retrogression that led to the liberation of CO_2 and H_2O which formed in an early less dense phase followed by a late higher density phase. Tectonically, the Upper Kaghan nappe shows variation in exhumation rates from the outer sheet to the core of 0.75 - 1.3 mm/year. It is related to a model of anti-clockwise change in the tectonic transport direction, which has been earlier ascribed to the structural evolution of the Hazara-Kashmir and Kaghan syntaxis. The finding of this early, high pressure phase of eclogite facies metamorphism renews speculations that an initial Indian plate impingement occurred in the Northwest Himalayan region at around 65 Ma and that successive west - east suturing of the Indian and Asian plate continents occurred subsequently in the Central and Eastern Himalaya.

Key words: Tectonics, Kaghan valley, Himalaya.

S/481. Spencer, D.A., 1995a. Where is (Is there a?) Main Central Thrust in the NW Himalayas of Pakistan. *Journal of Nepal Geological Society* 11, 63-72.

The term ‘Main Central Thrust’ was first introduced into Himalayan terminology in 1939. Still today, much discussion exists about whether the Main Central Thrust is actually one, two or three thrust surfaces, especially in the Central Himalaya of India and Nepal. As the Main Central Thrust is widely accepted as the intracontinental thrust that separates the Higher and Lesser Himalaya, its recognition is therefore implicit in using these unit names in the Pakistan Himalayas. The location of any ‘Main Central Thrust’ in the Pakistan area of the Northwest Himalayan region is likely to remain controversial for some time. This is simply because the area where the Main Central Thrust was last seen, to the south of the Kashmir Basin, was some 100 km away from the next suggested location in the Neelum and Kaghan Valleys. This intervening area between the last known location and any new suggested location is only scantily mapped in part. Eleven suggestions of locations of the ‘Main Central Thrust’ have been made in Pakistan and a review of their indicative features is given for discussion. Only one position of the Main Central Thrust, at Batal in the Kaghan Valley, is generally accepted by the majority of northwest Himalayan workers (who do believe in continuation of the MCT) as the correct location for a major tectonic contact which might correlate with the Main Central Thrust.

Key words: Tectonics, MCT, Himalaya.

S/482. Spencer, D.A., 1995b. Volatile alteration and metamorphic facies: Release of H_2O and CO_2 in the Panjal volcanics of the NW Himalaya. *Journal of Nepal Geological Society* 11, 89-102.

Whilst the bulk rock geochemistry of a basalt, subjected to progressively increasing metamorphic grade, may remain on the whole isochemical, it has been known that volatiles are likely to be released. Three volatiles which should change through an increase in metamorphic grade are H₂O, CO₂ and O₂. The various metamorphic grades of the Panjal Volcanics in the NW Himalayas (unmetamorphosed, greenschist, amphibolite and eclogite facies) provide an ideal opportunity to test these ideas and possibly act as chemical indicators of the prograde metamorphism. Direct and indirect determination of CO₂ and H₂O were made on numerous samples. Direct determination of CO₂ content in a rock sample has been made by coulometric titration for five main groups: Zaskar Tethyan Shelf-Panjali Volcanic basalts (Ba); Lesser Himalaya-Panjali Volcanic basalts (PJ); Higher Himalaya Second Cover-Panjali Volcanic amphibolites (A); Higher Himalayas Second Cover-Panjali Volcanic dolerites (D) and Higher Himalaya Second Cover-Panjali Volcanic eclogites (E). The main observation on the occurrence of % CO₂ in the Panjal Volcanic with increasing metamorphic grade is that there is a decrease in CO₂ that appears to be fairly gradual. This therefore suggest that with increasing metamorphism, CO₂ is being driven off by decarbonation reactions. Estimation of the volatile content in a sample can be made by the simple weight loss on ignition, and used as a method of indirect determination of H₂O. The loss on ignition (L.O.I) and the H₂O (+FeO) in the Panjal Volcanics show that with an increasing metamorphism, volatiles are being removed by dehydration reactions. Comparison of the results of this work with the results of some published theoretical calculations are made for wt.% H₂O of subducting, and therefore dehydrating, oceanic crust or tholeiitic basalt. Here, predictions were made by combining calculated pressure-temperature paths with a model of metabasalt phase equilibria, where a progression (for the upper parts of the oceanic crust) pass through greenschist to amphibolite to eclogite facies. The agreement between these two independently produced sets of data is clearly apparent.

Key words: Geochemistry, metamorphic facies, Panjal volcanics, Himalaya.

S/483. Spencer, D.A., 1995c. Continental collision in the northwest Himalayan Tethyan region. In: Ahmed, R. & Sheikh, A.M. (Eds.), *Geology in South Asia-1. Proceedings, First South Asia Geological Congress Hydrocarbon Development Institute Pakistan, Islamabad*, 185-202.

Consult Spencer (1994a).

Key words: Continental collision, Himalaya, Tethyan region.

S/484. Spencer, D.A., 1995d. The Indus suture zone (Northwest Himalaya, Pakistan): Problems of high pressure lithology interpretation. Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 5-8.

The nature (i.e. structure and lithology) of the Indus Suture in Pakistan is traced. The blueschists (yielding 100±20 to 67±12 Ma) in the suture mélange in Shangla (Swat) and adjacent areas is described, as are 49±6 to 43±1 Ma eclogites from Kaghan valley. The Himalayan deformation play an important role with the evolution of the high pressure rocks, yet these ages are interpreted as resulting from a pre-Himalayan event.

Key words: Indus Suture Zone, blueschists, eclogites, Shangla, Kaghan, Himalaya.

S/485. Spencer, D.A., 1996a. "Collapse folding" as a mechanism of explaining the early ductile extension along the Indus Suture and the subsequent exhumation of the Himalayan eclogites (Upper Kaghan, Pakistan). Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 141-142.

The structural evolution of the Higher Himalayan and Tethyan units of Upper Kaghan has been suggested to show a remarkable similarity to the "Pennine style of nappe formation" and deformation in the Alps: i.e., complex large-scale folding subsequent to fold nappe emplacement (Spencer, 1991, 1993). However, one of the major problems that exist in the interpretation of the "Penninic folding" model for the Upper Kaghan Nappe, is the Indus Suture. Whilst no evidence for extensional movement on the Indus Suture was found in the brittle structures, extensional movement during ductile deformation could have occurred. The Indus Suture may have had, in its early stage of deformational history, a significant effect on the eclogite facies metamorphism because the pressure-temperature-time data show that a significant amount of early exhumation had taken place during the first 15 m.y. since peak

metamorphism. Erosion alone is probably not fast enough to achieve the exhumation and the suggestion of an early phase of extensional tectonics along the suture is likely.

Froitzheim (1992), describing the D2 folds of the Swiss Austroalpine nappes, suggested that the footwall folding during extensional tectonics is not only possible, but exists to depths of several kilometers even with only moderate shear deformation. He shows the D2 folds in the Ela and Err-Carungas nappes are related to ductile crustal stretching and thinning contemporaneous with normal faulting in the Silvretta nappe. High competence contrasts and the fact that the folds are not restricted to mylonite zones, are used to suggest that a sheath fold model does not apply. A pure or simple shear extension model is suggested where both would result in footwall folding. In simple shear extension, it is suggested that the most intense folding is likely to occur in layers that dip in the same direction as the shear plane, but at a slightly steeper angle. The model is termed “Collapse Folding”.

The “Collapse Folding” model provides a solution for the formation of recumbent folds in a simple shear environment (thrusting at the base and extensional tectonics at the top). It also allows for the vertical thinning (and, therefore, exhumation) of footwall lithologies. A combination of the deformation with a thrust fault at the structurally lowest level (Main Central Thrust), recumbent nappe folding between the structurally lowest and highest levels and extensional movement at the structurally highest level (Indus Suture) is described and can explain how footwall folding (eclogite uplift in the core of the Upper Kaghan Nappe) can occur from extensional movements. The effect of uplifting the footwall with folding and lowering the hanging wall (essential for eclogite exhumation) is relatively unknown. Moreover, the timing of these features is important. If the extensional sense of movement had occurred along the Indus Suture, this would have had to develop at the same time as the footwall deformation, which produced the recumbent folds.

The following listed evidence suggests that the Upper Kaghan Nappe may be associated with the first (and subsequent second) major phase of deformation (50-35 Ma):

Rapid cooling rates within the Upper Kaghan Nappe from 50-35 Ma

Change in cooling paths within the Upper Kaghan Nappe at 32 Ma

Rapid exhumation rates within the Upper Kaghan Nappe from 50-35 Ma

Change in exhumation paths within the Upper Kaghan Nappe at 35 Ma

Convergence of cooling paths from the footwall and hanging wall of the Indus Suture after 20 Ma, suggesting that the movement that had caused their separation was now complete and underwent a common thermal history. The localized nature of the eclogite facies metamorphism which is interpreted as being controlled by the first phase of folding in that it only occurs in the core of the Upper Kaghan Nappe

Thrusting on the Main Central Thrust, which forms the lower boundary plane of the nappe, is shown by the large mylonite zone that marks its delineation with all sense of shears showing a “top-to-the-southwest” sense of movement

Early thrusting on the Main Central Thrust is shown by the fact that leucogranites, which are suggested to be formed by movements along the shear zone, give ages of $\approx$ Ma (Zeitler and Chamberlain, 1991).

The “Collapse Folding” model relies on the fact that ductile deformation can occur in an extending crust below a certain depth, which is in turn dependent on the magnitude of the least principals stress, geothermal gradient, fluid pressure and deformation mechanisms, amongst other factors. For the model to be applied in mountain-forming orogens, a steep initial orientation of the layering and then a phase of lateral extension is then required for footwall ductile folding to occur. Extension can be caused by any mechanism (gravitational spreading, pull-apart extension, lateral, etc.) and the results are suggested to be the same.

An interpretation of the above evidence explains the rapid exhumation of the Upper Kaghan Nappe whilst the early D1 folding was occurring (Spencer, 1993). The “Collapse Folding” is interpreted to occur coeval with the thrusting along the Main Central Thrust and extension along the Indus Suture. The fact that the “Collapse Folding” occurred so early in the deformational history allows for the conditions of ductile folding to occur in the footwall whilst the extension is still occurring. Most importantly however, unroofing and uplift that would not be present if the Indus Suture maintained its thrust sense of shear. Discussion on the reasons for the change from thrusting to extensional movement at or around 50 Ma and a model to show the formation of recumbent folds in a simple shear, “Collapse Folding” regime will be shown.

Key words: Structural evolution, collision, Kaghan valley, Himalaya.

S/486. Spencer, D.A., 1996b. The Upper Kaghan Nappe (NW Himalaya, Pakistan): Regional Synopsis. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 145-146.

The tectonic evolution of the Upper region involves two simple considerations: the mechanism of subducting the Indian Plate to depths within a specific time that is constrained by the large-scale plate tectonic forces and, secondly, its subsequent exhumation to the surface where it is found today. The relation between the timing of peak metamorphism and the timing of collision of the Indian Plate shows that Himalayan metamorphism in the Upper Kaghan region was well under way by 50 Ma and that peak metamorphic conditions were reached very soon after collision. It is important to ascertain whether the Upper Kaghan eclogites can be subducted to the appropriate depths in the given time available and whether the lithologies will heat up to produce the suggested 650°C suggested for the peak metamorphic temperatures. Theoretical thermal observations suggest that Himalayan metamorphism is the result of thermal relaxation after crustal thickening and has been used by previous researchers as a type example in the continental collisional models. Predictions necessitate that at least 20-25 m.y. is needed for thermal equilibrium to heat the Indian Plate to 650°C, unless an alternative heat source is found. If the Himalayan metamorphism is not related to crustal thickening, then its relationship to the actual processes of subduction of the Indian Plate beneath the Kohistan Island Arc is the most viable alternative. Plate models rely on a rather simplistic set of parameters: plate velocity, depth of subduction, distance of subduction, angle of subduction and finally the time needed for subduction.

The results for the rates of subduction, with variations in the angles of subduction range from 5° to 45° which subsequently alters the distance to subduct (to eclogite forming depths of 60 km) from 42 km to 688 km. This is coupled with the velocity of the plate movement, which is varied from between 15cm/year to 1cm year. If the most generally accepted velocity of Indian Plate movement (15cm/year) and angle of subduction (30°) are considered, then only a minimum time interval of less than 1 m.y. is needed to produce the depth sufficient to attain eclogite facies metamorphism in the Upper Kaghan region. With virtually any angle of subduction from 5°-45°, the subducting slab will reach depths of eclogite formation in less than 5 m.y. This suggests that collision can have occurred at any time from 0.8-4.6 m.y. before the peak metamorphism, and any estimate that can therefore range from 50-56 Ma for the timing of collision is acceptable for the depths achieved for eclogite formation. The time needed to reach the temperature of formation of the eclogite is calculated by solving the one-dimensional conduction equation. Here, temperature of eclogite formation can be obtained by heating as a result of subduction as the depth of penetration of a given isotherm increases with plate velocity. Therefore, the depth of the slab temperature inversion within the slab decreases with increasing plate velocity, easily resulting in the necessary temperature recorded by the Upper Kaghan eclogites. The fundamental key to achieving this result is the temperature recorded by the Upper Kaghan eclogites. The fundamental key to achieving this result is the velocity of the Indian Plate at the initiation of collision. If it is fast, subduction will be rapid and eclogite depths of formation easily achieved with corresponding medium (600°C) temperatures.

Exhumation consists of the amount of material that has been removed by erosion or tectonic thinning (i.e., relative uplift combined with erosion). The exhumation rate is the rate at which a rock rises from depth of burial towards the earth's surface. Time-averaged rates of exhumation can be obtained from depth-time averages. Maximum pressure estimates of the eclogite path give 16-18 Kbar, which equates to depths of formation at 60-65 km with peak metamorphism at 49 Ma. The average exhumation rate is, therefore, 1.2-1.3 mm/year. By contrast, maximum pressure estimates for the amphibolite path give 8-9 Kbar which equate to depths of formation at 30-35km with peak metamorphism around 40 (?) Ma. The exhumation rate is, therefore, 0.7-0.9 mm/year. These exhumation rates are more or less consistent with previous authors, interpretations of exhumation rates for the areas to the west of Upper Kaghan e.g., for Nanga Parbat at 1 mm/year and for the Suru region at 1.4-2.1 mm/year. Nevertheless, whilst these exhumation rates are comparable for the Northwest Himalaya, they bring rocks in the core of the upper Kaghan nappe to the present surface from depths of almost double those exposed in Nanga Parbat. This is simply due to the timing of peak metamorphism and the depths from which they originated. Exhumation rates can also be derived from pressure-temperature paths (i.e., the appropriate depth at which the cooling age occurred). The amphibolite facies area plots with an early stage of rapid exhumation and then a slowing down at 35 Ma. For the eclogite nappe core, the results again show an early stage of rapid exhumation and then a slowing down at 35 Ma. This shows that the exhumation was much greater in the early part of the Himalayan orogeny than in the later. Perhaps as much as two thirds of the exhumation took place in the first 15 m.y. with a noticeable change in the exhumation rates at around 37 Ma. This exhumation is suggested to be related to two main tectonic processes: early extension along the Indus Suture with associated "Collapse Folding" and late fold superposition combined with erosion. The evidence shows a fast exhumation history in the first 15 m.y., that is, in the early stages of the nappe emplacement combined with extension. This is suggestive of exhumation during convergence. Other evidence, however, does come from the pressure-temperature path which changes from the perturbed/stable to the relaxed state (i.e., heating begins signifying that the subduction is over). The underplating of the Indian Plate below the nappe is considered to be of

crucial importance in driving the exhumation as it is this that creates the normal faulting along the Indus Suture that appears to thin the crust and exhume the nappe.

In summary, the exhumation history and exhumation rates all point to the fact that Upper Kaghan appears to be the most far traveled nappe known so far in the Northwest Himalayas and possibly in the Himalayas. This may assert that, during the collision of the Indian Plate, the Upper Kaghan nappe was the first impinging part of the Indian Plate to collide due to the Indian Plate promontory and again suggests that the Indian Plate collision was not simply one of head-on collision, but one that varied from west to east across the Himalayan belt. For an overview of some of the features associated with the Upper Kaghan Nappe, a time chart for the structural, metamorphic and cooling history, related to the Indian Plate motion, is given. Its aim is to show how many aspects of the tectonic history of Upper Kaghan show some remarkable interactions with each other. A summery model of the collision and subsequent exhumation of the Upper Kaghan Nappe is also presented.

Key words: Structural evolution, continental collision, Kaghan valley, Himalaya.

S/487. Spencer, D.A., 1996c. Structural geology of the upper Kaghan nappe, NW Himalayas, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 151-152.

The structural geology of the Upper Kaghan area shows a complex history of Himalayan-aged deformation which resulted in the formation of many small-scale and large-scale features. Many observations of small-scale structure were made at the micro-, macro- and megascale.

Planar Structures

Planar structures, such as the preservation of original sedimentary bedding surfaces, which are surfaces of primary accumulation, are only preserved in the Higher Himalayan First and Second Covers. No evidence was found for bedding in the Higher Himalayan Basement. A schistosity is often parallel to a gneissic foliation or banding consisting of impersistent laminae and segregations of mineral grains. All evidence suggests that the schistosity that is observed in the Upper Kaghan region is of Himalayan age. This is based on the fact that the mineral grains show a preferred orientation (such as mica, flattened quartz and amphibole) that form as a result of the imposed tectonic strain field have been dated as Himalayan. No evidence has been found that suggests that the schistosity cuts a pre-existing penetrative fabric. The orientation of the schistosity in the Upper Kaghan area is extremely varied, explained by subsequent refolding of the S1 schistosity by a later F2 folding event. An axial planar crenulation cleavage occurs that is approximately parallel to the axial planes of the folds of the deformation, which produced the schistosity. The axial planar crenulation cleavage generally has a northeast-southwest or north-south orientation and are parallel (or subparallel) to the F2 folds. The position of the limbs and hinges of the fold cause a striping known as the crenulation cleavage fold axes to occur. This banding forms due to the relative enrichment or depletion of insoluble and soluble minerals such as quartz and mica. The calculated crenulation cleavage fold axes lies close to the great circle of the F2 fold axes and the F2 fold axis congregate around this position. The mean vector of all the data shows a consistent northeast-southwest orientation. A plot of the crenulation cleavage traces joins the axial surfaces of the small-scale crenulation cleavage folds. These directions can generally not be extended over very large areas as the folds are often impersistent. Nevertheless, they provide further indication of the strain ellipse XY plane orientation of the second phase of deformation. All crenulation cleavage traces indicate a ubiquitous northeast-southwest orientation, apparently parallel to the crenulation cleavage fold axes and the L1 mineral-stretching lineation.

Planar-linear and linear structures

Four lineations were measured. An intersection lineation is either aligned parallel to the axes of the F1 folds showing a low to moderately dipping, northeast-southwest orientation or sub-parallel to the mineral-stretching lineation. A mineral-stretching lineation is defined by mica, amphiboles and phyllosilicates and is low to moderately plunging, with a southwest-northeast orientation. The lineation is far less common around the Basal area due to the fact that the Basal area comprises of the structural core of the Upper Kaghan nappe where the metamorphism appears to predate the main deformational period. A few observations of a crenulation cleavage intersection lineation are found in regions where the F2 folds form a fold hinge. Variations in orientations ranged from plunges of north to northeast, although always at moderately dipping angles.

Folds

Folds form an important structural component of the Upper Kaghan area. The large, nappe scale F1 fold axes were never directly measured in the field (as no hinges to these major folds were directly observed). The existence of the F1 folds through smaller scale folds however possibly relate to the major fold axes. In general, the fold axes strike

form northwest-southeast, plunging at low to high angles. The F1 fold axes are sub-perpendicular to the mineral-stretching lineation. The folds are generally recumbent (tight to isoclinal). F1 fold axial planes were generally oriented at low dips, although the values were often quite variable due to subsequent refolding by F2. F1 fold axial traces varied throughout the Upper Kaghan nappe due to the refolding of F2. In the Besal area, this probably had an initial strike east-west, but this direction was subsequently changed orientation to north-south. The F2 fold axes are found to be associated with the crenulation cleavage folds and crenulation cleavage and were probably formed synchronously. The F2 fold axes show a northeast-southwest trend and plunge at moderate to very steep angles. The dimensions of the F2 fold are regional in scale. They are open to tight folds. The axial planes have a northeast-southwest orientation with dips to the southeast and, occasionally, to the northwest. The F2 fold axial planes are almost vertical-moderately dipping tectonic features that could be fairly continuously traced through the Upper Kaghan Nappe in a northeast-southwest orientation. The F2 fold axial trace structures continue across the whole region and roughly trend with the present outcrop of the Indus Suture suggests that there is a common link between them. A structural domain calculated F2 fold axial plane is virtually vertical-dipping 87° to the southeast. The folds are tight due to the wide spread of the poles to bedding over the great circle. Other minor structures that were found in the Upper Kaghan are syn-sedimentary extension faults, veins and joints.

Strain Analysis

Strain analysis was attempted on strain markers such as xenoliths, schlieren, marble lenses, amygdaloids, folded veins, stretched feldspar in augen gneiss and a stretched amphibole dyke. Two main types of strain ellipse were found in the Upper Kaghan Nappe: one of uniaxial flattened ellipsoids and the other of uniaxial constricted ellipsoids. Amounts of extension in stretched grains varies to a maximum of 32%. All strain analysis indicates that the strain values are very high, typical for the internal zones of mountain belts where ductile deformation is the main style for deformation. Sense of shear of the movement along the suture zone, such as imbrications, ramping, rotated boudins, overfolds, slickensides, kink bands, crenulation cleavage fold axes, crenulation cleavage and mineral-stretching lineation relations, fold intersection lineation, orientations of the fibres and overstepping fibres all give a “top-to-the-south” sense of shear. No evidence for brittle extensional movement was found along the Indus Suture at Babusar Pass.

Regional Tectonics

The geometric relationships of the mesoscopic structures can be used in the Upper Kaghan region to infer what is happening on a more regional scale. The delineations of the geometric relationships suggest that two/three? major phases of deformation will account for what is observed. The superposition observed does not seem to fall under a simple classification. It appears to be a series of domes or basins of the type 1 classification, which, due to the high ductility environment in which they were found, resulted in the rotation of the first formed fold axis sub-parallel to the second tectonic transport direction, especially noted in the Naran area. In the Besal area, the interference pattern that occurs is possibly a type 1 to 3, where 1 is the dome itself and 3 is the convergence and divergence pattern of the first formed fold axis. The two main phases of deformation are: a First phase of deformation (D1) and Second phase of deformation (D2) although locally there are indications of a Third phase of deformation (D3) and a Pre-Himalayan deformation. D1 consists of the development of the Indus Suture followed by the Main Central Thrust with deformation continuing throughout early stages of fold formation; extension along the Indus Suture and southwest-northeast transport movement producing major folds, schistosity and mineral-stretching lineation. D2 is fold formation with southeast-northwest regional fold superposition, crenulation cleavage formation, although it may be a progression (i.e., anticlockwise rotation transport direction) of D1. This is followed by a late regional fold compression leading to the basin and dome formation, possibly east-west.

Comparison of the suggested structural evolution of the Upper Kaghan nappe to the other regions of the Higher Himalaya which lie to the east (Nanga Parbat Syntaxis and Zaskar area) and the west (Besham area and Swat region) show that similarities exist with the Zaskar and Swat regions for the overall regional deformation. However, the thrust imbrication of nappe pile by late stage tectonic movements is not seen and correlations with the tectonic history of Besham are difficult. Except for the timing of the tectonic events, broad correlation can be made with the Nanga Parbat area, in terms of the structural style of deformation, although the latter formed in a time period by which the deformation in the Upper Kaghan area was virtually complete.

Key words: Structural geology, Kaghan valley, Himalaya.

S/488. Spencer, D.A., 1997. Reactivation of early collisional structures-the long and varied geological history of the Indus suture (NW Himalaya Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 223.

Suture zones are boundaries between crustal blocks carried on two different tectonic plates that were subsequently juxtaposed by plate motions. As such, they are sites of former oceans that play an important role in our interpretation of the geodynamic evolution of orogenic belts. Almost by definition, a suture zone marks one of the earliest events in any collisional cycle. Paradoxically, these early zones of deformation are often reactivated at later stages in their tectonic history, to such an extent that even neotectonic activity can be seen along these older structures. These late stage deformational events can, in many cases, completely wipe out any evidence of the typical suture zone lithologies (such as ophiolites).

Although suture zones are often characterized by the presence of ophiolites, their subsequent obduction and preservation is inevitably a question of their structural evolution throughout the subsequent collisional processes. As continental collisions themselves are generally not simple head-on processes, it is inevitable that the along-strike development and preservation of suture zones vary. For example, there is a marked difference along the strike of the Indus Suture, which separates the Indian Plate and the Asian Plate. This is especially so in the western part of the Himalayan chain (i.e., Northwestern India and Northern Pakistan) where the suture between the Indian Plate and the Asian Plate is located at the base of the Kohistan-Ladakh complex.

Why are suture zones targets for fault reactivation? What do they inherit that allows them to be subsequently deformed by later tectonic movements? It is known that documented ophiolite remnants in the Himalayas of Pakistan are restricted to a few regions (e.g., Shang-La, Dargai). Intervening areas have been strongly affected by post collisional deformation that has now removed most of the evidence that this tectonic boundary was once a former site where oceanic subduction had taken place. Intriguing questions therefore remain about what controls these post-collisional movements? In particular, why is it that across the border from Pakistan into India, the Suture Zone is preserved almost relatively free from any of the severe deformation associated with the Himalayan Orogeny? In this context, it is necessary to examine the reasons why (in Pakistan) one of the earliest structures associated with the oceanic subduction/continental collision cycle seems to play such an important role in the late stage deformational (and therefore exhumation) history of the footwall plate.

Key words: Collisional structure, Indus Suture, Himalaya.

S/489. Spencer, D.A., Chaudhry, M.N., Ghazanfar, M. & Hubbert, M.S., 1995. The role of the Indus suture in the exhumation of the Indian plate (NW Himalaya, Pakistan). *Terra Abstracts, European Union of Geologists Meetings, Strasbourg*, 7, p.118.

Key words: Exhumation, Indian Plate, Indus Suture, Himalaya.

S/490. Spencer, D.A. & Gebauer, D., 1996. Shrimp evidence for a Permian Protolith age and a 44 Ma metamorphic age for the Himalayan eclogites (Upper Kaghan, Pakistan): Implications for the subduction of Tethys and the subdivision terminology of the NW Himalaya. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 147-150.

Since the discovery of the High Pressure Metamorphism in the Upper Kaghan region (Pakistan), a number of questions were raised that needed to be answered for a better understanding of the geodynamic evolution of the eclogites and their country-rocks. Some of these questions have now been answered and the results published (summary give below). New results are presented here to solve another question, which is related to the eclogite protolith age and a more age of HP-metamorphism.

Proof of eclogite existence

Microprobe analysis showed the presence of omphacite + garnet (no plagioclase was found), confirming the discovery of high-pressure eclogite facies metamorphism in the Himalayan belt. A typical high-pressure assemblage found in the Upper Kaghan consists of omphacite-garnet-quartz-rutile (Spencer et al., 1990, 1991; Pognante and Spencer, 1991; Spencer, 1993).

Pressure-temperature conditions of formation

The analysis of the eclogites has given calculated depths of formation, based on mineral geobarometry, of around 60 km (Spencer et al., 1990; Pognante and Spencer, 1991; Spencer 1993) and are the deepest known rocks to have been exhumed from the Indian Plate. Geothermometry calculations of the suggested peak metamorphism by the garnet-clinopyroxene geothermometer gives $T=650^{\circ} \pm 50^{\circ}\text{C}$.

Geochronology of eclogites

Tonarini et al. (1993) showed that the eclogite facies metamorphism of Upper Kaghan was of Himalayan age. Specifically, a peak metamorphic age of 49 ± 6 Ma was obtained by the Sm/Nd method in garnet-clinopyroxene. Cooling ages were obtained with the Rb/Sr radiometric dating in phengite at 43 ± 1 Ma and U/Pb in rutile at 39–40 Ma, both of which are interpreted to constrain the thermal evolution of the eclogite down to $\approx 500^\circ\text{C}$. Tonarini et al. (1993) and Spencer (1993) also showed that Ar/Ar and K/Ar analysis of phengite and hornblende can give meaningless results when compared to the Sm/Nd, Rb/Sr and U/Pb ages obtained in the same sample. This is almost certainly due to excess argon.

Mechanism of exhumation

The fact that the high pressure rocks are located within the NW Himalayan syntaxial region suggests that, in part, their late-stage erosion-dominated exhumation was also controlled by the large-scale late-stage folding associated with the syntaxial formation. However, evidence exists that the majority of the exhumation was achieved by a reactivation of the Indus Suture from initial thrust tectonics (associated with the subduction of the Indian Plate beneath the Kohistan Island Arc) to ductile extensional tectonics, a “collapse folding” scenario which is driven by the movements on the Main Central Thrust (Spencer, 1993).

Geochemical characteristics

Bulk rock geochemistry and Sr-Nd isotopic composition were made and results were compared to lower grade metamorphic equivalents of rocks of the same as well as to unmetamorphosed basalt. Major and trace element diagrams indicate tholeiitic to alkalic magma compositions, which evolved by fractional crystallization. $^{87}\text{Sr}/^{86}\text{Sr}$ initial values 270 Ma for the eclogite are 0.7053–0.7073 with values increasing for metabasites of lower metamorphic grade. $^{147}\text{Sm}/^{144}\text{Nd}$ values range from 0.1397–0.2096. Nd(270) from +4.9–10. The lowest initial values occur in the least metamorphosed rocks. Based on their bulk geochemistry and isotopic data, the eclogites could be the equivalents of the Permian Panjal Traps (Spencer et al., 1995).

Protolith age

In the Higher Himalaya of Kaghan Valley (and in the areas further to the west), a basement-cover sequence was recognized that is clearly different from the last known occurrence of the basement-only lithologies to the east in Zaskar (Greco et al., 1989). The basement consists of the Higher Himalayan Crystalline (*sensu stricto*) with granitoids and metagranites. This is overlain by a cover unit of metagrawackes of suggested Lower Paleozoic age with a clear sedimentary origin. This is then diachronously and unconformably overlain by a distinctively mappable unit consisting of some 30–40 extensive amphibolite layers at the base of the cover. It is associated with syn-volcanic marine deposits (marble). This sequence then develops into an extensive dolomite-rich shelf sequence with minor mica-schist horizons.

Two main ideas exist on the age of the cover units and the associated eclogites:

The metasedimentary units were thought to be part of the Precambrian Salkhala Formation proposed by Wadia 1931. This interpretation has been incorporated into numerous works since.

Greco et al. (1989) and Papritz and Rey (1989) first made the suggestion that the cover sequence was not Precambrian, but suggested a correlation and comparison between adjacent regions. To the east, for example, the Permian Panjal Traps and overlying Triassic series have a distinct similarity to the Cover units found in Upper Kaghan. Subsequently, numerous lines of evidence link the metamorphosed (eclogite/amphibolite facies) cover to the unmetamorphosed (with up to greenschist facies transition) equivalent (Greco et al., 1989; Papritz and Rey, 1989; Spencer et al., 1991; Spencer, 1993). This is based on field, petrographic, geochemical, stratigraphic, structural, fossil, stable isotope and regional correlations.

Accurate determination of protolith and metamorphic peak ages of mafic rocks is a difficult geochronological task (for a summary, see Gebauer, 1990). This fact is also illustrated with the Upper Kaghan eclogites as Sm-Nd whole-rock data (Spencer, 1993; Spencer et al., 1995) yielded an unpublished errorchron ‘age’ of 337 ± 434 Ma. SHRIMP-dating, especially when combined with cathodoluminescence information of the zircon to be dated, is the most promising technique available today to obtain this required information (e.g., Gebauer et al., 1988; Gebauer, 1990, in press; Schafer et al., 1993; Vavra et al., in press). Thus, zircons from the eclogites of Upper Kaghan (Sample 90/80 used in Tonarini et al., 1993) were analyzed to help solve the problem of the disputed and geochronologically poorly constrained protolith ages of the Higher Himalayan Cover and hopefully get a precise as possible age of high pressure metamorphism. Within the oscillatory-zoned zircon domains that were formed during precipitation of zircon in the mafic protolith, a Permian protolith age of about 269 Ma was found. It is important to note that, based on the size of the magmatic zircons, the protolith was not effusive (basaltic) but intrusive (e.g. gabbroic). This is in accordance with the outcrop locality—a basement feeder (Tonarini et al., 1993; Spencer, 1993); this data confirms a Tethyan affinity and, therefore, the stratigraphic correlations that were first suggested by Greco et al. (1989). Apart from a number of clearly discordant ages, a metamorphic rim age of 44 ± 3 Ma was found, in accordance with the Sm-Nd mineral data of Tonarini et al. (1993) which gave 49 ± 3 Ma. However, due to the smaller error of the

SHRIMP-data, the pressure peak, coinciding closely with the temperature peak, is now better constrained. One spot age giving ca. 470 Ma in a magmatic domain proves the presence of inherited zircon components of very probably early Paleozoic age. This may therefore indicate that the Higher Himalayan Basement can be correlated with the ≈ 500 Ma Lesser Himalayan “Mansehra” Granites of the “Pan-African” event. This contamination is probably one reason for the scattered Sm-Nd WR-data and subsequent errorchron ‘age’.

Implications for the Subduction of Tethys

Not only do these new results provide for a modified extension of the Tethyan Himalaya into Pakistan, they more importantly give geologists a unique metamorphic record of a continental collision. The Panjal Traps, which consist of basalts with interlayered carbonates, can be stratigraphically mapped in Upper Kaghan (Pakistan), where they are found in eclogite, amphibolite-eclogite facies and amphibolite facies, along-strike to their lower grade equivalent (greenschist facies and unmetamorphosed) in the Tethyan Himalaya of Zaskar (India). This complete record of vertical (dominantly depth-controlled) progressive metamorphism for a colliding and subducting continent has been differentially exhumed to its now relatively horizontal position. One stratigraphic unit can therefore be traced in five metamorphic grades to provide a unique record of a colliding continent. Each metamorphic grade will show the effects of the prevalent pressure-temperature conditions and provides a progressive record of the subducting continent on the same stratigraphic protolith.

Implications for the Subdivision Terminology of the NW Himalaya

The arcuate curvature of the Himalayan mountain belt becomes more complex in the northwest (Pakistan and India) and northeast (Tibet and India) syntaxial regions. The northwest Himalayan syntaxial region is dominated by the structural anomalies of the Nanga Parbat, Kaghan, Hazara-Kashmir and Besham syntaxes (Spencer, 1994). Here, the linearity of the Himalayan topography changes in direction from a general northwest-southeast orientation to a more southwest-northeast orientation. The structural reorientations of lithologies that resulted from syntaxial formation give evidence for some of the fastest exhuming metamorphic regions in the world. Subsequently, the interpretations of the tectonic setup to the Himalayas changed from one of relatively simplicity to a complicated terminology with numerous indications suggesting that the Lesser-, Higher- and Tethyan Himalaya terminology should be totally abandoned in these areas. Only recently have both the separation, terminology and definitions of the Lesser- and Higher Himalaya become apparent (Chaudhry et al., 1994; Greco and Spencer, 1993). The new SHRIMP evidence now shows that the Higher Himalaya and Tethyan Himalaya can also be clearly distinguished in the NW Himalayan region. However, the Tethyan Himalaya is clearly modified in this region and, for the sake of consistency and conformity, we suggest that the term “Higher Himalaya” be kept in the Pakistan Region, even though it is now shown that this Higher Himalayan unit act as a basement to its cover of the “Tethyan Himalaya”.

Key words: Permian protolith, Eocene metamorphism, eclogites, Kaghan, Himalaya.

S/491. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1988. Deformation on the Main Mantle Thrust zone at Babusar Pass Karakoram Highway Pakistan. Geological Bulletin, Punjab University 24, 44-60.

The Main Mantle Thrust Zone passes through the Babusar Pass area as a complex zone of, not just one, but three thrust faults that enclose a complex assemblage of two tectonic mélanges. This Indus Suture Mélange Group includes an earlier subduction-related ultramafic mélange and a later metavolcanic mélange. Deformation on the suture zone results in the formation of various structures that give a six phase deformation history, dividing the area into four structural domains. This leads to a four stage tectonic evolution, comprising of a subduction stage, obduction stage, lateral movement stage and a neotectonic stage.

Key words: Deformation, MMT, Babusar, KKH.

S/492. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990a. Structural of the Higher Himalaya, upper Kaghan valley, NW Himalaya, Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 1-2.

The Higher Himalaya of the NW Himalaya is a complex sequence of granites, gneisses, metapelites, marbles, amphibolites, quartzites and in situ ultramafics. It is bound by two major thrusts: the Main Central Thrust (MCT) to the south and the Main Mantle Thrust (MMT) to the north, which have subsequently led to the exposure of some of the deepest level rocks of the Indian plate during collision with the Asian plate. A complex deformational history of pre-, syn-, and post-“Himalayan” age is associated with a pre- to syn- deformational upper amphibolite (kyanite to

sillimanite) facies metamorphism which reached in places over 6500C, as evidenced by in situ migmatization and granitization.

The Higher Himalaya of Kaghan Valley is structurally positioned between three major syntaxes: the Hazara-Kashmir syntaxis (HKS), the Kaghan Syntaxis (KS) and the Nanga Parbat Syntaxis (NPS) which are interpreted as forming due to a change in transport direction. Between the Kaghan Syntaxis and the Nanga Parbat Syntaxis, the Higher Himalaya consists of a polyphase, superposed folded domain which produces the Burawai synform, the Besal antiform and other large-scale features located to the south in Neelum Valley. The fold interference patterns are affected by the extreme ductility of the rocks and caused the rotation of, not only the first fold axis, but also the whole interference structure itself, as seen by the asymmetrical shape of the Besal antiform.

A provisional tectonic analysis of the features observed suggest that the first southwestwards-directed phase of nappe transport led to a thickening of the tectonic pile, and that thickening was followed by a northeast-southwest directed deformation. This is in accordance with movements suggested for the formation of the Hazara-Kashmir and the Kaghan syntaxis and leads to the suggestion of a similar model, with a further increment of anticlockwise transport direction change, for the formation of the Nanga Parbat Syntaxis.

Key words: Structure, Kaghan Valley, Himalaya.

S/493. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990b. Fold interference patterns in the higher Himalayan crystalline unit, upper Kaghan valley, NW Himalaya, Pakistan. Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.58.

The Higher Himalayan Crystalline Unit (HHCU) of the NW Himalaya is complex sequence of granites, gneisses, metapelites, marbles, amphibolites, quartzites and insitu ultramafics. It is bound by two major thrust: the Main Central Thrust (MCT) to the south and the Main Mantle Thrust (MMT) to the north, which have subsequently led to the exposure of some of the deepest level rocks of the Indian plate during its collision with the Asian plate. A complex deformational history of pre-, syn-, and post "Himalayan" age is associated with a pre- to syn-deformational upper amphibolite (kyanite to sillimanite) facies metamorphism which reached in places over 6500C, as evidenced by insitu migmatization and granitization.

The HHCU of Kaghan Valley is structurally positioned between three major syntaxis: the Hazara-Kashmir Syntaxis (HKS), the Kaghan Syntaxis (KS) and the Nanga Parbat Syntaxis (NPS) which are interpreted as forming due to change in transport direction. Between the Kaghan Syntaxis and the Nanga Parbat Syntaxis, the HHCU consists of a polyphase, superposed folded domain which produces the Burawai synform, the Besal antiform and other large-scale features located to the south in Neelum Valley. The fold interference patterns are affected by the extreme ductility of the rocks and caused the rotation of, not only first fold axis, but also the whole interference structure itself, as seen by the asymmetric shape of the Besal antiform.

A provisional tectonic analysis of the features observed suggest that the first southwestward-directed phase of nappe transport led to a thickening of the tectonic pile, and that thickening was followed by a northeast-southwest directed deformation. This is in accordance with movements suggested for the formation of the Hazara-Kashmir and the Kaghan syntaxis and leads to the suggestion of a similar model, with a further increment of anticlockwise transport direction change, for the formation of the Nanga Parbat Syntaxis.

Key words: Structure, HHC, MMT, MCT, Hazara Kashmir syntaxis, Kaghan Valley, Himalaya.

S/494. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990c. Eclogite in the Indian plate of NW Himalaya, Pakistan. Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.76.

Key words: Eclogite, Kaghan Valley, Himalaya.

S/495. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1990d. Structure of the higher Himalaya, upper Kaghan valley, NW Himalaya, Pakistan. Second Pakistan Geological Congress, Peshawar, 2p.

Key words: Structure, Kaghan Valley, Himalaya.

S/496. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1991a. Eclogite in the Indian plate of NW Himalaya, Pakistan. Abstracts of Meeting, European Union of Geologist, Strasbourg.

Key words: Eclogite, Kaghan Valley, Himalaya.

S/497. Spencer, D.A., Ghazanfar, M. & Chaudhry, M.N., 1991b. The higher Himalaya crystalline unit, upper Kaghan valley, NW Himalaya, Pakistan. Geological Bulletin, University of Peshawar 24, 109-125.

Kaghan valley, in north Pakistan, provides an unparalleled cross-section of the Indian Plate in the Himalaya, with all of the tectonic units, structural features and metamorphic grades of the Indian Plate exposed in one valley. The Higher Himalaya Crystalline of the NW Himalaya, which exposed in one valley. The Higher Himalaya Crystalline of the NW Himalaya, which crops out in the upper reaches of the valley, is a complex sequence of granites, gneisses, Calc-pelites, metapelites, marbles, amphibolites, quartzites and eclogites. It is bound by two major thrust: The Main Central Thrust (MCT) to the south and the Main Mantle Thrust (MMT) to the north, which have subsequently led to the exposure of some of the deepest level rocks of the Indian plate during its collision with the Asian plate. A complex deformational history of pre-, syn-, and post- "Himalayan" age is associated with a pre- to syn- deformational upper amphibolite (kyanite to sillimanite) to eclogite facies metamorphism, which reached in places over 6500C, as evidenced by minor insitu granitization.

Key words: Indian plate, tectonics, HHC, Kaghan Valley, Himalaya.

S/498. Spencer, D.A. & Herren, E., 1992. Geochemistry of higher Himalayan leucogranites: Comparison between upper Kaghan, Zaskar, Manaslu and Bhutan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 128.

Late stage leucogranite Intrusions In the Higher Himalaya and Tethyan covers are well known all along the length of the Himalayas, although they are far more prolific in the central parts of the Himalayas than the NW Himalaya. A few exposures of these Intrusions have been recorded in Kaghan In the NW Himalaya. They are of special Interest for Himalayan evolution as they are one of the rare magmatic products of the Himalayan collision zone. Geochemical analysis of leucogranites has been previously carried out by workers at the Swiss Federal Institute of Technology with leucogranites from two other areas (Zaskar and Bhutan) from the Himalayan belt. Similar methods of preparation and measurement have been made on the Kaghan rocks and allows direct comparisons between the major and trace element analysis with a higher degree of certainty. The analysis of the Zaskar leucogranite were carried out by Herren (1987) and of the Bhutan leucogranite by Dietrich and Gansser (1981). Reference is also made the Manaslu Leucogranites (Le Fort et al., 1987).

Analyses are presented in three chemical mineralogical diagrams (Debon and Le Fort, 1983). In a Q-P Diagram, the Manaslu leucogranites center on the adamellite sector; Zaskar leucogranites range from granites to granodiorites, whilst the Kaghan leucogranites range from adamellite to granodiorite. Characteristic mineral (A/B) plots show all samples In the leucocratic field ($B < 38.8$), with the exception of one sample. In the O-B-F diagram, all samples plot In the leucogranites field, with most plotting below the critical quartz-poor field line. Kaghan. Manaslu and Zaskar leucogranites show a negative correlation between Na₂O and K₂O with (Na₂O+K₂O) varying from 8-8.5 for Manaslu, 7.9-8.6 for Zaskar and 7.2-8.9 1 for Kaghan.

Major and trace element spider diagrams for Kaghan and Zaskar were normalised to a Bhutan mean standard deviation. Discrimination Is made for the tourmaline-, garnet-biotite and garnet-varieties in the Zaskar region, but only tourmaline leucogranites are found in the Kaghan region. The Kaghan leucogranites, compared to Bhutan normalizations, are enriched In Ba, Sr, Y, Zr, Ti, Sc and Zn but are depleted In Rb, K, P, Na, K, Pb and Co. The actual values more or less mirror the Zaskar tourmaline leucogranite, except that the Kaghan samples are far more enriched or depleted In the respective minerals with the notable exceptions of Sr, Zr, Ti and Zn. A-F-M plots of the Kaghan leucogranite compared to a typical calc-alkaline differentiation trend, for example in granitoid rocks from the Trans-Himalayan Batholith, are unusual In that they seem to be the only leucogranites that show any differentiation. Selected trace element variation diagrams (Zr, Y, Ba and Rb) with increasing SiO₂ also show a magmatic differentiation trend.

These results show that there is a variation along the Himalaya of the leucogranites in terms of selective major and trace element geochemistry. Previous workers (e.g. Villa, 1988 and Pognante, 1991) have also noted changes in leucogranites in terms of cooling ages (20-19 Ma in the NW Himalayas to 16-14 Ma in the eastern Himalayas) and PT evolution (kyanite $\pm$ sillimanite bearing in the NW Himalayas and cordierite - andalusite bearing in the eastern Himalayas). The main reason for this variation is due to the timing of collision and the state of development of the MCT for the liberation of large quantities of fluid and anatexis melting of the crust. The MCT was mature enough for this process in the central Himalayas, but not in the Kaghan region. Furthermore, PT paths and cooling histories of the Upper Kaghan nappe suggest that the relaxation of the geotherm was very rapid, with a decrease of temperature below the level where anatexis melting is possible. As such, inverse prograde metamorphism below the MCT in Kaghan was probably too fast to liberate large quantities of fluid necessary to produce the melting temperature of this crustal source and therefore only produce a limited number, and rather differentiated suite, of leucogranite. Zeitler and Chamberlain (1991) also notes SHRIMP ion microprobe analysis to obtain U-Pb dates on zircon in leucogranites in Upper Kaghan of about 50 Ma, which would again support the notion of rapid metamorphism and exhumation after collision.

Key words: Geochemistry, leucogranites, Kaghan Valley, Zaskar, Manaslu, Bhutan, Himalaya.

S/499. Spencer, D.A., Hubbard, M.S. & West, D., 1995. The role of the Indus suture in the exhumation of the Nanga Parbat massif (Indian Plate, NW Himalayas). Abstracts, International Symposium on Himalayan Suture Zone of Pakistan. Pakistan Museum of Natural History, Islamabad, 8-9.

Whilst there is no doubt that the initial sense of movement along the Indus Suture has to be a bulk 'top-to-the-south' thrust sense of shear associated with the subduction and underthrusting of the Indian Plate underneath the Kohistan Island Arc it is obvious that, if this sense of movement, continued from the time of collision until the present day a very active type of exhumation process would be needed to explain how the Higher Himalayan Crystalline in the footwall of the suture is exhumed. In the Central Himalaya, the effective means of exhuming the Higher Himalayan Crystallines has been achieved by extensional tectonics (accompanied by erosion), occurring along the boundary that separates the Higher Himalayan Crystalline and the Tethyan Sedimentary Series. In Pakistan, these Tethyan sediments were subducted with the Indian Plate and arc now overlying the Higher Himalaya Crystalline.

Recent fieldwork results from locations along the Suture Zone show that extensional deformation has been, in part, responsible for the exhumation of the Indian plate. However, this clearly varies in timing duration and the amount of exhumation that has occurred and was, in most locations, subsequently overprinted by brittle, top-to-the-south thrust sense of shear. This is interpreted as the end of the extensional tectonics and the welding together of the plates.

Hubbard and Spencer (1990; Geol. Bull. Univ. Peshawar, Vol. 23, pp.101-110) and Hubbard, Spencer and West (1995, Earth and Planetary Science Letters), also investigate the Indus Suture around parts of the Nanga Parbat Syntaxis. Numerous studies have documented the recent uplift of this massif as one of the fastest rising metamorphic terrains in the world. New structural and kinematic analysis of the Nanga Parbat region shows that extensional deformation has been, in part, responsible for the exhumation of the gneissic rocks of the Indian Plate basement complex that dominates the Nanga Parbat Massif. Fieldwork along the Suture Zone and within the Indian plate rocks in the area between Babusar Pass and Toshe Gali, southwest of the peak of Nanga Parbat, provides evidence from shear fabrics and a shallowly-plunging stretching lineation for a dominant phase of extensional deformation that moved rocks of the Kohistan sequence and the Indian Plate Cover sequence to the west-southwest relative to the rocks of the Indian plate basement, including the Nanga Parbat gneissic rocks. This ductile fabric is pervasive at the Suture Zone contact and within the Indian plate cover sequence below the suture, but decreases in the Indian Plate basement rocks and the Nanga Parbat gneisses. The fabric is post metamorphic and, with $^{39}\text{Ar}/^{40}\text{Ar}$ geochronology of hornblendes, the age of pre-deformational, amphibolite facies metamorphism has been constrained to 40-56 Ma. Published cooling ages from the Babusar Pass region further document that the extensional deformation was completed by 20 Ma. This ductile, extensional shear is interpreted as being the mechanism responsible for significant tectonic exhumation of the gneissic and granitic rocks of the Nanga Parbat Massif which may have then been followed by flexural, surface uplift and accompanying erosion which continues to the present.

Key words: Exhumation, Indian Plate, Indus Suture, Himalaya.

S/500. Spencer, D.A. & Mullis, J., 1994. Fluid inclusion analysis in eclogites and associated high pressure rocks, Upper Kaghan, NW Himalaya, Pakistan. *Journal of Nepal Geological Society* 10 (Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu), 135-136.

Fluid inclusions are small quantities of liquid (or glass) and/or vapour trapped in cavities, a “sample” of the fluid phase present in the rock at some time during its evolution. They provide information on one or more intervals in the history of a metamorphic rock between peak temperatures of the metamorphism and arrival of the rock at the surface. The vast majority of fluid inclusions in metamorphic rocks are secondary, the fluids being trapped along fractures of various sizes. Most fluid inclusions in metamorphic rocks originate by devolatilization reactions in the immediately surrounding rock and are in equilibrium with the host mineral assemblage at the time of the formation of the inclusion. Inclusions are most commonly found in quartz due to the fact that it is stable at all metamorphic conditions within the crust. Studies in high-pressure lithologies (such as blueschist and eclogite facies metamorphism) are relatively rare and to date, the maximum-recorded depth of fluid inclusion formation is around 45 km. In general, most densities observed were much lower than inferred peak metamorphic pressure-temperature conditions and the synmetamorphic fluids were not present.

Fluid inclusions were analyzed in Upper Kaghan by the non-destructive microthermometry technique using an optical microscope combined with a heating and freezing stage. In all the samples studied, some primary (?) but mainly secondary fluid inclusions were found. The host minerals of the fluid inclusions were obviously dependent on the rock lithology. Results were obtained for five samples. Sample 89/55.A is a quartz host in quartzite, which shows one population of fluid inclusions and one cluster of inclusions. The single phase system suggests that the inclusion consists essentially of CO₂ and that other gases than may be present (e.g. N₂ or CH₄) are very minor. Sample 89/55.B is a quartz host in quartzite, which shows a population of secondary inclusions consisting of aqueous H₂O rich solutions of intermediate density. Sample 89/56.B.2 also shows another population of inclusions, which are not found in trails, but clusters. The inclusion cluster is a higher density aqueous H₂O rich solution inclusion showing no bubble before heating. After heating the bubble was one of a different size, indicating that stretching and decrepitation had taken place. Sample 89/86 is a quartzite showing secondary inclusions consisting of gaseous CO₂-rich solution of low density. Sample 89/178.A is a garnet host in eclogite, which shows one population of fluid inclusions consisting of gaseous CO₂-rich solution of high density.

Based on the melting and homogenization temperatures, as well as the estimated gas water volumes, the composition of the fluid and the density of the fluid inclusions were determined. Isochores were then calculated using a Redlich-Kwong form for the equation of state, which are modified for the relevant system of H₂O-CO₂-NaCl (89/55.B and 89/156.B), H₂O-CO₂-CH₄ (89/55.B and 89/56.B) and CO₂ (89/55.A and 89/56.B, 89/86 and 90/178.A). From the isochore calculations, the secondary conclusions show that they were all produced in the late stages of metamorphic retrogression, and subsequently can be interpreted as forming as a result of retrogressive reactions that lead to the liberation of H₂O and CO₂.

There are two main phases of fluid inclusions: early and late. The early fluid inclusions are characterized by low fluid pressures whereas the late inclusions are characterised by higher fluid pressures suggesting a younger retrograde fluid evolution event. The relationship between these early and late inclusions is somewhat contradictory to what is normally expected in metamorphic rocks. The maximum densities are commonly assumed to characterize the fluid closest to the peak metamorphism. However, other recordings of the exceptions where there is a density increase for later inclusions (generally related to conditions where the isochores pass above or below the peak metamorphic temperatures and pressures and do not represent a syn-metamorphic fluid phase) are published. Timing relationships also help confirm the observations of the two phases of fluids: the earlier lower density fluid inclusions are cut by the later higher density fluid inclusions. Subsequently, as a result of this renewed activity, the earlier inclusions are evacuated and filled with the later more dense fluid along the same trail. The main evidence that supports this hypothesis is the occurrence of trails of several inclusions in the same direction. An alternative explanation is that the two separate fluid densities reflect a true metastability or that one is a late filling of the other, although no observational evidence for this was found. One of the most obvious questions that result from the observations made on the fluid inclusions is the source of the CO₂ and H₂O. The most likely and accepted source of H₂O in inclusions in deep-seated metamorphic belts is by dehydration and devolatilization. The most reasonable source for the CO₂ is decarbonation, a well-known result of regional metamorphism.

Key words: High pressure rocks, eclogites, fluid inclusions, Kaghan, Himalaya.

S/501. Spencer, D.A., Pognante, U. & Tonarini, S., 1995. Geochemical and Sr-Nd isotopic characterisation of higher Himalayan eclogites (and associated metabasites). *European Journal of Mineralogy* 7, 89-102.

Key words: Geochemistry, isotopes, eclogites, Himalaya.

S/502. Spencer, D.A., Ramsay, J.G., Cervato, C.S., Pognante, U., Chaudhry, M.N. & Ghazanfar, M., 1990. High pressure (eclogite facies) metamorphism in the Indian plate, N.W. Himalaya, Pakistan. *Geological Bulletin, University of Peshawar* 23, 87-100.

A zone of high pressure (eclogite facies) metamorphism, characterized by eclogites with an assemblage of omphacite - garnet - quartz - rutile -+ yhengite, has been recognized in the higher Himalaya in the Indian Plate of NE Pakistan. This suggests that the Upper Kaghan nappe is the deepest derived part of the Indian Plate to have been subducted and subsequently uplifted along the whole length of the Himalaya. Mineral chemistry by microprobe analysis suggests that the eclogites formed at temperatures of 650~50 OC and pressures of 13-18 kbar, suggesting depth of eclogite formation at 60 km. The eclogites show an incipient decompressional re-equilibration which probably occurred at decreasing temperatures.

Key words: Eclogite, high pressure rocks, Indian Plate, Himalaya.

S/503. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991a. A revised stratigraphy for the higher and Tethyan Himalaya in North Pakistan. *Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France*, 81.

Recent investigations into the stratigraphy of the Higher Himalaya in Upper Kaghan valley, north Pakistan has led to a complete revision for the tectono-stratigraphy for this region of the Himalayas. The whole of the region south of the suture was always correlated with Salkhala unit until workers located the Main Central Thrust and divided the area into the Lesser and Higher Himalaya. The later unit was again all classified under one group, the Sharda Group (Ghazanfar et al., 1989), until recently when another reclassification (Greco et al., 1998) was made. Modifications to this are now proposed:

Basement: The oldest pre-Cambrian unit consists of granitoids that have intruded into an even older meta-pelite.

First cover: Unconformably overlying the basement is a lower Paleozoic metagraywacke unit. The unconformity is only recognized on a regional scale with a transgression gently cutting out the underlying granite. Excellent metamorphically-reversed graded bedding is found in the unit showing the original way-up structure. Its composition suggest a turbidite environment.

Second cover: Unconformably above these two units is a Tethyan sedimentary sequence. Recognition of this unit is difficult and controversial, as it was metamorphosed and deformed during the nappe formation to eclogite and amphibole grade, which is not seen in the rest of the Himalaya where they are unmetamorphosed. It unconformably lies over the first cover and then eventually the basement, again showing the transgressive nature of the unit. They begin with the Permian Panjal Traps, which are subaerial basaltic lavas with intercalated limestone, now marble, horizons, before a Triassic sequence of marbles, dolomites and garnet-mica schists.

Himalayan leucogranites: All the units are cut by Himalayan age tourmaline-bearing leucogranites with some minor in situ anatexis found.

The Higher- and Tethyan Himalayan units are bound to the south by the Main Central Thrust mylonites which separate it from the Lesser Himalayan Salkalah Unit and to the north by the Indus Suture Mélange Group which separates it from the Kohistan Island Arc Group. This revised stratigraphy has already been used in the recognition of the controversial Main Central Thrust in the Swat area of the western Himalaya.

Key words: Stratigraphy, Kaghan valley, Himalaya.

S/504. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991a. Penninic style of nappe deformation in the NW Himalaya. *Abstracts, Tectonic Studies Group Meeting, University of Liverpool*, p.67.

Consult the Spencer et al. 1991 for further information.

Key words: Deformation, orogeny, Himalaya.

S/505. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991b. Penninic style of nappe deformation in the NW Himalaya. Abstracts, Swiss Tectonic Studies Group Meeting, p.35.

Consult the Spencer et al. 1991 for further information.

Key words: Deformation, orogeny, Himalaya.

S/506. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1991c. Penninic style of nappe deformation in the NW Himalaya. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 83-84.

The Upper Kaghan nappe of the NW Himalaya is of crucial importance in the understanding of deep seated orogenic processes associated with the Himalayan collision. Bounded by the Main Central Thrust to the south and the Indus Suture to the north, this Higher Himalayan and Tethyan tectonic unit thus represent the deepest exposed part of the Indian plate. Evidence of the deep subduction and subsequent erosion of the tectonic unit is shown by the presence of eclogites- the only eclogites so far recorded in the whole of the Himalayan belt –from which recent analysis suggest formation at temperatures of $650^{\circ}\text{C} \pm 50^{\circ}\text{C}$ and pressures of 14 kbar (Pognante and Spencer, in prep.). The exhumation rate for this unit is very rapid.

Stratigraphically, the basement consists of granites that have intrude into a garnet-mica schist: its first cover (a metagraywacke unit showing excellent metamorphically reversed graded bedding) and a second cover of Permian Panjal Trap volcanics with associated syn-sedimentary marine deposits, which give carbon and oxygen stable isotope ratios of a high temperature, deep marine water environment (Spencer and Spencer-Cervato, in prep.). All units have a very unusual metamorphic history of progressive eclogite facies metamorphism and retrogressive amphibolite facies metamorphism.

The structural evolution of the High Himalayan and Tethyan units in Pakistan show a remarkable similarity to the Pennine style of nappe formation and deformation in the Alps: i.e. complex large scale folding subsequent to nappe emplacement. Previous research suggests that, in general, the large-scale crustal nappes in the NW Himalaya are each internally imbricated and separated from each other by late thrusts.

However, in the Higher Himalaya of Kaghan, where ductile deformation was the main process of deformation, this is certainly not the case, as no internal thrusts or shear zones were recognized. Evidence suggests that polyphase ductile- penetrative overprinting occurred after the original nappe forming movement. This led to the development of a system of major post nappe folds, which deformed a pre-Himalayan history of deformation.

As with the Pennine nappes of the European Alps, the post-nappe folds can be subdivided into two groups: main Himalayan folds and late Himalayan folds. The main Himalayan folds are large, isoclinal and recumbent fold structures, which produce a series of sheets that are associated with a penetrative foliation, which is either a newly formed axial planar schistosity or a rotated and modified earlier foliation on the limbs of folds. The late Himalayan folds, which affect an already developed penetrative foliation and, when present, lineations show a minor crenulation cleavage. They are superimposed on the main Himalayan folds with type 1 or 3 interference patterns giving very large scale domes, which are found in the Hazara-Kashmir, Kaghan and Nanga Parbat syntaxes, as well as basins and domes in the areas between the syntaxes, such as that in Upper Kaghan.

Key words: Deformation, orogeny, Himalaya.

S/507. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1992a. Nappe deformation the NW Himalaya. Abstracts First South Asia Geological Congress, Islamabad, p.65.

Key words: Deformation, orogeny, Himalaya.

S/508. Spencer, D.A., Ramsay, J.G., Ghazanfar, M. & Chaudhry, M.N., 1992b. Stratigraphic boundaries for the higher and Tethyan Himalaya in North Pakistan. Abstracts First South Asia Geological Congress, Islamabad, 64-65.

Key words: Stratigraphy, orogeny, Himalaya.

S/509. Spencer, D.A., Ramsay, J.G., Pognante, U., Ghazanfar, M. & Chaudhry, M.N., 1991a. High pressure (eclogite facies) metamorphism in the Himalayan belt. Abstracts of Meeting, European Union of Geologists, Strasbourg 3, p.88.

Key words: Eclogite, high pressure rocks, Indian Plate, Himalaya.

S/510. Spencer, D.A., Ramsay, J.G., Pognante, U., Ghazanfar, M. & Chaudhry, M.N., 1991b. The significance of eclogites in the Indian plate, NW Himalaya. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 85.

High-pressure assemblages are widespread in the Alpine belt with blueschist and eclogite facies rocks occurring both in ophiolitic and in continental rocks. However, in the Himalayan belt, only blueschist rocks have been recognized in the ophiolites associated with the suture and, to date, true high-pressure assemblages were never recognized in the continental rocks. A new discovery of eclogite facies metamorphism in the Higher- and Tethyan Himalaya of the Indian plate in north Pakistan leads to the suggestion that the Upper Kaghan nappe represents the deepest derived rocks of the Indian shield known.

The medium grained, granoblastic and metamorphically foliated eclogites consist of: sodian augite and omphacites with $X_{\text{Jd}} < 0.42$, almandine garnets ($X_{\text{Alm}} = 0.46-0.60$) with low grossular and pyrope contents. Only slight zoning with almandine and spessartine rims occur and minor simplectic reaction rims are seen, consisting of diopside and albite. Preliminary temperatures estimates, based on the CPX-GRT geothermometer, give $T = 650 \pm 50^\circ\text{C}$, while pressure estimates, based on the stability of the omphacite ($X_{\text{Jd}} < 0.42$) and quartz, give $P > 13-14$ Kbar. These pressure estimates are significantly greater than any other estimates concerning the Higher Himalaya of Indian plate. The eclogite facies assemblage shows an incipient recrystallization producing amphibole, epidote, diopside and albite. This recrystallization registers a decompressional path at decreasing temperatures, which probably reflects high uplift rates. This was achieved initially by thrusting along the Main Central Thrust and then by post-nappe folding, resulting in the doming of the structure to its present elevation.

The significance of this only true high pressure assemblage to be discovered so far in the Indian plate Himalaya raises many questions as to why it only occurs in one particular area (total area approx. 700-km²) of the orogenic belt. A relationship to the Indian plate promontory and the syntaxes of the western Himalaya is suggested which account for some of the most unusual tectonic features of the Himalaya. A comparison is also made to the Central parts of the Himalaya where none of these features are seen.

Key words: Eclogite, ultra-high pressure rocks, Indian Plate, Kaghan, Himalaya.

S/511. Spencer, D.A., Ramsay, J.G., Pognante, U., Ghazanfar, M. & Chaudhry, M.N., 1992. Higher pressure assemblages in the Himalayan collision belt: Significance of Indian plate eclogite. Abstracts, First South Asia Geological Congress, Islamabad, p.65.

Key words: High pressure rocks, eclogites, Indian Plate, Himalaya.

S/512. Spencer, D.A. & Spencer-Cervato, C., 1992a. Stable isotope analysis of Tethyan carbonates in the Higher and Lesser Himalayan, North Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.42.

Key words: Isotopes, Tethyan carbonates, Himalaya.

S/513. Spencer, D.A. & Spencer-Cervato, C., 1992b. Exhumation and cooling history of eclogite and amphibolite facies rocks in the Upper Kaghan Nappe. NW Himalaya. Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 85.

The Upper Kaghan Nappe in the NW Himalayas appears to have gone through a tectonic history that involved differential subduction and differential exhumation. The nappe does not show constant metamorphic, deformational, cooling or exhumation histories, but rather a gradual gradient between the structurally deeper Inner core and the more outer shallower sheet structures. This has been described as a 'Penninic style of nappe deformation'. A traverse, from southwest (Type area: Safu Maluk) to northeast (Type area: Besal) across the nappe, most strikingly shows these differences in the metamorphic grade: from amphibolite facies in the southwest to lithologies that contain a high pressure eclogite facies mineral assemblage of omphacite - almandine garnet - quartz - rutile at Besal (formation at $650 \pm 500^\circ\text{C}$ at 15 kbar). Detailed structural mapping has shown that there are no tectonic imbrications of any type, as documented in the nappes to the west of Upper Kaghan (e.g. Besham, Hazara). Furthermore, the deformation is pre- to syn-metamorphic in the Besal area and syn-metamorphic in the Safu Maluk area. Pressure-temperature paths show a characteristic anticlockwise rotation, as expected for continental collision belts.

Further insights into the cooling history of the Upper Kaghan Nappe can be made with multisystem radiometric dating. Ten different systems have been used on lithologies from the Upper Kaghan Nappe (Sm/Nd - garnet and clinopyroxene; U/Pb - rutile; Rb/Sr - phengite, garnet and clinopyroxene; Rb/Sr - biotite; K/Ar - hornblende; K/Ar - muscovite; K/Ar - biotite; Ar/Ar - muscovite; Fission Track - zircon and Fission Track - apatite). These ages have been obtained by Tonarini et al. (Submitted), Zeitler (1985) and Treloar et al. (1989). The ages suggest that the cooling history varies with locality with cooling rates differing between the two type areas, although the trends are similar. The eclogite nappe core initially cools rapidly at $19.30^\circ\text{C Ma}^{-1}$ for 15 Ma until 35 Ma; it then slows to $7.20^\circ\text{C Ma}^{-1}$ for 33 Ma until 2 Ma and then rapidly cools again at $600^\circ\text{C Ma}^{-1}$ in the last 2 Ma. A similar trend (i.e. rapid - slow - rapid), but with different rates, is found for the amphibolite path (outer sheet at Safu Maluk). This sheet initially cools rapidly at $400^\circ\text{C Ma}^{-1}$ for 7 Ma until 33 Ma; it then slows to $7.50^\circ\text{C Ma}^{-1}$ for 36 Ma until 4 Ma; and then rapidly cools at $250^\circ\text{C Ma}^{-1}$ in the last 4 Ma. It is difficult to envisage such a cooling history, where the eclogite and amphibolite cooling paths cross each other during their exhumation in any other environment other than a nappe. In comparison, cooling paths of the adjacent regions of Besham and Nanga Parbat, are very different. Nanga Parbat shows progressively increasing cooling rates from 20 Ma onwards to present, whilst the Besham area shows the complete reverse of the Upper Kaghan area (slow - rapid - slow) in a much shorter time span. The cooling history is also significantly different from the East Central Kohistan Island Arc, with the notable exception of the last 15-17 Ma, where a time averaged cooling was simultaneously $110^\circ\text{C Ma}^{-1}$.

Exhumation rates can be obtained from depth-time averages. Maximum pressure estimates of the eclogite path give 15-16 kbar, which equates to depths of formation at 60 km with peak metamorphism at 49.7 Ma. The average exhumation rate is therefore 1.2-1.3 mm/yr. Maximum pressure estimates for the amphibolite path give 8-9 kbar which equate to depths of formation at 30-35 km with peak metamorphism around 40 Ma. The exhumation rate is therefore 0.7-0.9 mm/yr. These rates provide supportive evidence for the exhumation model of fold superposition, which predicts that exhumation rates cannot be constant (higher relative uplift by folding in the core of the nappe produces greater relative erosion rates). Searle (1991) calculated the exhumation rates for Nanga Parbat (1 mm/yr.) and for the Sum region (1.4-2.1 mm/yr.). These exhumation rates are comparable for the NW Himalaya, but bring rocks in the core of the Upper Kaghan nappe to the present surface from depths of almost double those exposed in Nanga Parbat. This is simply due to the timing of peak metamorphism and the depths from which they originated. The Upper Kaghan Nappe was the first part of the Indian Plate to collide in Eocene times: it was the deepest part of the Indian plate to subduct and began its exhumation long before the 'Main' Central Himalayan Collision. This could only have been due to a promontory on the Indian plate that had a major influence on the deformational history of the NW Himalaya.

Key words: Exhumation, cooling history, eclogite, amphibolite facies, Kaghan Nappe, Himalaya.

S/514. Spengler, W.H., 1985. The Katlang pink topaz mine, North West Frontier Province, Pakistan. *Journal of Gemmology* 19, 664-671.

This is a description of the location, mining, and other information of the unique pink topaz of Mardan. Some properties of gemstones are given along with 12 photographs of the area and the gemstone.

Key words: Gemology, topaz, Mardan.

S/515. Staley, J.F., 1963. Hunza-Nagar and the Minapin Glacier. *Explorers Journal* 41, 12-18.

Key words: Glaciers, Minapin, Hunza.

S/516. Stanin, S.A., 1966. Laterite and other aluminous deposits of West Pakistan. US Geological Survey/Geological Survey of Pakistan, Information Release, PK-11, 25p.

Laterite and other aluminous deposits in West Pakistan are briefly described, and their locations are shown on accompanying base sheets of West Pakistan, scale 1:2,000,000. Localities in Muzaffarabad, kotli tehsil, and Sangar Marg, Azad Kashmir, and in the margalla Hills, Rawalpindi District, may contain bauxite that could be mines profitably. These deposits may extend into the Garhi Habibullah area of Hazara district. The laterite rocks near surg and Campbellpore, Attock District, might be valuable for alumina production. The laterite in the Ziarat area, Sibi and Loralai districts, are rich in Fe₂O₃; these deposits may contain iron resources. Small production of laterite for several year at one locality in Loralai District furnished material for the manufacture of cement.

Detailed stratigraphic, structural, lithologic, mineralogic and economic studies are required to evaluate the resources and potential of these and other deposits in West Pakistan and to appreciate their value as raw materials for aluminum, abrasive, refractory, chemical and other industrial uses.

Key words: Minerals, laterite, West Pakistan.

S/517. Stanin, S.A. & Hasan, M.S., 1966. Reconnaissance for phosphate in West Pakistan. Geological Survey of Pakistan, Information Release 32, 7-11.

Low-grade phosphatic nodules have been found in (1) the lower argillaceous sections of the Jakkher group in the Pab Range; (2) strata of the Mughal Kot formation, Drazinda Shale Member, Domanda Shale Member, and the lowermost beds of the Ghazij Shale in the Sulaiman Range; (3) the Patala Formation and the basal shale member of the Chhidru Formation in the Salt Range; and (4) the basal glauconitic beds of the Chichali Formation in the Kohat Range. The phosphatic nodules seem to be original constituents of the containing rocks. X-Ray diffraction data show that the phosphate in nodules from the Chichali Formation derives from apatite. The Habib Rahi limestone member along the eastern flank of the Sulaiman Range contains beds of slightly phosphatized, dark-coloured, cherty limestone that suggests these rocks may have been deposited under upwelling marine conditions. None of the formations in the areas investigated seem to contain sufficient reserves to be of economic importance. Encouraging indications, however, of phosphate in the Habib Rahi limestone member, Ghazij Shale, and Chichali Formation warrant detailed investigations of these formations in adjacent areas.

Key words: Reconnaissance, phosphates.

S/518. Stauffer, K.W., 1963. Reconnaissance map of the Khyber Pass, West Pakistan. GSP

Consult Stauffer (1968b) for further information.

Key words: Reconnaissance, mapping, Khyber pass.

S/519. Stauffer, K.W., 1964a. Geology of the Gilgit Hispar area, Gilgit Agency, Pakistan. U.S. Geological Survey, PK-19, 41p.

Key words: Mapping, geology, Gilgit.

S/520. Stauffer, K.W., 1964b. Stratigraphy of Northwestern Pakistan and Northwestern Kashmir. 22nd International Congress, New Delhi, Proceedings, 8, 99-111.

Key words: Stratigraphy, Kashmir.

S/521. Stauffer, K.W., 1967. Devonian of India and Pakistan. In: Oswald, D.H. (ed.), Proceedings, International Symposium on Devonian System. Alberta Petrological Society, Calgary, 1, 545-556.

Key words: Palaeontology, Devonian, stratigraphy, India, Pakistan.

S/522. Stauffer, K.W., 1968a. Silurian-Devonian reef complex near Nowshera, West Pakistan. Bulletin of the Geological Survey of America 79, 1331-1350.

The first Paleozoic reef belt on the Indo-Pakistan subcontinent has recently been recognized near the town of Nowshera (lat 34°00' N., long 72°00' E.) in northern West Pakistan. It consists of nine separate hills aligned in a 15-mile-long, east-west band rising out of the Peshawar alluvial plain. Each hill is composed of one or more reef cores whose thicknesses range from less than 100 feet to more than 700 feet. The reef cores are separated by relatively unfossiliferous carbonate rocks thinner than the reefs.

The reef belt contains a fauna entirely new to Pakistan that has been dated as Early Devonian to Late Silurian (Ludlovian to Gedinnian). The reef carbonates are the first sediments of possible Silurian age found anywhere in the country and the southernmost Devonian deposits in West Pakistan. Individual reef cores consist of faunal zones or layers that indicate a gradual growth of the reef mass from relatively quiet water upward into rough water.

The presence of these reefs and correlative fossiliferous carbonate sediments in the Peshawar area suggests that in Silurian and Devonian times much of northern West Pakistan was covered by warm, shallow seas bordered by reefs or containing reef platforms. The association of these Paleozoic reefs with extensive deposits of fetid black limestones and porous dolomites may indicate economic potential for the accumulation of oil.

Key words: Palaeontology, Devonian, stratigraphy, reef complex, Nowshera.

S/523. Stauffer, K.W., 1968b. Geology of Khyber Pass, Khyber Agency, West Pakistan. US Geological Survey/Geological Survey of Pakistan, Information Release, PK-22, 42p.

The defile of the Khyber Pass is cut in massive gray recrystallized Limestone whose thickness exceeds 3000 feet. Although no fossils have been found in the immediate vicinity of the pass, assemblages collected at the end of the last century from 5 miles south of the pass, and recently collected fossils from Afghanistan suggest strongly that the limestone is Carboniferous to Permian and perhaps Jurassic in age. The basal contact of Khyber Limestone in places appears to be conformable upon the quartzites and tuffs of Ali Masjid Formation; elsewhere it is probably an unconformity or a fault, especially where the limestone lies directly on the Ordovician to Carboniferous Landi Kotal Slates. The Ali Masjid Formation overlies the shagai Limestone, which, in turn, rests in fault contact on the Landi Kotal slates. A sodic granite intrusion 10 miles northeast of the Khyber Pass on the Kabul River has altered nearby parts of the Khyber Limestone to a fine-quality marble that is today the only mineral resource of commercial importance in the Khyber area.

Structurally the area is characterized by at least four major, roughly east-west trending thrust or reverse fault, along which relatively older rocks have moved southward over younger rocks. A north-northeast-trending system of alternating anticlines and synclines has been superimposed on the earlier structures. Elevated terraces and alluvial valleys suggest a very recent uplift of about 600 to 1000 feet.

Key words: Stratigraphy, structure, Khyber pass, NWFP.

S/524. Stauffer, K.W., 1968c. Heavy minerals in the stream sands of the southern Hazara, West Pakistan. Geological Survey of Pakistan, and U.S. Geological Survey, Information Release, PK – 18, 42p.

The real distribution of heavy minerals in 99 samples from stream sands in the southern Hazara District, West Pakistan, indicate that the metamorphic grade of the rocks in the area increase towards the northwest. Minerals of potential economic value in the heavy-mineral samples include scheelite from the Oghi-Batgram-Battal area and hematite from the Galdanian area. The total weight of magnetite sand grains transported down the Indus Rive past

Darband is calculated to be about 200,000 tons per year, a quantity which may be of economic value. Radioactive minerals are not present in any of the samples in sufficient quantity to be of economic importance.

Key words: Heavy minerals, panning, stream sand, Hazara.

S/525. Stauffer, K.W., 1968d. Geology of the Gilgit-Hispar area, Gilgit Agency, West Pakistan. United States Geological Survey, Information Release PK-10, 42p.

This is an account of the geology of the lower Hunza river valley. The transect from Gilgit to Matum Das is occupied by granitic rocks (now called the Kohistan Batholith). Further north is a wide terrain of pillowed volcanic rocks stretching up to Chalt. Then on is a mixture of low grade pelitic to calcareous metasedimentary rocks and some talcosic rocks. Onward of Hini is a sequence of higher grade metasedimentary rocks followed by granitic rocks of the Karakoram Batholith. In the present day terminology the rocks between Chalt and Hini are considered to be Suture zone mélangé, whereas those to the north are put in the Karakoram plate.

Key words: Geology, Hispar, Gilgit

S/526. Stauffer, K.W., 1969. Devonian laterite in Chitral State, West Pakistan. Economic Geology 64, 252-254.

A Devonian laterite has recently been discovered near Reshun in the Mastuj valley of Chitral State, West Pakistan. It is believed to be the fourth recorded Paleozoic laterite in the world. The laterite is entirely within a thick carbonate of the Shogram Formation of Upper Devonian (Frasnian) age. A chemical analysis of the laterite shows the principal constituents to be: Al_2O_3 35.5%, SiO_2 21.7% Fe_2O_3 16.0%, FeO 10.3%, TiO_2 3.5% CaO 0.97%, and MgO 0.70%. Minerals determined by X-ray analysis include hematite, boehmite, diaspore, anatase, rutile, kaolinite, pyrophyllite and what is probably chamosite.

Key words: Metallic minerals, laterite, Chitral.

S/527. Stauffer, K.W., 1971. Geology of the Reshun area, Chitral State, West Pakistan. U.S. Geological Survey, Information Release, PK-24, 44p.

Key words: Maps, geology, Chitral.

S/528. Stauffer, K.W., 1975. Reconnaissance geology of the central Mastuj valley, Chitral State, West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-24, 51p.

The Mastuj Valley in Chitral state is a part of the Hindu Kush Range, and is one of the structurally most complicated areas in northern Pakistan. Sedimentary rocks ranging from at least Middle Devonian to Cretaceous, and perhaps Early Tertiary age lie between ridge-forming granodiorite intrusion and are cut by thrust faults. The thrust planes dip 10 to 40 degrees to the northwest. Movement of upper thrust plates has been towards the southeast relative to lower blocks.

If this area is structurally typical of the Hindu-Kush and Karakoram ranges, then these mountains are much more tectonically disturbed than previously recorded, and suggest compression on a scale compatible with the hypothesis that the Himalaya, Karakoram, and HinduKush Ranges form part of a continental collision zone.

The thrust faults outline two plates consisting of distinctive sedimentary rocks. The lower thrust plate is about 3000 feet thick and consist of the isoclinally folded Upper Cretaceous to perhaps Lower Tertiary Reshun Formation. It has overridden the Paleozoic metasedimentary rocks of the Chitral Slate unit. This thrust plate is, in turn, overridden by an 8000 foot thick sequence containing largely of Devonian to Carboniferous limestones and quartzite.

Key words: Maps, reconnaissance geology, Mastuj, Chitral.

S/529. Stauffer, K.W. & Calkins, J.A., 1966. Heavy mineral prospecting. US Geological Survey/Geological Survey of Pakistan, (IR) Pk-16, 35p.

Heavy mineral prospecting is a method of tracing potential ore minerals to their source by systematically examining the heavy minerals of stream sand. The heavy minerals are partially concentrated in the field by panning. In the laboratory the heavy minerals are further concentrated by floating off the quartz and feldspar in a heavy liquid, such as boroform, having a specific gravity of 2.89. Magnetite is separated magnetically and scheelite is identified under short-wave ultraviolet light. To obtain quantitative results on the minerals present, the sample is reduced by coning and quartering, mounting on a slide in oil, and a count of a minimum of 250 grains made. The chi-square test applied to the splitting and counting techniques shows them to be statistically valid. The properties of some heavy minerals most useful for their rapid identification is listed. Methods here described are those utilizing a minimum of field and laboratory equipment and may be appropriate for application in many areas of the world.

Key words: Prospecting, heavy minerals.

S/530. Stefanini, G., 1917a. Echinidi Mesozoici del Caracorum raccolti dalla Spedizione Italiana nell'Asia Centrale (1913-1914). *Rendiconti della Reale Accademia Nazionale dei Lincei, Series 2*(26), 49-50.

Key words: Italian expedition, palaeontology, Mesozoic echinide, Karakoram.

S/531. Stefanini, G., 1917b. Su l'esistenza de depositi cenomaniani e di altri livelli mesozoici nel Caracorum (Asia Centrale). *Rendiconti della Reale Accademia Nazionale dei Lincei, Series 2*(26), 190-195.

Key words: Italian expedition, Mesozoic, Karakoram.

S/532. Stefanini, G., 1928a. Echinidi mesozoici del Caracorum. In: *Relazioni Scientifiche della Spedizione Italiana de Filippi nell'Himalaia, Caracorum e Turkestan, Cinese (1913-1914)*, Series 2(6), 41-100. Zanichelli, Bologna.

Key words: Italian expedition, Mesozoic echinide, Karakoram.

S/533. Stefanini, G., 1928b. Moluschi e Brachiopodi calloviani del Caracorum. *Relat. Scient. Spediz. De Filippi etc.*, II, 6, 41-100.

Key words: Palaeontology, molluscs, brachiopods, Karakoram.

S/534. Stellrecht, I., 1992a. Environmental perception and vertical classification in Hunza valley (North Pakistan). In: Shams, F.A. (ed.), *Culture Area Karakorum Research Project in the Northern Areas, Pakistan. Proceedings of the Pak-German joint Workshop, December 1991, Lahore*, 104-116.

Key words: Environment, Hunza valley, Karakoram.

S/535. Stellrecht, I., 1992b. Perception of environment in a high mountain area: Vertical classification in the Karakorum (Hunza valley/Pakistan). Abstracts, International Symposium on the Karakorum and Kunlung Mountains, June 5-9, 1992, Kashi.

Key words: Environment, classification, Hunza valley, Karakoram.

S/536. Stellrecht, I., 1992.c Umweltwahrnehmung und vertikale klassifikation im Hunza-Tal (Karakorum). *Geographische Rundschau* 44, 426-434.

Key words: Environment, classification, Hunza valley, Karakoram.

S/537. Stern, L.A., Johnson, G.D. & Chamberlain, C.P., 1993. Carbon isotope signature of environmental change found in fossil ratite eggshells from a South Asian Neogene sequence. *Geology*, 22, 419-422.

A > 10-my.-long sequence of ratite (e.g., ostrich) eggshells from Siwalik Group sedimentary deposits of northern Pakistan and India shows a dramatic (~8‰) increase in the $\delta^{13}\text{C}$ in biomineralogic calcite by ~4 Ma. Values of $\delta^{13}\text{C}$ from ratite eggshell carbonate older than 7 Ma are about the same as those from carbonate from contemporaneous fossil mammal tooth enamel and paleosols. However, after 4 Ma, the ratite eggshell carbonate $\delta^{13}\text{C}$ values are ~5‰ less than these coexisting materials. These findings are evidence of the development of a C3-C4 vegetative mosaic probably mirroring the sedimentologic-edaphic mosaic of the aggrading alluvial plain of the Siwalik depositional system.

Key words: Carbon isotope, neogene sequence, Siwaliks, northern Pakistan.

S/538. Stewart, A.G., 1990. For debate: Drifting continents and endemic goiter in northern Pakistan. *British Medical Journal* 300, 1507-1512.

Although Baltistan, north East Pakistan, is in a region of iodine deficiency disorders, the distribution of goiter within the district, according to age and sex, has not been clearly defined. To establish the prevalence of the condition and to measure the reported difference in prevalence in the north and south of the district thyroid size was assessed in new patients attending the Aman clinic, Khapalu, and outlying areas between April and September from 1981-1986. Samples of potable water collected from villages were analysed for iodine (as iodide) concentrations in Britain. Population weighted prevalences were: in the north in males 28.1% and in the south in males 13.9%, in females 21.2%. There was an overall deficiency of iodine in the water (mean iodine (as iodide) concentrations (north) 11.0 nmol/l (1.4 µg/l), (south) 11.8 nmol/l (1.5 µg/l) (95% confidence interval -0.7 to 0.9). The differences followed the Main Karakoram Thrust, suggesting a geological goitrogen in the north, which might be minerals containing ions such as BF_4 and SO_3F , and molybdenite and calcium which are present in rock in Baltistan.

A new hypothesis for the genesis of endemic goiter is proposed—that is, that continents on crustal plates drift across the earth and collide, one plate sliding under the other and melting, giving rise to characteristic mineral assemblages in the overlying rocks. As the minerals weather out they enter the diet of the local population, where in the presence of iodine deficiency they produce or enhance iodine deficiency disorders. Despite the current iodised oil campaign by the Pakistani government with UNICEF a long term working iodisation programme is still urgently needed.

Key words: Medical geology, goiter, iodine deficiency, MKT, Baltistan.

S/539. Stewart, J.L., 1860. Notes on the geology of the Wazereer Country. *Journal of the Asiatic Society of Bengal* 29, 314-318.

Key words: Geology, Waziristan.

S/540. Stuart, M., 1919a. Suggestions regarding the origin and history of the rock salt deposit of the Punjab and Kohat. *Geological Survey of India, Records*, 51 (1), 57-97, pls 9-25.

Key words: Rock salt deposits, Punjab, Kohat.

S/541. Stuart, M., 1919b. The potash salts of the Punjab Salt Range and Kohat. *Geological Survey of India, Records* 50(1), 28-56.

Key words: Potash salt, Punjab, Kohat.

S/542. Stuart, M., 1919c. Natural gas bituminous salt from Kohat. Geological Survey of India, Records 50(4), 263-267.

Key words: Natural gas, Kohat, India.

S/543. Stuart, M., 1922. The geology of the Takki Zam valley, and the Kaniguram-Makin area. Waziristan. Geological Survey of India, Records 54(1), 87-102.

Key words: Geology, Waziristan.

S/544. Stump, E. & Sorkhabi, R.B., 1993. Syntaxial tectonics at Nanga Parbat and Denali. Abstracts with Program, Annual Meeting of the Geological Society of America, p.A-123.

NangaParbat (NP) and Denali (Mt McKinley), two of the loftiest and most rapidly exhuming massifs on earth occur at syntaxies of major fault systems from FT analysis. The average rate of exhumation for Denali is more than 1 mm/yr for the last 6 my; for NP exhumation has increased for the past 7 ma from 0.5 mm/yr to over 7 mm/yr. the differences in tectonic settings of the two areas include: 1. NP sits at the corner of two obliquely opposed thrust systems; denali occurs at the apex of and orcuate right-lateral strike – slip fault, 2. In map view, NP is a tightly appressed structure; Denali is open, 3. NP results from continent-continent collision; Denali occurs in a continental margin orogenic belt, 4. The current pulse of exhumation of NP follows a long history of uplift of the Himalaya (at least 20 ma), whereas that of Denali had no precursors prior to 6 ma.

The tectonic feature of that both denali and NP share is that they have formed in large-scale plan view, convergent stress systems.

Key words: Tectonics, Nanga Parbat, Himalaya.

S/545. Su, Z., Zhang, X. & Gu, Z., 1980. The thickness and the quality of ice of the Batura Glacier. In: Shi, F. (ed.), Professional Papers on the Batura Glacier in the Karakoram Mountains. Science Press, Beijing.

Key words: Glaciers, geomorphology, Batura.

S/546. Sulaiman, M. & Iqbal, S., 1972. Geology of the northern part of Jandul, District Dir, N.W.F.P., M.Sc. Thesis, University of Peshawar, 51p.

The northern part of the Jandul valley is underlain by the Palaeozoic rocks of the amphibolite facies. These metamorphic rocks were intruded by the igneous rocks in the Mesozoic times. The early phase of intrusive activity is represented fey diorites, granodiorites, granite and apparently later phase by morite. During the Tertiary period these intrusives were followed by the volcanic rocks of andesitic and dacitic composition. The volcanic rocks also include porphyritic volcanic dykes which are abundant in both palaeozoic and Mesosoic rocks. The porphyritic rocks have suffered a low grade metamorphism. This phase was followed by a granite intrusion. Quartz and pegmatitic veins represent the last phase of igneous activity.

Structurally the area is very complex. Shearing and local folding is very prominent. Repeated tectonic activities seem to have occurred in the area as is evident from deformation. Copper mineralization and vein quartz, which occur in the area, are not of any economic value at present.

Key words: Structure, metamorphic rocks, igneous rocks, Jandul, Dir

S/547. Sullivan, M., 1990. The roof zone of the Kohistan batholith, Pakistan. In Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 59.

The final stages in the evolution of the Kohistan terrane are represented by the eruption of volcanic material onto a continental margin, formed after the Cretaceous collision of Kohistan with the Asian plate.

Recent fieldwork during 1988-1989 has shown that the sub-volcanic basement lithologies of this area include meta-pelitic schists and metaquartzites of the Kamila amphibolite belt, which were intruded into by Cretaceous hornblende-biotite-pyroxene diorite and granodiorites.

Uplift and erosion of this basement preceded volcanism, with the development of a basal unconformity in the tuffaceous material, stretching from Swat westwards into Dir. Volcanism was predominantly explosive with the development of between 700m-1000m of reworked ash and agglomerate/breccia. Lavas are more restricted (200m-500m) and these range in composition from andesite to rhyolite, often ignimbritic. These volcanics are dated as Paleocene/Lower Eocene by foraminifera assemblages (*Discocyclina*, *Elphidium* and *Ranikothalia bermudezi*).

The volcanic pile was then intruded by later Paleocene/Middle Eocene calc-alkaline diorites, granodiorites and granites, with associated pegmatites. Finally, southeastward directed thrusts imbricated the roof zone and provided pathways for copper-rich fluids to develop strata-bound mineralization in the Dir area.

Key words: Tectonic evolution, volcanic, erosion, Kohistan batholith, Himalaya.

S/548. Sullivan, M.A., 1991. Continental margin volcanism along the leading edge of Eurasia: the Dir Volcanics. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Grenoble, France, 91.

In northwestern Pakistan (Kohistan) volcanic rocks associated with the northward subduction of Indian oceanic crust beneath Eurasia record two discrete episodes of activity:

1/Early tholeiitic and calc-alkaline basalts, andesites and rhyodacites, which make up part of the Kohistan, island-arc (early Cretaceous Chalt Volcanics).

2/ Later silicic lavas and tuffs (Dir Volcanics dated 55 Ma 40Ar-39Ar) which erupted subsequent to the accretion of the Kohistan arc onto Eurasia, but prior to the collision of India.

Mineralogical and geochemical characteristics indicate that as a whole the Dir volcanics belong to an calc-alkaline continental margin series. They are L.I.L.E. enriched, depleted in H.F.S.E. (i.e. Nb) and show L.R.E.E. enrichment. The majority of material is rhyolitic in composition with few basalts. Such substantial amounts of silicic volcanism imply the existence of extensional tectonics. Limestone clasts in conglomerate at the base of the Dir Volcanics are dated at 58 Ma, and record a period of marine incursion onto the margin of Eurasia. Attenuation of the continental lithosphere may have resulted in the development of small marginal seas, in contact with the ocean, which later were subject to uplift and erosion at the onset of volcanism at 55 Ma.

Along the northern margin of Kohistan the Shamran Volcanics have yielded a radiometric age of 54 Ma (40Ar-39Ar). This implies that rather than being associated with the Chalt Volcanics they are more likely contemporaneous with the later Dir Volcanics. They have similar geochemical characteristics and indicate that the extent of continental margin volcanics in Kohistan is greater than was first thought, recording perhaps the migration of the magmatic-arc with time.

Key words: Volcanism, tectonics, Eurasia margin, Dir-

S/549. Sullivan, M.A., 1992. A palaeogeographic reconstruction of the Dir group: Evidence for magmatic arc migration in the N.W. Himalayas. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 89.

The Dir Group records the resumption of volcanic activity along the southern margin of Eurasia after a prolonged period of uplift and erosion. Two contrasting depositional environments are identified; a distal deep-water marine fore-arc (Baraul Banda Slate Formation) and a proximal subaerial volcanic core facies (Utror Volcanic Fm. and Shamran Volcanics). Eruptive style was predominantly explosive, with poorly sorted polymict volcanic breccias and sandstones testifying to the importance of epiclastic processes. Sedimentary thicknesses and the abundance of rhyolite lavas and pyroclastic flows indicates extensional tectonic control (hinge roll-back) even though the arc developed at a convergent margin. Fore-arc sediments show provenance from a dissected arc source implying either blockage of volcanogenic detritus due to coastal topography or by-passing by submarine canyons. Juxtaposition of the two different facies along the Dir Thrust excludes any record of shoreline or coastal processes from the volcanic stratigraphy. The inferred original geographical separation of the two environments (50-100 km), coupled with their individual relationships to dated plutons reveals that between Upper Cretaceous (ca. 78 Ma) and early Eocene (ca. 48 Ma) times the locus of magmatic activity within the Kohistan-arc migrated northward. Furthermore this

palaeogeographic reconstruction also implies that considerable shortening has taken place within the Kohistan Terrane subsequent to the closure of Tethys.

Key words: Palaeogeography, magmatic arc, sedimentology, volcanics, Dir group, Kohistan.

S/550. Sullivan, M.A., 1993. The geology of the roof zone of the Kohistan batholith, northwestern Pakistan. Ph.D dissertation, University of Leicester.

Key words: Geology, tectonics, structure, Kohistan batholith, Himalaya.

S/551. Sullivan, M.A., Saunders, A.D. & Windley, B.F., 1996. The petrology and geochemistry of the Utror and Shamran volcanic Formations, Kohistan, NW Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 155.

The Utror and Shamran Volcanic Formations represent the extrusive parts of the Dir Group, and are remnants of an elongate, dominantly subaerial volcanic arc that was active along the southern edge of Eurasia during the subduction of the Indian plate. They were erupted between ca. 55 Ma and 48 Ma, above an erosion surface cut deep into the Kohistan Batholith, during a brief period of caldera activity prior to continent-continent collision. They are broadly contemporaneous with the Dras II and Khardung Volcanic sequences of Ladakh and the Lingzizong Volcanics of Tibet.

Fragmental material dominates the volcanic record, and pyroclastic flows and ignimbrites testify to a highly explosive eruptive style. Coherent lava flows consist of a variably-altered suite of tholeiitic and calc-alkaline lavas, that range in composition from basalt to high-silica rhyolite. All lavas are holocrystalline, although there is textural evidence for the existence of originally glassy rhyolite. All lavas are holocrystalline, although there is textural evidence for the existence of originally glassy rhyolite flows. Lavas are strongly porphyritic throughout the compositional spectrum, containing between 5% and 45% (volume) of phenocrysts.

Secondary alteration effects, such as devitrification, polyphase hydrothermal alteration, and metamorphism influence the petrology of both lava suites. Augite, hornblende, titanomagnetite, and Ca-rich plagioclase dominate in the more basic compositions. Ferromagnesian minerals have Mg-rich compositions, with no tendency to show Fe enrichment, indicating that conditions were sufficiently oxidizing to prevent a tholeiitic evolutionary trend. Hornblende and pyroxene phenocrysts rarely coexist and probably reflect varying water contents of the magmas. Dacites and rhyolites are dominated by quartz and plagioclase feldspar. No primary ferromagnesian phases are observed and there is a notable absence of orthoclase feldspar. Textural evidence suggest that many of the rhyolites were originally obsidian with phenocryst contents indicating high viscosities.

Plagioclase, hornblende, clinopyroxene and titanomagnetite controlled early mineral fractionation with fO₂ fluctuations resulting in two identifiable trends. LILE are enriched relative to HFSE (Ba/Nb=4.7-101) and LREE relative to HREE (Ce/Ybn=2.3-9.9). Unlike typical orogenic arcs, which are dominated by andesite/dacite volcanic rocks, much of what remains of the Utror and Shamran Volcanic fields consist of a bimodal suite of andesite and rhyolite lavas and ash-flow tuffs. Crustal anatexis although favored by volume considerations does not agree with observed fractionation trends and thin-section evidence. Unfortunately considerable petrological variability exists even within a restricted geographical location, and this, coupled with an intense and varied alteration state, make detailed petrogenetic modeling inappropriate. Much of the variability that does exist appears related to initial source characteristics, magma ascent paths, fluctuating oxidation conditions and fractionation crystallization processes. Geochemical characteristics confirm existing isotopic data indicating that the Shamran Volcanics are contemporaneous with the continental margin suite of rocks (Dir Group) rather than with the earlier Chalt Volcanic island-arc suite.

Key words: Petrology, geochemistry, Utror, Shamran, Kohistan, Himalaya.

S/552. Sullivan, M.A., Windley, N.F., Saunders, A.D., Haynes, J.R. & Rex, D.C., 1993. A paleogeographic reconstruction of the Dir group: Pakistan. In: Treloar, P.J. and Searle, M.P. (Eds), Himalayan Tectonics. Geological Society of London, Special Publication 74, 139-160.

The Late Palaeocene Dir Group records the resumption of volcanic activity along the southern margin of Eurasia after a prolonged period of uplift and erosion. The group forms an integral part of the Kohistan Batholith and is readily divisible into two distinctly contrasting volcanic successions.

The Baraul Banda Slate Formation comprises 2700 m of fore-arc sandstones and siltstones. The basin formed during the collapse of the Kohistan continental margin and was filled initially by subaerial debris and mass-flow deposits. Subsidence was rapid such that >90% of the sedimentary record consists of thin-bedded sheet turbidites. These maintain a remarkable lateral continuity and indicate deposition in a restricted deep-water environment. Rare interbedded limestones have yielded a Thanetian (60.2–54.9 Ma) marine fauna of *Miscellanea miscella* and *Actinosiphon tibeticus*.

In direct contrast the Utror Volcanic Formation comprises 3000 m of volcanoclastic sedimentary material, lava flows and ignimbrites. Eruptive style was predominantly explosive with fragmental material dominating the volcanic record. Lavas range in composition from 53% to 79% SiO₂ with rhyolite the predominant rock type. A basaltic andesite has an ⁴⁰Ar-³⁹Ar age of 55 ± 2 Ma. Although the volcanic stratigraphy is complex preliminary investigations suggest accumulation in a predominantly subaerial ring-plain or flanking facies distal to the main focus of volcanic activity. Sedimentary thickness and the abundance of silicic lavas and pyroclastic flows imply extensional tectonic control even though the arc developed at a convergent margin.

Juxtaposition of the two facies along the Dir Thrust excludes any record of shore-line or coastal processes from the volcanic stratigraphy. The inferred original geographical separation of the two environments coupled with their relationships to isotopically dated plutonic suites reveals that between Late Cretaceous and Early Eocene times the locus of magmatic activity within the Kohistan arc migrated progressively northward.

The Shamran volcanic rocks although originally correlated with the island-arc Chalt Volcanic Group are now identified on the basis of a 58 ± 1 Ma (⁴⁰Ar-³⁹Ar) age as a northern continuation of the Late Palaeocene volcanic arc.

Key words: Palaeogeography, magnetic arc, sedimentology, volcanics, Dir group, Himalaya.

S/553. Sultan, M., 1970. Volcanic rocks from Kalam, Upper Swat. Geological Bulletin, University of Peshawar 5, 138-141.

Green and pink mottled volcanic rocks occur about three miles northwest of Kalam. A detailed investigation of these rocks has not been carried out so far, and the purpose of this paper is to give a preliminary report on the petrography of some of them. This report is based on the study of three thin-sections cut from rocks apparently different in hand specimen; one of these is a banded dacite, and two are pyroclastic dacite. The writer considers that the Kalam volcanics are a part of the Panjal Volcanics of Upper Carboniferous age.

Key words: Petrography, volcanics, Kalama, Swat.

S/554. Sultan, M., 1996. Heavy and trace metal abundance related to pollution in Peshawar Cantt, and along Jamrud Road, N.W.F.P., Pakistan. M.Phil. Thesis, University of Peshawar, 89p.

Polluted air, water and soil are considered to be the sources of several fatal diseases in human beings and animals. Among other pollutants, heavy metals are one which if incorporate with air, water and soil, could cause many diseases in human beings. The heavy metals incorporate with air, 'water and soil from different sources like mineral and ore processing industries, chemical industries, glass and paper industries, textiles, fertilisers, petroleum refining and vehicular emanations. Pakistan is one of the developing countries where the rapid growth of infrastructure including mad systems and vehicular traffic is in progress. One of the major sources of heavy metals along the roadsides, in the big cities of the Pakistan, is automobiles. Besides cocktail of toxic gases, exhaust from automobiles contain various heavy metals, which directly contaminate air, and when fall on ground, could enter into the surface and subsurface water systems. Such waters, if reach the aquifer and are utilised by the municipality, could be distributed in the city for both drinking and agricultural/ gardening purposes.

The present study has been conducted to analyse and determine the levels of heavy metals including Cr, Co, Cu, Ni, Zn, Fe and Pb in air, sewerage drains and subsoil samples from various parts of Peshawar cantonment and along Jamrud road. Air dust samples (48) were taken from different busy chouks/intersections from the Peshawar cantonment and along Jamrud road. In addition 30 sewage water and mud samples were taken from the sewerage system of Peshawar cantonment to determine the contamination levels in drains which ultimately join the Kabul river. Ten soil samples were taken along the Jamrud road and from the busy chouks in Peshawar cantonment at a

depth of two feet, and one foot away from the metalled roads to find the extent and effect of surface air pollution in the subsurface soils along the roads.

Results revealed that higher concentration of heavy metals especially Pb, Fe and Zn were present in air and sewage samples. In general the deposition and dispersion systematics of these metals are related to their atomic masses as well as to their availability in the surroundings. It was found that Pb is the most prevalent element in the air along the roads of Peshawar. Emission from automobiles is one of the major sources of lead in the atmosphere.

Analysis of all the sewage samples showed the presence of high levels of heavy metals. The heavy metals, being heavier than water, tend to settle at the base of the drains. The mud sewage samples contained more heavy metals than water sewage samples. Different shops, working in metals, printing presses and roads contiguous to the uncovered drains are the major sources of heavy metals in the drains of the Peshawar cantonment. These drains, containing heavy metals, ultimately fall into the Kabul river through Shahi kata and Budni canal. Soil samples show the levels of heavy metals within the normal ranges and are, therefore, not bothersome from environmental point of view.

Key words: Heavy metals, trace elements, pollution, Peshawar, NWFP.

S/555. Sultan, M. & Ali, A.N., 1970. Sedimentology and petrography of Ghundai Sar reef complex, Jamrud, Khyber Agency. M.Sc. Thesis, University of Peshawar, 64p.

A belt of Silurian-Devonian. Coralline Limestone of pink, yellowish-pink, and greyish-white colour, is exposed in the hills of Ghundai Sar, near Jamrud; Khyber Agency. This belt, which unconformably overlies the Phyllitic rocks, (Kandar phyllite) intruded by dolerite and gabbroid intrusion, is divisible in two definite units, that is,

(1) the Reef Core and (2) Reef Breccia. The two collectively are known as the Nowshera formation. The entire formation represents deposition on a stable shelf, the environments were conducive for the development of coral reefs. The orthoquartzite associated with dolomite and limestone support this observation,

In this paper, petrography and sedimentology of the reef limestones is discussed in detail 101 Samples were collected and 30 sections were cut to describe the petrography. The Limestone and dolomite show variations in their mineralogical composition. All variations from arenaceous limestone to calcareous orthoquartzite occur.

It is observed that dolomite is both primary (originally secreted by organisms) and secondary, introduced by low grade regional metamorphism afterward. Early Tertiary and Late Cretaceous intrusions have caused silicification and introduction of crystalline Quartz and feldspar in limestone. Limonitization is most probably a recent phenomenon, and might have introduced by the leaching of iron from overlying arenaceous formation.

Key words: Sedimentology, petrography, reef complex, Khyber agency.

S/556. Sultan, S.A. & Arbab, K.U., 1985. The Geology and the structure of a part of southern flank of Attock-Cherat Range, West of Indus River, N.W.F.P. (Pakistan). M.Sc. Thesis, Department of Geology, University of Peshawar, 84p.

The area of investigation covers 25 square kilometres on the eastern side of Attock-Cherat Range which stands as a structural high between southern portion of Peshawar Plains and Nizampur valley.

Structural style of the area is controlled by two major thrust faults, i.e. Khairabad fault in the north, which separates Dakhner Formation of late Pre-Cambrian age from Utch Khattak Formation and Cherat fault towards southern end of Attock-Cherat Range, which separates Dakhner Formation from Palaeozoic rock sequence. The Tertiary sequence is represented by Lockhart limestone, lying in the form of isolated patches and bands in Dakhner Formation. Their contact is considered to be of tectonic origin. Some strike-slip faults are identified in the area which may have formed in response to southward movement of the sequence along Cherat thrust.

Economically, the area holds a promise for setting up Cement Industry in future.

Key words: Structure, geology, Attock-Cherat Range, Indus River.

S/557. Suzuki, M. & Khan, S.R., 1992a. Geochemical exploration in Jijal area. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad 2, 79-109.

This report describes the results of a geochemical exploration targeting mainly precious metals (Gold and Platinum Group) in the Jijal Complex, north of Besham, which was carried out by Japan International Cooperation Agency

(JICA) and Geological Survey of Pakistan (GSP). The study area occupies the southern limit of the Kohistan island arc terrain and samples were collected mostly from the area between Indus River and Duber Khwar. From Jijal to the eastern foothill of Mt. Gabar, a jeepable metalled road is available. However the general topography of the area is quite steep, and accessibility is poor on the whole. The geological mapping and the sampling of stream sediments were carried out for 30 days during October, 1990 to February, 1991, and the check survey to the results of geochemical analyses was conducted for 5 days in May, 1991.

Key words: Geochemistry, exploration, ultramafics, Jijal, Kohistan, Himalaya.

S/558. Suzuki, M. & Khan, S.R., 1992b. Regional geochemical exploration in Gilgit area, Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 2, 110-159.

The present report is to summarize the results of a geochemical exploration targeting gold in the Gilgit Agency.

The study area is divided into the northern and southern parts by the EW-trending Main Karakorum Thrust (MKT) in the central part. The Aslan Plate terrain on the northern side of the thrust is largely underlain by Paleozoic to Mesozoic sedimentary formations that have been intruded by Jurassic to Tertiary batholiths, whilst the Island Arc terrain on the southern side consists mainly of sedimentary and volcanic formations, which have been intruded by granitoids ranging from 102 to 25 Ma. Sampling for the geochemical exploration, which used stream sediments and panned concentrates as media, was conducted along the main streams of the Hunza and Gilgit Rivers and their major tributaries. Sampling density was slightly enhanced in the neighborhood of Gilgit, where a number of alteration zones have been found. One hundred and twenty samples of stream sediments were analyzed for gold, while 92 samples of panned concentrates underwent chemical assays of Au, Ag, As, Bi, Cu, Mo, Pb, Sb, and Zn in Chemex Laboratory.

Gold contents in the study area are generally higher than the average of the earth crust, implying a high probability of some gold mineralization in this area. A univariate analysis demonstrates that all elements except Cu and Mo show high concentrations along the MKT and on the northern side as a whole. Gold shows particularly high concentrations along the MKT. Factor analyses have led to the extraction of the following two factors related to gold mineralization: 1) a factor represented by a combination of Au-Ag-As-Sb (Factor 4) and 2) a factor represented by a combination of Bi-As-Ag-Au (Factor 2). High factor scores for the Factor 4 are found along the MKT. High-scored points for the Factor 2 are distributed mainly around the glacial areas.

A survey on the alteration zones was conducted in the northern area of Gilgit simultaneously with the geochemical exploration. Results of gold assays for prominent quartz-veins and highly silicified zones were disappointing. The results of the geochemical exploration and geologic survey on the alteration zones indicate a low potentiality of economically promising gold mineralization. The present survey leads to a conclusion that it is along the MKT, above all, the Chatorkhand area showing high contents of 11.0 ppm and 50.5 ppm Au as well as high scores for factor 4 that deserves a high priority to a follow-up survey.

Key words: Geochemistry, exploration, ultramafics, Gilgit, Himalaya.

S/559. Suzuki, M., Khan, S.R. & Khan, I.H., 1992. Lithogeochemical exploration in Mansehra area. Proceedings of Geoscience Colloquium, Geoscience Lab, Geological Survey of Pakistan, Islamabad, 3, 35-83.

The present report is to summarize the results of lithogeochemical exploration targeting tungsten and surveys of the mineralized zone. The study area is underlain by the Tanawal Formation consisting of schists and quartzites, the Mansehra Granite composed of granitic gneisses and schistose granites, and the Younger intrusions comprising porphyritic granites, aplites and diabbases. Sampling for the exploration was implemented on the basis of a grid net with an interval of 200 m in a 4 km by 4 km area selected by the previous geochemical exploration by stream sediments. The following 25 elements were analyzed: Ag, Al, Ba, Be, Bi, Ca, Cu, Cr, Co, F, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sr, Sn, Ti, V, W, and Zn. Analysed samples amount to 305.

Univariate analysis led to detection of a large anomaly of W, F, Al, and P and a small anomaly of Ba, Ca, K, Ti, and V. Above all, F has been found to be an effective index element, which forms strong geochemical anomalies around the porphyritic granites, an ore bringer. As a result of factor analysis, W, F, Al, Ca, P, Ti, and V were extracted as elements related with W-mineralization (Factor 5). The distribution map of this factor shows a widespread distribution of high-scored areas from the Khabbal primary school to the southeastern slope of the Mt. Manna

Danna, indicating that they are most promising in the study area. In addition, comparison with univariate analysis demonstrate the effectiveness of factor analysis for erasing anomalies derived from background fluctuations.

W-mineralization found in the vicinity of the Knabbal primary school is of greisen type, which occurred near the top of a sheet-shaped intrusion of porphyritic granites. Impermeable caprocks covering the porphyritic granites presumably prompted concentration of scheelite. Showings of the mineralization in this area are so small for the strong geochemical anomalies, that any more discovery of larger mineralizations seems impossible.

Key words: Lithology, geochemistry, exploration, Mansehra, Hazara.

S/560. Suzuki, M., Khan, S.R. & Khan, I.H., 1995. Lithogeochemical exploration for scheelite mineralization in Mansehra area, northern Pakistan. *Geologica* 1, 13-59.

Key words: Lithochemical, exploration, scheelite, Mansehra, Hazara.

S/561. Sweet, W.C., 1970. Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan. In: Kummel, B. & Teichert, C. (Eds.), *Stratigraphic Boundary Problem; Permian and Triassic of West Pakistan*. University of Kansas, Special Publication 4, 207-276.

Key words: Palaeontology, conodonts, Permian, Triassic, Salt Range, Trans-Indus Range.

S/562. Syed, A.F. & Jabbar, M., 1984. Petrology of a part of Ambela granitic complex (Malandari area) district Mardan, NWFP. M.Sc. Thesis, University of Peshawar, 89p.

Key words: Petrography, Ambela granitic complex, Mardan.

S/563. Symes, R.F., Bevan, J.S. & Jan, M.Q., 1987. The nature and origin of orbicular rocks near Deshai, Swat Kohistan, Pakistan. *Mineralogical Magazine* 51, 635-647.

Orbicular dioritic-noritic rocks from an area of mixed metamorphic and igneous rocks in Swat Kohistan, northern Pakistan, have been examined petrographically and chemically in order to determine the nature and origin of the orbicular texture. Using textural and compositional sequences it has been possible to relate the apparently different orbs to one another, and obtain a sequence of orb formation. The majority of the orbs comprise a series of distinct layers (shells) surrounding a central zone (core). Plagioclase, clinopyroxene, orthopyroxene and hornblende form the bulk of the shells. The cores have been extensively recrystallized. The development of a 'comb-layered' texture in some orbs and in associated layered rocks is comparable to that commonly described from other occurrences. A dual igneous/metasomatic crystallization history is invoked to explain the features of the orbs in this locality, the oscillatory zoning of the orbicular structure being caused by the alteration of primary minerals, such as pyroxene to amphibole, due to fluctuations in the p_{H_2O} of the magma.

Keywords: Orbicular rocks, diorite, norite, Swat Kohistan.

T/1. Tahir, M., 1986-85. Geology of Dhamtaur Baghsari Area. Institute of Geology, Punjab University, Lahore, 1-82.

Key words: Geology, lithology, Abbottabad.

T/2. Tahir, M.A., Dastgir, G., Riaz, M. & Ahmad, M., 1996. Landforms of NWFP and FATA. Programme and Abstracts, 8th All Pakistan Geographic Conference, Peshawar, p.11.

Key words: Geography, landforms, NWFP, FATA.

T/3. Tahir, N., 1995. Industrial minerals and dimension stones. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 197-204.

Key words: Industrial minerals, dimension stones.

T/4. Tahirkheli, R.A.K., 1959a. Report on lead-zinc deposits near Ushu, Swat State, West Pakistan. GSP, Information Release 9, 7p.

Ushu valley is occupied by metasediments and volcanics of the Kalam Group in the south, followed by a strip of Utror volcanics. But much of the valley contains plutonic rocks ranging from diorite, through quartz diorite to granite of what is now called the Kohistan batholith. The small lead-zinc deposits here are associated with the granitic rocks of the Falaksair area.

Key words: Mineralization, lead-zinc, Swat.

T/5. Tahirkheli, R.A.K., 1959b. Report on kyanite showings near Landaki, Swat State, West Pakistan. GSP, Information Release 12.

Kyanite pockets occur in quartz veins and pegmatites associated with granitic rocks of Swat area. The granites intrude pelitic and calcareous rocks metamorphosed under Barrovian-type conditions. This report describes kyanite showings near Landakai at the border of Malakand Agency.

Key words: Kyanite, Swat.

T/6. Tahirkheli, R.A.K., 1960. Investigations of gold and other placer minerals in the Indus alluvium. GSP, Information Release 14, 9p.

This report furnishes the interim results of field and laboratory studies on samples collected from a selected 25 acre area at Amb, and results of analyses of four samples of concentrates from Bunji, Amb, Mian Dheri, and Attock.

The radioactivity of the Indus alluvium at Amb ranges from 0.013 to 0.18 mR/hr with the mantle sand giving slightly higher reading than gravel. Content of uranium in the Indus alluvium at Amb ranges from less than 0.001 to 0.007 percent.

Gold won by the local goldwashers from a ton of sand scrapped from between boulders and cobbles in the gravel bar averages about 0.25 grams. Study of gold washing shows that each working day, a goldwasher collects 3 to 4 pounds of a highly concentrated product containing these heavy minerals, listed in decreasing order of relative abundance; magnetite, ilmenite, garnet, zircon, scheelite, monazite, uranorthorite, uraninite, and gold.

Key words: Gold, placers, alluvium, Indus.

T/7. Tahirkheli, R.A.K., 1965a. Economics of Indus River sands. Geological Bulletin, University of Peshawar 2(a), 11-15.

The Indus River has for centuries attracted the attention of the prospectors and geologists because of gold in its alluvials. The goldwashers are still working along the Indus River banks, using primitive methods to extract gold by washing sand and gravel. Recent studies conducted by the author show that an experienced goldwasher extracts about 1.05 grains of gold per cubic yard. The high value minerals left behind in gold tailings are scheelite, uraninite, and cassiterite. An attempt has been made in this paper to evaluate their proportions in the heavy fraction and bulk sands to see whether they can be won economically as co-products of gold.

Key words: Economic geology, gold, Indus River.

T/8. Tahirkheli, R.A.K., 1965b. Recent observations on the undifferentiated Attock Group. Geological Bulletin, University of Peshawar 2(b), 10-23.

Under the light of recent investigations the Attock Slates are found to contain five distinct lithological units which are easily differentiated in the field and belong to different ages. Three of these units are dated to be Upper Mesozoic, one is assigned a pre-Cambrian age and the fifth unit is still under observation and is tentatively placed in the Paleozoic. The argillaceous part of the Attock Group which was previously, considered to be one homogeneous unit is split into two divisions and named "Manki Slates" and "Dag Slates." The later contain fossilized bands of limestone and on the basis of diagnostic fossil (Cerithiopsidea), have been dated to be Upper Cretaceous age. These two slates have got tectonic contact and the older Manki slates are found to have thrust over the younger Dag slates.

Key words: Lithology, slates, Mesozoic, Pre-Cambrian, Attock, Manki.

T/9. Tahirkheli, R.A.K., 1967. Reconnaissance for radioactive minerals in Dardistan, Baltistan and Haramosh in Gilgit agency, West Pakistan. GSP Information Release, 33, 17p, one map.

The eastern and north eastern parts of the Gilgit Agency which constitute Baltistan, Dardistan and Haramosh were reconnoitered for radioactive minerals during the period of July – October 1960. A geological map of the traverse – route was prepared and radioactivity of the rocks exposed was plotted thereon. Samples of sand were collected from the tributaries of Indus river for radiometric and mineralogical study. The radioactivity in the gneissic band in metasediments measured between 0.035 and 0.7 mR/hr. some of the granite intrusions and acid dykes of later phases read 0.03 to 0.07 mR/hr. few sand samples from the tributaries of the Indus yielded relatively high radioactivity, pointing the possibility of uranium mineralization in their catchment areas. These favourable indications of possible mineralization warrant an expeditious programme for having a thorough radiometric check in this area.

Key words: Reconnaissance, radioactive minerals, Baltistan, Dardistan, Haramosh.

T/10. Tahirkheli, R.A.K., 1968a. Size analysis of the Indus River sands, West Pakistan. Geological Bulletin, University of Peshawar 3, 1-9.

In this paper an attempt has been made to evaluate the grade of the sand-size material in the Indus alluvium between Kalabagh and Skardu. The most widely used statistical devices of quartile measures were applied to describe the sediments. Some of the results obtained are comparable with those of similar work carried out in other parts of the world.

Key words: Alluvium, sand, size analysis, Indus River, Kalabagh, Skardu.

T/11. Tahirkheli, R.A.K., 1968b. Stratigraphy of the outcrops exposed along the eastern bank of the Indus at Attock, West Pakistan. Geological Bulletin, University of Peshawar 3, 19-25.

The outcrops exposed on the eastern bank of the Indus at Attock are examined to establish time-rock sequence for correlation. The rocks exposed here represent a typical Mesozoic sequence. No rocks older than upper Triassic (Kingriali Formation) are exposed in this area.

Key words: Stratigraphy, Mesozoic, Indus River, Attock.

T/12. Tahirkheli, R.A.K., 1968c. A new look at the Attock slate series. Geological Bulletin, University of Peshawar 3, 31-32.

A greater part of Attock – Cherat Range, which exposes slates, has been mapped on 1":1 mile scale map and various lithological units, having separate entity in the series, have been differentiated. This note is intended to provide preliminary results on the stratigraphy of the Attock Slate series – based on the author's observations.

Key words: Lithology, stratigraphy, slates, Attock-Cherat.

T/13. Tahirkheli, R.A.K., 1969a. Present status of the Attock slate series. Sind University, Science Research Journal, Special No. (Geology Symposium), 51-58.

The Attock slates are divided into twelve mapable units. Descriptions are given for Manki slates, Kingriali formation, Rubbli limestone and Attock slates.

Key words: Lithology, stratigraphy, Attock slates.

T/14. Tahirkheli, R.A.K., 1969b. Another Paleozoic reef discovery in Tangi Ghar, Peshawar District. Geological Bulletin, University of Peshawar 4, 90-91.

The Tangi Ghar spread over some three square miles, and is divided into seven isolated rounded to subrounded hillocks, the highs attaining a height of 1582 feet. The general trend of the ridge is east - west, which conforms to the strike of the rocks, which dip to the north. The major hillock (1982 feet) forms a steep escarpment along the northern edge. The mountain ranges exposed around Tangi Ghar lie at distances varying between 8 and 20 miles; the nearest ones are those of Takhtbai and Mohmand Tribal Territory, lying towards the east and west respectively. Three distinct lithological units are 1) Light to dark gray slate, phyllite and phyllitic schist, 2) Thin-bedded to massive crystalline siliceous limestone, 3) Slate, phyllite and phyllitic schist.

Key words: Lithology, stratigraphy, Palaeozoic, Peshawar.

T/15. Tahirkheli, R.A.K., 1970a. Mineral and minings; Resources base on economic programme of the Peshawar Valley: A study conducted by Economic Department, Peshawar University for Planning and Development, Regional Development Plan, Peshawar, 53-79.

Key words: Mineral resources, mining, Peshawar.

T/16. Tahirkheli, R.A.K., 1970b. Descriptive geological notes on Uch Khattak and Hissar Tang sections in the Attock Range. Geozine, Geology Department, Peshawar University 1, 20-23.

Consult Tahirkheli (1970c) for further information.

Key words: Geology, stratigraphy, Attock-Cherat.

T/17. Tahirkheli, R.A.K., 1970c. The geology of the Attock-Cherat Range, West Pakistan. Geological Bulletin, University of Peshawar 5, 1-26.

The Attock-Cherat Range is exposed in an area of about 50 square miles in Attock district and 360 square miles in the Peshawar district, on both the sides of the Indus River. Around Attock the relief is low; the elevations range from 1300 to 2079 feet which on the other side of the Indus culminate to 4546 and 5033 feet at Cherat and Jalala Sar respectively, which are the commanding heights in the Peshawar Plain. Between Attock and Mir Kalan village, the general trend of the range is east-west which coincides with the strike of the rocks. Beyond this point, the range swings to the south-west and ultimately merges into the Nizampur-Kohat mountains in Darra Adam Khel tribal territory. In the Attock plain the slates are lost beneath the alluvium beyond Kamra hillock till they crop out again in southern Hazara. In the west, the last slate outcrop mapped is exposed near Dag village, beyond which the slates are covered by thick alluvium till they crop out in the Khyber Mountains.

Two types of lithological elements, with a tectonic contact, are exposed in the Attock-Cherat Range. One comprises the Paleozoic metasediments (phyllite, phyllitic slate, slate and crystalline limestone) forming the northern face of the range. They are correlated with the rocks of Khyber in the west, Hazara in the east and Swabi-Lower Swat in the

north. The dominantly sedimentary rocks belonging to the Mesozoic-Tertiary eras, developed along the southern face of the Attock-Cherat Range, may be correlated with the rocks of Samana Range, Kala Chitta hill, Salt Range and Hazara.

The pelites of the Attock-Cherat Range are divided into two parts on the basis of fossil evidences. The older, Manki Slate is of Lower Silurian age and the younger, Attock Shale has been placed in the Middle Jurassic-Cretaceous. Altogether, thirteen mappable lithological units have been distinguished in the Attock-Cherat Range. Of these, four have been placed in the Paleozoic, four in the Mesozoic and five in the Tertiary. The Shahkotbala Formation is the oldest lithological unit exposed in this area and is (?) Upper Ordovician to Lower Silurian in age. No Precambrian rocks have been recorded in the Attock-Cherat Range.

The two major thrust faults running along the northern and the southern fronts of the range traverse the area in the east-west direction. The northern thrust is the result of overturning of the southern flank of an anticlinal fold. Another anticlinal fold skirts the Attock-Cherat Range on the south in the Nizampur valley. The northern limb of this fold is intact. The southern limb is eroded away and is buried under the alluvium. The Attock Shales are folded into asymmetrical parallel isoclinal folds with their axes dipping towards the north. The faulting pattern in the Attock-Cherat Range yielded imbricate type structure, which are conspicuously observed all over the area.

Key words: Geology, stratigraphy, Attock-Cherat.

T/18. Tahirkheli, R.A.K., 1971a. The geology of the Gandghar Range, District Hazara, NWFP, Pakistan. Geological Bulletin, University of Peshawar 6, 33-42.

The Gandghar Range is located on the western tip of the Hazara district, due to its isolated position it could attract a few geologists during the past. In the Geological Map of Pakistan (1964), the Range is partly mapped as Pre-Cambrian and partly Silurian-Devonian.

The Gandghar Range exposes a suite of metasedimentary rocks, comprising of slate, phyllite, phyllitic-slate, schists, quartzite and crystalline limestone. Five lithological units are differentiated which have been correlated with the Palaeozoic sequences of the southern Hazara and the Attock – Cherat Range. The oldest unit is the Mohat Nawan Limestone and the youngest is the Pirthan Limestone, which are respectively homotaxial to the Shahkotbala formation of the Attock-Cherat Range and the Sirban Formation of the Abbottabad Group in the southern Hazara. The former is placed in the Upper Ordovician – Lower Silurian and the latter in the Permo – Carboniferous.

Key words: Stratigraphy, metasedimentary rocks, Hazara.

T/19. Tahirkheli, R.A.K., 1971b. Phosphatic mineralization as a basis for stratigraphic correlations. Geological Bulletin, University of Peshawar 6, 117-119.

The author during geological mapping of Gandghar Range in the western Hazara, Cherat Range east of Peshawar, and the Rajgal area of Tirah in Khyber Agency has located a thick sequence of siliceous dolomitic limestone which was considered identical to Sirbon Formation on lithological grounds. To further authenticate this correlation, the author had collected scattered samples from each section, for chemical examination, to confirm whether phosphorite mineralization of same type as in the Kakul and Sirbon Formation in their type sections, is also present.

Key words: Phosphate, Kakul, Khyber Agency, Gandghar Range.

T/20. Tahirkheli, R.A.K., 1971c. Industrial rock resources of the Kohat District, N.W.F.P West Pakistan. Directorate of Mineral Development, Govt. of N.W.F.P. Information Release 1, 14p.

The rock salt, gypsum and limestone form an important geological horizon in the Trans-Indus Salt Range of Kohat. This belt covers about 2000 square miles area in the eastern part of the district.

At present, only rock salt is being mined, substantial part of which goes for domestic consumption and a fraction supplied to the Industries located outside the district,

This short paper is intended to provide useful geological information to bring the enormous reserves of the Industrial rocks of the Kohat district to some industrial usage.

Key words: Industrial rocks, Kohat.

T/21. Tahirkheli, R.A.K., 1971d. The raw material for refractories in N.W.F.P. and Tribal Territories, Pakistan (West). Directorate of Mineral Development, Govt. of N.W.F.P., Peshawar, Information Release 2, 12p.

Every industry which employs high temperature must utilize refractories. Due to rapid development of refractory-consuming industries in the country, the demand of high refractories is bound to increase.

The common refractories are grouped under fire clay, high alumina, silica and basic refractories, Kaolin, quartz, quartzite, bauxite; dolomite, chromite, limestone and olivine are some of the important raw materials available in workable reserves in the N.W.F.P. and the adjoining tribal territories on which refractory industries can be based. This short paper is intended to provide a geological base for planning such industries in this region.

Key words: Refractories, raw material, NWFP.

T/22. Tahirkheli, R.A.K., 1971e. The raw material for refractories in N.W.F.P. and Tribal Territories, (West) Pakistan. The Peshawar Economist 1, 22-35.

Consult the preceding account for further details.

Key words: Refractories, raw material, NWFP.

T/23. Tahirkheli, R.A.K., 1971f. Mineral map of the N.W.F.P. and Tribal area. Directorate of Mineral Development, Govt. of N.W.F.P., Peshawar, Information Release 3.

Several mineral deposits have been discovered in the North-West Frontier Province and the adjacent Federally Administered Tribal Territory. The author shows the location of the minerals of commercial interest in the map.

Key words: Mapping, minerals, NWFP.

T/24. Tahirkheli, R.A.K., 1971g. Phosphate occurrences in Hazara and other contiguous areas of N.W.F.P. and the Tribal Territories. Directorate of Mineral Development, Govt. of N.W.F.P., Peshawar, Information Release 5, 18p.

Key words: Phosphate, Hazara, NWFP.

T/25. Tahirkheli, R.A.K., 1972. A proposed mineral strategy for the N.W.F.P. and the adjoining Tribal belt. Directorate of Mineral Development, Government of N.W.F.P., Peshawar, Information Release 6, 27p.

A number of metallic and non-metallic minerals occur in the accessible areas in the N.W.F.P. and the tribal territories, which do not need much investment to raise an infrastructure for their development and exploitation. Therefore it is advised to first plan mining ventures and mineral industries based on these minerals. A number of mineral based industries have been suggested in various parts of this province where suitable raw material is available.

During future planning for the road and railway extensions in this region, care should be taken to give priority to open up those areas which are potentially favourable for the natural resources, such as minerals, forest, etc.

Bank loans, railway freight concessions, even for the domestic markets along with other technical and economic incentives discussed in this paper, can provide a sound basis for the progressive development of the mining industry in this province. A substantial part of this province remains geologically unexplored and thus needs proper planning to gear up exploration based on modern scientific lines to trace the history of subsurface mineralization of the surficial metallic mineral showings.

The private investment on mineral ventures has become shy because of lack of the above mentioned incentives. Therefore it is in the interest of the government to create favourable conditions to make the mining sector more attractive. This would solve three fold purpose, (a) participation of the private sector in raising the infrastructures, thus sharing a considerable part of the capital cost which otherwise would have to be invested by the government,

(b) to make the minerals located in the far flung interior more competitive in the market, because of relatively low cost of mining venture by the private sector as compared to the public sector, and (c) infusion of technical know-how and inflow of private finances which are directly needed to create a sound footing for the mining industry in this region.

Key words: Minerals, NWFP.

T/26. Tahirkheli, R.A.K., 1974. Alluvial gold prospects in the northwest Pakistan. University of Peshawar, Information Release 7, 48p.

The auriferous alluvials of Chitral, Gilgit, Hunza and the Indus rivers have been discussed in the paper. A goldwashing Industry, based on primitive technique, have flourished for centuries in this region, and even now one can see goldwashers working on wooden sluice, locally called nava. The river alluvials are composed of mantle sand, bouldergravel, cobble-gravel, and pebble-gravel, ranging in size from over 6 feet in diameter to less than 1/256 mm. The assemblage of heavy minerals including gold is relatively higher in the gravel deposit. The mantle sand shows higher concentrations of heavy minerals where the natural accumulates in the form of streaks and thin films occur.

The closely-packed pebble-gravels usually form the favourite sites to wash sands for gold, though in the upper reaches of the mountainous terrain, boulder-gravel and cobble-gravel have indicated reasonably high concentrations of gold.

Among the valuable minerals which would be won as co-product of gold are opaque ore minerals, zircon, garnet, monazite, scheelite, cassiterite, apatite, rutile. In size, over 85 percent of these minerals pass through minus 80 mesh screen. The distribution of gold in the alluvials is erratic. A rough estimate based on nava, washing revealed the following results:

Twenty-eight percent of the alluvials are barren with No gold showings, 58 percent of the alluvials yielded gold worth less than 35 paisas per cubic yard and only 14 percent of the alluvials showed consistent gold occurrences and yielded from 35 to 650 paisas of gold per cubic yard.

The treatment of goldwasher's stage III concentrate

(magnetite-free) in Isodynamic Magnetic Separator revealed the following mineral assemblages in various fractions, 1st fraction - dominantly opaque ore minerals.

2nd fraction - 75-85 percent opaque ore minerals.

3rd fraction - garnet-rich.

4th fraction - gold, zircon, monazite, scheelite, cassiterite, apatite, rutile; recovery of gold is 100 percent.

Key words: Alluvial gold, Indus River, northern Pakistan

T/27. Tahirkheli, R.A.K., 1979a. Geology of Kohistan and adjoining Eurasian and Indo-Pakistan continents, Pakistan. Geological Bulletin, University Peshawar 11, 1-30.

Kohistan constitutes about 36000 square kilometers of territory located between the Indo-Pakistan and Eurasian Plates, on the northwestern tip of the Himalaya. Earlier, Desio (1964) has differentiated this part as a tectonic zone of Karakoram.

Bulk of Kohistan sequence consists of amphibolite, diorites, meta-norites (pyroxene-granulites) and associated volcanic rocks which are considered to be the crust of an ancient calc-alkaline island arc. This sequence has been obducted on to the Paleozoic rocks of the Indo-Pakistan continent on the south and subducted under the Eurasian Platform along the northern megashears.

The northern megashear along Hini-Chalt-Yasin-Drosh was formerly used to be considered the only extension of the Indus suture west of Nanga Parbat. Recent studies by Tahirkheli et al (1977, 77) have brought to light a southern megashear marked by the occurrence of ultramafics and high pressure metamorphic rocks, called Main Mantle Thrust (MMT), which delineates the southern contact of the Kohistan Island arc and the Indo-Pakistan continent. This confirms the bifurcation of the Indus suture into two suture zones, west of Nanga Parbat.

In this paper, an attempt has been made to introduce the geology of Kohistan island arc and the adjoining Eurasian and Indo-Pakistan continents.

Key words: Stratigraphy, structure, Kohistan, Eurasia, Indo-Pak plate.

T/28. Tahirkheli, R.A.K., 1979b. Geotectonic evolution of Kohistan. Geological Bulletin, University of Peshawar 11, 113-130.

Kohistan Zone is located on the north-western tip of the Himalaya and constitutes a tectonic unit in the Indo-Pakistan-Eurasia suture zone between Himalaya and Karakoram. Its characteristics nature distinguishes it from the surrounding well known geological provinces of Hazara and Kashmir on one side and Gilgit, Baltistan and Chitral on the other side. Most of Swat and Dir belong to Kohistan along with the southern part of Gilgit, Chitral and northern Hazara.

The Kohistan Zone is bounded by two megashears: the Hini-Chalt-Yasin-Drosh fault lying to the north, which extends into Baltistan through Tissar-Hashupa in Shigar Valley and Machelu in Shyok Valley. Another is recently deciphered Main Mantle Thrust traversing the southern periphery of Kohistan.

In addition, there exists a series of late thrust tectonic features, the two prominent among them being the Hazara syntaxial bend located on the south and a dominant Naze of Nanga Parbat – Haramosh massif on the northeast, which was considered by Wadia to be a horst of the Indian Peninsula, but the author interprets it as a transverse antiform fold.

These major tectonic features, located in the vicinity of the Kohistan Zone, have played a major part in the evolution of its structural history. A chronological account of various tectonic episodes is presented in this paper.

Key words: Tectonics, Kohistan, MMT, Himalaya.

T/29. Tahirkheli, R.A.K., 1979c. An indepth analysis of Pakistan's mineral policy with special reference to northern region. Geological Bulletin, University of Peshawar 12, 41-54.

Since the creation of Pakistan all the Governments have shown keen interest in the development of mineral resources for which various steps were taken to accelerate and generate momentum in the development of minerals. In spite of these efforts no concrete results were achieved.

The author being a member of the advisory committee on planning for mineral resources has observed some pitfalls which directly or indirectly created sluggish environment which caused the retardation in the development and exploitation of mineral resources. In this paper the author has attempted to shed light on the impediments in order to generate a healthy climate for strengthening the base to raise structure in which the mineral could get a square deal for their economical and commercial exploitation. This paper was presented in a seminar held at Lahore and had a limited circulation. The publication of this paper in this bulletin is intended for its wider publicity both in private and public sector in order to create awareness for skittling the loopholes faced by the mineral-based industry.

Key words: Mineral resources, Mineral policy, Pakistan.

T/30. Tahirkheli, R.A.K., 1980a. Major tectonic scars of Peshawar vale and adjoining areas, and associated magmatism. Geological Bulletin, University Peshawar 13, 39-46.

The Vale of Peshawar, spread in about 1800 sq. km area, constitutes an important tectonic zone in the northwestern margin of the Indo-Pakistan plate. It is surrounded by well carved mega-tectonic features, which originated during post collisional alpine orogenic episodes, starting from Late Cretaceous and lasting till Early Pleistocene. The main tectonic evolutionary history of the Vale is syngenetic to these episodes, though some pre-alpine tectonic scars have also been distinguished.

Ten major fault tectonics have been described in this paper, out of which six located within the Vale and the remaining four occur in the adjoining areas. An attempt has been made to decipher these tectonic scars and to delineate associated magmatism in the Vale of Peshawar.

Key words: Tectonics, magmatism, Peshawar Valley.

T/31. Tahirkheli, R.A.K., 1980b. The Main Mantle Thrust: Its score in metallogeny of northern Pakistan. Geological Bulletin, University of Peshawar 13, 193-198.

Major shear zones in the collisional orogens like the ones exposed in Pakistan, can create important pathways for the movement of the mineralized solutions along with magmatic emanations. The Main Mantle Thrust (MMT), which has come to limelight recently, constitutes one of the important major tectonic scars on the northwestern terminus of

the Himalaya. It extends for over 500 km across the northern part of Pakistan, welding the Indo-Pakistan plate with the Kohistan island arc. Several magmatic bodies, some of them of batholithic dimensions are associated with this megashear.

In this paper an attempt has been made to focus upon the magmatic environments associated with MMT to discern various episodes of metallic mineralizations and their localizations in the subducted Indo-Pakistan marginal mass, obducted Kohistan mass and in the main Mantle Thrust zone.

Key words: Metallogeny, Shear zones, MMT, Himalaya.

T/32. Tahirkheli, R.A.K., 1980c. An extended domain of the Yasin group in the Karakorum and Hindu Kush. Wadia, Institute of Himalayan Geology, Dhera Dun, India, 2p.

The Yasin group is a Late Cretaceous, highly fossiliferous, group of sedimentary and volcanic rocks. Many authors have described its fossil assemblages and stratigraphy from the type area Yasin. This paper shows the extension of the group laterally into Kohistan up to Chalt in Hunza valley and beyond.

Key words: Stratigraphy, Yasin group, Cretaceous, Karakoram, Hindukush.

T/33. Tahirkheli, R.A.K., 1981a. Geological zonation of Karakorum and southern Hindu Kush in Pakistan. National Centre of Excellence in Geology, University of Peshawar, Special Issue 1.

For further information, consult Tahirkheli (1982 and 1992-93).

Key words: Geology, tectonics, Hindu Kush, Karakoram.

T/34. Tahirkheli, R.A.K., 1981b. Geological complexation of unfossiliferous Lesser Himalayan sequence in Pakistan; a review. In: Sinha, I. (ed.), Contemporary Geoscientific Research in Himalayas 1, 21-30. Singh, Dehra Dun.

Key words: Tectonics, unfossiliferous, Lesser Himalaya.

T/35. Tahirkheli, R.A.K., 1981c. An analysis of litho-tectonic zones associated with the Himalayan orogeny, in northern Pakistan. Geological Bulletin, University of Punjab 16, 98-110.

The Karakorum Himalayas is characterized by some unique tectonic features, which distinguish it from the rest of the Himalayas. Some of these are; occurrence of an Island arc on its north-western margin, existence of two suture zones west of Nanga Parbat-Haramosh antiform, and the absence of the Main Central Thrust, which, in the Central Himalaya demarcates so prominently the boundary between the Lesser Himalaya and the Himalayan Crystallines.

In this paper, under the light of new tectonic data, an analysis is attempted to differentiate various litho-tectonic zones in northern Pakistan, which were involved in the Himalayan orogeny.

Key words: Tectonics, MMT, MKT, MCT, Himalaya.

T/36. Tahirkheli, R.A.K., 1982. Geology of the Himalaya, Karakoram and Hindukush in Pakistan. Geological Bulletin, University of Peshawar 15, 1-51.

The northern segment of Pakistan hosts three of the best known mountain chains of the world, namely, the Himalaya, Karakoram and Hindu Kush. Among them the Lesser Himalaya received more attention by the earlier workers because of an easy access, but the other two were landlocked and remained isolated till 1960's, when the Karakoram Highway patched them with the modern amenities.

In spite of manifold problems, the geologists remained attracted to this segment of the Central Asia and continued their relentless efforts from the mid 1970's to bring this unsympathetic but enchanting terrain within the fold of geological investigation. Some of them intruded this terrain along with the climbing and scientific expeditions and a few made solo efforts, which paved a good base to provide a best possible geological account on this area. In this regard, the author gratefully acknowledges the pioneering efforts of these stalwarts who for the sake of science faced all kinds of hardships while taming this terrain and have emerged with wealth of information which enabled their

successors to continue smoothly. The author's first acquaintance with the geology of the Karakoram-Hindu Kush was cherished in 1957 while accompanying the Kyoto University (Japan) scientific expedition. Subsequently, this visit was fostered into a permanent feature during which a mapping program was initiated. Since, 1964, after being transferred from the GSP to Peshawar University, this work was accelerated and more attention was given to mapping of the virgin terrain lying blank on the first geological map of Pakistan, published in 1964. This work has helped to discover a new crustal section intervening the Indo-Pakistan and the Eurasian plates, which now is well known as the "Kohistan Island Arc". Although some geological base was attained by the Karakoram-Hindu Kush, yet there existed a vacuum to provide a comprehensive coherent regional geological interpretation to this terrain under the context of plate tectonics. The presence of the Kohistan Island arc juxtaposed between the two mighty continents produced a mosaic other than existing in the rest of the Himalaya, which further aggravated this problem.

These shortcomings greatly handicapped a regional geological correlation with Ladakh and northeastern Afghanistan with which the Karakoram and Hindu Kush respectively, are geographically linked.

To answer and arrest these problems, the best course to be adopted for their solution was to conduct a geological mapping program. Firstly, to knit together the observations made by the earlier workers lying dispersed in the isolated valleys and secondly to supplement this with fresh data to augment and up to date the already known informations on the geology of this region.

To achieve these objectives, a new geological map of the Karakoram and Hindu Kush has been introduced, a stratigraphic scheme of each geological domain has been devised which partly overlaps those produced by the earlier workers and diagrammatic sketches of all the important sections in the Himalaya, Karakoram and Hindu Kush giving a regional bias to their geological setup have been added. Besides, a regional correlation based on the new observations is attempted through with meager published literature available to the author from across the border. This is first attempt to present a regional geological mosaic of approximately 165000sq. Km area in the northern Pakistan, which was cradled by the tectonic emerging from the Indo-Pakistan-Eurasian collision and culminated during the attainment of structural configurations by the Pamir Knot, Nanga Parbat-Haramosh loop and the Hazara-Kashmir syntaxis.

The author is well aware of the shortcomings because of limitations in observations made by the author, lack of published literature and inaccessibility to nearly one-third of the area. However, it is hoped that this humble contribution will be helpful to bridge the geological gap existing between the Himalaya, Karakoram, Hindu Kush and the adjoining areas across the border.

Key words: Tectonics, geology, Himalaya, Karakoram, Hindukush.

T/37. Tahirkheli, R.A.K., 1983. Geological evolution of Kohistan island arc on the southern flank of the Karakoram-Hindu Kush in Pakistan. *Bollettino di Geofisica Teorica Applicata (Pamir-Himalaya)* 25, 351-364.

The Kohistan island arc covers approximately 36000 sq. km in the Northern part of Pakistan. It is bounded by two sutures, namely, the Main Karakoram Thrust (MKT) and the Main Mantle Thrust (MM1) which tectonically differentiate it from the Eurasian and the Indo-Pakistani plates respectively.

In the Himalaya, ophiolitic rocks mark the suture between the Eurasian and Indian continents. But in Pakistan along the southern flank of the Karakoram and the Hindu Kush an approximately 40 km thick complex of calc-alkaline plutonic/volcanic and metasedimentary rocks is emplaced between the two sutures and is considered to represent a complete cross-section of an island arc. On the north, this arc is subducted under the Eurasian marginal mass (Baltic Group and Chitral Slates) along the MKT and on the south is obducted onto the Indo-Pakistan plate (unfossiliferous lesser Himalayan sequence) along the MMT.

This arc had evolved due to intraoceanic subduction subsequent to the northward movement of the Indo-Pakistani plate which began during Late Jurassic. Its first contact with Eurasia, based on sedimentation and faunal evidences, is postulated during Late Cretaceous-Early Tertiary time and subsequently the second contact with the Indo-Pakistani plate occurred during post Paleocene.

However, Klootwijk et al. (1979), based on paleomagnetic data from Ladakh, considers the Ladakh arc to have collided first with the Indian plate during Late Paleocene-Early Eocene and with Eurasia during Eocene-Oligocene time.

Key words: Metasediments, evolution, Kohistan island arc, Karakoram, Hindukush.

T/38. Tahirkheli, R.A.K., 1985. Recent additions of the geotectonic net of northern Pakistan. Proceedings, First Pakistan Geological Congress, Lahore, 82-91.

The northern region of Pakistan comprises a variety of litho-tectonic domains, namely northwest Himalaya, Kohistan island arc, Karakoram plate and Hindukush Range. This contribution presents the new contributions to the already complex geology, structure and tectonics of the region.

Key words: Tectonics, Himalaya, Karakoram.

T/39. Tahirkheli, R.A.K., 1986. An overview of the major tectonic and geologic elements of the Himalaya and Karakoram in northern Pakistan. Geological Society of America Annual Meeting, 18.

In north Pakistan, there are three distinct geological domains, comprising NW Himalaya (Indian plate), Kohistan island arc, Karakoram-Hindukush Eurasian block. These are separated by major sutures, the Main Mantle Thrust (or Indus suture) in the south and the Main Karakoram Thrust (or Shyok suture) in the north. There are other major faults, including the Main Boundary Thrust.

Key words: Tectonics, Kohistan, Himalaya, Karakoram.

T/40. Tahirkheli, R. A. K., 1987. Shontargali thrust: an analogue of the main central thrust (MCT) in the NW Himalaya in Pakistan. Geological Bulletin, University of Peshawar 20, 209-214.

The Main Central Thrust (MCT) is one of the three principal megashears of the Himalayan orogenic belt which is formed as a result of collision between the Indian and Eurasian plates. Present studies in the substreams of the Kel Nala, one of the tributaries of the Nilam river in Kashmir and in another section located in Baloshbar area about 12 Km south of Astor in close vicinity of the Nanga Parbat massif, have revealed a new megashear which in stratigraphic, tectonic and metamorphic settings appears to be an analogue of the MCT in the NW Himalaya. This megashear is named Shontargali Thrust and like MCT, separates the Salkhala series of the Lesser Himalaya from the Nanga Parbat Gneisses of the Great Himalaya in Kashmir and Hazara in Pakistan.

Key words: Tectonics, MCT, Shontargali Thrust, Himalaya.

T/41. Tahirkheli, R.A.K., 1988. Presence of the Main Central Thrust in the tectonic domain of northwestern Himalaya in Pakistan. Geological Bulletin, University of Peshawar 21, 131-140.

The tectonic model of the northwestern Himalaya remained obscure for years for lack of demarcation of the Indus Suture Zone (ISZ) and Main Central Thrust (MCT) which are the two important tectonic features of the rest of the Himalaya. The problem of the ISZ was solved about a decade ago by locating two suture zones, the main Mantle Thrust (MMT) and the Main Karakoram Thrust (MKT) with an intervening Kohistan island arc (Tahirkheli et al., 1976, 1979). The location of MCT remained a debatable issue because of its discontinuity beyond west (Simla) Himalaya towards northwest in Kashmir and northern Pakistan. As a result, the Main Boundary Thrust and the Panjal Thrust in Kashmir and NW Himalaya, respectively, were considered as analogues of MCT.

This paper discusses a newly discovered deep level thrust named "Shontargali Thrust" which on the basis of geographic location and tectono-stratigraphic setup, compares favourably with the Main Central Thrust.

Key words: Tectonics, Shontargali Thrust, MCT, Himalaya.

T/42. Tahirkheli, R.A.K., 1989. Whether newly discovered Shontargali Thrust is an analogue of MCT in the Northwestern Himalaya in Pakistan. Kashmir Journal of Geology 6 & 7, 23-28.

Shontargali Thrust is a newly discovered megashear in the northwestern domain of Himalaya. A brief introduction to its broad geological aspects is intended in this paper. Its geographic location is at the base of Nanga Parbat massif, Higher Himalaya. It has been investigated for a stretch of about 50 km in Barai stream, a tributary of

Neelam=Kishenganga river in Kashmir and in Mir Malik stream, a tributary of Astor river, in Gilgit Agency. Both of these streams follow the strike of the thrust.

In the Shontargali Thrust, the Salkhala series Jatog Fm. is thrust over by the Nanga Parbat gneisses Central crystalline Vaikritta Group. The thrust has a northeast-southwest strike and dips between 250-350 towards east. In more tectonized sections, the angle of dip could be more. The Shontargali Thrust zone, between 3-5 km wide, is highly deformed giving rise to squeezed recumbent or reclined folds. Imbrication in the footwall zone of the thrust is manifest in highly deformed sections which usually give rise to duplex structures. The presence of mylonite and migmatite point to ductile deformation which is frequently noticed in the footwall zone of the thrust. On the basis of its geographic location and grade of metamorphism of the associated rocks, couple with its stratigraphic and tectonic settings, the author considers the Shontargali Thrust as an analogue of the Mian Central Thrust (MCT) in the northwest Himalaya in Pakistan.

Key words: Tectonics, MCT, Shontargali Thrust, Himalaya.

T/43. Tahirkheli, R.A.K., 1990. Tectonic zonation of the northwestern Himalaya in Pakistan. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, 6-7.

The tectonic zonation of the NW Himalaya in Pakistan, for years, could not be spelt out adequately because of the absence of the major tectonic scars which are so prominently manifest in the rest of the Himalaya. Recent studies on this problem have added a new dimension to the interpretation of the tectonic frame of this region by locating the extension of the Indus Suture Zone (ISZ) and the Main Central Thrust (MCT) in the NW Himalaya in Pakistan.

The ISZ, west of Ladakh, bifurcates into two sutures with a sandwiched Island arc. The northern suture which welds the Kohistan arc with the Eurasian plate is called the Main Karakorum Thrust. The southern suture juxtaposes the Kohistan arc with the Indo-Pakistan plate and is named the Main Mantle Thrust. Nowhere in Pakistan, the Eurasian Plate comes in direct contact with the Indo-Pakistan plate.

The two sutures and the Kohistan Island arc have been given due attention in several papers published within the country and abroad. But the extension of the MCT is a new addition which completes the regional tectonic net for correlation of the tectonic Zonation of NW Himalaya with the rest.

The analogue of the MCT in NW Himalaya is called the Shontargali Thrust and is mapped in the Kel stream, a tributary of the Kishanganga-Neelum river in Kashmir and the Mir Malik stream, a tributary of Astor river in Gilgit Agency. On the basis of geographic location, stratigraphic setting, tectonic frame and mode of deformation of the rocks involved, the Shontargali Thrust appears as an analogue of the MCT in the NW Himalaya in Pakistan.

Key words: Tectonics, stratigraphy, MCT, Himalaya.

T/44. Tahirkheli, R.A.K., 1991. Tectono-stratigraphic zonation of the northwestern Himalayas in Pakistan. Abstracts, 1st Postgraduate Training Course in Plate Tectonics, Punjab University, Lahore, p.7.

Consult the preceding account.

Key words: Tectonics, MCT, stratigraphy, Himalaya.

T/45. Tahirkheli, R.A.K., 1992a. Shontargali Thrust: The Main Central Thrust (MCT) of northwestern Himalaya, Pakistan. In: Sinha, A.K. (ed.) Himalaya Orogen and Global Tectonics. Shiva Printers Derhra Dun, 107-120.

For further information, consult Tahirkheli (1987, 1988, 1989).

Key words: Tectonics, Shontargali Thrust, MCT, Himalaya.

T/46. Tahirkheli, R.A.K., 1992b. Shontargali thrust: An addition of new megashear akin to the Main Central Thrust, in the northwestern Himalaya tectonic domain. Abstracts, First South Asia Geological Congress, Islamabad, 42-43.

For further information, consult Tahirkheli (1987, 1988, 1989).

Key words: Tectonics, Shontargali Thrust, MCT, Himalaya.

T/47. Tahirkheli, R.A.K., 1992-93. Tectono-metamorphic domains of the Karakoram in Pakistan. Regional Postgraduate Training Course in Plate Tectonics, Punjab University, 24-25.

The Karakoram constitutes the southern marginal mass of Eurasia which is tectonically delineated from the Himalaya-Kohistan/Ladakh arc by the Main Karakoram Thrust, the northern suture. Its northern, eastern and western boundaries are shared respectively, by Kun Lun-Wakhan (SE Pamir), southern Tibet, east of Shyok and the eastern Chitral along Yarkun River. On the basis of tectono-metamorphic settings, the Karakoram terrain is divisible into three east-west trending linear belts:

(1) The southern Preheroyanian marginal crystalline mass, (2) The central magmatic domain, and (3) the northern Permian-Jurassic Karakoram microplate.

The southern marginal mass is comprised of metasediments ranging from slate, phyllite, various types of schists, para-gneisses, flaggy quartzite, conglomerate, medium crystalline limestone and very coarse grained marble. The grade of metamorphism is low, but in more tectonized sections, this level could rise to kyanite and sillimanite grade. The rocks are named Chitral Slate in Chitral, Darkut Group in the Yasin valley, Damurdu Formation and Baltit Group in the Hunza valley. The ages assigned to these rocks by various authors are, Cretaceous by Calkin et al., (1981), PermoCarboniferous by Ivanac et al., (1956), Permo-Triassic by Desio (1975), Triassic by Pudsey et al., (1985) and Precambrian by Tahirkheli (1982).

The central magmatic domain in the Karakoram is named Axial Karakoram Batholith and constitutes a composite assemblage of hornblende granodiorite, granites, pegmatites, aplites and vein quartz belonging to pre- and post-tectonic phases. The radiometric dates (Debon et al., 1987) place various magmatic phases in three broad categories: Middle Cretaceous (ca 110-95 Ma), Palaeogene (ca 43 Ma) and Neogene (ca 15-9 Ma).

The upper Hunza valley (UHV) sequences of the northern Karakoram microplate investigated along the Karakoram Highway reveal the following sequential order (Tahirkheli et al., 1990): Gircha Formation, Passu Slate, Dih Quartzite, Gugal Dolomite and Shanoz Conglomerate. This is a modified stratigraphic scheme, earlier presented by Desio et al. (1972). Their age ranges from Permian (on faunal basis) to Cretaceous (Shanoz Conglomerate) on lithostratigraphic correlation with the Reshun Conglomerate in Chitral. This microplate is Gondwanic (Gaetani et al., 1990) and is accreted on to Eurasian margin during pre-Main Karakoram Thrust (MKT) accident.

On the basis of lithostratigraphic, tectonometamorphic and biostratigraphic evidences, it appears that there existed two paleogeologic domains in the Karakoram. The northern one on faunal support is assigned a Permo-Jurassic age (Gaetani et al., 1990) and the southern one has a pre-Devonian/Ordovician basement. In a tectonic scenario of the Karakoram with the northern Karakoram microplate, it will be problematic to find an adjustable place for the southern mass. The northern Karakoram microplate has two neighbours Kun Lun and Qiantong microplates which have their ancestors located in Eurasia. The lithostratigraphic and tectonometamorphic frames of the southern mass of the Karakoram relate it sympathetically with the Kabul and Lhasa microplates, lying on its east and west respectively.

Key words: Tectonics, metamorphism, Karakoram.

T/48. Tahirkheli, R.A.K., 1995. A macro-overview of geology of Pakistan. Proceedings, International Round Table Conference on Foreign Investment in Exploration and Mining in Pakistan, Islamabad, October 16-18, 1994, 47-55.

Key words: Geology.

T/49. Tahirkheli, R.A.K., 1997. Tectono-stratigraphic framework of the Hindukush Range in Chitral, Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, 68-69.

The rock formations encountered in the Chitral domain of Hindukush are:

i. The Chitral Slates are dominantly pelitic ranging from slates to various types of schists along with para-gneisses, interbedded flaggy quartzites, medium crystalline limestone and conglomerate. Two principal mappable lithologies incorporated in the Chitral Slates are Kaghozai Greenschists and Gahirat Marble. Diorite, dolerite and amphibolite intrusions in the basic realm and pegmatite, aplite and vein quartz in the acid are common. Based on

lithostratigraphic correlation with their counterparts in the west, (in Nuristan) in Afghanistan and in the east in the Karakoram and Ladakh, the Chitral Slates are placed in the Precambrian-Lower Palaeozoic.

ii. The Broghil Formation is composed of medium crystalline limestone, siliceous dolomitic limestone, flaggy quartzites and interbedded siliceous slates. About 5 meters thick bed of siliceous dolomitic limestone bed has yielded conodont fossils on the basis of which this sequence has been assigned and Ordovician age.

iii. The Shogran Formation at its stratotype is about 900 m thick and is divisible into three faunal units; a lower crinoidal massive dolomite, a middle coral-bearing thick bedded dolomite along with interbedded black shales and upper flaggy quartzite and thin bedded limestone with brachiopods. A lower to upper Devonian age is assigned to Shogran Formation.

iv. The undifferentiated Turikho Group constitutes a thick sequence of dominantly argillaceous rocks with subordinate crystalline limestone, quartzos sandstone and conglomerate along with host of acid and basic sills and dykes. These rocks have been mapped in different sections as Lun shales, Sirikol Shales, Khandhot Shales, Wakhan Slates and Fusilina Limestone. Some limestone beds in the Mastuj valley have yielded fossils, on the basis of which Permo-Carb, Triassic and Jurassic ages have been assigned to the rocks of this group.

v. The Reshun Formation is divisible into three litho-stratigraphic units. The lower one is medium crystalline, thick bedded to massive Krinj Limestone, followed by Awi Conglomerate with larger part of its clasts derived from the underlying limestone and from the Chitral Slates. The top bed consists of maroon marly shales. Some Orbitolina-bearing pebbles conglomerate along with Hippurites in Krinj Limestone in Lutkho valley places Reshun Formation into the Cretaceous.

vi. The Tirich Mir Granites occur in isolated plutons intruding Turikho Group of rocks and constitute an assemblage of quartz diorite, granodiorite, monzogranite and granite. Rb/Sr radiometric age on granodiorite has yielded an age of 115 my.

vii. The westward termination of the Axial Karakoram batholith in the Hindukush of Chitral is marked by three east-west trending plutons located within the Chitral Slates. The Buni Zorn pluton west of Sor Laspuir among them, is the largest. Granodiorite and granites are its main constituents with basic and acid sills and dykes occurring as minor intrusions. Radiometric dates on granodiorite and granites of Karakoram batholith range from 96 to 15 my. The four major tectonic scars in the Chitral area are, (a) Reshun Fault, (b) Ayun Fault, (c) Tirich Fault and (d) Shishi Koh Fault. The last one is regarded to demarcate the northern Himalayan suture, namely the Main Karakoram Thrust. Tirich Fault in the northern domain has indicated some basic igneous and metavolcanic signatures and could mark a boundary between Hindukush and Southern Pamir Block.

Key words: Stratigraphy, tectonics, Hindukush, Chitral.

T/50. Tahirkheli, R.A., Asif, M.K. & Tahirkheli, T., 1992. Regional geological framework of the Karakorum in Pakisatn. In: Zheng, D., Zhang, Q. & Pan, Y. (Eds.), Proceedings of international symposium on the Karakorum and Kunlun mmountains. China Meteorological Press, Beijing, 54-71.

The 600x150 km Karalorum Range covers about 90,000 km² area of Pakistan, China and India. It comprises three linear belts, from S to N, 1: Southern Pre-Hercynian (Precambrian-Early Paleozoic) crystalline marginal mass which is delineated from the Kohistan arc and Himalaya by the Main Karakorum Thrust; 2: The central magmatic domain of batholithic dimension. It comprises pre-tectonic phases of Late Cretaceous age and post-tectonic phases emplaced in Miocene, and 3: The northern Hercynian (Pero-Cretaceous) sedimentary belt, referred to in the paper as the Upper Hunza Valley sequence.

Key words: Tectonics, Northern Karakoram plate, Main Karakorum Thrust, Hunza

T/51. Tahirkheli, R.A.K., Baqri, S.R.H. & Dawood, H., 1992. A new status of the pelitic sequences in the upper Hunza valley in Karakoram, Pakistan. Abstracts, First South Asia Geological Congress, Islamabad, p.43.

Briefly describes the pelitic rocks (e.g., Misgar slates) that cover large areas in northern Hunza valley, in the central Karakoram Range. For further detail, See Tahirkheli, SUN, Pan et al., 1990.

Key words: Pelitic sequence, slates, Hunza, Karakoram.

T/52. Tahirkheli, R.A.K. & Jan, M.Q. (Eds.), 1979a. Geology of Kohistan, Karakoram Himalaya, northern Pakistan. Geological Bulletin, University of Peshawar, 11, 187p.

This volume contains a compilation of 11 papers on geology of Kohistan. Contributors include R.A.K. Tahirkheli (2), M.Q. Jan (4), M.A. Khalil and A.G.K. Afridi (1), M. Majid (1), J. Khan (1), M.S. Badshah (1), F.A. Shams and S. Ahmad (1), and regional geological map by Tahirkheli and Jan. the papers are summarized in appropriate places.

Key words: Ultramafics, metamorphism, Island arc, Tectonics, Kohistan, Himalaya.

T/53. Tahirkheli, R.A.K. & Jan, M.Q., 1979b. A preliminary geological map of Kohistan and the adjoining areas, N. Pakistan. Geological Bulletin, University of Peshawar 11.

This is the first compilation of the geological map of northern Pakistan, where much of the blank area shown on the Geological map of Pakistan (Bakr & Jackson, 1964) was also covered. The terrain is divided into Eurasian, Kohistan island arc, and Indian plate domains. Major thrust faults, i.e., Main Karakoram Thrust, Main Mantle thrust and Main Boundary Thrust, are also shown on the coloured map.

Key words: Geological map, Indian plate, Kohistan, Karakoram.

T/54. Tahirkheli, R.A.K. & Jan, M.Q., 1984. The geographical and geological domains of the Karakoram. In Miller K.J. (eds), The International Karakoram Project, Volume 2, 57-70. Cambridge University Press.

This paper deals with some of the existing geographical and geological problems of the Karakoram and the authoress presents their views for their solution and better understanding.

The western and eastern boundaries of the Karakoram with the Hindukush and the Himalaya, respectively, still remain an unsettled issue. The authors on the basis of their observations have extended the western boundary to the high ranges forming the main divide between the Gilgit and the Yarkun rivers, lying southwest of Mastuj between 72° and 73° E. In the north this boundary passes slightly east of Broghil between Long. 73° and 74° E.

In the east, the limit of the Karakoram has been stretched deep into Ladakh; and the eastern extent of the Deosai-Ladakh range with its eastern boundary with the Himalaya.

Under the context of plate tectonics, the rock sequence established by authors in the western section of the Karakoram (Hunza valley), from south to the north as follows:

Kohistan Island Arc Mass	Ladakh Granodiorite
Chalt Ophiolite	
Yasin Group	
Main Karakoram Thrust	
Asian	Darkut Group
Karakoram Granodiorite	
FAULT	
The rock sequence of the Tethyan folded belt lying towards north of the Main Karakoram Range	

Key words: Tectonics, geology, geography, Karakoram.

T/55. Tahirkheli, R.A.K., Jan, M.Q. & Majid, M. (Eds.), 1980. Proceedings of the International Committee on Geodynamics. Geological Bulletin, University of Peshawar, 13, 213p.

This is a compilation of 23 papers by international experts on the geology and geodynamics of the Himalayan region, especially northern Pakistan. Individual papers are annotated in appropriate places in this volume.

Key words: Geodynamics, Himalaya

T/56. Tahirkheli, R.A.K., Jan, M.Q. & Mian, I., 1971a. Graphite occurrence in Spinkai area, Tirah, Khyber Agency, Directorate of Mineral Development, Govt. of N.W.F.P., Peshawar, Information Release 4, 10p.

For details consult the following account.

Key words: Metamorphic rocks, graphite, Khyber Agency.

T/57. Tahirkheli, R.A.K., Jan, M.Q. & Mian, I., 1971b. Hydrothermal graphite in Tirah, Khyber Agency. Geological Bulletin, University of Peshawar 6, 114-117.

During recent years, some samples of graphite from Tirah, Khyber Agency, which were analysed in various laboratories in Pakistan, have yielded over 50 % fixed carbon. This created special interest for the authors to conduct investigations concerning the origin and economic potentials of the mineralization. The graphite is located near Spinkai (Lat. 33° 55' ½, Long. 70° 41') in Tirah tribal territory and is accessible through Chora, Bazar, Bara and Rajgal Valleys. The area can also be approached from Kohat via Sra Mela and Maidan. The mineralized area is along the northern slope of Bijor Sar (ca. 9,000 feet) at an elevation of about 6,500 feet.

Key words: Metamorphic rocks, graphite, Khyber Agency.

T/58. Tahirkheli, R.A.K., Jan, M.Q. & Mian, I., 1975. A geological traverse through Tirah, Khyber Agency, NWFP, Pakistan. Geological Bulletin, University of Peshawar 7 & 8, 79-88.

This short paper presents the results of a geological traverse conducted through the northern part of Tirah in Khyber Agency during the last week of July, 1971. The rocks encountered between Lala China and the Rajgal area are, Lala China Slaty-shale, Chura Kandao Limestone, Walai Limestone, China Limestone, Spinkai Limestone, Mughalbagh Shales, Paleocene Limestone and Murree sandstones and shales; the latter two units are well developed in the Bara and Rajgal valleys, west of Bazar.

The Palaeozoic sequence, besides Lala China and Chura Kandao (Khyber Pass), were encountered at two places; in a Khwar about 3 miles upstream of Mughalbagh and in Baraghat nala in the Rajgal area. Four differentiable mapable units from bottom to top are; Lwarai Mela Limestone, Baraghat Slate, Barai Quartzite and Spinkai Limestone, which have been placed as members of the Rajgal Formation. Acid igneous intrusions consisting of granite and granite-gneiss with pegmatite and aplite veins lie in contact with the upper part of Spinkai Limestone. Graphite mineralization occurs in the granite and granite-gneiss near the contact of the Spinkai Limestone.

Key words: Reconnaissance, mapping, Palaeozoic, Khyber Agency.

T/59. Tahirkheli, R.A.K. & Kamal, M., 1981. Whether tectono-magmatic regimes offer any prospects for primary uranium mineralization in northern Pakistan. Geological Bulletin, University of Peshawar 14, 95-100.

The northern segment of Pakistan inhabits some of the loftiest mountain systems of the world. Nearly forty per cent of the rocks covering the surface area in this terrain are igneous, out of which over seventy per cent belong to the acid igneous domain. The Late Mesozoic – Cenozoic orogenic events had brought into being some of the major lineaments, which have regional dimensions. Magmatic emanations associated with these shears belong to several generations; some of them belonging to the late phases have indicated metallic mineral associations. A few known primary uranium mineralizations in this region are associated with some of these magmatic episodes. This paper discusses the tectono-magmatic environment of the northern Pakistan and delineates the metallogenic zones under the context of plate tectonics – where favorable conditions may exist for finding primary uranium mineralization.

Key words. Tectonics, magmatism, uranium mineralization, Gilgit-Baltistan

T/60. Tahirkheli, R.A.K. & Majid, M., 1977. Geology of the Tanawals in the southwest Tanawal and Gandghar Range, Hazara, Pakistan. Geological Bulletin, University of Peshawar 9 & 10, 1-21.

In the Hazara Paleozoic sequence, the Tanawal Formation overlies the Hazara Slates and underlies the Abbottabad Formation. A pebbly bed marks the contact between the Hazara Slates and the Tanawals, which is not persistent, but elsewhere in Kashmir and the Central Himalayan sections gradational contact has been reported by the earlier worker.

The Tanawal comprise dominantly of arenaceous rocks which constitute quartzite, quartzitic schist and quartzitic sandstone with interbedded arenaceous slaty shales, slates, phyllitic slates and conglomerate which are intruded by the igneous rocks. Among the quartzose rocks, arkosic wacke, suabarkose, arenites and quartz arenites are differentiated. Amphibolites, epi-diorites, porphyritic micro-tonalite, dacite, rhyo-dacite, pegmatite and quartz veins are the igneous rocks which occur in the Tanawals as sills, dykes and veins.

The Tanawals are unfossiliferous. Their sympathetic stratigraphic relationship with the fossiliferous Paleozoic rocks in Kashmir, Central Himalaya and Swabi – Lower Swat areas, suggest for them a Devonian – Lower Carboniferous age. The discovery of Hyolithids of Cambrian age near the contact of overlying Abbottabad Formation and Hazira shales will depress the age of the Tanawals to Precambrian. However, this fossil find is very localized and appears to have been derived from the older horizon and incorporated in these rocks.

Key words: Stratigraphy, Palaeozoic, Hazara.

T/61. Tahirkheli, R.A.K., Mattauer, M., Frost, F. & Tapponnier, P., 1977. Donnees nouvelles sur la suture Inde-Eurasie auo Pakistan. Colloques Intrenacionale, CNRS (Himlaya Science de La terre) 268, 209-212.

Consult the following for further information

Key words: Sutures, India-Eurasia.

T/62. Tahirkheli, R.A.K., Mattauer, M., Frost, F. & Tapponnier, P., 1979. The India-Eurasia suture zone in northern Pakistan: synthesis and interpretation of recent data at plate scale. In: Farah, A. & Dejong, K.A. (eds) Geodynamics of Pakistan. GSP, 125-130.

In north Pakistan, there are three distinct geological domains, comprising NW Himalaya (Indian plate), Kohistan Mountains, and Eurasian block. These terrains are separated by major faults. The authors were amongst the earliest ones to propose that the Kohistan terrain is a sandwich of an island arc between Eurasia in the north and Indian plate in the south. Its northern boundary is delineated by a regional fault that they named as the Main Karakoram Thrust, and its southern boundary with the Indian plate delineated by what they called the Main Mantle Thrust.

Key words: Sutures, tectonics, Kohistan, Indian plate, Eurasian plate.

T/63. Tahirkheli, R.A.K. & Riaz, M., 1991. Tectono-stratigraphic implication in extending the Panjal thrust, west of the Hazara-Kashmir syntaxis. Geological Bulletin, University of Pakistan 24, 25-32.

The Panjal Thrust (PT) is one of the principal tectonic scars of the Lesser Himalayan domain in Kashmir. Its type section is located in the Panjal Range from where it extends northeast wards along the eastern flank of the Hazara-Kashmir syntaxis and terminates at its apex. In the Panjal Thrust the Precambrian Salkhalas thrust over the Permo-Triassic Panjal Group. This tectonostratigraphic setup is retained by this thrust throughout its course in Kashmir. During recent years, some geologists have extended this thrust west of the syntaxis through Galiat, Abbottabad, Gandghar Range, and terminated it across the Indus in the Attock-Cherat Range. The tectono-stratigraphic and lithostratigraphic frames of these sections are not akin to the ones displayed in the Panjal Thrust sections in Kashmir. This controversial aspect of the Panjal Thrust has been studied to ascertain whether the western counterparts of the Panjal Thrust west of the Hazara-Kashmir syntaxis has any justification to be correlated with its tectono-stratigraphic net displayed in Kashmir.

Key words: Tectonics, stratigraphy, structure, Panjal thrust, Hazara-Kashmir-syntaxis.

T/64. Tahirkheli, R.A.K., Sun, D., Pan, Y., Deng, W., Zhang, Y., Baqri, S.R.H. & Dawood, H., 1990. Review of stratigraphy of the upper Hunza valley (UHV), NW Karakoram, Pakistan. Geological Bulletin, University of Peshawar 23, 203-214.

Recent collaborative work of Pakistani and Chinese scientists has established five mapable stratigraphic units which, from old to young, are: i. Gircha Fm., ii. Pak-China Friendship Fm (Dih Fm.), iii. Passu Slate, iv. Gujal Dolomite, and v. Shanoz Conglomerate. A NNW-SSE trending Sost Anticline is the major structure in this area which bifurcates the stratigraphic net of this valley. The oldest formation exposed in the core of Sost Anticline is Gircha Fm. The base of the Gircha Fm is not exposed in UHV. The age of stratigraphic sequence in the UHV, based on fauna, ranges from Late Permian to Late Cretaceous-Early Tertiary.

Key words: Stratigraphy, structure, Hunza valley.

T/65. Tahirkheli, T., 1998. Geochemistry, mineralogy and petrology of the sulfide mineralization and associated rocks in the area around Drosh, north Pakistan. Ph.D. thesis, NCE geology, University of Peshawar.

Copper mineralization in the Drosh-Shishi area is localized in the upper crust of the Kohistan arc terrane in Chitral, northern Pakistan. It is confined to the Gawuch Formation in the area, comprising variably metamorphosed volcanics and sediments intruded by the plutons of diorite and granodiorite composition. The metavolcanics of the Gawuch Formation and the diorite-granodiorite minor plutons have calc-alkaline compositional characteristics. In comparison, the metavolcanics of the Darosh Formation, occupying the top of the succession, are island-arc tholeiites. Copper mineralization in the area is related to hydrothermal activity and is mainly associated with altered diorites and quartz veins. It occurs in different forms; in the quartz veins, along the foliation planes, in dissemination and as supergene enrichment. Tetrahedrite, chalcopyrite, pyrite and galena are the dominant ore minerals along with subordinate amounts of sphalerite, magnetite, malachite and azurite. Fluid-inclusion studies indicate that the salinity of the hydrothermal solution is <26 equivalent wt% NaCl and the homogenization temperature is in the range of 160 to 350°C. Oxygen isotope data suggest that the quartz in the mineralized quartz veins has $\delta^{18}\text{O}$ values ranging from 14.49 to 18.32 per mil with mean value of 16.63 ‰. This, when combined with the homogenization temperature obtained from the fluid-inclusion studies, indicates involvement of magmatic fluids ($\delta^{18}\text{O} = 5.79\text{--}9.62\text{‰}$) in the formation of quartz veins and associated copper mineralization.

The lead isotopic compositions of three galena samples suggest that $^{206}\text{Pb}/^{204}\text{Pb}$ ranges from 18.728 to 18.793, $^{207}\text{Pb}/^{204}\text{Pb}$ from 15.658 to 15.728 and $^{208}\text{Pb}/^{204}\text{Pb}$ from 39.040 to 39.285. These Pb-isotope ratios yield model ages of 42 – 140 Ma with the μ values of 9.86 to 10.01. The minimum age (i.e., 42 Ma) is in close agreement with 40Ar-39Ar age of the Lowari pluton, which is considered to be the source of hydrothermal solutions. The lead isotopic composition of studied galena samples indicate involvement of lead derived from older sources. These sources could be the arc volcanics or pelagic sediments of oceanic crust of Neotethys or the continental crust of the subducting Indian plate. It is concluded from these studies that the copper mineralization in Drosh-Shishi area was produced by the hydrothermal activity related with syntectonic dioritic magmatism.

Key words: Geochemistry, mineralogy, petrology, sulfide mineralization, Chitral.

T/66. Tahirkheli, T., Khan, M.A. & Mian, I., 1990. A- type granites of Warsak, Khyber Agency, N Pakistan: Rift-related acid magmatism in the Indian plate. Geological Bulletin, University Peshawar 23, 187-202.

Three varieties of granite from Warsak have been analysed for their geochemical composition, particularly trace elements. Two of the three varieties contain aegirine and riebeckite and are thus peralkaline. The third variety comprises biotite and muscovite with rare garnet, and varies between meta- and peraluminous compositions. Irrespective of these differences in mineralogical and major-element characteristics, there is a close match in incompatible trace elements between all the three varieties of granite from the studies area. A close scrutiny of the trace-element composition reveals A-type nature of the Warsak granites. Palaeozoic fragmentation of Gondwana,

involving breakaway of India, may be responsible for the generation of the Warsak A-type granites and other similar granites in the Peshawar plain at Ambela, Shewa-Shahabazgarhi, Malakand and Terbela.

Key words: Geochemistry, petrology, granites, magmatism, Indian plate.

T/67. Tahirkheli, T., Khan, M.A. & Mian, I., 1993. The Warsak basic rocks: Initial- rift stage continental tholeiites of Permo-Triassic “Panjal” affinity. Geological Bulletin, University of Peshawar 26, 17-33.

A suite of basic rocks, comprising microgabbros, dolorites, metabasalts and volcanoclastic sediments, occurs associated, both in space and time, with the alkaline granites at Warsak near Peshawar. Detailed geochemistry, mainly based on trace elements, suggests that the magmatism responsible for the Warsak basic rocks was tholeiitic in composition and was erupted/intruded in a within-plate continental setting. Furthermore, the Warsak basic rocks have geochemical composition closer to rift volcanics rather than the plateau basalts.

The Warsak basic rocks, in this study, have been identified to be related with the suite of tholeiitic basalts commonly encountered as dykes and sills in the Lower Palaeozoic or older rocks of northern part of the Indian plate. The volcanic and volcanoclastic component in the Warsak area is directly correlatable with the Karapa greenschist in Ambela area, and the amphibolite marker horizon in the upper part of the Marghazar Formation of Lower Swat, which are in turn correlatable with the Permo-Triassic Panjal volcanics of Kaghan and Kashmir.

Key words: Geochemistry, petrology, granites, magmatism, Indian plate.

T/68. Tahirkheli, T., Khan, M.A. & Shah, M.T., 2001. Geochemistry and petrogenesis of igneous rocks in Drosh-Shishi area, Chitral, Northern Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.11.

Drosh-Shishi area is localized in the upper crust of the Kohistan arc terrane in Chitral, northern Pakistan. It comprises two groups of igneous rocks, metavolcanics and diorites. Metavolcanics occur as two stratigraphic entities i.e. Gawuch and Drosh formations. Gawuch Formation comprises of variably metamorphosed volcanics and sediments intruded by the plutons of diorites and granodiorite composition.

The metavolcanics of Gawuch Formation are divided into two types: porphyritic and fine-grained to glassy. The former vary from fresh to highly altered and commonly dissected by quartz and calcite veins. Volcanic rocks belonging to the Drosh Formation are massive to weakly foliated, fine-grained and commonly altered. In composition, they are mostly andesitic. Three varieties of diorites are distinguished in Gawuch Formation on the basis of texture and degree of alteration, 1) diorites, 2) altered diorites, and 3) gneissose diorites. Geochemistry involving major and trace elements have been used to characterize the petrology and tectonic setting of igneous rocks of the area. Detailed geochemistry suggests that the magmatism responsible for diorites and volcanics of the Gawuch Formation was calc-alkaline, while that of Drosh Formation was tholeiitic in composition. Detailed treatment in terms of mantle-normalized trace element patterns and discrimination diagrams suggest that diorites and the two groups of volcanics, despite differences in their petrological character, originated with a strong subduction component.

Key words: Geochemistry, petrogenesis, Chitral, Kohistan arc.

T/69. Tahirkheli, T., Shah, M.T. & Khan, M.A., 1997. Mineralogical isotopic and fluid inclusion studies of copper mineralization in Drosh-Shishi area, Chitral, northern Pakistan. Nation. Symp. Econ. Geol., (Abstract) p.9-10.

Key words: Geochemistry, mineralogy, copper, Chitral.

T/70. Tahirkheli, T., Shah, M.T. & Khan, M.A., 1997a. Lead isotopic signature of the hydrothermal copper mineralization in Drosh-Shishi area, Chitral, Northern Pakistan. Abstracts, 3rd Pakistan Geological Congress, University of Peshawar, p.69.

For details consult the following account.

Key words: Geochemistry, mineralogy, isotopes, lead, Chitral.

T/71. Tahirkheli, T., Shah, M.T. & Khan, M.A., 1997b. Lead isotopic signature of the hydrothermal copper mineralization in Drosh-Shishi area, Chitral, Kohistan arc terrane, Northern Pakistan. *Geological Bulletin, University Peshawar* 30, 209-217.

Copper mineralization in Drosh-Shishi area is a part of the upper crust of Kohistan arc terrane in Chitral, northern Pakistan. It is generally confined to the Gawuch formation in the area. This formation comprises of variably metamorphosed volcanics and sediments intruded by plutons of diorite and granodiorite. Copper mineralization is related to the hydrothermal activity and is mainly associated with altered diorites and quartz veins.

The lead isotopic ratios of three samples of galena from quartz veins in Drosh-Shishi area were determined. $^{206}\text{Pb}/^{204}\text{Pb}$ from 18.728 to 18.793, $^{207}\text{Pb}/^{204}\text{Pb}$ from 15.658 to 15.728 and $^{208}\text{Pb}/^{204}\text{Pb}$ from 39.040 to 39.285. These lead-isotopic ratios yield wide range of model ages of 42 to 140 Ma. This mineralization is very young in terms of age and have μ values of 9.86 to 10.01. The studied galenas have comparable Pb-isotope ratios to that of Rossie-Type veins of USA and Canada and are more radiogenic to the conformable massive sulfides and less radiogenic to Mississippi Valley-Type sulfide deposits. The Lead isotopic data further suggest that the lead in galena may have been derived from the arc volcanics or pelagic sediments of ocean crust of Neo-Tethys or continental crust of Indian plate and may have relation with orogeny.

Key words: Geochemistry, copper mineralization, isotopes, lead, Chitral.

T/72. Tahirkheli, T., Shah, M.T. & Khan, M.A., 1998. Oxygen Isotopic Signature of the Hydrothermal Copper Mineralization in Drosh-Shishi Area, Chitral, Pakistan. *Acta Mineralogica Pakistanica* 9, 111-116.

Copper mineralization in Drosh-Shishi area is a part of the upper crust of Kohistan arc terrane in Chitral, northern Pakistan. It is generally confined to the Gawuch Formation in the area. This formation comprises of variably metamorphose volcanics and sediments intruded by plutons of diorite and granodiorite. Copper mineralization is related to the hydrothermal activity and is mainly associated with altered diorites and quartz veins.

Nine samples of mineralized quartz veins in Drosh Shishi area were analyzed for oxygen isotopic ratios. The $\delta^{18}\text{O}$ value of quartz veins range from 14.49 to 18.32‰ with a mean value of 16.63‰. The $\delta^{18}\text{O}$ value of the mineralizing fluid of the area has been calculated at the man temperature (255°C) as determined by fluid inclusion studies. The estimated $\delta^{18}\text{O}$ value of the mineralizing fluid ranges from 5.79 to 9.62‰ with a mean value of 7.98‰. This indicates the involvement of magmatic fluids in the formation of quartz veins and associated copper mineralization in the investigated area.

Key words: Geochemistry, oxygen isotopes, copper mineralization, hydrothermal, Chitral.

T/73. Tahirkheli, T., Shah, M.T. & Khan, M.A., 2000. Mineralogical, isotopic and fluid inclusion studies of copper mineralization in Drosh-Shishi area, Chitral, Northern Pakistan. In: Hussain, S.S. & Akbar, H.D. (Eds.), *Proceedings, National Symposium on Economic Geology of Pakistan, 1997*, Islamabad, 59-71.

Key words: Geochemistry, mineralogy, isotopes, copper, fluid inclusions, Chitral.

T/74. Tahirkheli, T., Shah, M.T. & Khan, M. A., 2000. Genesis of copper mineralization in the western Kohistan island arc terrane, NW Himalaya-Hindukush, N. Pakistan. *Abstract Volume, 15th Himalaya-Karakoram-Tibet Workshop*, Chengdu, China, 410-411.

Key words: Mineralogy, copper, Kohistan island arc, Himalaya, Hindukush.

T/75. Tahirkheli, T., Shah, M.T. & Khan, M.A., 2000. Copper mineralization in the western Kohistan island arc terrane, NW Himalaya-Hindukush, N. Pakistan. Abstracts, Third South Asia Geological Congress, Lahore, 175-177.

The Kohistan Terrane in N. Pakistan straddles the suture zone between the collided Indian and Eurasian plates in the NW Himalayas of N. Pakistan. Initiated as an intra-oceanic island-arc crust in Neotethys, the terrane accreted with the southern margin of the Karakoram Plate in the Late Cretaceous (~90 Ma). Continued subduction at its southern margin resulted in Andean type magmatism and tectonics, until collision with the Indian Plate in the Early Eocene. Whereas much of the central and eastern Kohistan expose Cretaceous volcanic and sedimentary rocks of intra-oceanic island arc setting, the western Kohistan in Swat, Dir, Chitral and upper Ghizer valleys preserves remnants of the Late Paleocene-Early Eocene volcanism and sedimentation of Andean type setting. These volcano-sedimentary lithologies in western Kohistan are geographically divisible into two, separated by the Lowari Pluton; 1) Dir-Swat Belt, 2) Drosh-Shamran Belt. Late Paleocene-Early Eocene siliceous volcanics termed Utror Volcanics and Shamran Volcanics are common in the two belts and so are the plutons intrusive into these volcanics (Late Stage-II of the Kohistan Batholith). The difference is in the sedimentary successions present in the two belts. Whereas in the Dir-Swat belt, the sedimentary succession comprises Baraul Banda Slate Formation, deposited in deep-water fore-arc setting and contemporaneous in age with that of the nearby Utror Volcanic Formation (~55-60 Ma), the sediments in the Drosh-Shamran belt are distinctly red beds of fluvial origin (the Purit Formation) those overlie unconformably on top of the Shamran Volcanics and their equivalents. Copper mineralization in western Kohistan is associated with the both volcano-sedimentary belts described above. In the following we outline salient features of copper mineralization in the belts.

Copper Mineralization in Dir-Swat Belt:

In Dir-Swat belt copper mineralization is confined to the Eocene Utror Volcanic Formation. Greenschist facies metavolcanics host the mineralization in quartz veins, shear zones, sphalerite-bearing copper-rich zones and copper and iron-bearing chloritized zone. Chalcopyrite is the main copper-bearing phase along with subordinate amounts of pyrite, bornite, and chalcocite. Malachite and azurite occur as supergene enrichment. High $\delta^{18}\text{O}$ values for mineralized quartz veins (average 10.1 ‰) and the mineralized metavolcanics (8.1-10.3‰) suggest involvement of isotopically heavy fluids ($\delta^{18}\text{O} = 5.9$ ‰) probably related with the late-stage (post-Early Eocene-Stage II) intrusives of the Andean-type Kohistan Batholith. A chemical gain-loss comparison between the mineralized and unmineralized rocks suggests that the mineralizing fluids induced enrichment of elements like Cu, Zn, Pb, Mo, As, Cd, Ag, and Au in the former.

Copper Mineralization in Drosh-Shamran Belt:

The copper mineralization in the Drosh-Shamran belt, unlike the Dir-Swat belt, is localized in the Late Cretaceous volcano-sedimentary sequence (i.e., Gawuch Formation) rather than the Eocene Shamran Volcanic Formation that is equivalent and probably cogenetic with the Utror Volcanic Formation. Within the Gawuch Formation, mineralization is particularly intense in the granodiorites that occur as minor intrusives within the metavolcanics of the Gawuch Formation. A marble band of 2 to 3 meter thickness occurring at the contact of the Gawuch Formation and overlying fluvial sediments of the Purit Formation is most mineralized, suggesting entrapment of migrating mineralizing fluids. Tetrahedrite, galena, chalcopyrite and pyrite are the dominant ore minerals along with subordinate amounts of sphalerite, magnetite, limonite, malachite and azurite. $\delta^{18}\text{O}$ in the mineralized quartz veins is high (14.49 to 18.32‰) that is even higher than those in Dir. The $\delta^{18}\text{O}$ of the mineralizing fluid is calculated to be at average 7.98‰, that falls in the range of values known for magmatic liquids (i.e., 5-9‰). The localization of mineralization in the Late Cretaceous Gawuch Formation suggests that mineralization, unlike in the case of the Dir mineralization, may be of any age between Late Cretaceous and Late Eocene. However, the two plutons close to the mineralized zone indicate ages younger than Early Eocene. The Lowari pluton that separates the Dir-Swat Belt from the Drosh Shamran Belt yields a ^{40}Ar - ^{39}Ar cooling age of 45 Ma while the Mirkhani pluton in the Drosh area intrudes Eocene Shamran Volcanic formation. Therefore there is great probability that copper mineralization in the Drosh Shamran Belt is Post-Early Eocene, related with the late phases of the Kohistan Batholith.

Conclusions:

The two principal copper mineralization zones in western Kohistan, at Drosh and Dir are localized in volcanic lithologies of different ages, Late Cretaceous and Early Eocene, respectively. Both are however characterized by high $\delta^{18}\text{O}$ values suggesting role of magmatic fluids in their origin. Late phases of Kohistan Batholith are considered to be the source of these fluids in both cases.

Key words: Mineralogy, copper, Kohistan island arc, Himalaya, Hindukush.

T/76. Tahirkheli, T., Shah, M.T. & Khan, M.A., 2001. Mineralogical, isotopic and fluid inclusion studies of copper mineralization in Drosh-Shishi area, Chitral, Northern Pakistan. *Journal of Asian Earth Sciences* 19, p.66.

Key words: Geochemistry, mineralogy, isotopes, copper, fluid inclusions, Chitral.

T/77. Tahirkheli, T., Shah, M.T., Khan, T. & Khan, M.A., 1996. Fluid inclusion studies of the copper-bearing quartz veins in Gowuch Formation, Drosh-Shishi area, Chitral, northern Pakistan. *Geological Bulletin, University of Peshawar* 29, 51-57.

Copper mineralization, generally confined to the Gowuch Formation, in Drosh-Shishi area is part of the upper crust of Kohistan arc terrain in Chitral, northern Pakistan. It is related to the hydrothermal activity and is mainly associated with altered diorites and quartz veins. It occurs in different forms; within quartz veins, along foliation planes, in dissemination and as supergene enrichment. Fluid inclusion studies indicate that the salinity of the hydrothermal solution is 12.28-13.40 equivalent wt% NaCl and the homogenization temperature ranges from 160 to 350° C. This suggests that the copper mineralization is related to the late stage vein formation as a result of diorite and granodiorite intrusion.

Key words: Geochemistry, mineralogy, copper, fluid inclusions, Chitral.

T/78. Takahashi, Y., Kausar, A.B., Takahashi, Y. & Khan, T., 1993. Field relationship between the rock units of the Chilas complex, Chilas, northern Pakistan. *Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad* 4, 41-50.

The Geoscience Laboratory, Geological Survey of Pakistan has started a joint collaborative project with JICA experts who were mainly despatched from the Geological Survey of Japan on the Chilas Igneous Complex in Chilas area as one of the technology transfer programs for the Geoscience Laboratory established under a grant in aid project by JICA, Japan.

The survey in Chilas area is being carried out jointly by experts of both the countries. For the 1991 work, the first phase, the GSJ despatched a survey team consisting of 3 geologists during a period from Nov. 4 to Nov. 19, 1991 (Kubo *et al.*, 1992). For the 1992 work, the second phase, the JICA despatched a team consisting of 2 geologists from Oct. 27, 1992 to Nov. 23, 1992. During 1991, 1 geologist and during 1992, 2 geologists from Geoscience Laboratory participated in this research programme.

The primary purpose of this research is to focus on the following points:

1. Relationship between the gabbro-norite and ultramafic-mafic bodies.
2. Variation of rock facies within the Chilas igneous complex
3. Relationship between ultramafic and mafic rock facies.
4. Layered structure in ultramafic and mafic units.
5. Finding out original flow structure in gabbro, norite-gabbro, and gabbro-norite and then interpreting the younging direction.

Key words: Petrology, Chilas complex, Kohistan arc, Himalaya.

T/79. Takahashi, Y., Khan, T., Takahashi, Y., Kausar, A.B. & Kubo, K., 1996a. Mode of plagioclase twinning of two plutonic bodies in Kohistan terrane, northern Pakistan. *Journal of Mineralogy, Petrology and Economic Geology* 91, 242-249.

Mode of plagioclase twinning is examined in the Chilas complex and Kohistan batholith, which are large plutonic bodies in the Kohistan terrane, northern Pakistan. The frequency of C twins, which are defined as all laws other than albite and pericline twins, is mostly 10 to 20% in the tonalite and granodiorite of the Kohistan batholith. These values characterize igneous rocks.

Frequency of C twins in the Chilas complex is low (0 to 5%) in the eastern part and high (20 to 30%) in the central part. The former represents metamorphic features and the latter igneous features. These features result from the

difference of the erosional surface of the complex and explain the petrological discrepancy that the complex is deduced to have been metamorphosed to the granulite facies, but that it locally intruded and gave thermally altered effect to the surrounding amphibolite.

Frequency of pericline twin is almost the same in both bodies. This consistency may be developed by a result of the same tectonic event, i.e., collision between the Indian plate and the Kohistan terrane.

Key words: Mineralogy, plagioclase, twinning, plutonic, Kohistan terrane.

T/80. Takahashi, Y., Khan, T., Takahashi, Y., Kausar, A.B. & Kubo, K., 1996b. Mode of plagioclase twinning of two plutonic bodies in Kohistan terrane, northern Pakistan. In: Kausar, A.B. & Yajima, J. (Eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc*. Proceedings of of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 15, 69-82.

Consult Takahashi et al (1996a) for further information.

Key words: Geochemistry, mineralogy, plagioclase, twinning, plutonic, Kohistan terrane.

T/81. Takahashi, Y., Kubo, K., Takahashi, Y., Sawada, Y., Kausar, A.B., Khan, T. & Khan, I.H., 1994. The Chilas Igneous Complex in Kohistan island arc, Northern Pakistan. Abstract volume Symposium on Himalayan Geology, 3–9 Sept. 1992. Matsue, Japan.

For details consult the following account.

Key words: Mineralogy, petrology, Chilas complex, Kohistan island arc.

T/82. Takahashi, Y., Kubo, K., Takahashi, Y., Sawada, Y., Kausar, A.B., Khan, T. & Khan, I.H., 1994. The Chilas Igneous Complex in the Kohistan Island Arc, Northern Pakistan. *Journal of Geological Society of Nepal* 10, Abstract Volume, 9th Himalaya-Karakoram-Tibet Workshop, Kathmandu, 140.

The Chilas Igneous Complex is one of the major geological unit in the Kohistan Island Arc Region, of which southern end is bounded by the Main Mantle Thrust (MMT) and northern end is by the Main Karakoram Thrust (MKT) (Searle, 1991). The Chilas Complex is 60-km wide and elongated 300-km almost parallel to the MMT and MKT. It is intruded into the amphibolite (Kamila Amphibolite), which develops widely on the southern half of the Kohistan Island Arc Region. The Complex is composed mainly of gabbro-norite and contains several masses of ultramafic-mafic complex as large xenolith. Ar/Ar and K/Ar ages of the hornblende from the Complex are at around 80Ma, which may date cooling through 500°C, the hornblende blocking temperature (Treloar et al., 1989). The Complex consists of host gabbro-norite and several masses of ultramafic-mafic complex (UMC). Both of them are deformed together exhibiting foliations, which form several antiforms and synforms striking WNW-ESE, subparallel to the igneous body. Some structures of deformation on the Chilas Complex are discussed.

Key words: Mineralogy, petrology, Chilas complex, Kohistan island arc.

T/83. Takahashi, Y., Takahashi, Y., Kausar, A.B., & Kubo, K., 1994a. Modes of plagioclase twinning in the Chilas complex and Kohistan batholith, northern Pakistan. *Proceedings of Geoscience Colloquium*, Geoscience Lab, GSP, Islamabad 9, 51-58.

The ratios of pericline twins in the twinned plagioclase of Chilas complex (CC) and Kohistan batholith (KB) are overlapped, suggesting that these are deformed under same physical conditions. The ratio of C twins (all twins other than albite and pericline) in the KB are more than those in the CC. The ratio of C twins in the KB are more than 8%, indicating their igneous origin. The ratio of C twins of the CC is less than 5%, indicating metamorphic origin. It is noted that the CC has been emplaced at depths first and subsequently metamorphosed, which is characterized by low ratio of C twins. On the other hand the KB show high ratio of C twins suggesting comparatively shallow depth of emplacement and lack of metamorphism after emplacement.

Key words: Mineralogy, Plagioclase, twining, Chilas complex, Kohistan batholith.

T/84. Takahashi, Y., Takahashi, Y., Kausar, A.B., Khan, T. & Kubo, K., 1994b. Contrasting frequency of plagioclase twinning in two plutonic bodies in Kohistan terrane, Northern Pakistan. Abstract International joint Symposium IGCP Projects 283–321–359 in Japan (Hokkaido Univ.), From Paleo-Asian Ocean to Paleo-Pacific Ocean, 75–79.

Key words: Mineralogy, Plagioclase, Twining, Plutonic, Kohistan terrane.

T/85. Takahashi, Y., Mikoshiba, M., Kubo, K., Kausar, A.B., Khan, T.K., Takahashi, Y. & Shirahase, T., 1998. Geological relationship between the Chilas complex and the Kamila amphibolite belt, northern Pakistan-Implications for the tectonic development of the Kohistan island arc. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 192-193.

The Kohistan terrain in the western Himalaya, northern Pakistan, is regarded as a tilted island arc type crust sandwiched between the Asian and Indian continental crusts [1]. The Kohistan island arc is bounded along the south by Main Mantle Thrust (MMT), and along the north by Northern Suture (or Main Karakoram Thrust, MKT), which can be divided into some geological units.

The Chilas complex is a huge basic intrusion about 50km wide and elongates 300-km almost parallel to the MMT and the MKT, which is composed mainly of gabbro-norite and several masses of ultramafic-mafic anorthosite association [21]. It has been interpreted as the magma chamber root zone of the Kohistan island arc [3]. On the other hand, the Kamila amphibolite belt is composed of highly deformed amphibolite-facies meta-plutonic and meta-volcanic rocks with calc-alkaline geochemistry [41] situated to the south of the Chilas complex. Geological relationship between the Chilas complex and the Kamila amphibolite belt is not yet confirmed, although they are main constituents of lower crust in the Kohistan island arc. Some people consider that the Chilas complex and the Kamila amphibolite were originally same, but the Chilas complex was metamorphosed to granulite facies and the Kamila amphibolite belt to amphibolite facies [5,6]. On the other hand, it is considered that the Chilas complex and the Jijal complex are lower crusts of different island arcs and they are separated by the Kamila shear zone (Kamila amphibolite belt) [6]. Accordingly, northern part of the Kamila amphibolite belt is hydrated and recrystallized product from the gabbro-norite of the Chilas complex.

The geological relationship between the Chilas complex and the Kamila amphibolite belt is fundamentally important to consider the geologic development of the Kohistan island arc, because they are main constituents of lower crust in the Kohistan island arc. In this paper, we present detailed geological and geochemical data around the boundary between the Chilas complex and the Kamila amphibolite belt and discuss on the relationship between them.

In the Swat valley, the Chilas complex is bounded on the south by the Kamila amphibolite belt. Around the boundary several xenoblocks of the Kamila amphibolite are observed in gabbro-norite of the Chilas complex and gabbro-norite dikes of the Chilas complex occur in the Kamila amphibolite. At the lower reaches of Miandam River which is a small branch of Swat River coming from the east, a xenoblock (about 20*5m) of the Kamila amphibolite occurs in gabbro-norite of the Chilas complex. The amphibolite and gabbro-norite are just contact to each other and a foliation develops in both the amphibolite and gabbro-norite which is oblique to the lithologic boundary. The amphibolite is composed mainly of hornblende and plagioclase, in which original plutonic texture still persists. Under the microscope, hornblende and biotite are aggregates of fine crystals exhibiting a decussate texture, which indicates thermal effect. On the other hand, the gabbro-norite is composed mainly of plagioclase, clinopyroxene and orthopyroxene with minor hornblende and biotite, which is slightly deformed, but there is no evidence of thermal effect. Therefore, it is evident that the Kamila amphibolite was intruded by gabbro-norite of the Chilas complex and suffered contact metamorphism and after that a foliation was formed in both the gabbro-norite and amphibolite by ductile deformation, which may be related to the collision of Kohistan to the Asian continent.

The eastern part of the Chilas complex is bounded on the north by amphibolite. At the upper reaches of Khanbari River, which is a small branch of Indus River coming from the north, gabbro-norite of the Chilas complex and amphibolite are just contact to each other. The amphibolite is composed mainly of hornblende and plagioclase, in which original plutonic texture still persists. Under the microscope, hornblende and biotite are aggregates of fine crystals exhibiting a decussate texture. On the other hand, the gabbro-norite is composed mainly of plagioclase,

clinopyroxene and orthopyroxene with small amount of biotite and hornblende, which is slightly deformed. Therefore, it is evident that the amphibolite was intruded by the gabbro-norite of the Chilas complex and suffered contact metamorphism. The northern amphibolite may correspond to the Kamila amphibolite, because these features are just like those in the Swat River. It is important to note that the Chilas complex is a large intrusive body in the Kamila amphibolite belt.

Key words: Tectonics, petrology, Chilas complex, Kamila amphibolite, Kohistan island arc.

T/86. Takahashi, Y., Takahashi, Y., Kausar, A.B. & Mikoshiba, M., 1996. Geology and geochemistry of eastern part of the Chilas complex, northern Pakistan- Implications for the tectonic development of the Kohistan island arc. In: Kausar, A.B. & Yajima, J. (Eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 15, 183-205. (Also published in the Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 14, 39-61)

Geological and geochemical studies of the eastern part of the Chilas complex, Northern Pakistan have been carried out by GeoLab research team. On the basis of the results, a model of tectonic development of the Chilas complex is proposed. The Chilas complex is composed mainly of gabbro-norite and several masses of ultramafic-mafic association (UMA). The UMA is composed mainly of olivine (with or without clinopyroxene) cumulate (dunite, wehrlite) and plagioclase clinopyroxene-orthopyroxene cumulate (two pyroxene gabbro), with minor amount of clinopyroxene-orthopyroxene cumulate pyroxenite). Geochemistry of the gabbro-norite is suitable to island arc non-cumulate, and the UMA is suitable to island arc cumulate. Major element geochemistry of the gabbro-norite and the UMA is explained by cumulate and noncumulate model. Rare earth element and trace element geochemistry of the gabbro-norite indicates island arc type feature, and the UMA indicates its cumulate character.

Key words: Geochemistry, tectonics, Chilas complex, Kohistan island arc.

T/87. Takahashi, Y., Khan, T., Takahashi, Y., Kausar, A.B., & Kubo, K. 1996. Mode of Plagioclase Twinning of two Plutonic Bodies in Kohistan Terrane, Northern Pakistan.

Mode of plagioclase twinning is examined in the Chilas complex and Kohistan batholith which are large plutonic bodies in the Kohistan terrane, northern Pakistan. Frequency of C twins, which are defined as all the other laws than albite and pericline twins, is mostly 10 to 20 % in tonalite and granodiorite of the Kohistan batholith. These values represent igneous character. Frequency of C twins in the Chilas complex is low (0 to 5 %) in eastern part and high (20 to 30%) in central part. The former represents metamorphic feature and the latter igneous feature. These features result from the difference of the erosional surface of the complex and explain the petrological discrepancy that the complex is deduced to have been metamorphosed to the granulite facies but that it locally intruded and gave thermal effect into the surrounding amphibolite. Frequency of the pericline twin is almost the same in both bodies. This consistency of the frequency may be developed due to the same tectonic event, i.e., collision between Indian plate and Kohistan terrane.

Key words: Plagioclase, twinning, plutonic bodies. Kohistan Terrane.

T/88. Talent, J.A., 1976. Provincialism in the Himalayan region. Seminar on Himalayan Geology, New Delhi.

Key words: Palaeontology, Himalaya.

T/89. Talent, J.A., 1999. Bibliography of Phanerozoic palaeontology and stratigraphy of Pakistan. Abstract volume International Geological Congress, Program 421 Meeting. North Gondwana Biogeography, Bioevent Patterns in relation to Crustal Dynamics, Peshawar, Pakistan, 35-65.

Key words: Palaeontology, stratigraphy.

T/90. Talent, J.A. & Bhargava, O.N., 1999. Silurian of the Indian subcontinent and surrounding regions. Abstract book, Peshawar meeting IGCP 421 (8-26 September 1999), 27 National Centre of Excellence in Geology, University of Peshawar.

Consult the following for further information.

Key words: Palaeontology, stratigraphy, Silurian.

T/91. Talent, J.A. & Bhargava, O.N., 2003. Silurian of the Indian subcontinent and surrounding regions. New York State Museum Bulletin 493, 221-239.

An overview of the Silurian of the Indian subcontinent and adjacent regions, illustrated by ten stratigraphic columns, underscores uncertainties in precise correlation. Silurian sequences with some biostratigraphic control are documented from the Dasht-e-Nawar region, Afghanistan; the Peshawar Basin, Pakistan; central Nepal; southernmost Tibet; and Shan State, Myanmar (Burma). Near-shore, primarily siliciclastic sequences with reef developments in the western Himalaya, that range from Late Ordovician to Middle and, conceivably, younger Silurian, are not tightly constrained biostratigraphy. Similar sequences in the central Himalaya, often referred to as the Muth Quartzite and regarded as broadly Devonian, are largely Silurian, but need renewed study. The Paleozoic of Bhutan, assumed by some to include Silurian rocks, appears to have a Middle Cambrian-late Devonian hiatus. There is urgent need for a multi-pronged re-investigation of these Silurian and associated late Ordovician and Devonian sequences, particularly if transgression-regression patterns and changes in palaeogeography are to be documented adequately.

Key words: Palaeontology, stratigraphy, Silurian, Indian subcontinent.

T/92. Talent, J.A., Conaghan, P.J., Mawson, R., Molloy, P.D. & Pickett, J.W., 1976. Intricacy of tectonics in Chitral (Hindu Kush): Faunal evidence and some regional implication. Abstracts, Himalayan Geology Seminar, Delhi, 13-17 September, 1976, 76-77. Geological Survey of India, Calcutta.

Key words: Palaeontology, tectonics, Chitral, Hindukush.

T/93. Talent, J.A., Conaghan, P.J., Mawson, R., Molloy, P.D. & Pickett, J.W., 1982. Intricacy of tectonics in Chitral (Hindu Kush): faunal evidence and some regional implications. Himalayan Geology Seminar, 1976, Section IIA. Geological Survey of India, Miscellaneous Publication 41, 77-101.

Key words: Palaeontology, tectonics, Chitral, Hindukush.

T/94. Talent, J.A., Gaetani, M., Mawson, R., Molloy, P.D. & Conaghan, P.J., 1999. Early Ordovician and Devonian Conodonts from the Western Karakoram and Hindu Kush, Northernmost Pakistan. Abstracts, IGCP 421, North Gondwanan mid-Palaeozoic Bioevent/Biogeography Pattern in Relation to Crustal Dynamics, Peshawar Meeting, p.28.

For details consult the following account.

Key words: Palaeontology, conodonts, Ordovician, Devonian, Karakoram, Hindukush.

T/95. Talent, J.A., Gaetani, M., Mawson, R., Molloy, P.D. & Conaghan, P.J., 1999. Early Ordovician and Devonian Conodonts from the Western Karakoram and Hindu Kush, Northernmost Pakistan. *Rivista Italiana Paleontologia e Stratigrafia* 105, 201-230.

Extensive tracts of Devonian and older sedimentary and igneous units occur within the axial region of the western Karakoram Block of northernmost Pakistan over a distance in excess of 200 km between the headwaters of the Karambar valley in northwestern Gilgit Agency to southwestern Chitral. Conodont data indicate that the oldest sedimentary unit so far discriminated within this belt, the Yarkhun Formation, includes horizons of Ordovician (Arenig) age, consistent with an earlier-presented acritarch-based Arenig age for part of the same unit. Conodont data from the "Lun Shale", a stratigraphic potpourri with little known Silurian and Devonian tracts, demonstrate the presence of Early Devonian (early Emsian) horizons. The Shogram Formation, widely distributed through the region, spans an appreciable interval of the Middle and Late Devonian mid-Givetian through until at least early Famennian. A major lacuna in sedimentation may be present, represented by all or most of the earlier half of Frasnian time. A biostratigraphically and possibly biogeographically important new species, *Icriodus homeomorphus*, is described; it is encountered in horizons of early Famennian age (Late triangularis Zone to? Early crepida Zone).

Key words: Palaeontology, conodonts, Ordovician, Devonian, Karakoram, Hindukush.

T/96. Talent, J.A., Goel, R.K., Jain, A.K. & Pickett, J.W., 1988. Devonian and supposed Devonian of India, Nepal and Bhutan: a commentary. *Courier Forschungsinstitut Senckenberg*, 106, 1-57.

Key words: Devonian, India, Nepal, Bhutan.

T/97. Talent, J.A. & Mawson, R., 1979. Palaeozoic-Mesozoic biostratigraphy of Pakistan in relation to biogeography and the coalescence of Asia. In: Farah, A. & DeJong, K.A. (Eds.), *Geodynamics of Pakistan*. GSP, Quetta, 81-102.

An overview of Paleozoic-Mesozoic biostratigraphy of Pakistan, especially the northern mountainous region, is given providing, inter alia, preliminary reports of the presence of unequivocal Ordovician (NE Chitral), Silurian (Peshawar district), and carboniferous sequence (S Khyber and NW Gilgit agencies); all systems from Proterozoic to recent are now known to be represented in Pakistan. Comparison of Paleozoic and Mesozoic faunas from Pakistan with approximately coeval faunas from elsewhere in Asia underscore; 1. The provincial heterogeneity of Asia through these time intervals, though only preliminary comments are made on the change within these patterns due to coalescence of the various continental blocks. 2. That the only region of Pakistan with surety not formerly part of Gondwanaland is a narrow strip of the northern mountain region stretching through Chitral, Gilgit (N of the Ghizar valley) and Hunza, i.e. N of the Upper Shayok-Hini (or Chalt)-Drosh-Kunar fault. 3. The zoogeographic integrity of Paleozoic and perhaps Mesozoic faunas south of this lineament, and its E-W extension in Afghanistan beyond the 'Kabul vortex', the Hari Rud or Herat fault zone, is in accord with these areas having been once part of Gondwanaland; conversely, the contrast between faunas from these areas and faunas from regions north of the above lineaments is taken as testimony to the latter not having been parts of Gondwanaland. 4. Nevertheless, there are still insufficient published palaeontologic data to be able to comment on the history of fragmentation, dispersal and reamalgamation of the various bits and pieces of the old portions of Gondwanaland west of the Bela-Quetta-Muslimbagh-Waziristan 'Axial Belt', but the prospects are exciting and the Mesozoic molluscan faunas may yet yield useful biographic as well as chronologic data for this exercise.

Key words: Palaeozoic, Mesozoic, biostratigraphy, coalescence.

T/98. Talent, J.A. & Mawson, R., 2001. Bibliography of Phanerozoic palaeontology and stratigraphy of Pakistan. *Geological Bulletin, University of Peshawar* 34, 1-81.

The stratigraphy and palaeontology of Pakistan covers almost all intervals of geologic time, Precambrian to Recent, some more elegantly than others, especially Permian and younger sequences from the southern two-thirds of Pakistan. Palaeozoic sequences of pre-Permian age are restricted to northern Pakistan where metamorphism has tended to obliterate fossils, and where tectonic complexity-especially frequent thrust faulting-often obscures relationships and, in the absence of fossils, ages may remain controversial and stratigraphic relationships problematic. Palaeontology, taking advantage of occasional "windows of opportunity" with materials which have escaped severe deformation, will continue to have an important role in unravelling the structure of this vast region.

The foundations of the stratigraphy and palaeontology of Pakistan go back to the remarkable pioneering work of. W. T. Blanford, A. B. Wynne, C. L. Griesbach, W. Waagen, F. Noetling and C. S. Middlemiss in the 19th century, to the work of H. H. Hayden and E. W. Vredenberg early in the 20th, to the labours in Hazara of D. N. Wadia and the exemplary mapping by E. R. Gee in the Salt Range 50-70 years ago and, in more recent time, the impact of the sustained energies of R. A. K. Tahirkheli.

Remarkable work was achieved, often under conditions for which the word adverse would be an understatement. E. W. Vredenberg comes to mind, with camel and violin, collecting his way across Baluchistan-a palaeontologist analogue perhaps of artist-violinist J. A. D. Ingres ... G. E. Pilgrim early in this century, and expanded by recent work by a galaxy of vertebrate palaeontologists, especially by P. D. Gingerich, L. L. Jacobs, M. Pickford and D. R. Pilbeam. These faunas are now chronologically constrained by integrated high-precision stratigraphic/sedimentary and magnetostratigraphic investigations undertaken by several people, among them D. W. Burbank, G. D. Johnson, and N. D. Opdyke, working in highly effective collaboration with the Geological Survey of Pakistan and with numerous staff and postgraduate students of the University of Peshawar. The origin of this bibliography derives from the discovery that less than 25 % of the geological literature published in Pakistan is cited in GEOREF, the main source for obtaining a swift coverage of the literature published on a specific topic or specific region. The situation is least satisfactory with regard to literature on vertebrate palaeontology; this has been poorly covered by both GEOREF and Biological Abstracts, though the Zoological Record is useful in helping fill this lacuna. Our compilation is not exhaustive; it expands on a preliminary version issued to participants in the First Pakistan Palaeontological Convention and 6th international meeting of IGCP 421, North Gondwana mid-Palaeozoic bioevent/biogeography patterns in relation to crustal dynamics held at the University of Peshawar in September 1999. There are few references to unpublished reports and postgraduate theses. Not included are numerous articles in which stratigraphy has been incidental to economic geology, mineralogy, structural, tectonic or petrologic presentations, notably for the Kohistan Terrane and the Nanga Parbat Syntaxis (e.g. Khan et al., 2000). Numerous citations of such literature can be found in the excellent overview of the geology and tectonics of Pakistan by A.H. Kazmi & M. Qasim Jan (1997). Useful for older literature and for literature on areas adjoining Pakistan to the east and west are the Bibliography of Indian Geology by La Touche (1917), the Bibliography on Himalayan Geology by Kapoor et al. (1976) and the Bibliography on the Geology of Afghanistan by Kastner (1971). Many of the cited references have not been checked against the original publications-a mammoth task beyond the means of compilers without access to all relevant libraries in Pakistan and India. Because most titles provide a clear indication of content, no attempt has been made to annotate the bibliography. It is hoped, nevertheless that even casual perusal of it will draw attention to many publications, including some long forgotten, which include important data and opinions.

Key words: Bibliography, Phanerozoic, palaeontology, stratigraphy.

T/99. Talent, J.A., Mawson, R. & Khan, F.R., 1999. Mid-Palaeozoic of Pakistan, Conodont-based perspectives. Abstracts, IGCP 421, Errachidia Meeting, 42-43.

Key words: Palaeozoic, conodonts.

T/100. Talent, J.A., Molloy, P.D. & Morante, R.J., 1988. The Devonian of Pakistan. In: McMillan, J., Embry, A. & Glass, D. (Eds.), Proceedings of 2nd International Symposium of the Devonian System, Calgary 1987,

Key words: Devonian.

T/101. Tandon, A.N. & Srivastava, H.N., 1975. Focal mechanism of some recent Himalayan earthquakes and regional plate tectonic. Bulletin of Seismological Society of America 65, 963-969.

Focal mechanism solutions of 12 recent earthquakes along the northern boundary of the Indian-Eurasian plates, from Hindukush to Burma, have been determined assuming the double-couple hypothesis. It has been found that the majority of earthquakes are of thrust type with the pressure directions acting at right angles to the faults/mountains, but, for a few of the earthquakes the orientations of the pressure directions are almost along the strike of the faults.

Such observations could be partly explained in terms of the concept of “flake tectonics” as proposed for continent-continent collisions. A number of earthquakes in the eastern Himalayas and Burma show normal dip-slip or predominantly strike-slip movements. These anomalies call for further refinements of the plate theory in this zone of complicated deformation.

Key words: Earthquakes, seismology, tectonics, Himalaya.

T/102. Tandon, S.K., Thakur, V.C. & Jain, A.K., 1974a. Tilloids from N.W. Pakistan. *Geological Magazine* 111, p.568.

This note refers to a recent letter in this journal by Kempe (1973) wherein he has recorded a “Tilloid” occurrence near Warsak and advanced the line of the known Himalayan localities of subcontinental tillites more than 200 km. It may be pointed out that the gneiss; of the Himalayan diamicts is still an open question. Rallan (1913) recognized the Manjir Conglomerate (Chamba Tillites of Powell & Saxena, 1971) to be part of a flysch sequence. In recent years, a debate has also ensued on the origin of the Blaini Conglomerate and related formations (Bhargava, 1972; Bhattacharya & Niyogi, 1971; Casshyap, 1969; Gaur & Dave, 1971; Niyogi & Bhattacharya, 1971; Rupke, 1968; Saxena & Pande, 1969; Valdiya, 1970, 1973). We may also add that many of these controversial 'tillite' horizons form part of different tectonic units and may not all be the Stratigraphic equivalents. The premise of Kempe (1973) regarding the extension of the Himalayan tillite localities has thus to be viewed in the above framework.

Key words: Tilloids, Mulagori, Warsak.

T/103. Tandon, S.K., Thakur, V.C. & Jan, A.K., 1974b. Tilloids from Pakistan. Reply by Kempe, R.D.C., *Geological Magazine* 111, 568-569.

Tandon, Thakur & Jain refer above to the tilloids from NW Pakistan (Kempe, 1973), suggesting that this Himalayan diamict should be treated as one of several of which the true origin is still in dispute. I entirely agree. My objective in drawing attention to this unusual rock, which I referred to as a tilloid [which] may thus be the most northwesterly of the known sub-continental tilloids, was in the hope that it would be visited and examined by those who, unlike myself, are familiar with Indian and other tillites and are thus in a better position to decide in such cases on the origin of the rock.

Key words: Tilloids, Mulagori, Warsak.

T/104. Tanoli, S.K., 1990. Shallow marine sediments of the Patala Formation of Paleocene age, Kohat area, Pakistan. *Geological Bulletin, University of Peshawar* 23, 111-121.

The Patala Formation in Kohat area consists of four lithofacies which are; PF1 sandstone with shale interbeds, PF2 shale and siltstone with limestone interbeds, PF3 shale with interbeds of siltstone, and PF4 shale and marl interbeds. These facies were deposited in shallow marine shelf environments ranging from upper shoreface to offshore possibly middle to outer shelf environments.

Facies PF1-PF4 in general depict deposition in a continuously deepening or transgressive conditions. The lateral variations in lithology within the Patala Formation are suggested to be mainly related to the local variations in paleogeographic setting.

Key words: Sediments, Paleocene, Patala formation, Kohat.

T/105. Tanoli, S.K., Gandapur, M.A. & Mahsood, S.K., 1978. Geology of the part of area northwest of Kohat, North West Frontier Province, Pakistan. M.Sc. Thesis, University of Peshawar, 50p.

Key words: Mapping, stratigraphy, Kohat.

T/106. Tanoli, S.K., Rashid, S.M., Qamar, B., Awad, M. & Jabeen, N., 1990. Depositional environment of the Patala Formation of Paleocene age, Kohat area. Abstracts, 2nd Pakistan Geological Congress, University of Peshawar, p.19.

The Patala Formation in Kohat area is divisible into four lithofacies which are; PF1 sandstone with shale interbeds, PF2 shale and siltstone with limestone interbeds, PF3 shale with interbeds of siltstone, and PF4 shale and marl interbeds. These facies are interpreted to have been deposited in shallow marine, ranging from upper shoreface to offshore, shelf environments. Facies PFI-PF4 in general depict deposition in a more or less continuously deepening basin. The lateral variations in lithology within the Patala Formation are suggested to be mainly related to the local variations in paleogeographic setting.

Key words: Sediments, Paleocene, Patala formation, Kohat.

T/107. Tarar, R.N., 1982. Water resources investigations in Pakistan with the help of LANDSAT imagery-snow survey (1975-1978). International Association of Hydrol. Sci. Publ. 138, 177-190.

Key words: Remote sensing, LANDSAT imaging, hydrology, water resources.

T/108. Tariq, S., 1984. Geology of Jawan Pass, Khabal village, Swat. M.Sc. Thesis. Geology Department, Peshawar University, 120p.

Key words: Geology, Jawan pass, Swat.

T/109. Tariq, S., 1992. Geology and clay mineralogy of Patala Formation in Salt Range and Kalachitta Range with reference to Paleo-Environments. M.Phil. Thesis, University of Peshawar, 177p.

The Patala Formation was studied in Salt Range and Kala Chitta range. About 99 samples were collected to investigate clay mineral composition and to understand the paleo-environments and diagenetic/ sedimentological control of the clay minerals. The samples from the Salt Range representing the southern end of the Potwar basin contain mostly kaolinite _illite and a mixed-layer clay mineral (a mixture of general illite/montmorillonite). The chlorite mineral was detected only in five samples from the Nilawahan area (central Salt Range).

The samples from the Kala Chitta Range (Khawri Khawar section) contain mostly illite, chlorite and mixed-layer clay mineral. The kaolinite was found in 12 samples. It was concluded that the illite, chlorite mineral are the detrital clay –minerals which were brought into the depositional basin through erosional and sedimentological processes from a source rock exposed in the south.

The kaolinite from both localities, was found to be partly diagenetic and partly of detrital origin. The mixed-layer clay mineral was observed to be of diagenetic origin. The kaolinite in Khawri Khawar section (Kala Chitta Range) was interpreted as detrital mineral. The comparison of clay composition from the Salt Range and Kala Chitta Range (Khawri Khawar section) indicated that kaolinite decreases in the samples of Kala Chitta Range while illite and chlorite show increase. The mixed-layer clay mineral did not Show any significant variations. The decrease of kaolinite in Kala Chitta Range samples was interpreted as a sedimentological/ depositional control.

The crystallinity indices of illite and kaolinite Show a decrease in crystallinity in the samples from the Kala Chitta Range as compared to the Salt Range samples. It is 0.77 for kaolinite, 0.37 for illite in Kala Chitta Range, and 0.26 for kaolinite and 0.19 (average) for illite in Salt Range. The decrease in crystallinity of illite and kaolinite again verify the transportation of kaolinite and illite from south to north of the depositional basin which was the direction of deepening of the basin.

Key words: Clay, mineralogy, Patala Formation, Salt Range, Kalachitta.

T/110. Tariq, S., 2001. Environmental geochemistry of surface and subsurface water and soil in Peshawar basin, NWFP, Pakistan. Ph.D. thesis, NCE geology, University of Peshawar.

Peshawar Basin is situated at the southern foothills of Himalayas between the longitude 71° 15' and 72° 45' E and latitude 33° 45' and 34° 30' N in the North-West- Frontier Province (NWFP) of Pakistan. Major cities of the basin are Peshawar (capital), Mardan, Charsadda and Nowshera. The E-W flowing Kabul river and its tributaries irrigate the basin and join the Indus at the eastern exit. Peshawar Basin is surrounded by mountain ranges of Khyber in west

and northwest, Attock-Cherat in south and Swat in the northeast. The basin is filled with Quaternary sediments ranging from Pleistocene to recent in age. These sediments overlie rocks of Paleozoic age. The Quaternary sediments of the Peshawar Basin are physio-graphically classified as Peshawar Piermont-sediments, Peshawar lacustrine sediments and Peshawar flood plain/ stream channel sediments.

The sediments present in the foot-hills of the mountains in the western (Khyber Range) and southern Attock-Cherat Range) part of the Peshawar Basin are coarse deposits of sand and gravel. However, the sediments of the central part of the basin contain relatively large proportion of fine material and are characterized as the lacustrine sediments. On the basis of existing lithologies the aquifer of Peshawar Basin has been classified as Peshawar Piedmont aquifer and Peshawar Lacustrine aquifer. The Peshawar Piedmont aquifer has further been divided in to Khyber mountain range piedmont aquifer, Attock-Cherat Range Piedmont aquifer and Lower

Swat Range Piedmont-aquifer.

Fast growing urbanization and industrialization in and around the major cities is threatening the air as well as the surface and subsurface water systems of the Peshawar Basin. In the cities, air is consistently polluted by vehicular emanations, industrial effluents and metals-born dust, which ultimately make their way to surface and underground water. This study is part of a large project concerning surface and groundwater and soil pollution of major and trace elements and heavy metals. The isotopic data of surface and groundwater of the Peshawar Basin has also been evaluated in order to identify the sources of pollution.

The hydro-physical and chemical parameters of the water of Peshawar Basin determined during the present study include pH, Temperature (T) electrical conductivity (Ee), total dissolved solid (TDS) calcium (Ca), magnesium (Mg), potassium (K), chromium (Cr), nickel (Ni), copper (Cu), cobalt (Co), lead (Pb) cadmium (Cd), bicarbonate (HCO₃), sulfate (SO₄) and chloride (Cl). Surface and groundwater of all the aquifers and rivers respectively have been classified as normal alkaline fresh water and alkaline earth fresh water with higher contents of alkalies. This suggest that the cations and anions have played an important role in categorizing the waters of the Peshawar Basin. On the basis of physical parameters (i.e., pH, T, Ee and TDS), the water of all the rivers and aquifers of Peshawar Basin can be generally classified as "fresh", however, "Slightly saline" water is also present at various places. The groundwaters of some areas have pH in acidic range and have high SO₄ contents suggesting the contamination through coal and sulfide seems having metal sulfides. These areas of unsuitable drinking water have been delineated during this study.

In order to establish the chemical contamination in the water of the various aquifers of Peshawar Basin, the above mentioned parameters have been compared among various aquifers and also with the permissible limits of US-EPA and WHO.

Various cations (e.g., Ca, Na, K, and Fe) anions (e.g. SO₄, Cl, HCO₃) and trace elements (e.g., Cu, Pb, Zn, Ni, Cr, Co and Cd) in the drinking water of Peshawar are generally within the permissible limits set by US-EPA and WHO. However, Ca, Mg, Na, K, Fe, Pb, Cr, SO₄, Cl, and HCO₃ at some places exceed the permissible limit. This could generally be attributed to the compositional changes in the lithology of the area. The oxygen isotopic characteristics of both surface and groundwaters of the Peshawar Basin have been determined. The three rivers, Kabul, Swat and Indus have distinct ¹⁸O signature with Indus river being the most depleted, Swat river being the most enriched and Kabul river midway between the two. The oxygen isotopic data for the underground water system of the Peshawar Basin indicate that the aquifers in the Peshawar Basin are recharged both by rainwater and waters from the Kabul and Swat rivers. In this respect the Kabul river remain dominant over the Swat river. This data also indicate that the shallow waters in the basin are more contaminated than the deep water. This suggests that there are chances that any pollution in the surface water can very easily be transferred to the underground water. This study also indicate that the soils of Peshawar Basin have higher contents of few major elements such as MgO, CaO, Na₂O, K₂O and trace elements such as Cu, Pb, Cr and Ni when compared with the normal soil elsewhere in the world. This could possibly be correlated with the surrounding rocks (ultrabasic to acidic nature) of Peshawar Basin.

It is evident from this study that though the waters of the piedmont aquifers are safe both for agricultural and drinking purposes but still the special measures shall be taken to protect the underground water of the area from contamination if the industries are to be established in these areas of the Peshawar Basin in future. In this regard, some recommendations are also given at the end.

Key words: Geochemistry, groundwater, Peshawar basin.

T/111. Tariq, S., Baqri, S.R.H. & Rehman, O., 1997. The distribution of clay minerals in Patala Formation of the Kala Chitta and Salt Ranges: Implications for paleoenvironments. Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 227.

During the Paleocene, the predominantly shaly rocks of the Patala Formation were deposited in an extensive Potwar Basin, stretching from the Salt Range to the Kala Chitta Range. Ninety nine samples were collected to investigate the clay mineral composition and to understand the paleoenvironments and diagenetic sedimentational control of the clay minerals in the basin. The samples from the Salt Range, representing the southern end of the Potwar Basin, contain mostly kaolinite, illite, and a mixed-layer clay mineral consisting of illite and montmorillonite. Chlorite was studied only in samples from the NW area of the central Salt Range. The samples from the Kala Chitta Range contain mostly illite, chlorite and mixed-layer clay mineral.

Kaolinite found in twelve samples. It is concluded that the illite-chlorite mineral and the detrital clay minerals were brought into the depositional basin through erosional and sedimentational processes from a source rock exposed in the south. The kaolinite was found to be partly diagenetic and partly of detrital origin. The mixed-layer clay mineral was observed to be of diagenetic origin. The kaolinite in Kala Chitta Range is interpreted as detrital mineral. The crystallinity of kaolinite and lute minerals were also studied in samples. The comparison of clay minerals composition from the Salt Range and Kala Chitta Range show that kaolinite decreases while illite and chlorite increase with depth towards north in the samples from the Kala Chitta Range. The mixed-layer clay mineral does not show any significant variation. The decrease of kaolinite in Kala Chitta Range samples was interpreted as related to a sedimentational/depositional control, because comparatively coarse grained kaolinite was deposited in abundance in shallower parts and hardly transported into the deeper parts of the basin towards north. The fine grained illite-chlorite minerals were transported and deposited in abundance in the deeper part of the basin. The crystallinity indices of illite and kaolinite show a decrease in crystallinity in the samples from the Kala Chitta Range as compared to the Salt Range samples. It is 0.77 nm for kaolinite, 0.37 nm for illite in Kala Chitta Range, and 0.26 nm for kaolinite and 0.19 nm for illite in Salt Range. The decrease in crystallinity of illite and kaolinite minerals again verify the transportation of these minerals, and deepening of the depositional basin from south to north.

Key words: Sediments, clay, Paleocene, Patala formation, Kalachitta, Salt Range.

T/112. Tariq, S., Baqri, S.R.H. & Rehman, O., 1998. The distribution of clay minerals in patala formation of the potwar basin: implications for palaeo environments. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 193-195.

During the Paleocene, the predominantly shaly part of the Patala Formation was deposited in Potwar Basin, stretching from the Salt Range in the south to the Kala Chitta Range in the north. The paleoenvironments interpreted by the diagenetic sedimentational control of the clay minerals in the basin by analysing the clay mineral composition in 99 samples. The samples contain kaolinite, illite, chlorite and a mixed-layer clay mineral of illite/montmorillonite. It is concluded that the kaolinite/ illite and chlorite minerals are the detrital clay minerals, brought into the depositional basin due to erosion of the source rocks exposed in the south of partly diagenetic origin. The clay minerals composition from the south to north show that the kaolinite decreases while illite and chlorite increase. The decrease of kaolinite in Kala Chitta Range is most likely due to sedimentational/ depositional control, because coarse-grained kaolinite was deposited in abundance in shallower parts and hardly transported into the deeper parts of the basin towards north. The fine-grained illite and chlorite minerals were transported and deposited in abundance in the deeper parts of the basin. No significant variation observed in mixed-layer clay mineral. The crystallinity indices of illite and kaolinite decrease in the Kala Chitta Range as compared to the Salt Range. The decrease in crystallinity in clay mineral again verify the transportation, and deepening of the depositional basin from south to north.

Key words: Clay, Paleocene, Patala formation, Potwar basin.

T/113. Tariq, S., Hamidullah, S. & Shah, M.T., 1998. Preliminary environmental geochemistry of surface and subsurface waters from Peshawar Basin, north Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume 13th Himalayan-Karakoram-Tibet International Workshop, 195-196.

The Peshawar Basin is semi-circular low-lying broad depression ($\approx 8000 \text{ km}^2$) situated at the southern margin of foot hills of Himalayas and north-west of the Indus Plain. Unplanned urbanization and industrialization due to a very high rate of population increase have affected the major cities of N.W.F.P., particularly those situated in Peshawar

Basin. Air is highly polluted in the major cities and industrial estates and both surface and underground water are also facing a significant threat. This study is part of a large project concerning with the investigation of surface and subsurface water pollution related to major and trace elements, particularly heavy metals in Peshawar Basin. Here we present the major element chemistry of the various types of water from the basin. On the basis of stratigraphic correlation five types of semi-confined aquifers, namely, Khyber piedmont aquifer (west and south-west), Attock-Cherat piedmont aquifer (south and south-east), Lower Swat-Bunner piedmont aquifer (north and north-east), floodplain and lacustrine aquifers in the central part of the basin have been identified. A total of 112 water samples collected from surface (river) and subsurface water (shallow, dugwell; deep, tubewell) have been analyzed. Majority of the surface and subsurface water samples appear to be hydrogencarbonatic (Ca-Mg-HCO_3 type) and sulfatic (Cl-SO_4 type) of the alkaline earth fresh water with high contents of alkalies.

Sodium-chloride (NaCl) and magnesium-sulfate (MgSO_4) are the major ionic pairs in these waters. Based on the major ions comparison with Quality Standards of Drinking Waters, most of the waters of the Peshawar Basin are classified as normal waters. Few dugwells (shallow water) from the Khyber and Attock-Cherat piedmont aquifers (Zahairabad and Ghari Chandan respectively), a dugwell and two tubewells from lacustrine aquifer of the central part of the basin (Amman Kot) indicate relatively higher concentration of sodium, calcium, magnesium, potassium, iron, chloride, sulfate, and total dissolved solid (TDS) as compare to the standard Maximum Contaminant Level (MCL) of potable water. The high concentration of these radicals at these locations, in the basin, can be attributed to, a) the presence of evaporites at the depth, e.g. gypsum, limestone, dolomite and halite etc., b) water logging and salinity, c) greater use of fertilizers. Therefore no contamination from a source related to industrialization and urbanization was found in waters of these areas.

Key words: Geochemistry, environment, water, Peshawar basin.

T/114. Tariq, S., Shah, M.T. & Hamidullah, S., 2001a. Stable isotopic composition of surface and subsurface water from Peshawar basin, north Pakistan. *Journal of Asian Earth Sciences* 19, p.66.

Key words: Geochemistry, isotopes, water, Peshawar basin.

T/115. Tariq, S., Shah, M.T. & Hamidullah, S., 2001b. Environmental geochemistry of surface and subsurface water from Peshawar basin, north Pakistan. *Journal of Asian Earth Sciences* 19, p.67.

Key words: Geochemistry, environment, water, Peshawar basin.

T/116. Tassy, P., 1983. Les Elephantoides Miocenes du plateau du Potwar, groupe du Siwalik, Pakistan; 1, Introduction, cadre chronologique et geographique, Mammutides, Amebelodontides. *Annales de Paleontologie* 69, 99-136, 235-297, 317-354.

These three papers give details of the Siwalik Miocene Elephantoides of the Potwar Plateau. Information is also given on chronological framework, geography, Mammutides and Amebelodontides.

Key words: Palaeontology, elephantoides, Miocene, Siwalik, Potwar.

T/117. Tauxe, L. & Opdyke, N.D., 1982. A time framework based on magneto stratigraphy for the Siwalik sediment of the Khaur area, northern Pakistan. *Palaeogeography, Palaeoclimatology, Palaeoecology* 37, 43-61.

The magnetostratigraphy of eleven new sections in the Khaur area of northern Pakistan is presented. All specimens have been subjected to thermal demagnetization. The sections, taken in adjacent ravines incising the Siwalik formations nearly perpendicular to strike, form a temporal framework in which to interpret the biological and lithological information. A composite section is constructed from several long sections and is correlated to the magnetic polarity time scale (Chron 6 to Chron 15), providing absolute age information for the biostratigraphic zonations of Barry et al. (1982). Detailed sections along the strike of major stratigraphic marker beds document an

isochronous horizon and form the basis for paleoenvironmental reconstructions. The preservation of a polarity transition in fluvial sediments suggests continuity of sedimentation on a time scale of 10^3 – 10^4 years.

Key words: Magnetostratigraphy, sediments, Siwaliks.

T/118. Teichert, C., 1967. Nature of Permian glacial record, Salt Ranges and Khisor Range, West Pakistan. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 129, 2: 167-184.

Key words: Glacial deposits, Permian, Salt Range, Khisor Range.

T/119. Teichert, C., 1981a. Permian glaciation in Pakistan. *Geological Society of Australia, Abstracts*, 3, p.17.

Key words: Glaciation, Permian.

T/120. Teichert, C., 1981b. Permian glaciation in Pakistan. In: Harland, W.B. & Hambrey, M.J. (Eds.), *Earth's Glacial Record*, 278-286. Cambridge University Press.

Key words: Glaciation, Permian.

T/121. Teichert, C. & Stauffer, K.W., 1965. Palaeozoic reef discovery in Pakistan. *GSP, Records* 14(3), 1-10.

Consult the following account for further information

Key words: Reefs, limestone, Silurian, Devonian, Palaeozoic, Nowshera.

T/122. Teichert, C. & Stauffer, K.W., 1965. Palaeozoic reef in Pakistan. *Science* 150(3701), 1287-1288.

A Silurian, and perhaps Devonian, limestone belt in northern West Pakistan contains the first Paleozoic reefs found on the Indo-Pakistan subcontinent. The belt contains a rich fauna entirely new to Pakistan. Its presence indicates that this area was inundated in Silurian and Devonian times by seas bordered by reefs or containing reef platforms.

Key words: Reefs, limestone, Silurian, Devonian, Palaeozoic, Nowshera.

T/123. Templeton, R.S.M., 1973. Ideas on the tectonics of the Afghan-Pakistan geosyncline. *Geological Survey of Pakistan. Geonews*, 3, 7–8.

Key words: Tectonics, geosyncline, Afghan-Pakistan.

T/124. Teng, J.W. & Lin, B.Z., 1984. Earthquake activity and tectonics of the Himalaya and its surrounding regions. In: Miller, K.J., *The International Karakoram Project*, 1, 221-235. Cambridge University Press.

Using teleseismic data from the Himalaya and surrounding regions plus observations from local seismic networks located on both side of the Yarlung Zungbo River during 1975-1979, both large and small earthquake fault plane solutions are obtained, and the relationship between the seismicity of the plateau and plate tectonics is investigated. Shallow earthquakes are dominant on the Qinghai-Xizang (Tibet) Plateau, whilst intermediate earthquakes are common at the east and west extremities of the arc. In the central part of the arc intermediate depth shocks are rare. According to the fault plane solutions the directions of compressive stress are mainly north and northeast, i.e., basically perpendicular to the strike of the arcuate system. The extremely thick crust and other geophysical data

fields in this regions suggest that the stress field is caused by the collision and compression of the Indian and the Eurasian plates.

Key words: Tectonics, seismicity, Himalaya.

T/125. Terai, Y., Niida, K. & Khan, S.R., 1998. Origin of ultramafic rocks in the Jijal Complex, Kohistan, Pakistan. Abstract volume 105th Annual Meeting, Geological Survey of Japan, p.201.

Key words: Ultramafics, Jijal, Kohistan, Himalaya.

T/126. Terra, H. de, 1935. Geological studies in the northwest Himalaya between the Kashmir and Indus Valleys. Connecticut Academy of Arts and Sciences, Memoirs, 82, 18-76.

Key words: Mapping, petrology, Kashmir, Indus, Himalaya.

T/127. Thakur, V.C., 1983. Granites of western Himalayas and Karakorum structural framework, geochronology and tectonics. In: Shams, F.A. (ed.), Granites of the Himalayas Karakorum and Hindu Kush. Institute of Geology, Punjab University, 327-339.

Key words: Tectonics, geochronology, structure, granites, Himalaya, Karakoram.

T/128. Thakur, V.C. (ed.), 1992. Geology of Western Himalaya. Pergamon Press, Oxford. Physics and Chemistry of the Earth 17 & 18, 1-363.

This monograph gives a comprehensive account of various aspects of the geology of the western Himalaya. Brief references are also made to northern Pakistan. Following introduction, there is a detailed discussion of the outer Himalayan Zone (including Potwar Plateau); Lesser Himalayan Zone (including Attock-Cherat Kala Chitta and Salt Ranges, Nowshera and Hazara region and western syntaxis); Higher Himalayan Zone (including Nanga Parbat, Hazara, Besham, Swat and Kaghan region); Tethys Himalayan Zone; and Trans Himalaya (including Karakoram and Kohistan region). The final chapter deals with tectonic synthesis followed by a comprehensive bibliography spread over 35 pages.

Key words: Tectonics, potwar, Attock-Cherat, Salt Range, Nanga Parbat, Kohistan, NW Himalaya.

T/129. The Aerosol Magnetism Research Team, 1996. Application of rock magnetic method to atmospheric aerosol discrimination: A preliminary observation in Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 107-108.

Key words: Rock magnetism, atmospheric aerosol.

T/130. Theobald, W., 1877a. On the occurrence of erratics in the Potwar, and the deduction that must be drawn therefrom. Geological Survey of India, Records 10(3), 140-143.

For further information, consult Theobald 1880 below.

Key words: Potwar, India.

T/131. Theobald, W., 1877b. Remarks, explanatory and critical on some statements in Mr. Wynne's paper on the Tertiaries of the North West Punjab in Records 10(3). Geological Survey of India, Records 10(4), 223-225.

For further information, consult Theobald 1880 below.

Key words: Tertiary, Punjab, India.

T/132. Theobald, W., 1879. On a marginal bone of an undescribed tortoise, from the Upper Siwaliks, near Nila, in the Potwar, Punjab. Geological Survey of India, Records 12(4).

Key words: Palaeontology, Siwaliks, Potwar, Punjab.

T/133. Theobald, W., 1880. On some Pleistocene deposits of the northern Punjab and the evidence they afford of an extreme climate during a portion of that period. Geological Survey of India, Records 13(4), 221-243.

Theobald provided fairly detailed information about the geographic distribution, lithology and size of the Punjab erratics. Many blocks are located on the east bank of the Indus River in the territory between Indus and Haro rivers and the Grand Trunk Road, particularly near Attock, south of Haji Shah, near Attock city, and Lawrencepur. More blocks occur further north near old Tarbela village, and in the valley of the Dor River, and also on the eastern bank of the Indus river south of the Kala Chitta Range near Nara, Jand and Pindi gheb. The blocks are mostly of granite, gneiss, basalt, and limestone, and range from angular to surrounded in shape, with dimensions up to 20 m³. The blocks rest on a terraced surface suspended some 10 m above the present course of the Indus, about 300-400 m above sea level. Based on lithology, the boulders are considered to have been brought from the north. Theobald states that the erratics were carried and deposited directly by the glaciers or by fallen ice blocks in the ancient Indus and looks upon them as proof of the expansion of the Pleistocene glaciers as far as the foot of the mountain range, below 600 meters.

Key words: Pleistocene, climate, Punjab.

T/134. Theobald, W., 1881. The Siwalik group of the Sub-Himalayan region. Geological Survey of India, Records 14(1), 66-125.

Key words: Siwaliks, Himalaya.

T/135. Thewissen, J.G.M., Gingerich, P.D. & Russell, D.E., 1987. Artiodactyla and Perissodactyla (Mammalia) from the early-middle Eocene Kuldana Formation of Kohat (Pakistan). University of Michigan, Contributions from the Museum of Paleontology, 27, 247-274.

Chorlakkhi, yielding approximately 400 specimens (mostly isolated teeth and bone fragments), is one of four major early-to-middle Eocene mammal localities on the Indo-Pakistan subcontinent. On the basis of ungulates described in this paper we consider the Chorlakkhi fauna to be younger than that from Barbora Banda older than the Kalakot fauna, and possibly comparable in age to the Ganda Kas/Lammidhan fauna. Artiodactyls are abundant in the Chorlakkhi fauna. Two families are represented: Dichobunidae and Raoellidae. A new dichobunid, *Pukibune chorlakkhiensis* n. gen. et sp., and a new raoellid, *Indohyus majar* n. sp., are described. A new diagnosis of Raoellidae is given here. Perissodactyls are rare at Chorlakkhi. However a few elements identified as isctolophid tapiroids brontotheriids and hyracodontids are known.

Raoellidae is endemic to the Indo-Pakistan subcontinent and may be related to European Dacrytheriidae. Pakistan dichobunids too seem to have European affinities. The perissodactyls are possibly more closely related to Eocene taxa from the rest of Asia than to those from Europe.

Key words: Palaeontology, Mammalia, Eocene, Kuldana Formation, Kohat.

T/136. Thewissen, J.G.M., Hussain, S.T. & Arif, M., 1994. Fossil evidence for the origin of aquatic locomotion in archaeocete whales. Science 263, 210-212.

Recent members of the order Cetacea (whales, dolphins, and porpoises) move in the water by vertical tail beats and cannot locomote on land. Their hindlimbs are not visible externally and the bones are reduced to one or a few splints that commonly lack joints. However, cetaceans originated from four-legged land mammals that used their limbs for locomotion and were probably apt runners. Because there are no relatively complete limbs for archaic archaeocete cetaceans, it is not known how the transition in locomotory organs from land to water occurred. Recovery of a skeleton of an early fossil cetacean from the Kuldana Formation, Pakistan, documents transitional modes of locomotion, and allows hypotheses concerning swimming in early cetaceans to be tested. The fossil indicates that archaic whales swam by undulating their vertebral column, thus forcing their feet up and down in a way similar to modern otters. Their movements on land probably resembled those of sea lions to some degree, and involved protraction and retraction of the abducted limbs.

Key words: Palaeontology, mammalia, Eocene, Kuldana Formation, Kohat.

T/137. Thewissen, J.G.M., Hussain, S.T., Arif, M., Aslan, A., Madar, S.I. & Roe, L.J., 1997. The origin of the modern orders of mammals within the context of Paleogene deposition in the northern Pakistan. Abstracts, 3rd GEOSAS Workshop on Siwaliks of South Asia, Islamabad. GSP, Records 109, 80-84.

One of the greatest enigmas of the evolution of life is the origin of the modern orders of mammals. Many recently mammal orders appear in the fossil record abruptly, and no morphologically-similar ancestors are known. Krause and Maas (1990) have proposed that Indo-Pakistan could be the birth place for many of these orders and that investigation of Paleocene and Eocene sediments of the subcontinent could solve these enigmas. Collaborative investigations of teams from Howard University, the Northeastern Ohio Universities College of Medicine (NEOUCOM), and the GSP have resulted in significant collections of Eocene mammals, elucidating the origin of several orders of modern mammals. The most primitive artiodactyl in the world is *Diacodexis* and one of its species, *D. pakistanensis* has been found in Kohat District (Thewissen et al., 1983). Thewissen and Hussain (1990) suggested that it is the most primitive member of its genus. Spectacular fossil discoveries have been made with respect to the origin of cetaceans (whales and their relatives). The oldest known cetaceans, so called pakecetids, are known from Punjab and NWFP (West, 1980; Gingerich and Russell, 1981). Important new fossil material of these animals has been found in the Kala Chitta Hills, allowing a better understanding of the evolution of underwater hearing (Thewissen et al., 1992) and the ability of whales to drink sea water (Thewissen et al., 1996B). A complete skeleton of another cetacean, *Ambulocetus natans* from Punjab, is the only cetacean known to preserve much of the hands and feet of the ancestral cetaceans and allows the study of locomotion of amphibious whales (Thewissen et al., 1994, 1996A). Anthracobunids, a group only known from Pakistan and India, played an important role in the origin of siremans and proboscideans (Wells and Gingerich, 1981; West, 1981), and true siremans have been recovered in several areas of Punjab (Gingerich et al. 1995). New fossil material for Eocene primates (Thewissen et al., in press) and hyaenodontid creodonts, may solve important biogeographical questions of these orders of mammals, and some of the earliest rodents are known from NWFP (Hussain et al., 1978).

Understanding of the depositional environment of Punjab and NWFP is of great importance in the recovery of early mammals. The Cretaceous-Tertiary Boundary of the Kohat-Potwar Province (Punjab and NWFP) is characterized by an unconformity which is commonly expressed as a taterite near the northern edge of the Potwar Plateau. Paleocene deposits of the Kohat-Potwar Province are marine and can be more than 1000m thick (Meissner and Rahman, 1973). These deposits have been interpreted as documenting a continental shelf and deep sea basin sequence (Wells, 1983), and Gardezi et al (1976) identified Paleocene clastic deposits that may document a more near-shore environment. Beck et al. (1995) interpreted the Paleocene rocks as having been deposited immediately after the collision between the Indian and Asian continents. This is consistent with magnetostratigraphic data (Klootwijk et al., 1994).

In the early Eocene, shallow water sedimentation dominates, resulting mainly in extensive limestone deposits that are part of the Ghazij Group of Pivnik and Wells (1996). In the Potwar Plateau area, these include the Margala Hill and Chor Gali Formations which are generally considered to be Ypresian in age (Fatmi, 1973).

Early Eocene marine sedimentation is followed by deposition of continental sediments that are the regressive part of the Laki sequence. These are usually referred lower Kuldana Formation in Punjab or the Mami Khel formation in North-West Frontier Province. Meissner et al. (1974) recovered Foraminifera indicating an early Eocene age for these beds in Kohat District. The lower Kuldana Formation consists mainly of red muds, but occasional indurated conglomerates and sandstones are also present. It is the Kuldana Formation that has yielded most of the important paleontological discoveries of Eocene Indo-Pakistan.

The faunas of the two lithologies of the lower Kuldana Formation differ. Most of the collections described by Dehm and Oettingen-Spielberg (1958) were collected in the muds. The fauna here contains a large number of perissodactyls, especially tapiroids and brontotheres. Wells (1984) interpreted these muds as overbank deposits.

The conglomerates of the lower Kuldana Formation are laterally restricted (several meters) and thin (usually less than 1 m beds). Individual grains are cemented by calcite and commonly show concentric rings in cross-section. They have been interpreted by Wells (1983) as soil nodules that were reworked into channels representing lag deposits. Wells (1984) proposed that the nodules were formed in soils during alternating warm-wet and warm-dry conditions, and that occasional torrential rains may have concentrated them into channels. The faunas found in different conglomerates vary greatly, but are generally different from those of the muds in the low numbers of perissodactyls, especially brontotheres.

Howard-GSP Locality 62 in the Kala Chitta Hills is an example of a conglomerate. The preservation of the fossils is unusually good (Asian and Thewissen, in press), fossils from this site include such delicate elements as braincases and scapulae. This suggests that no high-energy transport has taken place. On the other hand, no articulated elements are known from this locality, suggesting that all soft tissues were destroyed before diagenesis. Pakicetids and anthracobunids are the most common taxa among the recovered mammals, and perissodactyls are extremely rare. Freshwater fish and aquatic turtles are also common, and it is likely that the depositional environment of Locality 62 is aephemeral pond. Asian and Thewissen (in press) proposed that the sediments at this locality were deposited in a short time, possibly less than 1,000 years.

Another fossiliferous conglomerate occurs near Barbora Banda in Kohat District. The fauna at this site consists nearly exclusively of two forms. By far the most common is *Diacodexis pakistanensis*, but some individuals of an iscetolopkid tapiroid are also known (Thewissen et al., 1983). Articulated partial skeletons are common for both taxa at this locality (Thewissen and Hussain, 1990). Wells (1983, 1984) studied the genesis of this conglomerate and suggested that a catastrophic flood swept a group of animals in to a channel and buried them with soil nodules that were eroded from the floodplain. Some scavenger activity is also apparent (Thewissen and Hussain, 1990).

Lower Kuldana sediments are followed by a variety of thin beds including varicolored shales, limestones (sometimes dolomitic), and silts. These beds are sometimes described as the upper Kuldana Formation (Wells, 1983), or included in the Mami Khel formation (Meissner et al., 1974; Pivnik and Wells, 1996). We follow Shah (1977) and include the Mami Khel clays in the Kuldana Formation. There is a quick succession of different lithologies, including both freshwater and mare beds. Given the differences in depositional environment, faunal variation is significant. Terrestrial faunas include primates, hyaenodontids, mesonychians, and brontotheres, whereas aquatic faunas include anthracobunids and cetaceans. Wells (1984) interpreted the upper Kuldana deposits as representing coastal plain and near shore deposits, including brine pools, freshwater lakes, marshes, lagoons and bays. There is also evidence for paleosol development (Aslan and Thewissen, in press).

The top of the Kuldana Formation is conformable with the overlying Kohat Formation. A thick (approximately 1 m in the Kala Chitta Hills) mud with many bivalves and gastropods marks the boundary between the formations. It is underlain by green silts with occasional marine snails and bivalves. The vertebrate fauna of silts and oysterbed includes cetaceans, sirenians, bony fishes, and sharks. Abundant plant remains occur in some sites, and induration varies. These deposits represent the transition from paralic to restricted marine environments (Wells, 1984). *Ambulocetus* was found at a locality near the top of the Kuldana Formation.

The Kohat Formation consists of grey muds and limestones with locally abundant benthic foraminifera. Shah (1977) proposed a later Early or early Middle Eocene age for the Kohat Formation. The Kohat Formation is topped by an unconformity after which Miocene freshwater sediments of the Murree Formation are deposited. The base of the Murree Formation commonly consists of a conglomerate that includes reworked Eocene rocks (the Fatehjang Beds).

Key words: Palaeontology, Mammals, Paleogene, Eocene.

T/138. Thewissen, J.G.M., Hussain, S.T. & Arif, M., 1996. New Kohatius (*Omomyidae*) from the Eocene of Pakistan. *Journal of Human Evolution*, 32, 473-477.

Further information not available to the authors.

Key words: Palaeontology, Eocene.

T/139. Thewissen, J.G.M., Madar, S.I. & Hussain, S.T., 1996. *Ambulocetus natans*, an Eocene cetacean (Mammalia) from Pakistan. *Courier Forschungs-Institut Senckenberg*, 190, 1-86.

Key words: Palaeontology, Mammals, Paleogene, Eocene.

T/140. Thewissen, J.G.M., Roe, L.J., O'Neil, J.R., Hussain, S.T., Sahni, A. & Bajpai, S., 1996. Evolution of cetacean osmoregulation. *Nature* 381, 379-380.

Key words: Palaeontology, Cretaceous.

T/141. Thewissen, J.G.M., Russell, D.E., Gingerich, P.D. & Hussain, S.T., 1983. A new artiodactyl (Mammalia) from the Eocene of North-West Pakistan. Dentition and classification. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Series B*, 86, 153-180.

Key words: Palaeontology, Mammals, Eocene.

T/142. Thomas, H., 1977. Un nouveau bovide dans les couches a Hominoidea du nagri (Siwalik moyens, Miocene superieur), Plateau du Potwar, Pakistan, *Elachistoceras khauristanensis* gen. Et sp. Nov. (Bovidae, Artiodactyla, Mammalia). *Bulletin de la Societe Geologique de France, serie VII*, 19, 375-383.

Key words: Palaeontology, Miocene, Potwar, Siwaliks.

T/143. Tilman, H.W., 1949. *Two Mountains and a River*. Cambridge University Press, Cambridge. 233p. 18 plates, 6 maps.

A scarce book, this is one of the classic mid-twentieth century texts for mountaineers, explorers and adventurers, in which the author treks and climbs including Kashgar, Tashkurgan, Rakaposhi, the Kukuay Glacier, The Fainyor Nallah, Muztagh Ata, Kashgar, the source of the Oxus, Sarhad, Gilgit, and Ishkashim (where the author was arrested!), and others. The book has the noted Tilman qualities, sense of place, descriptive powers, never-failing humor, affection for many kinds of men, and a not too intolerant hate for a few. A unique work by a noted traveler, writer, and raconteur.

From the dustjacket:

When a couple of years ago Mr Tilman left with us a MS. of his book *Mount Everest*, 1938, he arranged for his own executors to deal with proofs, pictures, maps and index, and went out of civilization. He returned to England some months later. Few of his friends knew what he had been up to. This new book, *Two Mountains and a River*, now reveals everything.

It appears that he and two Swiss mountaineers went together to the Gilgit region of the Himalaya with the ambitious project of an attack on Rakaposhi (25,550 ft.). Rakaposhi beat them.

After defeat Tilman went on alone to Chinese Turkistan, having an appointment with an old Everest colleague, Mr E. E. Shipton, British Consul at Sinkiang, for a private attempt on the *Father of Ice-Mountains* which Sven Hedin had four times attempted. They did not reach the summit of their mountain, both got frost-bitten toes, and they had to give up that part of their ambition; but they did some heavy travelling among strange towns, which provided Tilman with just the travel copy he handles and photographs best.

Finally, Tilman alone took an alternative return route, which included a crossing of the frontier of Afghanistan (for which he had no visa) where he had an anxious and angering setback, being arrested as a spy by strange Afghan officials, and handed on under guard from town to town, until his final release.

The book has the Tilman qualities, sense of place, descriptive powers, never-failing humour, affection for many kinds of men, and a not too intolerant hate for a few. It is risky to say that Tilman reminds one of Borrow, but there is no doubt that this book will maintain his unique reputation as a traveller, writer, and raconteur.

Divided into the following sections:

- Food and equipment
- Karachi to Abbottabad
- The approach march

- Gilgit - arrival and departure
- The Jaglot approaches
- The two ridges
- The Dainyor Nallah
- The Kukuay glacier
- Chalt to Misgar
- Misgar to Tashkurghan
- Muztagh Ata
- To Kashgar
- Another way home
- The Oxus source
- Sarhad to Ishkashim - open arrest
- Ishkashim - close arrest
- Destination unknown
- Faizabad and freedom

Key words: Travel, Books.

T/144. Tilman, H.W., 1951. China to Chitral. Cambridge University Press, Cambridge.

A story of travel into China's mysterious inner massif where mountains rival Everest's height and the native tribesmen still have a time-suspended life unchanged since Genghis Khan's Golden Horde swept the civilized world. Tilman, a young Englishman, started out from Shanghai, took some easy stages by plane, then descended to earth and oxcart, then truck, to cross the deep interior into Sinkiang or Chinese Turkestan-the long, fabulous back of the beyond that lies north of the Himalayas. There he observed curiously costumed tribesmen, Turkish-bazaar towns, curly-roofed houses designed to keep devils out, and he achieved the ascent of some of the world's highest- and roughest- mountains. This hasn't a magic text to speed it along, but some maps, along with 69 photographs, will attract the travelogue fancier.

Key words: Geography, Chitral.

T/145. Tilton, G.R., Bryce, J.G. & Mateen, A., 1998. Pb-Sr-Nd isotope data from 30 and 300 Ma collision zone carbonatite in northwest Pakistan. *Journal of Petrology* 39, 1865-1874.

We present isotope data for the synorogenic Sillai Patti and Loe Shilman (30 Ma) and the pre-orogenic Koga and Jhambil (300 Ma) carbonatites, of the Indus Suture Zone. The younger carbonates are foliated-banded sheet-like bodies in the metamorphosed belts of the Higher and Lesser Himalaya, within the Indus Suture Zone. They appear to be collision related and have no relationship to the silicate rocks in the complex. The initial isotope ratios are: ϵ_{Nd} -3.1 to -3.8; $^{87}Sr/^{86}Sr$ 0.70463-0.70486 (ϵ_{Sr} +2.4 to +5.6); $^{206}Pb/^{204}Pb$ 19.01-21.35; $^{207}Pb/^{204}Pb$ 15.54-15.67; $^{206}Pb/^{204}Pb$ 38.29-40.63. The pattern is atypical given that carbonatites generally yield positive ϵ_{Nd} and negative ϵ_{Sr} . The Nd, Sr, and least radiogenic Pb isotope ratios also fit the pattern of carbonatites from the East African Rift, suggesting derivation from similar sources. In that case a lithospheric source for the 30 Ma Pakistan carbonatites was probably transported with the Indian Plate during migration from East Africa to the collision with the Asian continent. Intrusion of the carbonatites into rocks of the Himalayan orogenic zone apparently affected only the Pb isotopes on some of the plutons. Nd, Sr and Pb isotope patterns for the 300 Ma Pakistan plutons fit those for most intra-plate carbonatites, with positive ϵ_{Nd} and negative ϵ_{Sr} , showing that neither transport nor collision noticeably disturbed their isotope patterns.

Key words: Carbonatites, metamorphism, Loe Shilman, Sillai Patti, Indus Suture, Himalaya.

T/146. Tipper, G.H., 1921. Orpiment mines in Chitral. Geological Survey of India, Records 54(1): 16-17.

Key words: Mining, Chitral.

T/147. Tipper, G.H., 1922. Chitral. In Fermor, L.L., General report for 1921. Record of the Geological Survey of India 54, 55-57, Calcutta.

This general report of the Geological Survey of India also has geological information on Chitral.

Key words: Chitral

T/148. Tipper, G.H., 1924. Chitral. In Pascoe, E.H., General report for 1923. Record of the Geological Survey of India 56, 44-48, Calcutta.

This general report of the Geological Survey of India also has geological information on Chitral.

Key words: Chitral

T/149. Tipper, G.H., 1923/1924. Geology of Chitral. Geological Survey of India Records 60/61,

The report describes the geology and rocks of the Chitral area.

Key words: Geology, Chitral.

T/150. Tipper, M.H., 1905. Report on penetration of Malakand Tunnel. Geological Survey of India, Records 35, 35p.

Key words: Chitral

T/151. Tiratsoo, E.N., 1947. The search for oil in northwest India. Oil Weekly 125(10), 10-12 & 15-16.

This and the following contribution are not available to the authors. But, hopefully, they contain information on the oil wells that occur in the area of this report; hence the papers are included in this compilation of ours.

Key words: Hydrocarbons, India.

T/152. Tiratsoo, E.N., 1951. Oil fields of Asia and Africa, Pakistan and India. Petroleum Geology. Methuen & Co. London, 156-159.

Key words: Hydrocarbons, Asia, Africa, Pakistan, India.

T/153. Tiratsoo, E.N. 1979., Natural Gas, Gulf Publishing Co., Houston, Texas, p.1-360.

Key words: Hydrocarbons.

T/154. Tohma, M., 1959. On the mineral resources in West Pakistan. Mining Geology, Geological Society of Japan 9, 249-260.

Key words: Mineral resources.

T/155. Tonarini, S., Villa, I.M., Oberli, F., Meier, M., Spencer, D.A., Pognante, U. & Ramsay, J.G., 1993. Eocene age of eclogite metamorphism in Pakistan Himalaya: implications for India-Eurasia collision. Terra Nova 5, 13-20.

This eclogite occurs in the upper part of Kaghan valley, and is derived from mafic protolith. It gives an Eocene age of metamorphism. Implications on the tectonics of the burial of the precursor rocks, very high pressure metamorphism, and uplift of the eclogite are discussed.

Key words: Eclogites, metamorphism, Eocene, Himalaya.

T/156. Tongiorgi, M., Milia, A. de, Le Fort, P. & Gaetani, M., 1994. Palynological dating (Arenig) of the sedimentary sequence overlying the Ishkarwaz Granite, upper Yarkhun valley, Chitral, Pakistan. *Terra Nova* 6, 595-607.

A sedimentary sequence overlying a granite pluton near Ishkarwaz (upper Yarkhun valley, Chitral, Pakistan; Karakorum Microplate) contains abundant, but poorly preserved, acritarchs probably referable to the late early Arenig-early late Arenig interval. The palynological assemblages of Karakoram show a marked similarity to the cold water Peri-Gondwana assemblages; i.e. to those of Li Jun's *Arbusculidium*-*Coryphidium*-*Stiafoheca* 'Mediterranean' Bioprovince. Biogeographical and geological comparisons suggest that, before the accretion of Cimmerian microplates to the Eurasian continent, the Karakorum Microplate was located along the northern margin of Gondwana in a latitude intermediate between the Mediterranean region and South China (Yangtze Platform).

Key words: Ishkarwaz granite, palynology, Yarkhun, Chitral.

T/157. Torossian-Brigasky, W. & Hammer, V.M.F., 1996. Die "Turkishgrünen Steine" von Nagar in Nord-Pakistan. *Mineralien Welt* 7, 47-51.

Quartz of turquoise-green colour is described from Nagar in North Pakistan. The deposit is at 3400 m altitude.

Key words: Gems, semi-precious minerals, Nagar, Karakoram.

T/158. Treloar, P.J., 1989. Imbrication and unroofing of the Himalayan thrust stack of the North Indian plate, north Pakistan. *Geological Bulletin, University Peshawar* 22, 25-44.

The northern part of the Indian Plate in North Pakistan is dominated by a crustal scale south-verging thrust stack composed of a number of thrust nappes, each of which is stratigraphically distinct. Major nappes recognized in the Swat to Kaghan area of north Pakistan are the Besham, Swat, Hazara, Banna, Lower Kaghan and upper Kaghan nappe. Metamorphism was synchronous with early ductile stages of Himalayan deformation, the metamorphic pile being subsequently disrupted during the development of the thrust stack which marks the last phase of southeasterly directed Himalayan thrusting. Within each nappe the metamorphic grade increases upwards, an overall inversion that represents post-metamorphic imbrication within individual nappes, synchronous with the main phase of nappe stacking, rather than an originally inverted metamorphic gradient. As a result of this "within-nappe" imbrication each thrust slice within any particular nappe contains rocks of a higher metamorphic grade than those in the slice below, with sharp metamorphic breaks across the imbricating thrusts as well as across the major shears that bound the individual thrust nappes. Exhumation and unroofing of the rocks within the thrust stack was rapid. The assembly of the stack triggered rapid erosion, record in the Oligocene and Miocene molasse basins, and regional extension that included significant northward extension within the Main Mantle Thrust zone. Cooling ages imply that peak metamorphism was completed by 40 Ma ago, or within 15 to 20 Ma of collision; that the post-metamorphic thrust stack had been assembled by 25 Ma ago, and that much of the subsequent exhumation was completed by 18 Ma ago.

Key words: Tectonics, structure, stratigraphy, metamorphism, Indian plate, Himalaya.

T/159. Treloar, P.J., 1990. Collision processes in the NW Himalaya: Evolution of the Indian plate thrust stack, Pakistan Himalaya. In: Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, p.62.

In NW Pakistan Himalayan collision was between the Kohistan Island Arc (accreted to Asia about 100 Ma ago) and the Indian Plate, with Kohistan thrust south over India along the Main Mantle Thrust (MMT). In the crystalline internal zones of the Indian Plate, metamorphism, at temperatures of up to 650°C, was synchronous with ductile simple shear regionally developed in the MMT footwall. The metamorphic pile was subsequently imbricated within a crustal-scale south-verging thrust stack formed of a number of internally imbricate nappes, each lithologically distinct. The thrusts, which imbricate these nappes each, have higher-grade rocks in their hanging wall than in footwalls generating an overall inversion of the metamorphic sequence. It is stressed that this inversion results from

a post- metamorphic disruption of the metamorphic pile rather than from an originally inverted metamorphic gradient.

Internal zone evolution can hence be divided into two periods of deformation, each of which resulted in a, subsequently eroded, topographic high: an early period of thickening of India under Kohistan culminating in the metamorphic peak and a second phase of post-metamorphic stacking. Ar-Ar, K-Ar, Rb-Sr and fission track geochronology enables us to date these different events. The first period predates 40 Ma (the time of cooling back through the hornblende blocking temperature). Thermal modeling suggests that the crustal thickening, which drove the metamorphism, must have predated 60 Ma, which is earlier than the normally accepted timing of Himalayan collision. Post-metamorphic stacking of the internal zones was largely accomplished between 35 and 25 Ma ago subsequent to which this second topographic high was exhumed by a combination of extension in upper levels of the Indian plate and the overlying MMT zone, and rapid erosion reflected by molasses deposition in the foreland basins. Eocene and Miocene molasses sequences respectively date the erosion of these two mountain fronts. Since 25 Ma the crystalline zones have acted as rigid block transported southward over the foreland basin sequences.

Shortening estimates can be derived for different structures within the internal and external zones, geochronological date allowing us to date both when these structures were operative and the rates at which they accommodated shortening. Although total shortening across the zone is of the order of 500-kms, giving a time-averaged rate of ca. 1cm/yr, shortening rates varied throughout the post-collisional period. Within the internal zones the two deformation periods were separated by a phase of little or no apparent shortening. Shortening rates of 2 to 4 cm/yr can be estimated for the period of post-metamorphic stacking. Within the external zones similar variations can be observed. There is, however, little evidence of shortening between 25 and 12 Ma, after which shortening rates, as recorded by sequentially developed structures, varied from <1 to ca. 5 cm/yr.

Key words: Tectonics, metamorphism, MMT, Indian plate, Himalaya.

T/160. Treloar, P.J., 1991. P-T-t paths of metamorphism, Pakistan Himalaya: implications for crustal subduction and staking. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 93-94.

One of the main contributions that metamorphic petrology can make to our understanding of the tectonic evolution of orogenic belts is by contributing hard data pertaining to the P-T-t paths of crustal thickening, metamorphism and exhumation. This involves a consideration not just of thermodynamically calculated metamorphic Ps and Ts, but the use of inclusion suite thermobarometry and the forward modeling of P-T trajectories based on chemical zonations. Such trajectories, when coupled with microstructural analysis of fabric-porphyroblast relationships and Ar-Ar and fission track mineral cooling chronologies, enable the construction of well-defined P-T-t-deformation.

Within the crystalline internal zones of the Indian Plate, west of the Nanga Parbat syntaxis, fabric-porphyroblast relationships demonstrate that metamorphism was synchronous with early stage of ductile deformation. This deformation was related to the development of the first Himalayan mountain front. It is now well established that this metamorphic pile was subsequently deformed within a post-metamorphic thrust stack which contains a number of individual thrust nappes, each with tectonically controlled metamorphic inversions. This period of post-metamorphic thrust stack, which contains a number of individual thrust nappes, each with tectonically controlled metamorphic thrust stacking documents the development of a second Himalayan mountain front.

In the Upper Kaghan, Hazara and Swat nappes forward modeling of garnet zonation profiles in low variance assemblages, as well as changes in inclusion suite parageneses from core to rim (especially ilmenite in garnet cores and rutile in garnet rims in rocks saturated with plagioclase and kyanite), both indicate that the main period of metamorphic mineral growth was along a path of increasing T and P. maximum Ps of 9 to 12 kbar are routinely recorded, with ΔP s during metamorphism of ≥ 6 kbar. These substantial syn-metamorphic pressure increases reflect thickening of the Indian Plate crust during active subduction beneath Kohistan.

Within the Upper Kaghan and Swat nappes, near rim Ca zonation in garnets and the mantling of matrix rutile by ilmenite testify to a phase of pressure decrease, although still at elevated pressures, which must represent early stages of exhumation of the deeply buried rocks. This exhumation is recorded in the late Eocene molasse sediments of the Murree Formation. That no extensive down temperature and pressure cooling path recorded in the zonation profiles suggest extremely rapid cooling that can only have been accommodated by rapid unroofing such as uplift-driven erosion and upper crustal extension on the hanging wall of a major S-verging thrust located beneath the currently exposed crystalline rocks. That this cooling, from $>600^\circ\text{C}$, was rapid is indicated by mineral cooling ages that date cooling through 500°C at ca. 40 Ma. In passing we may note that this early timing of metamorphism and post-metamorphic cooling is inconsistent with a combination of the normally accepted timing of Himalayan

collisions and one-dimensional conductive models of the thermal evolution of thickened crust. They imply that either Himalayan collision was earlier than normally predicted, or that frictional processes of heating are more important in deformation zones than hitherto suggested.

Apart from the growth of calcic rims on garnets in the garnet and staurolite zones of the Hazara nappe there is little evidence for metamorphic overprinting during post-metamorphic stacking. These calcic rims are, though, important. Modeling across the zonations demonstrate that they record abrupt pressure increases, equivalent to about 10-kms of new tectonic burial. Inside the rim regions, the garnets record normal growth patterns relating to metamorphism during development of the first mountain front. The calcic rims relate to tectonic thickening during the second mountain building phase. Within the post-metamorphic stack, the ductile nature of the shear fabrics and K-Ar geochronology suggest that temperatures were >350°C throughout the period of stacking.

Within the post-metamorphic stack there is a systematic increase in metamorphic pressure from the structurally lowest to the structurally highest nappes. This is most clearly shown in the Kaghan Valley where pressures range from ca. 5 kbar in the lowermost nappes to eclogite conditions in the highest ones, as David Spencer has recently, and most excitingly, shown. This is convincingly firm evidence that, following subduction-related metamorphism, the subducted slab was acutely telescoped, largely by crustal scale thrusting that was entirely confined to sequences on the MMT footwall. That the uppermost nappes are essentially composed of cover sequences has important implications for processes of cover basement decoupling during continental subduction. Displacement amounts for those rocks originally most deeply subducted, and now structurally uppermost in the internal zones, must have been substantial and imply that total shortening amounts for the Indian Plate are well in excess of the 500-km or so generally assumed.

Consequently the full metamorphic story for the Indian Plate internal zones involves: pre 50 Ma, and associated with the growth of the first mountain front, syn-subduction metamorphism (were the heat for this metamorphism not largely driven by frictional heating the collision and crustal thickening must have pre-dated 60 Ma); rapid, pre-40 Ma, exhumation-driven, cooling; pre-25 Ma, and during the growth of the second mountain front, the telescoping and stacking of the cooled and partly exhumed subducted slab with tectonic metamorphic inversions; a second phase (pre-15 Ma) of extension and erosion-driven cooling.

Key words: Tectonics, orogeny, metamorphism, P-T-t path, Indian plate, Nanga Parbat syntaxis.

T/161. Treloar, P.J., 1992. Tectonic of the Himalayan collision between the Indian Plate and the Afghanistan Block: Regional Implication. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 132.

The tectonic history of Afghanistan is complex but can be simplified into deformations related to two main orogenic events. In the earlier of the two, the Triassic to Jurassic aged Kimmerian orogeny, blocks of Gondwanan affinity were sutured to the Asian Plate. Two ophiolitic sutures (Hari-rud and Panjao) can be traced eastward into, respectively, the Jingsha and Banggong sutures of Tibet. A calc-alkaline arc sequence, developed on the southern part of the Asian Plate *sensu stricto*, to the north of the Herat Fault, represents the magmatic products of the subducted intervening oceanic plate. Subsequent to the Kimmerian the Afghan block behaved as a part of Greater Asia.

Prior to Himalayan collision, subduction of the Tethyan oceanic plate beneath Afghanistan saw the development of volcanic arc plutonic sequences of Late Cretaceous age within the Helmand and SW Pamir blocks of the Afghan continental margin, and within the Nuristan extension of the Kohistan-Ladakh island arc. These plutons, and associated volcanics, represent the western end of the Trans-Himalayan batholith.

An important ophiolite emplacement event occurred during the Paleocene. This included emplacement of the Khost, Muslimbagh, Zhob and Waziristan ophiolites onto the western margin of Greater India, as well as ophiolite emplacement onto the Kabul block. The Kabul Block is interpreted here as being of great significance in the pre-Himalayan tectonic evolution of the NW Himalaya. Not only were ophiolitic units emplaced onto it from the northwest, but subsequent to the ophiolite emplacement events, the Kabul block remained separated from Greater India by oceanic crust to its east and southeast. Eocene to Oligocene flysch sediments of the Katawaz basin were deposited onto this oceanic crust subsequent to the ophiolite emplacement events. The Kabul block therefore appears to represent a sliver of continental crust separated from Greater India by a narrow slice of oceanic crust.

Timing of Himalayan collision is uncertain, but there is an increasing body of data which suggests that peak metamorphism in the NW Himalaya must have predated 40 Ma ago, and that metamorphism and leucogranite emplacement may have been as early as 51 Ma ago. If these ages predate true India-Asia collision, as seems likely, then we need to find a mechanism by which the northern margin of Greater India may have been telescoped and

thickened prior to India-Asia collision. Such a mechanism could involve the collision of the leading edge of India with an independent slice of continental crust, subsequently subducted beneath Kohistan and southern Asia. The Kabul Block may be the southwestern, and only remaining exposed, part of this strip of continental crust. The early metamorphism may, therefore, represent thermal relaxation following this pre-Himalayan collision between India and “Kabulistan”.

True India-Afghanistan collision did not take place until the mid- to late-Oligocene, the oceanic crust and overlying flysch sediments, that separated the Kabul Block from the Indian Plate, remaining intact until then. Dating of this collision is derived from the ages of: molasse sediments that postdate thrusting in the Sulaiman Ranges of West Pakistan; flysch sediments folded within the Katawaz Flysch Basin; Paleogene sediments deformed in basins within the Herat Fault zone; and Oligocene sediments and volcanics folded during deformation of the Farah Block of Afghanistan. Significant counter-clockwise rotation of northern Afghanistan took place as, following oblique collision, Afghanistan climbed onto the western margin of the Indian Plate.

The degree to which continental extrusion, accommodated by strike-slip faulting, has taken place in Afghanistan following the Oligocene is uncertain. The Herat and Chaman Faults cannot have acted together to accommodate such expulsion as the former was mainly active during the early Miocene, and the latter after that. Instead, much of the shortening consequent on collision and the continued indentation of India into Asia may currently be being taken up by the northwestward thrusting of the Hindu Kush Mountains over the Afghan-Tadzhik Basin.

Key words: Tectonics, deformation, Indian late, Afghan block, Himalayan collision.

T/162. Treloar, P.J., 1995a. Pressure-temperature-time paths and the relationship between collision, deformation and metamorphism in the North-west Himalaya. *Geological Journal* 30, 333-348.

For details consult the following account.

Key words: Tectonics, deformation, metamorphism, Himalaya.

T/163. Treloar, P.J., 1995b. P-T-t Paths and the relationship between collision, deformation and metamorphism in the NW Himalaya. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

In recent years, an increasing amount of attention has been given to the thermal controls of metamorphism and the P-T-t paths followed by evolving regional metamorphic terrains. One-dimensional models of conductive heat transfer within orogenically thickened crust clearly demonstrate that in the absence of the sudden injection of heat through magmatic processes, time-scales over which prograde regional metamorphism occurs should be measurable in tens of millions of years. As such, it has become commonplace to consider that the regional metamorphism of thickened crust is a lengthy process, with short lived regional metamorphic episodes being limited to regions, possibly of limited extent, that are characterised by the magmatic advection of heat from the mantle to the crust. In this paper I wish to explore mechanisms which may explain why areas of apparently large regional extent, can undergo regional metamorphism over short time-scales but in the absence of any magmatic heating. An area ideal for this study is the chlorite- to sillimanite-grade metamorphic pile developed on the leading edge of the Indian Plate in northern Pakistan, in the NW Himalaya.

Early Tertiary tectonic and metamorphic evolution of the Indian Plate in N Pakistan.

Within the NW Himalaya, collision was between the leading edge of the Indian Plate and the Kohistan-Ladakh island arc. The Kohistan arc, sutured to Asia at between 100 and 85 Ma ago (Treloar et al 1989a), was the last exotic terrain to be accreted to the Asian Plate prior to Tertiary collision between the Indian and Asian Plates. Prior to collision between the Indian Plate and Kohistan, a series of ophiolitic sheets were obducted onto the northern and western margin of the Indian Plate. Structural data from various ophiolites suggest ophiolite emplacement to have taken place about 65 Ma ago (Searle 1986, Beck et al 1995). When collision between the Indian Plate and the Kohistan island arc commenced, Kohistan was obducted onto the leading edge of the Indian Plate along the Main Mantle Thrust (MMT), a major north-dipping thrust fault that is the true westward continuation of the Indus-Tsangpo Suture Zone. Within the crystalline internal zones, the Indian Plate can be divided into three lithostratigraphic units. At the base is a Proterozoic complex comprised of biotite gneisses intruded by undeformed granites. Hornblende and zircon ages from the gneisses are about 1850 Ma (Treloar & Rex 1990a, b). The gneisses are overlain by a series of late Precambrian to early Cambrian sediments intruded by the Cambrian Mansehra

granite, and which underwent a Paleozoic low grade metamorphism (Baig et al 1989). Unconformably overlying these units is a sequence of pelites, calc-pelites, marbles and amphibolites which constitute the Carboniferous to Triassic Panjal Sequence of the Kaghan Valley and the Alpurai Schist sequence of the Swat Valley (Di Pietro et al 1993, Greco & Spencer 1993). These units must have been overlain, prior to collision, by a sequence of Mesozoic to Eocene continental margin limestones and sandstones, up to 4km thick.

Metamorphism on the footwall of the MMT, within the Indian Plate cover sequences, was synchronous with ductile deformation associated with collision with Kohistan (Treloar et al 1989b, c, d; DiPietro 1991). Spiral garnets, garnets with curving inclusion trails, and garnets with inclusion trails discordant to developed crenulation cleavages are all consistent with growth of metamorphic porphyroblasts early in the deformation history. Subsequent to the main phase of metamorphism, the metamorphic pile was disrupted within a S-vergent thrust stack which imbricated thrust nappes composed of basement rocks with thrust nappes composed of cover rocks. Within individual nappes, N-dipping thrusts placed rocks of a higher metamorphic grade on top of rocks of a lower metamorphic grade, thus generating a tectonically inverted metamorphic sequence, with metamorphic grade increasing both northward and structurally upward. The thrusts and shears which controlled this stacking disrupted the peak metamorphic assemblages and thus post-date the main phase of metamorphism. Although Tertiary cooling ages are readily retrieved through hornblende and mica Ar-Ar data from the Upper Kaghan, Swat and Hazara nappes, there is no evidence for a substantial Tertiary heating of the basement rocks, from within which undisturbed hornblende Ar-Ar spectra yield ages of ca 1850 Ma (Treloar & Rex 1990a, b). This implies either that the cover sequences, metamorphosed during the early Tertiary, were transported great distances during the post-metamorphic thrust stacking, or that the early Tertiary metamorphism was restricted to the upper part of the Indian Plate.

Geochronologic data from a variety of sources indicate that peak metamorphism predated 47Ma with cooling back through 5000C by 40 Ma (Treloar et al 1989a; Treloar & Rex 1990a, b; Zeitler & Chamberlain 1991; Tonarini et al 1993; Smith et al 1994). By contrast, timing of Himalayan collision between the Indian and Asian plates is poorly constrained although most reasonable estimates place it at between 65 and 50 Ma ago (Klootwijk et al 1992; Patriat & Achache 1984). However the timing of collision is defined, there is still an absolute maximum of 15 Ma between initial collision and the attainment of peak metamorphic conditions within the leading edge of the Indian Plate in Pakistan. This is insufficient to permit the attainment of middle amphibolite-facies temperatures by purely conductive heating of cold rocks following continental thickening, unless they had extremely high internal heat generating properties. Possible solutions to this dichotomy are either that the metamorphism predated the Tertiary collision of India, which appears unlikely, or that the driving force for metamorphism involved more than simply conductive heating following crustal thickening. Here I wish to assess the second of these possibilities.

Metamorphism in the Indian Plate. Metamorphic conditions have been derived for much of the internal zones of the Indian Plate exposed to the west of the Nanga Parbat syntaxis (Treloar et al 1989b, c; DiPietro 1991; DiPietro & Lawrence 1991; Pognante & Spencer 1991). For the Swat region, kyanite-grade rocks were metamorphosed at 625 + 500C and 9 + 2 kb. For the Hazara area, staurolite-grade rocks were metamorphosed at 480~620a(2 and 5-10kb, and kyanite-and sillimanite- grade rocks at 600-7400C and 7-12 kb. Kyanite- and sillimanite-grade rocks of the upper Kaghan Valley, on the hanging wall of, the Batal Thrust, were metamorphosed at ca. 650 + 500C and 9 + 2 kb. In addition, eclogitic rocks within the Upper Kaghan nappe yield P-T estimates of 650 + 500C and 14.5 + 2.5 kb. In the Lower Kaghan Valley, on the footwall, and to the south of, the Batal Thrust garnet-grade rocks yield P-T estimates of 540 + 400C at 10 + 2 kb.

Pressure-temperature-time (PTt) paths have been estimated for rocks from each of the major thrust nappes. Within the Swat region, garnet cores contain an assemblage including zoisite, calcite and ilmenite, and garnet rims contain an assemblage that includes kyanite and rutile. The transition from ilmenite in garnet cores to rutile in garnet rims and in the matrix is consistent with a pressure increase from core to rim. For the Hazara and Upper Kaghan region, PTt paths have been calculated through forward modelling of garnet zonation profiles. Calculated core to rim paths invariably involve increasing pressure trajectories, with little evidence from marginal rim compositions for a significant late pressure decrease.

Thus, in North Pakistan, metamorphism of the Indian Plate sedimentary cover was along a path of increasing pressure, synchronous with ductile shearing, consistent with metamorphism having occurred during active subduction of the leading edge of continental India beneath Kohistan. Peak metamorphism of the cover sediments was achieved by no later than 50 Ma, with cooling back through 5000C at 40 Ma. Subsequently, the rocks were stacked within an imbricate thrust pile within which higher grade rocks are always stacked on top of lower grade rocks. Any model that attempts to explain the metamorphic history of this part of the Indian Plate has to be able to account for the rapidity of heating and subsequent cooling, the syn-metamorphic path of increasing pressure, the subsequent tectonic stacking of the metamorphic sequence; and why, on the footwall of the MMT, it is largely the cover, and not the basement, sequences that show the effects of Tertiary metamorphism.

A Model for the early Tertiary thermal evolution of the NW Indian Plate.

Much of the numerical modelling of the thermal evolution of metamorphic terrains has been involved with explanations for the evolution of inverted thermal gradients across crustal-scale structures. Within 1-dimensional systems, it is easy to generate an inverted thermal gradient across a thrust fault by assuming instantaneous thrusting. However, such an instability will decay within a few Ma due to conductive heat transfer across the fault. Using 2-dimensional modelling, it can be shown that, at thrust displacement rates of $< 5 \text{ cm a}^{-1}$ and in the absence of dissipative shear heating, conductive cooling during thrusting would prevent the development of an inverted thermal gradient, even in the immediate vicinity of the fault (Ruppel & Hodges 1994). Even at thrust rates of $> 5 \text{ cm a}^{-1}$ a steady state temperature inversion cannot be maintained due to cooling of the hanging wall block by continued underthrusting of cold layers on the top of the footwall block: the so-called subduction refrigeration effect (Peacock 1987). To preserve a record of the inverted thermal gradient, it is necessary to accrete the metamorphosed footwall rocks onto the base of the hanging wall, and then to tectonically uplift them. By contrast, dissipative shear heating can generate an inverted temperature gradient on the footwall of the thrust, but with the temperature maximum on the thrust plane itself (Molnar & England 1990; England & Molnar 1993). The effects of dissipative shear heating will override any incipient cooling of the upper block, within which a stable geothermal gradient will be achieved after initiation of faulting at a time determined by the displacement rate along the fault and the thermal diffusivity.

The possible effects of dissipative shear heating along the fault that separated Kohistan from the Indian Plate have been modelled using equations 23 to 30 of England & Molnar (1993). Shear stresses have been calculated, using dips of 15 and 30° for the fault surface and displacement rates along the fault of 10 and 15 cm a^{-1} , for two different sets of P-T conditions (7250 at 10 Kb and 650°C at 10 Kb) that equate to kyanite to sillimanite bearing rocks of the Hazara nappe and the kyanite-bearing rocks of the Swat nappe respectively) and thus approximate to temperatures attained in the uppermost part of the Indian Plate on the footwall of the MMT. Derived shear stresses are a function of the angle of dip of the subduction thrust and the convergence rate, with high dips and high convergence rates favouring high shear stresses. The relatively low angles of dip of the subduction thrust are taken to account for the fact that buoyant continental, rather than dense oceanic, crust was being subducted beneath Kohistan. Displacement rates are based on early Eocene convergence rates between India and Asia. For these input parameters, shear stresses developed along the thrust at depths of 25 to 50 km are in the order of 57 to 116 MPa.

Using the calculated shear stresses, temperature gradients developed on both the hanging wall and footwall of the thrust can be retrieved. A steady state geotherm of $\text{Ca. } 20^\circ\text{C km}^{-1}$ will be attained in the hanging wall within about 5 Ma of the initiation of thrusting. For the footwall, and for depths of 35 km, a negative geothermal gradient of between -83 and -178°C km^{-1} will be attained. Thus, if the effects of dissipative shear heating along the MMT are considered, it is clear that at about 5 Ma after initiation of collision significant negative thermal gradient could have been established beneath Kohistan in the Indian Plate rocks on the footwall of the MMT, with temperatures on the immediate footwall $> 550^\circ\text{C}$.

Discussion.

Given the likely inverted gradients that developed during thrusting, it becomes possible to construct an approximate model for metamorphism on the footwall of the MMT, which might have developed within approximately 5 Ma of the initiation of collision between India and Kohistan. As the major isogratic reactions are temperature dependent, the temperature inversion developed on the footwall of the MMT should be matched by a metamorphic inversion. In order to be preserved, such inverted metamorphic sequences need to be accreted to the base of the over-riding fault block and brought rapidly back towards the surface. To do this the main zone of shearing has to step downward into the footwall so that the initially metamorphosed rocks can be uplifted on the hanging walls of new thrusts developed on their footwall. This accretion process is likely to achieve a thrust-type imbrication of the metamorphosed zone as a result of which rocks metamorphosed deeper within the thrust zone will be stacked on top of rocks metamorphosed at shallower levels within the thrust zone. These imbricating faults will be sub-parallel to the master fault, although with an anastomosing geometry, will stack higher pressure (and thus higher temperature/grade) rocks on top of lower pressure (and thus lower temperature/grade) rocks, and will tectonically thicken the metamorphic complex.

A number of predictions arise from this model. Firstly, the metamorphic pile will be relatively thin and concentrated in the upper part of the footwall block. This means that, as in N. Pakistan, the main metamorphism will be concentrated in the cover sequence of the downgoing plate, with the basement rocks insulated from the thermal effects of the thrust-related metamorphism. Secondly, to be preserved, the rocks that underwent rapid metamorphism during active shearing on the thrust footwall must be brought rapidly back towards the surface, and hence, as in N. Pakistan, will show rapid post-peak metamorphic cooling histories and only a brief residence at high temperatures and pressures. Thirdly, the thrust imbrication that develops during accretion and uplift should stack high-grade rocks on top of lower grade rocks, as is seen in N. Pakistan, thus re-enforcing the original syn-thrusting inverted metamorphic gradient. In the internal zones of N. Pakistan, there is no evidence for older rocks being stacked upon

younger rocks. Rather, the geometry is of rocks that had been deeper in the subduction zone being stacked upon rocks that have never been as deep. This implies that deeper rocks accreted onto the hanging wall first with increasingly shallower packages accreted onto their base during their tectonic exhumation. Exhumation of the metamorphic tectonites developed on the immediate footwall of the MMT would have been by a combination, firstly, of imbrication of the metamorphic rocks during their accretion onto the footwall of the MMT, and, secondly, by uplift of the MMT and the imbricated metamorphic rocks on the hanging walls of S-vergent thrusts developed as deformation stepped downward into the Indian Plate. This uplift would have been accompanied by erosive unroofing of Kohistan. The imbrication of the metamorphic rocks during accretion onto the MMT footwall thus provides a mechanism for producing a regional metamorphic signature of large areal extent, as a thin metamorphic “aureole” becomes tectonically thickened by intense subsequent imbrication.

The thermal models presented here are clearly approximations. At the subduction rates used here a zone with inverted thermal gradient could also be modelled on the MMT footwall through simple one-dimensional thermal modelling. However, it is clear that dissipative shear heating may be a significant factor in controlling metamorphism within thrust systems, and provides a mechanism by which areas of apparently large regional extent can undergo regional metamorphism over short time scales, but in the absence of any magmatic heating.

Key words: Tectonics, collision, deformation, metamorphism, Himalaya.

T/164. Treloar, P.J., 1995c. Short time scale events: are they the key signature of early stages of orogenesis? A framework for discussion. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

That the Himalaya form a wonderful (scenically and scientifically) open air laboratory within which to study orogenic processes is indisputable. What is maybe more debatable is the extent to which they form an ideal basis on which to build analogies for the evolution of old orogenic belts. If we accept the broad tenets of the Law of Uniformitarianism, it is obvious that modern day processes should form the key by which we understand the past. This is clearly demonstrated by recent papers by de Wit et al (1992) and Windley (1993) which utilise modern tectonic processes as analogues for Archaean and Proterozoic tectonism in the Limpopo Belt. As an example, I admit to a Tibetan analogy for the late Archaean tectonic evolution of the Limpopo Belt and adjoining Zimbabwe and Kaapvaal cratons (Treloar et al 1992), a model relatively uncritically accepted by southern African geologists, yet one with such serious flaws that it has to be viewed as untenable (Treloar & Blenkinsop, in press). One of the problems in applying Tibetan-Himalayan analogies to the Archaean, for instance, is in the time scales involved. In many cases, the errors on geochronologically dated apparently simultaneous events are almost as large, or even greater than, the total elapsed time since the initiation of the India-Asia collision!

Two features really form the gist of this discussion: time scales and rates of orogenic processes. Through a combination of isotope, fission track, palaeomagnetic and palaeontologic dating techniques it is now possible to constrain the timing of most of the critical events within the history of the Himalayan orogeny, and the rates at which those events took place. Ironically, the least well constrained event is the timing of initial collision between India and Asia (mais, c'est la vie!). What this chronology tells us is not only that a tremendous amount has happened within a relatively short time scale (< ca. 60 Ma), but that it happened quickly. Given that the initial India-Asia convergence rate was in the order of 20 cm a⁻¹, this may not be surprising, but it does raise a number of questions.

As a young metamorphic petrologist I, amongst many others, was influenced by the seminal papers of England & Richardson (1977) and England & Thompson (1984). Amongst the first to attempt to model the thermal evolution of tectonically thickened crust, these papers demonstrated the efficiency of purely one-dimensional conductive thermal relaxation of thickened crust in driving regional metamorphism and the fact that for most thickened crustal sections metamorphic P-T-t paths are of a “clockwise~ sense (if one assumes that pressure on the P axis of a P-T plot increases upwards. Geophysicists would likely describe these, probably correctly, as counterclockwise paths!) What these early attempts at thermal modelling showed, and this may be the critical message that struck home to a thousand hearts, is that time scales of regional metamorphism are LONG, measurable in many tens of millions of years. An unstated implication of the England & Thompson models, as well as other similar ones, is that regional metamorphism should be, BY DEFINITION, static. Thickening of the metamorphic pile occurs synchronously with deformation, but the peak metamorphic temperatures are attained many millions of years later. There is geochronological support for this. Both Burton & O'Nions (1991) and Vance & O'Nions (1992) have shown that growth periods of individual garnets may be measurable in terms of up to about 10 million years. However, the exciting, seminal and sometimes controversial work of Tim Bell and his colleagues (Bell 1985, Bell et al 1986, Bell and Johnson 1989, 1992) poses a major question to this simple assumption. Bell will aver that porphyroblast growth

in metamorphic rocks is synchronous with deformation. If we look at papers that describe metamorphic tectonites from the Himalaya, what do we see? Spiral garnets, garnets with curving inclusion patterns etc (e.g. Treloar et al 1989a, b). Whether one wishes to resort to “Zwartian” or “Bellian” classifications of porphyroblast-matrix relationships, these textures have to be consistent with syn-deformational growth of metamorphic porphyroblasts, the only thing that is logically not predicted by standard one-dimensional thermal modelling.

Let us take as an example, the early Tertiary metamorphism of the leading edge of the Indian Plate in the NW Himalaya of N Pakistan. It is clearly demonstrable that peak metamorphism there had occurred by between 47 and 50 Ma (Zeitler & Chamberlain 1991, Tonarini et al 1993, Smith et al 1994) and that subsequent cooling back through 5000C was achieved by 40 Ma (Treloar & Rex 1990a, b). Depending on how one constrains the timing of collision, peak metamorphism was within between 5 and 15 Ma of initial India-Asia collision. What price long time scales of regional metamorphism now? In a parallel paper to this (Treloar, this volume) an answer to this conundrum is provided, which builds on the numerical experiments of Molnar & England (1989) and England & Molnar (1993) in invoking dissipative shear heating as the driving thermal impetus for early Tertiary regional metamorphism in the NW Himalaya.

But, this rapid Early Tertiary regional metamorphism is not the only short-lived event that we recognise within the Himalaya. In no particular order of importance or chronology the following far-from-exhaustive list includes:

The synchronicity of thrusting along the Main Central Thrust, extension along the Zaskar Shear Zone/South Tibetan Detachment Zone granite generation and emplacement within the High Himalayan Crystallines (HHC) at about 22 to 20? Ma (references to numerous to mention! but see Searle et al., 1993, England & Molnar 1993). The near synchronicity of metamorphism, melting and granite emplacement within the HHC (a above) uplift and erosion of the HHC and deposition of derived sediments within the Himalayan foreland basins (Najman et al 1993) and the Bengal Fan (Copeland & Harrison 1990) and beyond (France-Lanord et al 1993). The rapid late Oligocene to early Miocene cooling of the internal zones of the Pakistan Himalaya (from > 350° to < 100°C in <8Ma in direct response to erosional and extensional unroofing of the pile (Treloar et al 1991).

The rapid (instantaneous?) late Miocene uplift of the Tibetan plateau (England & Houseman 1988).

The rapid uplift of the Nanga Parbat (Zeitler 1985, Treloar et al 1991) and Hazara syntaxes (Bossart 1988).

Lateral variations in the rapid rate of sediment accumulation in the foreland basins. In Kohistan, there is a possible linkage between probably short-lived regional scale metamorphism and lower arc melting and massive advective heat input from the mantle associated with emplacement of the Chilas body at ca 85 Ma.

There have to be many more examples of rapid metamorphism, sedimentation, exhumation, which as a group of Himalayan geologists we can identify, in discussion, at this meeting. It is true that it is not only just in the Himalaya that short-lived events are important in crustal evolution. As an example, emplacement of granitoid plutons into the Mesozoic arc developed along the western margin of continental South America in the Chilean Andes was not a continuous process. Instead a number of distinct short-lived pulses of pluton emplacement have been identified by precise hornblende Ar-Ar geochronology. Essentially pluton emplacement was controlled by intermittent periods of extensional activity within the trench parallel Atacania Fault system (Grocott et al 1994). When the fault system was not in extension, no space was available within the crust for magmas to stall and create plutons, hence periods of plutonism are separated by distinct periods of volcanism. Similar, highly responsive, relationships between changes in regional deformation and magmatic styles have been identified elsewhere (Glazner 1991). Harte & Dempster (1987) and Ridley (1989) have argued that lateral changes in metamorphic history and style within orogenic belts are a function of active tectonic boundaries, across which there may be significant lateral heat fluxes, and that prominent metamorphic zones within orogenic belts may be the product of tectonic boundary conditions and thus not necessarily representative of the overall thermal history of the belt. They inferred that these tectonic boundary zones and associated heat fluxes may be long-lived. However, Himalayan examples demonstrate that this may not necessarily be the case.

I do not wish to deny that there are a plethora of data that support the thesis that orogenic deformational and metamorphic features are long-lived. Particularly relevant here are the way that granulite terrains show evidence for long time-scales of high temperature, static annealing and metamorphism (Mezger et al 1990). It is clear that any overthickened crust, if left long enough, would follow the one-dimensional conductive thermal relaxation paths of England & Thompson (1984) and, over a long time scale, heat up and experience a long term, static regional metamorphism. There is little doubt, in my mind, that rocks currently located at depths of >40 km below the topographic surface in Tibet and the Himalaya are currently following the path of purely conductive heating and regional metamorphism. My picture of the lower crust beneath Tibet and the Himalaya is of zones of slowly heating isotropic granulites separated by fine-grained mylonitic shear zones. Dissipative heating along these shear zones may contribute fundamentally to the evolving thermal budget in these deep crustal regions. The significance of the above probably comes down to two points. Firstly, the role of shear zones, thrusts and faults in controlling many of

the processes witnessed within the Himalayan belt. These include crustal thickening, uplift, tectonic exhumation, space creation for pluton emplacement, a dissipative shear heating contribution to metamorphism, fluid access for retrogression and/or melt fluxing, all of which processes will be enhanced by high displacement rates. Secondly, that short-lived events within the Himalaya are important due to high convergence rates, and hence rapid displacement rates along shear zones and faults at all crustal levels. Implications of this include the following. Are short-lived events of less importance in orogenic belts in which strain rates are lower? Will short-lived events within the Himalaya-Tibet region become less significant as the convergence rate between India and Asia decreases? To answer these questions we probably need to consider what the late stages of orogeny involve and what will the Himalaya-Tibet region look like fifty or a hundred million years hence. Most of the features that we see now will have been re-distributed as sediment in the oceans to south and east. The thickened crust which currently underlies the High Himalaya and Tibet will probably have returned to a more normal crustal thickness by a number of processes (delamination, extension, but increasingly dominantly through isostatically driven erosion) such that rocks now at depth will be exposed at surface. Those rocks will show evidence for a long thermal history at depth, consistent with England & Thompson's (1984) early models. Evidence for the shear zones which accommodated much of the Tertiary thickening will be limited to annealed granoblastic rocks with little microstructural information, and the Ar and fission track cooling histories will tell us little about the major orogenic processes. It is probable that preserved deformation features will be dominated by those generated during the later stages of orogeny, when convergence rates, and hence strain rates, were lower.

My contention, which we should discuss at this meeting, is that, although over the duration of an orogeny, it may appear that long time scales of metamorphism, magmatism, erosion and uplift are the norm (and if we look at orogens such as the Appalachians, the Cadomian or the Caledonides where we see the roots of the eroded orogen this may appear a sensible conclusion) the reality is that short lived, and possibly localised, thermal, magmatic, metamorphic, erosive and sedimentary processes that result from short-lived faulting (thrusting and extensional) events (brittle at surface, ductile at depth) characterised by high displacement rates, are an important contributor to early stages of orogeny. Thus, if it is these short-lived, rapid events which dominate early orogenic processes the Himalaya are only really a true analogue for the early stages of orogenies characterised by high convergence rates, and we should not attempt to force too far analogies that explain the waning, late-stage orogenic processes recorded in many of our deeply eroded orogenic belts.

Key words: Tectonics, orogeny, Himalaya.

T/165. Treloar, P.J., 1997. Thermal controls on early-Tertiary, short-lived, rapid regional metamorphism in the NW Himalaya, Pakistan. *Tectonophysics* 273, 77-104.

During Tertiary collision in the NW Himalaya, the leading edge of the Indian Plate was subducted beneath the Kohistan island arc along the Main Mantle Thrust (MMT). Metamorphism within Indian Plate cover sediments was synchronous with ductile shearing, and took place along a path of increasing pressure during subduction beneath the island arc. Initial collision cannot have pre-dated 65 Ma and probably shortly pre-dated 50 Ma. Radiometric data constrain the metamorphic peak as shortly post-dating 50 Ma. As, firstly, initially subducted units are now probably located beneath Tibet, secondly, the subduction thrust separating the Kohistan arc terrane from the Indian Plate was probably cooled by continued underthrusting and, thirdly, the heat-producing Indian Plate cover sediments were delaminated from the basement during collision, metamorphism was more rapid than can be predicted by purely conductive models of thermal relaxation. Although dissipative shear heating along the MMT doubtless contributed to early stages of heating of the footwall rocks, the temperatures attained in the footwall are too high to support the shear stresses required to generate them solely through shear heating. A model is derived to account for both the rapid regional metamorphism and the equally rapid post-metamorphic cooling. Dissipative shear heating along the MMT generated an early inverted thermal profile in the upper units of the Indian Plate. As the hanging wall mafic rocks have a low thermal conductivity, they would have acted as a thermal reflector and the heat would have been conducted away only slowly. As footwall temperatures increased through the brittle-ductile transition, the role of dissipative shear heating decreased and continued heating became a function of internal heat generation within the footwall rocks, together with hanging wall thermal reflectivity. The metamorphic inversion was reinforced by imbrication of the metamorphic stack as it accreted onto the MMT footwall during early stages of uplift and exhumation. Dissipative shear heating within thrust systems provides a potentially important mechanism by which areas of large regional extent can undergo regional metamorphism over short timescales, in the absence of magmatic heating.

Key words: Tectonics, thermal modelling, Early Tertiary, metamorphism, Himalaya.

T/166. Treloar, P.J., 1999. Exhumation of high-grade Indian Plate rocks in North Pakistan: Mechanical implications of a multi-phase process. *Terra Nostra* 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 157-158.

Although syn-convergent extension has been described from many compressional orogens, evidence that it may partition into multiple discrete phases is less clear, even though extension is predicted as continuing for as long as shortening once a critical crustal thickness is attained. Geochronological and structural data from the Indian Plate of North Pakistan, to the west of the Nanga Parbat syntaxis, as well as from the structurally overlying Kohistan arc, permit construction of a model for Indian Plate exhumation that demands two discrete, short-lived phases of rapid exhumation separated by long periods of erosive exhumation with low unroofing rates. Here, the evidence for this is summarized, and the mechanical implications assessed.

Data collated from a variety of sources date peak metamorphism in the Indian Plate internal zones, that post-dated thrusting of Kohistan onto the Indian Plate along the Main Mantle Thrust, at $c. 47 \pm 3$ Ma at $T' > 6000^\circ\text{C}$ and P of 10 - 15 kbar (see review in Treloar, 1997). That maximum pressures were higher yet is indicated by the recent discovery of coesite in the Kaghan eclogites (O'Brien et al., this volume). Metamorphism was followed at $c. 40$ Ma. by rapid decompression-related cooling to $ca 5000^\circ\text{C}$ (Treloar & Rex 1990; Tonarini et al. 1993), much of it probably between 43 - 40 Ma at a cooling rate of 500°C/Ma . This cooling resulted from rapid exhumation of all the metamorphic rocks; not just the highest pressure ones. That all of the earliest formed metamorphic rocks were partially exhumed at this time, and that the highest pressure rocks are located in cover sediments rather than basement gneisses excludes the application of a simple Chemenda-type model for this period of exhumation and cooling (c.f. Anczkiewicz et al., 1998). Instead of uplift being driven by the rapid rise of a positively buoyant, deeply subducted basement slice, it is more likely to have involved accretion of metamorphosed cover rocks onto the base of the arc and uplift of the whole sequence on the hanging wall of structurally underlying south-vergent thrusts. K-feldspar Ar-Ar data from southern Kohistan date rapid cooling there at $ca 40-42$ Ma (Krol et al., 1996). This indicates that the Eocene-aged cooling and exhumation consequent on uplift was largely accommodated by extension in the upper, brittle, parts of the over-riding Kohistan arc slab. Although synchronous erosion of the Kohistan slab is recorded in the base of the Murree Formation in the Hazara syntaxis (Bossart & Ottiger, 1989), it is unlikely to have been fast enough to accommodate the extremely rapid cooling indicated by the Geochronological data.

A period of slow cooling in the upper Indian Plate followed until $ca. 22$ Ma when ductile through to brittle extensional displacement was initiated along N-vergent structures developed along the Main Mantle Thrust (MMT), and in rocks immediately above and below. This extension, coeval with renewed deposition in the foredeep, resulted in $ca 300^\circ\text{C}$ cooling at a rapid rate of $ca 600^\circ\text{C/Ma}$ in rocks on the MMT footwall (Burg et al., 1996; Vince & Treloar, 1996). Both of the discrete exhumation events can be linked to short-lived phases of ductile thrusting at the, then active, base of the thrust wedge. In the former case, this imbricated the metamorphic complex on the MMT footwall. In the latter, it transported the metamorphic complex south along the Panjal Thrust. Each thrust event had the effect of thickening the thrust wedge and can be coupled with the development of north-vergent extensional faulting in the upper part of the thickened crust. In the former case, the locus of brittle extensional faulting was at a high level within the Kohistan arc. In the later, extensional faulting, which spanned the ductile to brittle transition, developed within the Main Mantle Thrust zone. Both extensional events are coeval with sedimentary pulses within the foredeep. This suggests that they are the direct result of the erection of a topographic high as a result of ductile thrusting and imbrication at the base of the evolving thrust wedge. Extensional faulting in the Pakistan Himalaya, developed near the brittle-ductile transition, is a mechanical consequence of the requirement to maintain the critical taper of a wedge being thickened by ductile processes at its base. Not only does thrusting propagate downward within the wedge, but extension also steps downward following the brittle-ductile boundary. Periods when extension is dominant over erosion are the result of over-thickening of the orogenic wedge, possibly due to short-lived high rates of thrusting at the base of the wedge. Since the Miocene, the Pakistani topographic high has been reduced by erosion rather than extension. Although thrusting has continued at the base of the wedge, growth of high mountains has been retarded by the presence of an Eocambrian salt layer within which the basal thrusts are now located. As a result, critical taper of the wedge is now maintained by out-of-sequence thrusting at the rear of the wedge, rather than thickening at its frontal base.

Key words: Tectonics, exhumation, metamorphism, Himalaya.

T/167. Treloar, P.J., Brodie, K.J., Coward, M.P., Jan, M.Q., Khan, M.A., Knipe, R.J., Rex, D.C. & Williams, M.P., 1990. The evolution of the Kamila shear zone, Kohistan, Pakistan. In: Salisbury, M.H. & Fountain, D.M (Eds.), *Exposed Cross-Sections of the Continental Crust* Kluwer Academic, the Netherlands, 175-214.

The Kamila Shear Zone is a deep to mid crustal structure developed within the Kohistan island arc complex of North Pakistan prior to Himalayan collision: between Kohistan and India. Meta-gabbros of the Chilas complex were transported southwards across the shear zone onto a stack of high pressure rocks that had been assembled in the hanging wall of the Tethyan subduction zone. The shear zone is constituted by an anastomosing array of amphibolite facies ductile high strain zones within which fabric intensity varies although mylonitic zones are common. Shear criteria and kinematic indicators have a consistent SW-vergence. Little microstructural evidence for the high temperature ductile shearing is preserved, fabrics having been over-printed by post-deformational processes of recrystallisation, annealing and grain growth. A subsequent history of exhumation during decreasing temperature is documented by a progressive sequence of down temperature retrogression and deformation in superimposed shear zones which predominantly affected coarse grained rocks unaffected by the earlier crystal plastic deformation. The shearing involved dominantly cataclastic amphibolite to greenschist facies deformation culminating in lower greenschist facies shearing and mylonitisation, and the development of a distributed network of minor cataclastic and gouge-filled fault rocks.

Key words: Deformation, metamorphism, shear zone, amphibolite, Kamila, Kohistan.

T/168. Treloar, P.J., Broughton, R.D., Williams, M.P., Coward, M.P. & Windley, B.F., 1989. Deformation, metamorphism and imbrication of the Indian Plate, south of the Main Mantle Thrust, north Pakistan. *Journal of Metamorphic Geology* 7, 111-125.

South of the Main Mantle Thrust in north Pakistan, rocks of the northern edge of the Indian plate were deformed and metamorphosed during the main southward thrusting phase of the Himalayan orogeny. In the Hazara region, between the Indus and Kaghan Valleys, metamorphic grade increases northwards from chlorite zone to sillimanite zone rocks in a typically Barrovian sequence. Metamorphism was largely synchronous with early phases of the deformation. The metamorphic rocks were subsequently imbricated by late north-dipping thrusts, each with higher grade rocks in the hanging wall than in the footwall, such that the metamorphic profile shows an overall tectonic inversion. The rocks of the Hazara region form one of a number of internally imbricated metamorphic blocks stacked, after the metamorphic peak, on top of each other during the late thrusting. This imbrication and stacking represents an early period of post-Himalayan uplift.

Keywords: Metamorphism, deformation, tectonics, Besham, MMT.

T/169. Treloar, P.J. & Coward, M.P., 1991. Indian plate motion and shape: constraints on the geometry of the Himalayan Orogen. *Tectonophysics* 191, 189-190.

Sea-floor palaeomagnetic data that reflect variations in rate and vector of Indian Plate movement and rotation suggest that initial collision between India and Asia occurred at about 50–55 Ma ago. As the pre-collisional Indian Plate was diamond shaped, with the northern margin comprised of two oblique boundaries, collision was earliest where these boundaries meet, or in what is now the northwest Himalaya. Oblique convergence along each of these two boundaries would generate rotation of thrust sheets as they climb on to the Indian Plate. The oroclinal shape of the main Himalayan chain to the east of the northwest Himalayan syntaxes reflects a combination of the effects of oblique convergence, post-collisional anticlockwise rotation of the Indian Plate, and the pinning of the main thrusts at their northwestern terminations by crust thickened during the earliest collisional stage. The Indian Plate rotation enhances a strike-slip component of movement along the western oblique margin, with the transpressively sinistral Chaman fault zone now acting as a continental escape structure.

Key words: Plate movement, Himalayan orogeny, geometry, Indian plate.

T/170. Treloar, P.J., Coward, M.P., Chambers, A.F., Izatt, C.N. & Jackson, K.C., 1991. Thrust geometries, interferences and rotations in the northwest Himalaya. In: McClay, K. (ed.), *Thrust Tectonics*. Chapman and Hall, London, 325-342.

In North Pakistan the dominant transport direction throughout Himalayan collision has been to the S or SSE. Southward propagation of thrusts within the thickened Indian Plate has, however, been impeded by interference with SW-verging thrusts in Kashmir, at the western end of the main Himalayan oroclinal chain. As a result of this interference, thrusts within both the Pakistani and Kashmiri systems have become pinned at their lateral terminations. Lineation and palaeomagnetic data document substantial rotations of whole thrust sheets, of up to 40° around the pinned terminations, anticlockwise in Pakistan and clockwise in Kashmir. Although such rotations are best seen within the Pliocene to Recent structures of the external zones, similar rotations can be determined within Oligocene structures in the internal zones. The NW Himalayan syntaxes are crustal scale folds which have grown within the zone of convergence between the two thrust systems. The main Himalayan thrust system is interpreted as having been pinned within the Himalayan chain, rather than at its western termination, due to early thickening of the northwestern Indian Plate having acted as a mechanical impediment to the lateral propagation of the main Himalayan thrusts.

Key words: Tectonics, plate rotation, thrust geometry, Himalaya.

T/171. Treloar, P.J., Coward, M.P., Williams, M.P. & Khan, M.A., 1989. Basement-cover imbrication south of the Main Mantle Thrust, North Pakistan. In: MacFarlane, A., Sorkhabi, R.B. & Quade, J. (Eds.), *Himalaya and Tibet: Mountain roots to mountain tops*. Geological society of America Special Papers 232, 137-152.

India collided with the northern Kohistan/Asian plate at about 55 Ma. Subsequently, Asia has overridden India, developing a wide range of thrust slices at the top of the Indian plate. Balanced sections in the imbricated sedimentary cover of the Indian plate indicate a minimum displacement of more than 470 km since collision. This requires the Kohistan region to the north to be underlain by underthrust middle to lower Indian crust, the internal ductile deformation and thickening of which accounts for the main overall crustal thickening beneath Kohistan. In the Besham area of north Pakistan, a stratigraphy can be documented for the northern part of the Indian plate that includes basement sequences of quartz-feldspathic gneisses of the Besham Group, and of Precambrian schists of the Tanawal Formation intruded by the Swat-Mansehra granite. The basement rocks are unconformably overlain by carbonate-rich Paleozoic sedimentary rocks. Sedimentary rocks of both the basement and cover sequences were metamorphosed at an early stage of the Himalayan deformation during tectonic burial associated with crustal thickening. Structures just south of the suture related to this crustal thickening include a sequence of ductile mylonites thickened by thrust-related folding, a folded thrust stack involving basement rocks imbricated with cover strata, and late cross-folds. Much of the thickening of the Indian plate in the footwall of the Main Mantle Thrust can be related to the necessary changes in thrust wedge shape as it climbs through the crust.

Key words: Tectonics, imbrication, metamorphism, Himalaya.

T/172. Treloar, P.J., George, M.T. & Whittington, A.G., 2000. Cross-cutting mafic sheets from Indian plate gneisses in the Nanga Parbat Syntaxis: their significance in dating crustal growth and metamorphic and deformation events. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 25-50.

Indian plate, granulite facies, migmatitic basement gneisses exposed within the Nanga Parbat syntaxis host at least two generations of mafic sheets. In the southern part of the syntaxis, concordant sheets yield Palaeo-Proterozoic model ages of 2.2-2.6 Ga, which probably date early stages of continental growth. In the northern part of the syntaxis the sheets include a suite of discordant, silica-saturated or oversaturated sub-alkaline basalts extracted from a slightly depleted sub-continental mantle. Nd model ages and an imprecise Sm-Nd isochron yield an age of emplacement at between 1.6 and 1.8 Ga. That these dykes crosscut granulite facies migmatitic fabrics implies that peak metamorphism in the Indian plate gneisses was, at latest, Meso-Proterozoic and not Tertiary in age. Zircon and

amphibole ages published elsewhere suggest that this metamorphism was probably c. 1850 Ma in age. That the basement gneisses were refractory by the Tertiary has implication for the derivation of leucogranite sheets during the Neogene. Although the gneisses experienced a Tertiary-aged metamorphism, it was to lower temperatures than the Meso-Proterozoic metamorphism. Unless the gneisses were rehydrated during the Tertiary, the leucogranites need to have been soured from more fertile rocks underplating the granulite facies basement complex.

Key words: Mafic sheets, granulite, metamorphism, deformation, Nanga Parbat, Indian plate, Himalaya.

T/173. Treloar, P.J. & Izatt, C.N., 1993. Tectonics of the Himalayan collision zone between the Indian plate and the Afghan Block: a synthesis. In: Treloar, P.J. & Searle, M.P. (eds) *Himalayan Tectonics*. Geological Society of London, Special Publications 74, 69-87.

For details consult Treloar 1992.

Key words: Tectonics, deformation, Indian late, Afghan block, Himalaya.

T/174. Treloar, P.J., O'Brien, P.J. & Khan, M.A., 2001. Exhumation of early Tertiary, coesite-bearing eclogites from Kaghan valley, Pakistan Himalaya. *Journal of Asian Earth Sciences* 19, p.68.

The preservation of coesite in ultra high pressure eclogites now at surface raises questions about the structural mechanisms by which they were exhumed. As UHP rocks metamorphosed early in an orogenic cycle probably come to surface through more than one exhumation phase, often few structures remain that relate to the early part of the exhumation path that brought them to "mid"-crustal depths. Here, part of that early path is revealed for coesite-bearing eclogites from the Indian Plate internal zones of N. Pakistan. Metamorphism, at $725 \pm 25^\circ\text{C}$, 28 - 30 kbar, at c. 50 Ma, shortly post-dated subduction of the leading edge of continental India beneath Kohistan.

Structural restorations, field and petrographic data, show the eclogite-bearing rocks are flanked by thrusts below and extensional shears above and that thrusting, extension and the amphibolite to greenschist facies transition were synchronous. The eclogites lie immediately above a top-side-S thrust, S-C' fabrics related to which are overprinted by greenschist facies albite porphyroblasts. The dominant microstructures, though, are S-C' shear bands, penetratively developed throughout the eclogite facies metasedimentary sequences, which document a phase of pervasive top-side-N extension. Hornblende crystals locally parallel stretching lineations related to this extension. Albite porphyroblasts up to 10 cm in diameter overgrow extension related fabrics, although elsewhere they are flattened and stretched within those fabrics.

Top-side-S thrusting predated cooling through the amphibolite greenschist transition at 40 Ma, at which time the pervasive top-side-N extension was operating. This implies exhumation from metamorphic peak to greenschist facies within a few million years. It is likely that both the thrust and extensional sense shear zones represent the late-stage of a deformation continuum which commenced at UHP and brought the eclogites back to "mid" crustal levels. Subsequent Miocene extension brought the rocks near to surface.

Key words: Tectonics, eclogites, Kaghan valley, Himalaya.

T/175. Treloar, P.J., Petterson, M.G., Jan, M.Q. & Bignold, S.M., 1995. A re-evaluation of the Stratigraphy and Early Evolution of the Kohistan Arc Sequence: Implications for Magmatic and Tectonic Arc Building Processes. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The NW Himalaya are atypical of the Himalayan chain due to the separation of the Asian and Indian Plates by the Kohistan-Ladakh island arc. The arc was initiated during the mid-Cretaceous, offshore of Asia above a N-dipping subduction zone. The arc was sutured to Asia along the Shyok (or Northern) Suture at between 102 and 85 Ma (Treloar et al 1989). Thickening of the arc along S-vergent shear zones accompanying suturing. Subduction of Tethyan oceanic crust beneath the arc continued until about 55 Ma ago when Indian Plate continental rocks began to be underthrust beneath the arc along the N- dipping Main Mantle Thrust (MMT). Most of the penetrative shearing deformation within the arc is related to Cretaceous suturing to Asia rather than the early Tertiary collision with India (Treloar et al 1990). Extrusive volcanic activity spanned the mid-Cretaceous to Eocene, with the last phases of volcanism postdating the initiation of collision with continental India. On the basis of geochemical and

geochronological data, granitoids of the Kohistan batholith, intrusive into the volcanic sequence, have been divided into three. Stage 1 plutons, predate suturing of Kohistan to Asia. Post-suture stage 2 and 3 plutons, dated at 85 to 26 Ma, show a change from gabbroic to granitic types with time (Treloar et al 1989). Petrogenetic and structural models suggest that the infant arc was an extract from Cretaceous mantle and that the subsequent magmatic evolution was a function of the tectonic history. Sr and Nd isotope data document a change in magma source following suturing to Asia and associated arc thickening. The early post-suturing gabbro-diorites have a dominantly mantle-derived isotopic signature. With time, however, magmas emplaced into the arc show evidence for an increasing crustal input as the immature crust of the lower arc began to melt. The crust to mantle input ratio increased with time, such that the last stage magmas were entirely crustally derived (Pettersson & Windley 1990; Pettersson et al 1993). The full sequence thus shows characteristics that change from those of the juvenile stages of an island arc through those of a thickened volcanic arc accreted to a continental margin, to those of an arc underplated by continental crust.

Here we wish to present new field and structural data which enables us to redefine and clarify the stratigraphy of, and order of events within, the Kohistan arc; to this stratigraphy with an evaluation of the newly available geochemical data, not all of which is consistent with the hypothesis that the arc represents a simple calc-alkaline subduction related system, to derive a model for the tectono-magmatic evolution of the infant arc; and to comment on processes that may be generally relevant to early arc development.

A REVISED ARC STRATIGRAPHY.

We have mapped four sections across the southern part of the Kohistan arc: along the Indus Gorge from the MMT northward to the schists that outcrop to the north of the Chilas complex; a north-south section through Chilas that crosses the Indus Valley section; and along the Swat and Dir valleys from the MMT to north of the Chilas complex. The field relations that we recognise define the nature of the contacts of the Chilas body and this, together with the recognition of a regionally extensive sequence of sedimentary and volcanic rocks to the north of the Chilas body, enable us to redefine the basal arc stratigraphy.

The Kamila amphibolite belt. The southern margin of the arc is marked by a series of ultrabasic layered intrusions of which the Jijal body is the best known. The belt separates the Jijal and Chilas bodies, and can be divided into two. The southern part of the belt is marked by the variably sheared rocks of the Kamila Shear Zone, the only major crustal scale structure within the arc (Treloar et al 1990). The belt contains a mixture of variably deformed metabasalts and meta-gabbros, although the ratio of meta-basaltic to meta-plutonic material varies both along and across strike. Metamorphic grade is of amphibolite facies, with metamorphism synchronous with shearing. Hornblende Ar-Ar cooling ages of ca. 85 Ma from sheared rocks indicate that the main phase deformation and metamorphism is probably linked to suturing with Asia. On the basis of trace element and rare earth data that the mafic rocks can be divided into two (Khan et al 1993): a Ti-rich HFSE and HREE enriched subset and a Ti-poor HFSE and HREE depleted subset. The Ti-rich subset have remarkably flat REE and incompatible trace element diagrams. This chemistry is untypical of subduction-related magmatism, and is transitional between E- and N-type MORB. These basalts have an oceanic rather than a subduction-related affinity and closely resemble intra-oceanic plateau basalts such as the Ontong-Java, plateau basalts of the Pacific. By contrast, the Ti-poor subset have a transitional tholeiitic to calc-alkaline chemistry with a negative Nb anomaly and LILE/HFSE ratios more typical of subduction zone magmas and represent the early stages of development of a calc-alkaline arc constructed on the magmatically thickened oceanic crust.

The Jaglot schist belt. We identify schists, interbedded with volcanics, outcropping immediately N of the Chilas gabbro-norites wherever we have been able to access that contact. This belt of rocks extends from E to W right across the arc, and we identify it as a major Kohistan-wide stratigraphic unit located to the N of the Chilas complex which has not previously been formally defined. We propose that it be termed the Jaglot Schist Group. On the S side the Group is intruded by the Chilas gabbro-norites, on its N it is overlain by the Chalt volcanics. The Jaglot schist group is bimodal with greenschist facies metabasalts, sometimes pillowed, and volcanoclastic schists interbedded with metasedimentary schists. The schists are dominantly quartz-rich pelites with some psammitic and calc-silicate horizons. The sediments are similar to greywacke dominated lithologies, and probably represent input of terrigenous material into medium to deep water marine basins. Turbidity currents formed graded units. Where basalts crop out, they tend to dominate with a low proportion of sedimentary material. Sedimentation is evidence for crustal stretching and basin development in close proximity to a subaerial source for abundant amounts of terrigenous material. Such a setting would be consistent with a model of basaltic volcanic eruptions within an arc basin which was acting as a depo-centre for both sedimentary and volcanic rocks. Thus we favour deposition within a medial to distal basin developed behind the main frontal arc during active uplift and erosion of the arc. Basalts with both ocean plateau type and subduction type signatures outcrop within the belt, suggesting that the transition to full arc magmatism occurred during deposition of the Jaglot Group. In both the Indus and Dir Valley sections pillows have

been strongly stretched. The schists everywhere carry a strong tectonic fabric and are intruded by Stage 1 plutons (a mixture of gabbro-diorites and granodiorites), which have also been strongly deformed. The most southerly of the deformed stage 1 plutons crop out within half a kilometre of the northern margin of the Chilas body.

The Chalt, Hunza, Western and Shamran volcanics. Volcanic rocks crop out to the N of the schist belt along the northern margin of the arc over an area, which extends from the Hunza Valley east to Chitral. These form what has been previously termed the Chalt Formation. On the basis of geochemistry we divide this volcanic terrane into two: the Cretaceous Chalt or Hunza Valley volcanics, *sensu stricto*, which outcrop mainly in the E in the Hunza Valley, and the Western and Shamran Volcanics in the W. The Hunza Valley volcanics are overlain by the Yasin Group of turbiditic sediments, fossils within which yield Albian-Aptian ages (Pudsey 1986). The Chalt volcanics are strongly deformed with, in the Hunza Valley, stretched pillows common. There is a bimodal distribution into basaltic to andesitic lavas and rhyodacitic lavas, although the latter are volumetrically minor. Basalts and andesites of the Chalt volcanics have a tholeiitic trend and high MgO (6-15%), Cr and Ni contents with chemistries typical of boninites and, in extreme cases, basaltic komatiites. They have negative Nb-anomalies, high LILE/HFSE ratios and (Ce/Y)_N ratios close to unity, all similar to low-K tholeiites (Petterson et al 1990). The Western volcanics are calc alkaline in type, with high LILE/HFSE ratios, negative Nb anomalies and Ce/Y ratios consistent with high LREE/HREE ratios (Petterson et al 1990). They can be correlated geochemically with the Shamran volcanics which yield an Eocene Ar-Ar hornblende age of 58 ± 1 Ma (Treloar et al 1989) and both the Utror volcanics (Sullivan et al 1993), and the Drosch volcanics.

The Dir Group. Eocene volcanic rocks of the Dir Group outcrop in the Dir and Kalam regions. The Dir Group is divided into the volcanoclastic Baraul Banda Formation and the Utror Volcanics, and comprises a diverse assemblage of coarse volcanoclastic material, basaltic-andesite flows and porphyroclastic material. The lavas consist of a variably altered suite of tholeiitic to calc-alkaline lavas that range in composition from basaltic andesite to high silica rhyolite. They show selective enrichment of LIL elements with respect to the HFS elements, and LREE enrichment relative to the HREE with Ce/Yb ratios in the range 2.3 to 9.9 (Sullivan et al 1993). These trends are typical of subduction related volcanics. The Dir Group overlies granitic plutons dated at ca 75-78 Ma and is intruded by younger plutons dated at 45-48 Ma (Treloar et al 1989). Deposition of the Dir Group was as a marine fore-arc sequence following collapse of the continental margin.

The Chilas complex which marks the core of the arc, is a massive body of, locally layered, calc-alkaline gabbro-norites up to 50km wide and 300km long. The calc-alkaline magmas are similar in trace element composition to those of the low-Ti, HFSE depleted plutons within the amphibolite belt, in that they display a distinct negative Nb anomaly and high normalised LILE/HFSE ratios. The gabbro-norites were probably derived from partial melting of a mantle diapir emplaced during initial stages of arc splitting (Khan et al 1989, 1993). On its northern margin, the Chilas body is intrusive into meta-sediments intercalated with metavolcanics of the Jaglot Schist Group. The intrusive nature of the contact is clearly indicated by the presence of abundant schist xenoliths within the northern part of the Chilas body. Unlike the rocks of the schist belt to the north and the amphibolite belt to the south, both of which were strongly deformed and sheared during the crustal thickening event which postdated suturing of the arc to Asia, rocks of the Chilas complex are generally undeformed although cut by isolated narrow shear zones. Locally, though, the gabbro-norites are intensely deformed. No granodiorites are intrusive into the gabbro-norites. U-Pb ages on zircon separates from Chilas gabbro-norites in Upper Swat fall on a concordia of 84 Ma which would be consistent with a post-suturing emplacement of the Chilas Complex.

DISCUSSION.

To construct a model for the evolution of the Kohistan arc which has general relevance to early arc evolution scenarios, we need to consider the relative timing of volcanic and plutonic events, the significance of the changes in magma chemistries, the role of the repetitive switching from extension to compression in controlling magmatism, the effects of suturing of the arc to Asia in the late Cretaceous with subsequent arc thickening.

On field criteria, geochemistry and geochronology, we can identify a number of distinct units within the Kohistan arc. Although the contact between the Jaglot Schist Group and the Kamila Belt volcanics and intrusive gabbroic rocks is never exposed, the two being always separated by the Chilas gabbro-norite body, we argue that they are lithologically distinct. The greywackes present in the former are absent in the latter, and the mafic plutons present in the latter are absent in the former. On the basis of consistent northward dips within the volcano-sedimentary sequences, we argue that Kamila Amphibolites underlie the basalts and turbiditic sediments of the Jaglot schist belt. The mid-Cretaceous Chalt volcanics overlie the Jaglot Schist Group. The Western, Shamran and Utror volcanics, postdate suturing and are thus younger than the other three units.

Within the arc, we can define a number of geochemically distinct magma types in both the volcanic and intrusive sequences. The volcanic rocks of the Kamila Belt show a change from oceanic plateau to subduction type chemistry with time. The tholeiitic type, transitional between N-MORB and E-MORB, with High TiO₂ contents, low

LILE/HFSE ratios and flat REE and spidergram patterns, are typical of ocean plateau basalts and we interpret this basement volcanic sequence one of oceanic crust magmatically thickened within an intraoceanic setting. These are superceded by a calc-alkaline type with high LILE/HFSE and LREE/HREE ratios which include the bulk of the basic rocks in the Kamila amphibolite belt, and the Chilas gabbro-norites. A third type are the low TiO₂, high MgO low-K boninite and basaltic komatiites of the tholeiitic Chalt volcanics. This is a chemistry typical of extensional regimes. Fourthly, are the more silicic calc-alkaline magmas of the Kohistan batholith and of the basalts, andesites and rhyolites of the Utror and Western volcanics, which have high LILE/HFSE ratios. It is clear that, although the batholithic granitoids and some of the volcanic rocks are calc-alkaline in type with subduction zone type chemistries, many of the pre-suture volcanic rocks are not so. The first true calc-alkaline arc type rocks are the second stage low-Ti basalts within the Kamila amphibolite belt and the calc-alkaline plutons intrusive into the Kamila volcanics. Early parts of the Kohistan sequence are, therefore, NOT arc related. The timing of the final transition from ocean (plateau) to subduction related arc magmatism is uncertain but we infer it to have been during deposition of the Jaglot Schist Group.

There is clear evidence for at least three phases of rifling within the arc. The first of these involved the development of the back-arc(?) or intra-arc(?) basin within which the Jaglot Schist Group was deposited. It is likely that the sediments of the schist belt have an arc source, the remnants of which are visible in the plutonic rocks of the Kamila amphibolite belt. Thus the sediments and basalts of the schist belt may be contemporaneous with the later stage calc-alkaline plutonism of the amphibolite belt which marks the initiation of true arc style calc-alkaline activity. This period of crustal stretching probably continued until the extrusion of the Chalt volcanics and deposition of the turbiditic Yasin Group, with the peak of rifling being represented by extrusion of the primitive boninitic rocks of the Clink volcanic sequence. A second rifting event was linked to the emplacement of the Chilas body. The size of the Chilas complex and the transition from calc-alkaline gabbro-norites to the tholeiitic UMA association are both consistent with emplacement of the body into a tensional environment. The deformation state of the complex suggest emplacement after arc suturing to Asia. The third phase of rifling was accompanied by deposition of the Eocene Dir Group.

Rifling phases were separated by compressive phases. One such was related to suturing of Kohistan to Asia, accompanied by arc thickening. That thickening of the arc accompanied suturing is indicated by the deformed nature of the Stage 1 plutons but not of the Stage 2 plutons. The Kamila Shear Zone, deformation within which is dated as pre-80 Ma, is the major regional expression of this shortening. A second phase of compression is documented from the Dir area. Here, early Stage 2 batholiths (75-78 Ma) were eroded and exhumed prior to the unconformable extrusion of the Utror Volcanics onto their eroded surfaces and the subsequent intrusion of further plutons into the Dir Group at 48-45 Ma. For significant granite emplacement to take place within a volcanic arc, the over-riding plate must be in a state of either orthogonal tension or of transtension with plutonism inhibited during compressive phases. The clear hiatus in plutonism within the arc between 75 and 50 Ma would be consistent with a period of compression, during which intrusion was inhibited and regional uplift and erosion occurred, separating periods of extension or transtension. At about 55 Ma, arc regional extension replaced compression as the dominant strain with the resultant development of the fore-arc basin into which the Baraul Banda Slates and Utror Volcanics were deposited.

Thus we suggest a tectonic model within which the magmatic evolution of the Kohistan arc can be viewed. Arc evolution of the Kohistan was dominated by extensional tectonics with periods of tension separated by significant phases of shortening during which plutonism would have been inhibited. The earliest magmatism was related not to subduction driven arc growth but to magmatic thickening of oceanic crust, possibly within an ocean plateau setting. The earliest stages of arc growth were located on this magmatically thickened oceanic crust. Once subduction was initiated, extension in the back-arc developed, possibly in response to roll-back of the subduction zone. This extension included the development of the basin in which the Jaglot sediments were deposited and the extrusion of the boninitic Chalt volcanics, which may represent melting of upwelling asthenosphere beneath the zone of lithospheric thinning. This first phase culminated with melting of the lower arc crust generating the Stage 1 plutons of the Kohistan Batholith immediately prior to suturing of the arc to the Asian Plate. Subsequently, the arc returned to a state of active (trans?)-tensional rifling during which the Chilas Complex was emplaced. The thermal and magmatic history of Kohistan shows the initiation of the Stage 2 plutonism at about 85 Ma, essentially synchronous with the emplacement of the Chums Complex at about 84 Ma. Amphibole Ar-Ar data date regional cooling through ca 500°C at about 80 Ma. We infer that emplacement of the Chilas body, as a result of asthenospheric upwelling resulting from active extension and rifling in the arc, and the associated massive advection of heat from the mantle to the base of the arc crust, would have had a significant thermal effect on the volcanic rocks of Kohistan. In particular, sufficient heat may have been released to melt the base of the arc in the Kamila belt, drive the widespread regional metamorphism and initiate deep arc melting and subsequent stage 2 pluton creation. The cessation of this

period of extension is dated by erosive exhumation of the Stage 2 batholiths in the Dir and Swat region although what caused this is uncertain. Renewal of extension at c. 60 Ma, involving fore-arc collapse, resulted in extrusion of the Shamran and Dir volcanics and the deposition of the Baraul Banda Formation in a major extensional basin at about 60 Ma.

Key words: Tectonics, stratigraphy, magmatism, Kohistan arc, Himalaya.

T/176. Treloar, P.J., Petterson, M.G., Jan, M.Q. & Sullivan, M.A., 1996. A re-evaluation of the stratigraphy and evolution of the Kohistan arc sequence, Pakistan Himalaya: implication for magmatic and tectonic arc-building processes. *Journal of the Geological Society of London* 153, 681-693.

New field mapping and structural data, combined with published geochemical data, from the Kohistan arc in the NW Himalaya, enable a re-evaluation of the arc stratigraphy. Key lithological units and their relationships are more clearly defined, permitting the construction of a revised magmatic-tectonic history for the arc. The oldest units are transitional oceanic-type basalts, which form the basement to the subduction related sequence. Arc-type gabbroic sheets and plutons intrude the oceanic basalts; together these form the Kamila Amphibolite Belt. Metasediments and basaltic lavas were deposited, within an extensional basin, onto the Kamila Amphibolite Belt basement. This sequence, exposed across the arc, forms a distinct stratigraphic unit which is formally defined here as the Jaglot Group. Sediment-charged turbidity cements transported material into the basin, whilst submarine eruptions contributed the basaltic component. This period of extension culminated in the eruption of high-Mg boninites of the Chalt Volcanic Group which overlie the rocks of the Jaglot Group. The earliest granitoids of the Kohistan Batholith predate suturing and intrude the Jaglot and Chalt sequences. At c. 100 Ma Kohistan sutured to Asia, suturing being accompanied by thickening of the arc with the development of major intra-arc shear zones and a penetrative, regionally developed steep cleavage. At c. 85 Ma intra-arc rifting permitted the emplacement into the arc of the voluminous gabbro-norites of the Chilas Complex which clearly intrudes the Kamila Amphibolite Belt to the south and the Jaglot Group to the north. The Chilas Complex has been regarded as part of the pre-suturing, juvenile arc sequence. Field evidence summarized here show this to be not so. Heat advection associated with emplacement of the Complex caused amphibolite facies regional metamorphism, melting of the lower arc and plutonism. Some of the resultant granitoid plutons were unroofed and eroded during a compressional phase at between 80 and 55 Ma, before emplacement of further plutons and extrusion of basaltic through to rhyolitic volcanic rocks at between 55 and 40 Ma. At least three phases of extension and rifting, each separated by short lived phases of compression, characterized arc evolution. Much of the magmatism is controlled by extensional tectonics within the overriding plate of the kind commonly associated with a retreating subduction zone.

Key words: Geochemistry, structure, Himalaya, Kohistan Island arc.

T/177. Treloar, P.J., Potts, G.J., Wheeler, J. & Rex, D.C., 1991. Structural evolution and asymmetric uplift of the Nanga Parbat syntaxis, Pakistan Himalaya. *Geologisches Rundschau* 80, 411-428.

The Nanga Parbat syntaxis, in the NW Himalaya, is a still growing crustal-scale north-trending antiformal structure in the core of which Indian Plate gneisses have been uplifted from beneath the overthrust rocks of the Kohistan island arc. Isotopic and fission track geochronology show that uplift rates within the syntaxis have increased to present day rates of > 6 mm/yr. Uplift has been accommodated by a combination of initial northwest verging thrusting on the western margin of the syntaxis, followed by crustal scale folding within the syntaxis and latterly by dextral reverse faulting on the western margin. This thrusting, folding and faulting is the effect of deformation at the north-western lateral tips of the main Himalayan thrusts where they interfere with the south-southeast verging thrusts of the northwest Himalaya.

Key words: Structure, metamorphism, Nanga Parbat syntaxis, Himalaya.

T/178. Treloar, P.J. & Rex, D.C., 1990a. Cooling and uplift histories of the crystalline thrust stack of the Indian Plate internal zones west of Nanga Parbat, Pakistan Himalaya. *Tectonophysics* 180, 323-349.

Amphibole and mica K-Ar, Ar-Ar and Rb-Sr geochronology for the crystalline internal zones of the Indian Plate define both an extensive pre-Himalayan thermal history and a post-Himalayan metamorphism cooling history. South of the Main Mantle Thrust, near Besham, hornblende Ar-Ar ages from basement gneisses record an ca. 1850 Ma mid-Proterozoic thermal event. Hornblende, muscovite and biotite cooling ages from cover sequences metamorphosed during the Himalayan orogeny are 35 ± 4 , 30 to 24, and 29 to 22 Ma respectively. The mica ages, together with those derived from zircon and apatite fission track data (Zeitler, 1985) demonstrate a rate of cooling, of about 30°C/Ma, during the late Oligocene to early Miocene that was greater than that either before or since. This rapid cooling was initiated during the post-metamorphic evolution of the Indian Plate south-verging crustal-scale thrust stack, during which cover sequences metamorphosed during the Himalayan orogeny were imbricated with basement rocks thermally unaffected during that event. Most of the cooling, which happened during the stripping of some 10 ± 2 km of overburden, reflects exhumation due to a combination of erosion, recorded in the Miocene molasse sediments of the foreland basin, and major crustal extension within the MMT zone. Both erosion and extension were the direct consequence of the evolution of the thrust stack.

Key words: Geochronology, metamorphism, amphibole, Nanga Parbat syntaxis, Indian Plate, Himalaya.

T/179. Treloar, P.J., & Rex, D.C., 1990b. Cooling histories and their tectonic implications for the Indian plate crystalline thrust stack of northern Pakistan. In: *Crystal Dynamics and path way*. Symp. 21–24 Feb. 1990, Bochum, Germany.

For further information, consult the preceding account.

Key words: Tectonics, Indian plate, cooling history.

T/180. Treloar, P.J. & Rex, D.C., 1990c. Post-metamorphic cooling history of the Indian Plate crystalline thrust stack, Pakistan Himalaya. *Journal of the Geological Society, London*, 147, 735–738.

A post-metamorphic Himalayan cooling history for the crystalline internal zones of the northern Indian plate is defined by amphibole and mica K-Ar and Ar-Ar geochronology. Hornblende, muscovite and biotite cooling ages from cover sequences metamorphosed during the Himalayan orogeny are 35–40, 30 to 23, and 29 to 23 Ma respectively. The mica ages, together with those derived from zircon and apatite fission track data demonstrate a cooling rate of about 30°C/Ma during the late Oligocene to early Miocene. This rapid cooling was initiated during the post-metamorphic development of the Indian Plate south-verging crustal-scale thrust stack. Most of the cooling occurred during the stripping of some 10 ± 2 km of overburden through a combination of erosion, recorded in the Miocene molasse sediments of the foreland basin, and major crustal extension within upper levels of the Indian Plate and the Main Mantle thrust zone. Both erosion and extension were the direct consequence of the evolution of the thrust stack.

Key words: Structure, metamorphism, Nanga Parbat syntaxis, Himalaya.

T/181. Treloar, P.J., Rex, D.C., & Williams, M.P., 1991. The role of erosion and extension in unroofing the Indian plate thrust stacks, Pakistan Himalayas. *Geol. Mag.*, 128, 465–478.

In north Pakistan cooling history data show that metamorphism within the Indian Plate predated 40 Ma, and that the post-metamorphic thrust stack developed within the crystalline internal zones had cooled to less than 100 °C by c. 18 Ma. Much of this cooling occurred during late Oligocene to early Miocene time and can be equated to substantial unroofing of the metamorphic pile. This unroofing was by a combination of erosion, recorded in Lower Miocene molasse deposits within the foreland basins, and by large scale hinterland (northward) directed extensional normal faults developed within the upper parts of the Indian Plate and within the Kohistan-India suture zone and operative as late as 20 Ma. As up to 20 km of material was removed during exhumation, substantial uplift must have been synchronous with exhumation. Part of this may be accounted for by isostatic rebound of the thickened Indian Plate, and part by uplift in the hanging wall of major south-verging thrusts developed at the base of the crystalline pile.

Key words: Metamorphism, Indian plate, erosion, exhumation, Himalaya.

T/182. Treloar, P.J., Rex, D.C., Guise, P.G., Coward, M.P., Searle, M.P., Windley, B.F., Petterson, M.G., Jan, M.Q. & Luff, I.W., 1989. K-Ar and Ar-Ar geochronology of the Himalayan collision in NW Pakistan: constraints on the timing of suturing, deformation, metamorphism and uplift. *Tectonics* 8, 881-909.

Mica and hornblende K-Ar and Ar-Ar data are presented from each of the three crustal components of the Himalayan collision zone in North Pakistan: the Asian plate, the Kohistan Island Arc, and the Indian plate. Together with U-Pb and Rb-Sr data published elsewhere these new data (1) date the age of suturing along the Northern Suture, which separates Kohistan from Asia, at 102-85 Ma; (2) establish that the basic magmatism in Kohistan, which postdates collision along the Northern Suture, predates 60 Ma, and that the later granite magmatism spanned a range of 60-25 Ma; (3) show that uplift amounts within Kohistan are greater toward the Nanga Parbat syntaxis than away from it and that rate of uplift near the syntaxis increased over the last 20 Ma to a current figure of about 5.5 mm a year; (4) show that much of southern Kohistan had cooled to below 500°C by 80 Ma and that the major deformation which imbricated Kohistan probably predated 80 Ma and certainly predated 60 Ma and was related to the Kohistan-Asia collision rather than the Kohistan-India one; (5) imply that uplift along the Hunza Shear in the Asian plate together with imbrication of the metamorphics in its hanging wall took place at about 10 Ma and was associated with breakback thrusting in the hanging wall of the Main Mantle Thrust; (6) suggest that the Indian plate has a lengthy pre-Himalayan history with an early metamorphism at about 1900 Ma, major magmatism at 500-550 Ma and early Jurassic lithospheric extension or inversion; and (7) show that the Indian plate rocks were metamorphosed shortly after the collision within Kohistan, which occurred at circa 50 Ma, and subsequently cooled back through 500°C at circa 38 Ma and 300°C at 30-35 Ma with ages of cooling through 200°C and 100°C (as determined by fission track data) locally controlled by Nanga Parbat related uplift tectonics.

Key words: Geochronology, collision, suturing, deformation, metamorphism, Himalaya.

T/183. Treloar, P.J., Rex, D.C., Guise, P.G., Wheeler, J., Hurford, A.J. & Carter, A., 2000. Geochronological constraints on the evolution of the Nanga Parbat syntaxis, Pakistan Himalaya. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds) *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 137-162.

New amphibole, muscovite and biotite Ar-Ar and K-Ar data and zircon and apatite fission track data are presented from the western margin of the Nanga Parbat syntaxis as well as from the Indus and Astor valley section which cross the syntaxis. Amphibole data date a regional cooling through 500°C at 25±5 Ma and are inconsistent with earlier suggestions that the peak of regional metamorphism was Neogene in age, although there is no doubt that some rocks were still at upper amphibolite facies temperatures as recently as 5 Ma. The data can be used to constrain structural models for syntaxis uplift. After an initial phase of crustal-scale buckling, bodily uplift of the syntaxis was along subvertical shear zones developed along its margins, although with a significantly higher time-averaged strain rate for shears developed along the western margin than along the eastern margin. The latter may be antithetic to the former. These shears were operative from 10 to <1 Ma. In the southwestern part of the syntaxis, this subvertical uplift was superseded, since 6 Ma, by uplift along moderately SE-dipping NW-vergent shears on the hanging wall of which are located Neogene-aged migmatites.

Key words: Tectonics, metamorphism, geochronology, Nanga Parbat, Himalaya..

T/184. Treloar, P.J., Rex, D.C. & Hurford, A.J., 1992. Geochronology of the Indus Gorge Section through the Nanga Parbat Syntaxis: Constraints on uplift history Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 92.

The Indus Gorge provides a constant altitude east-west section across the north-trending Nanga Parbat syntaxis. The syntaxis is a structural half window, within the core of which Indian Plate gneisses are updomed from beneath a cover of overthrust volcanics of the Kohistan-Ladakh island arc complex. This section provides an opportunity for detailed, structurally constrained, sampling for both P-T-t path analysis and geochronology. Here we present data

from this traverse that enable us to constrain the uplift history of the syntaxis. 70 samples were collected for analysis by hornblende and mica Ar-Ar and K-Ar techniques, and by zircon and apatite fission track techniques. When those data of Zeitler (1985) and Zeitler and Chamberlain (1989) are included we have a copious, closely spaced data set.

A marked break in cooling ages occurs across the western margin of the syntaxis. This margin is marked by the Raikot-Sassi Fault Zone, a complex fault system with an overall oblique sense of displacement that includes both right lateral and thrust type displacements. The data imply that significant displacements have occurred along this zone within the last 1 to 2 Ma.

The eastern margin is marked by neither a significant fault zone nor a marked step in cooling ages. Instead cooling ages gradually decrease westward across the margin into the syntaxis, a decrease explained by exhumation during the growth of a large scale antiformal fold located within the syntaxis. Hornblende and mica ages are both younger within the western half of the syntaxis than in the eastern half. This is consistent with the recognition of a series of domal structures within the syntaxis not all of which grew synchronously. Within the Indus Gorge section, the data are consistent with the growth of an antiform within the eastern part of the section before 5 Ma ago, and the subsequent growth of a similar structure, at Ca. 3 Ma ago, in the western part of the section.

Neither zircon nor apatite ages show this age difference from east to west, indicating that folding may have become of secondary importance to uplift controlled by faulting along the eastern margin after about 2 Ma ago. Although a combination of early folding followed by later oblique slip thrusting along the western margin may explain the uplift and cooling history of the Indus Gorge section, it may be unwise to extrapolate this model without qualification to the rest of the syntaxis. The internal structure of the Syntaxis is best modeled as a series of nested domes. More detailed geochronology is required to demonstrate the extent to which these developed diachronously as well as their temporal relationships to thrusting along the western margin.

Total exhumation and overall uplift rates are difficult to quantify given the vertical telescoping of isotherms due to rapid uplift and unroofing, and the emplacements as recently as 2 Ma ago, of leucogranite dykes and bodies to high structural levels. However, due to the constant altitude of the Indus Gorge section, the antecedent nature of the river and the magnitude of the unroofing indicated by the cooling history data, we feel confident that exhumation amounts approximately equal bulk uplift amounts. As such, it is hard to escape the conclusion that fold amplification was exponential, or that recent uplift rates have been as high as 6mmyr⁻¹, as suggested by Zeitler (1985).

Key words: Geochronology, metamorphism, Indus gorge, Himalaya.

T/185. Treloar, P.J. & Searle, M.P., 1990. Himalayan Geology. NERC News. 15, 11-14.

Key words: Geology, Himalaya.

T/186. Treloar, P.J. & Searle, M.P., (Eds.), 1993. Himalayan Tectonics. Geological Society, London, Special Publications, 74

This contribution contains refereed and edited papers on various aspects of the Himalayan tectonic. The papers are presented under the headings: Karakoram and Afghanistan, North and West Pakistan, Tethyan Himalaya, High Himalaya, Main Central Thrust Zone, and Main Boundary Thrust, Lesser Himalaya, and Beyond. Individual papers are presented in appropriate places in this document.

Key words: Tectonics, Himalaya.

T/187. Treloar, P.J., Searle, M.P., Khan, M.A. & Jan, M.Q., 2000. Tectonic of the Nanga Parbat Syntaxis and the Western Himalaya: an introduction. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds) Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya. Geological Society, London, Special Publication 170, 1-6.

Often described as a natural laboratory, the Himalaya are probably the ideal place in which to study ongoing continent-continent collision. This volume focuses on the geology of the northwestern part of the Himalaya which provides the most complete and best-exposed transect across the range. Here, in northern Pakistan and in Ladakh in northwest India, the full profile across the south Asian continental margin, and the north Indian margin is superbly exposed in mountains reaching as high as K2 (8611 m) and Nanga Parbat (8125 m). The south Asian geology is exemplified in the Karakoram and Hindu Kush ranges along the north and northwestern frontiers of Pakistan. The

unique Kohistan-Dras island-arc terrane is sandwiched within the Tethyan suture zone between India and Asia. Rocks of the northern margin of the Indian Plate are exposed in both the Zaskar and the Pakistan Himalaya. The northern sedimentary carbonate platform of the Indian Plate, magnificently exposed in the mountains of Zaskar and Ladakh, is largely missing in Pakistan where the Kohistan arc has been obducted southward onto the metamorphosed rocks of the internal crystalline zones of the Indian Plate. The Nanga Parbat syntaxis represents an orogenic bend developed within a convergent zone in the thrust belt where the south-vergent thrusts of the central and eastern Himalaya swing around through 300 degrees.

The history of geological research in the Himalaya extends back to some of the earliest explorers and climbers who visited the region. Two significant problems have affected mapping of the topography and geology of the Himalaya. The first of these is the sheer logistical problem of attaining access to extremely rugged terrain. The second is a political problem. In the NW Himalaya, access to rocks along the disputed border between India and Pakistan is largely forbidden to foreigners. Similarly, easy access northward across the Chinese-Pakistan border has only been possible since the opening of the Khunjerab Pass in 1986. It is arguable that prior to the Russian invasion of Afghanistan in 1980, the geologically best known of the Himalayan nations was Afghanistan, largely through the detailed mapping of Wittekindt & Weipper (1973) and Wolfart & Wittekindt (1980). Since then, advances in understanding of the geology of Afghanistan have been limited to re-interpretations based on satellite imagery or increases in knowledge of the geology of surrounding states such as Pakistan. As a result of these problems, many regions of the Himalayan chain remain poorly mapped or completely unmapped. Containing many new maps, this volume goes part of the way towards addressing this shortfall.

Despite the problems of access, the Himalaya and adjoining mountain ranges continue to be a magnet to earth scientists. The geology of northern Pakistan was largely unknown until about 20 years ago. Until then much of what was known of the region was due to the work of the Geological Survey of India, especially Hayden (1915) and Wadia (1931, 1932). Some aspects of the geology were summarized in volumes that dealt with the geology of the whole of prepartitioning India (e.g. Wadia 1919). Some geology was carried out by geologists attached to major expeditions to the Karakoram (e.g. Desio 1930; Auden 1938). However, really detailed regional scale work truly commenced only in the 1970s during which R. A. K. Tahirkelli from the University of Peshawar carried out much pioneering work in the northern part of the Indian Plate, the Hindu Kush and Karakoram mountains of the southern part of the Asian Plate and what is now recognized as the Kohistan arc. This work was summarised in 1982 in a superbly illustrated Geological Bulletin of the University of Peshawar (Tahirkelli 1982) as well as in Tahirkelli et al. (1979). A then useful summary of the broader effects of the Himalayan orogeny was given in Farah & De Jong (1979). In 1980 the Karakoram Highway (KKH), that stretches from Islamabad in Pakistan through to Kashgar in China, was opened and this stimulated an extraordinary influx of geoscientists into the region. The KKH straddles not just the northern margin of the Indian Plate and the southern margin of the Asian Plate, but also the Cretaceous Kohistan island arc sandwiched between the two. An early synthesis of the geology along the Pakistani section of the KKH was given in the proceedings of an international expedition that traversed the KKH immediately on its completion (Miller 1982). A recent literature audit showed that between 1980 and 1997, over 200 papers had been authored or coauthored on the region traversed by the KKH by British, French and German geoscientists alone. A complete reference list up to 1996 and synthesis of the geology of N. Pakistan is given in Kazmi & Jan (1997). This volume builds upon this recent explosion of geological knowledge.

The essential geological framework of the Pakistan Himalaya is summarized briefly below. The Kohistan-Dras island arc was initiated offshore of Asia during the late Jurassic or early Cretaceous. The arc sutured to the southern margin of the Asian Plate at between 102 Ma, the age of emplacement of the pre-suturing Matum Das pluton (Pettersen & Windley 1985) and 85 Ma. The later age is derived from an c. 84 Ma U-Pb zircon age (Zeitler et al. 1981) for undeformed gabbro-norites of the Chilas complex, which contain xenoliths of Gilgit Formation gneisses that had been deformed during suturing. The age is compatible with a Rb-Sr age of 87 $\pm$ 19 Ma (Mikoshiba et al. 1999) assuming that their sample 92CH60 is included in the regression. After suturing the arc behaved as an Andean-style volcanic arc. Thickening of the arc accompanied suturing. Most of the deformation and metamorphism in the arc appears to have post-dated suturing, but predated collision with India. Deformation and metamorphism within the southern margin of the Asian plate appears to have been diachronous with tectonothermal events during the late Cretaceous (after suturing with Kohistan) and the Tertiary. A full review of the Cretaceous through to Tertiary history of the Asian Plate in Pakistan is given in Searle et al. (1999) and of the Kohistan arc in Treloar et al. (1996) and Searle et al. (1999). Collision between the arc and continental India followed closure of neo-Tethys. The age of collision is not precisely determined, although on the basis of the sedimentary record is likely to have been at about 55 Ma (see discussions in Garzanti et al. 1996, Pivnik & Wells 1996, Rowley 1996 and Treloar 1997). A late Cretaceous to Paleocene ophiolite emplacement event predated final closure of Neotethys (Searle 1986; Beck et al. 1995; Searle et al. 1997). Since collision the leading edge of the Indian Plate has undergone deformation, burial,

metamorphism and exhumation. In contrast to the main Himalayan chain to the east, peak metamorphism in the Pakistan Himalaya was Eocene in age (Treloar & Rex 1990). Exhumation during the early Miocene was by a combination of north-vergent extension (Burg et al. 1996; Vince & Treloar 1996) and erosion with sediments deposited in the foreland basins to the south of the topographic high (Burbank et al. 1996). Deformation of these sedimentary basins continues to the present day.

The northwest Himalaya differ from the main Himalayan chain for three main reasons. Here the Asian and Indian plates are separated by the Kohistan-Dras island arc, peak metamorphism was Eocene rather than Miocene in age, and the south-vergent thrust systems are deformed by the West Himalayan syntaxes. First recognized by Wadia (1931, 1932), the syntaxes are crustal scale, north-trending antiformal structures which are essentially half windows. The Hazara syntaxis to the south deforms thrusts of the external zones. Within its core, foreland basin sediments on the footwall of the Main Boundary Thrust have been tectonically uplifted (Bossart et al. 1988). The Nanga Parbat syntaxis deforms thrusts of the internal zones. Within its core, crystalline rocks of the Indian plate have been tectonically exhumed from beneath their cover of volcanic rocks of the Kohistan-Ladakh arc sequence that had been thrust onto the Indian Plate early in collision. Present day uplift rates within the Nanga Parbat syntaxis may be as high as 6 mm a⁻¹ (Zeitler 1985). Mechanisms of uplift and its deformational effects, timing of uplift, and the magmatic effects of rapid uplift and exhumation have been the focus of exhaustive research within the Nanga Parbat syntaxis during the last ten years. A number of British scientists funded by the Natural Environmental Research Council and the Royal Society have been working in the syntaxis. At the same time, a team from the USA under the leadership of P. K. Zeitler has been working in the area with funding from the National Science Foundation. Papers from both of these groups are included in this volume.

In setting the regional scene for the volume, Caporali describes the gravity field of the Karakoram Mountain Range and surrounding areas. He demonstrates the gravimetric low associated with the Nanga Parbat syntaxis which is a function of the rapid differential uplift within the syntaxis as well as the presence of large negative anomalies between the Karakoram Fault and the Main Karakoram Thrust. The relationship between crustal scale geological features (sutures, thrusts and syntaxes) and gravitational potential is clear when plotted on a regional scale geology map (Caporali, fig. 3).

The next seven papers deal with the Nanga Parbat syntaxis. In the first of these, Treloar et al. outline the significance of field relationships in defining long term geological histories. Mafic sheets within Indian plate gneisses within the Nanga Parbat syntaxis clearly document a polyphase deformation and metamorphic history. In stressing the importance of recognising complex histories, the authors recall the seminal work of John Sutton and Janet Watson in the Lewisian Complex.

The next papers relate to the structural and topographic evolution of the syntaxis. Butler revisits his earlier studies (Butler & Prior 1989a, b; Butler et al. 1989) on the western margin of the syntaxis to refine, in the light of recent field-work, an interpretation of the structures that accommodated bodily uplift of the syntaxis along west-vergent thrust faults. Edwards et al. describe structures exposed along the south-west of the syntaxis (i.e. to the south of those described by Butler). Uplift here was along steep, east-side up shear zones. Whereas Butler and Edwards et al. describe structures that accommodated uplift along the western margin of the syntaxis, Argles describes the structural evolution of part of the eastern margin of the syntaxis. Butler et al. describe a structural section that crosses the syntaxis and incorporate data presented here and elsewhere to derive a model for the structural evolution of the syntaxis as a whole. This model should be viewed in connection with that published by Schneider et al. (1999). As geochronological data were first used to hint at the speed of syntaxial growth (Zeitler 1985), it is appropriate that a more profound data set should be used in an attempt to constrain uplift mechanisms. To this end, Treloar et al. use geochronological data to outline firstly, that peak metamorphism within the syntaxis is Eocene-Oligocene, rather than Miocene, in age, and also to indicate how geochronological data can be used to refine the regional scale features that accommodated uplift within the syntaxis. This set of five papers provide a benchmark on which future structural studies of the syntaxis can be built. The Nanga Parbat massif encompasses greater than 6000m of relief. This relief is a function of the rapid Neogene uplift and results in rapid erosional unroofing of the crystalline basement complex. Shroder & Bishop explore aspects of this unroofing and demonstrate that late Pleistocene processes were sufficiently rigorous to produce the present-day pronounced relief. Whereas elsewhere in the Himalaya, extensional unroofing has played an important part in exhumation, at Nanga Parbat, where exhumation is most rapid, it appears not to have done so, a point also made by Edwards et al., Bishop & Shroder argue that accelerated uplift and erosion are part of a feed-back loop with tectonic uplift. They also use remotely sensed imagery to derive a hierarchical order of topographic complexity that is a function of erosion dynamics. The use of remote sensing is probably the prime way in which the topography of the Himalaya will be mapped in future. Large crustal-scale structures like the Nanga Parbat syntaxis should encourage debate. Two papers here do just that. In a far-reaching paper Burg & Podladchikov model the evolution of the Himalayan syntaxes numerically, (the

Nanga Parbat syntaxis and the Namche Barwhe syntaxis at the eastern end of the Himalayan chain). Their numerical modelling indicates that pure shear thickening and symmetric buckling accommodate shortening until, at a certain strain, an asymmetric thrust-like flow pattern occurs on a crustal to lithospheric scale and it is on this that the syntaxes grow. A side-effect of the model is that syntaxial growth is accompanied by the growth of marginal basins, in the case of the Nanga Parbat syntaxis these are the Kashmir and Peshawar basins. That these basins may be the result of syntaxial uplift is in contradiction to previous models which infer them to be piggyback basins developed above late-stage thrusts such as the Main Boundary Thrust. Whittington et al. use isotopic data to demonstrate that the crystalline Indian Plate rocks contained within the core of the Nanga Parbat syntaxis are typical of the Lesser Himalaya rather than of the Higher Himalaya. The implications of this are profound as they stress the differences between the Pakistan Himalaya and the Indian and Nepalese Himalaya, and indicate that models that suggest that the syntaxis is developed above the lateral tip of the Main Central Thrust may be incorrect.

The remaining papers in this volume provide a cross section across the Himalayan collision zone from the Asian plate through the Kohistan arc to the Indian plate. It has long been known that, prior to collision, the southern margin of the Asian plate was a tectonic collage formed of a series of exotic blocks sequentially accreted to the southern margin of continental Asia. The Kohistan-Dras arc was the last of these blocks to be accreted to Asia. Zanchi et al. describe one of the suture zones that encompassed the southward growth of Asia during the late Mesozoic and show how the Tirich Mir Fault Zone can be described as a suture on the basis of the presence of ophiolitic peridotites. Also on the Asian Plate, Hildebrand et al. describe the geological evolution of the Hindu Kush in the NW Frontier of Pakistan. They document a major late Mesozoic deformation probably related to suturing of Kohistan to Asia as well as an Oligocene-Miocene metamorphism-deformation event that was likely related to indentation of Kohistan into Asia following collision of Kohistan and India. This paper comes together with an important new geological map of a large part of the Hindu Kush.

Three papers deal with aspects of the Kohistan arc sequence. Yamamoto & Nakamura and Anczkiewicz & Vance date peak metamorphism within the Kamila amphibolite belt at the structural base of the arc at c. 95 Ma with amphibolite facies retrogression at c. 85 Ma (see Treloar et al. 1989). Arbaret et al. describe a variety of SW-vergent structures within the Kamila amphibolite belt that range from magmatic through sub-magmatic to amphibolite facies. This deformation spans the period documented geochronologically by Yamamoto & Nakamura and Anczkiewicz & Vance. What remains unclear is to what these deformation, magmatic and metamorphic events relate. Arbaret et al. interpret the magmatism and deformation as having occurred at the base of the arc during ongoing subduction of the Tethyan oceanic lithosphere beneath Kohistan. An alternative solution is that the deformation documents a change in subduction dynamics following on from suturing of Kohistan to Asia.

Three papers deal with the sutures that bound the arc. Weinburg et al. describe the suture zone between Asia and the Ladakh part of the Kohistan-Ladakh arc sequence and show that closure must have pre-dated 68 ± 1 Ma. Robertson and DiPietro et al. discuss the evolution of the suture between the Mesozoic arc and the Indian Plate. Robertson finds the Indus Suture Zone in Ladakh to be a zone of complex multi-stage processes involving deformational features which span the time interval from subduction through emplacement to post-collisional shortening. DiPietro et al. provide a detailed account of the Main Mantle Thrust (MMT) which separates the Kohistan arc from the Indian Plate and which is the true western continuation of the Indus-Tsangpo Suture Zone. They highlight the fact that the MMT is constituted of a number of strands of various ages. Although clearly a major early Tertiary tectonic feature, the MMT has been transposed many times during the Tertiary. Three papers detail the geology of the internal zones of the Indian Plate. Corfield & Searle describe the geology of the north Indian continental margin in Zaskar. They include an important new map and estimate shortening amounts across the north Indian margin. These estimates incorporate both late Cretaceous to Palaeocene ophiolite emplacement events and subsequent post-collisional shortening. Lombardo et al. describe the occurrence of glaucophane and barrosite-bearing eclogites from the Upper Kaghan Valley. Fontan et al. also describe high-pressure rocks from Indian plate sequences in the Neelum Valley. Although eclogites have previously been described from Indian Plate sequences of north Pakistan (Pognante & Spencer 1991), it is only recently that the high pressure nature of these rocks has been recognized (O'Brien et al. 1999). The full significance of these rocks is as yet unclear. Abassi & Friend explore the significance of exotic conglomerates in the Neogene Siwalik succession and relate them in part to growth of the Nanga Parbat syntaxis. They show the Pliocene-aged Janak conglomerate to be derived from a topographic high, with erosion shedding into the Neogene foreland basin. Finally, Badshah et al. provide a detailed map of part of the Pakistan-Afghanistan border. This important map forms a link between those of Jones (1960), Wittekindt & Weippert (1973) and Bender & Raza (1995) and with these documents an important part of the collision zone between the Indian Plate and the Afghanistan Block (see Treloar & Izatt 1993).

Key words: Tectonics, Nanga Parbat syntaxis, Himalaya.

T/188. Treloar, P.J., Wheeler, J. & Potts, G.J., 1993. Metamorphism and melting within the Nanga Parbat syntaxis (Pakistan) Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 54.

Metamorphism within the Indian Plate gneisses within the Nanga Parbat syntaxis reached kyanite-bearing granulite facies in which the assemblage quartz-plagioclase-orthoclase-garnet-biotite-kyanite (or sillimanite) -rutile was stable. Calculated peak metamorphic conditions were at about 10 kbar and 800°C achieved after a period of prograde metamorphism along a P-T path with positive slope. A leucogranite melt is intimately associated with the main fabric, within the plane of which is contained a south trending lineation. This melt is considered to be an in situ anatexitic melt derived by vapour absent melting during the main phase of south verging thrusting. Melt reaction topologies imply that such melting should be decompressive in nature and this may imply that late stages of the peak metamorphism were consistent with some unroofing of the metamorphic pile. Similar trends of regional metamorphism during pressure increase with some decompression at the metamorphic peak have been documented elsewhere in the Pakistan Himalaya.

That all these fabrics are folded by the large scale folds that dominate the Nanga Parbat syntaxis, and which date from syntaxial growth, as well as being cut by large garnet-tourmaline bearing leucogranite sheets poses a problem. Do these anatexitic melts date from a peak metamorphic phase that substantially predates syntaxial evolution or do they document early stages in that evolution? The lineation data within the layered anatexites is critical here, as it indicates that the fine scale anatexitic layering dates from a different tectonic environment from that of the syntaxial growth, that of southward thrusting rather than east-west shortening. Thus we infer the presence of two melt phases within the syntaxis. The first, under granulite facies conditions, dates from the main phase Himalayan metamorphic-deformation event which, elsewhere in Pakistan, reached its peak during the Eocene although reasons of structural geometry indicate that this could have been somewhat delayed within the Nanga Parbat region. The second is Neogene in age and is related to decompressive vapour-absent melting during active uplift and unroofing of the syntaxis.

Key words: Metamorphism, melting, neotectonics, Nanga Parbat, Himalaya.

T/189. Treloar, P.J., Wheeler, J. & Potts, G.J., 1994. Metamorphism and melting within the Nanga Parbat syntaxis, Pakistan Himalaya. *Mineralogical Magazine* 58A, 910-911.

The Nanga Parbat syntaxis, in the northwest Himalaya, is a region of increasingly rapid neotectonic uplift. Synchronous with uplift has been the emplacement into the syntaxis, within the last 10 Ma, of leucogranite sheets and bodies enriched in radiogenic Sr, the generation of which has been linked to processes of decompressive, vapour-absent melting of a continental crustal source (George et al., 1993; Zeitler et al., 1993; Smith et al., 1992). Recently published age data on monazites (Smith et al., 1992), zircons (Zeitler et al. 1993) and amphiboles (Treloar et al., in prep) demonstrate that parts of the syntaxis experienced high (> 500~ temperatures during the Neogene, interpreted by Smith et al. (1992) as a regional scale high grade metamorphism associated with granite generation and emplacement. If this argument follows, there is a causal link between Neogene high temperature metamorphism, melting and, granite emplacement during regional uplift and metamorphism. Here, we question some of the assumptions implicit in this model, in particular in relation to the timing of high grade metamorphism and melting. In the northwest Himalaya, collision was between the Kohistan island arc and the Indian Plate, Kohistan being thrust southward onto the leading edge of the Indian Plate. The Nanga Parbat syntaxis is a north trending structural half window, within the core of which Indian Plate gneisses have been uplifted from beneath the structurally overlying arc rocks. The tectonics responsible for this uplift have been outlined by Treloar et al. (1991). The Indian Plate rocks exposed within the core of the syntaxis include early Proterozoic biotite-rich quartzo-feldspathic basement gneisses, and late Proterozoic cover sediments intruded by Cambrian granites. Both sequences carry intense S-, L- and S-L-tectonite fabrics, are intruded by basic sheets and Neogene Himalayan leucogranites, and are characterised by variable, often extensive, migmatisation.

Key words: Metamorphism, melting, neotectonics, Nanga Parbat, Himalaya.

T/190. Treloar, P.J., Wheeler, J. & Potts, G.J., 1995. Polycyclic Deformation, Metamorphism and Melting within the Nanga Parbat Syntaxis, Pakistan Himalaya: From whence comes the

Neogene Leucogranites. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

Ever since Sutton & Watson (1951) demonstrated that the early history of the Lewisian basement complex of NW Scotland was divisible into two distinct tectonothermal events separated by a phase of dyke emplacement, geologists studying basement terrains have been conscious of the need to distinguish between different cycles of deformation in crustal sections which may have passed through more than one orogenic event. In a region such as the Himalaya, where it is tempting to ascribe all deformational and metamorphic features to Tertiary-aged orogenesis, the problems of polycyclic crustal evolution are acute. That not all granites within the Himalayan chain are Tertiary in age, has been demonstrated by the recognition, all along the length of the Himalayan chain, of Cambrian aged granites, some of which have been deformed during the Tertiary. In addition, a crustal evolution event at ca. 1850 Ma, which included the formation of a penetrative fabric and concluded with the emplacement of granites which crosscut that fabric, has been documented from within the most internal zones of the Indian Plate (Zeitler et al 1989; Treloar et al (1989). These basement gneisses were subsequently deformed within the Himalayan orogen.

In the NW Himalaya, collision was between the Kohistan island arc and the Indian Plate, with Kohistan thrust south onto the leading edge of the Indian Plate. The Nanga Parbat syntaxis is a N-trending structural half window, within the core of which Indian Plate gneisses have been uplifted from beneath the overlying arc rocks. The extreme youth of this increasingly rapid neotectonic uplift, which has been accommodated by a combination of NW- to W-vergent thrusting along the western margin of the syntaxis and large wavelength buckle folding within the core of the syntaxis (Butler et al 1988 1992; Madin et al 1989; Treloar et al 1991), is clearly demonstrated by extremely young mica Ar-Ar and zircon and apatite fission track ages within the core of the syntaxis (muscovite 3 Ma, zircon 2 Ma, apatite 0.4 Ma) which are significantly younger than those preserved in the rocks which flank it (e.g. some 10 km to the west of the syntaxis: muscovite 19 Ma, zircon 10 Ma and apatite 6 Ma) (Zeitler 1985; Treloar et al 1989, 1991; George et al 1993; Zeitler et al 1993).

Synchronous with uplift has been the emplacement into the syntaxis, within the last 10 Ma, of leucogranite sheets and bodies enriched in radiogenic Sr. the generation of which has been linked to decompressive, vapour-absent melting of a continental crustal source (George et al 1993; Zeitler et al 1993; Smith et al 1992). The youngest of these sheets are about 2 Ma old (Zeitler & Chamberlain 1991). Pb-Pb age data on monazites (Smith et al 1992) and zircons (Zeitler et al 1993) and Ar-Ar data on amphiboles (Treloar et al, in prep) demonstrate that parts of the syntaxis were at high (>500°C) temperatures until about 10 Ma ago. The monazite data have been interpreted as implying that the rocks exposed within the syntaxis experienced a Neogene, high grade regional metamorphism which was associated with granite generation and emplacement. If this argument follows, there is a causal link between Neogene high temperature metamorphism, melting and, granite emplacement during regional uplift and metamorphism. However, that the main metamorphic fabrics in the Indus and Astor Gorges are cut by dykes of probable pre-Tertiary age leads us to infer that models which attempt to constrain the timing of high grade metamorphism and melting within the syntaxis without considering the polycyclic nature of these rocks are oversimplifications.

Pre-Neogene deformation and metamorphism.

The pre-Tertiary metamorphic history of the Indian Plate rocks exposed within the core of the syntaxis has been described elsewhere (Wheeler et al., submitted; Treloar et al 1994). The Indian Plate rocks include early Proterozoic biotite-rich quartz-feldspathic basement gneisses (true Isclere gneisses), an a late Proterozoic cover sediments (the Shengus gneisses) intruded by Cambrian granites. Both sequences have been affected by pre-Tertiary deformation, metamorphic and magmatic events, are intruded by basic sheets and Neogene Himalayan leucogranites, and are characterised by variable, and often extensive, migmatisation. Within the Shengus para-gneisses, the main metamorphic paragenesis is quartz-plagioclase-orthoclase-garnet-biotite-kyanite and/or sillimanite-rutile. Over much of their outcrop the Shengus paragneisses are migmatitic, with a stromatic leucogranite melt segregated from the restitic pelite fabric. Field relations imply this to be an in situ anatexitic melt. The presence of kyanite and garnet in equilibrium with the melt is consistent with vapour-absent melting, initially of muscovite and latterly of biotite. The common absence of muscovite implies that muscovite was completely destroyed during melting. The presence of kyanite rather than sillimanite in equilibrium with the melt is consistent with high pressures and temperatures of melting. Petrogenetic grids constrain peak metamorphic conditions to about 10 Kb and 800°C.

That this high grade metamorphism is pre-Tertiary is demonstrated by field relationships. A series of basic dykes clearly cross-cut the layered rocks of the migmatite complex and contain xenoliths of migmatitic material. In places these sheets contain undeformed relicts of an ophitic plagioclase-clinopyroxene assemblage, with the pyroxenes rimmed by a corona-like development of fine-grained hornblende. Elsewhere, the sheets have been almost

completely amphibolitized with a metamorphic assemblage of hbde-bt-qtz-pl-(grt). Thus, the sheets have undergone a post-emplacement amphibolite facies metamorphism. On the basis of their mineralogy they have not experienced the granulite facies metamorphism recorded within the migmatitic rocks. Hornblende Ar-Ar cooling ages of ca. 20 Ma (Treloar et al. in prep) document a Tertiary age for the latest cooling.

Due to post-metamorphic deformation, the peak metamorphic assemblage is rarely preserved in an undeformed state. The migmatites show evidence for ductile shearing with the development of an intense mylonitic fabric that post-dates the peak metamorphism. In outcrop, this fabric appears as a series of intense S-, L- and S-L-tectonite fabrics, within which lineations plunge gently to either N or S, consistent with a southerly transport direction of Kohistan onto India. Although the basic dykes are commonly discordant to the S-tectonite fabrics, they locally carry an internal L-S tectonite fabric sub-parallel to that of the migmatite complex. In some of the sheets this fabric is penetratively developed throughout the sheet; in others it is limited to the margins. Thus although they postdate the main phase metamorphism and migmatization, the dykes predate the ductile shearing which pervasively deforms the metamorphic complex. We argue that this S-L fabric is Himalayan in age. The ductile shearing is itself postdated by a later thermal event, as indicated by the presence of sillimanite bundles which overprint the main tectonic fabric. Although the main metamorphism was pre-Tertiary, that sillimanite bundles overprint the main tectonite fabrics demonstrate a Tertiary-aged regional re-metamorphism during the Himalayan orogeny, after which the migmatite complex cooled back through 5000C at between 20Ma and 10 Ma (Smith et al 1992; Treloar et al, in prep).

The planar fabrics have been folded and define a series of N-trending domal structures (Madin et al 1989; Treloar et al 1991; Butler et al 1992). The simplest interpretation of the structures is that the L-S fabrics represent ductile simple shear deformation during the S-vergent thrusting of Kohistan onto the leading edge of the Indian Plate during early stages of the Himalayan collision, with folding of the S-surfaces dating from the large scale buckling that accompanied syntaxis growth (Treloar et al 1991), fold axes being sub-parallel to the earlier stretching lineation. That the fabrics which deform, and thus post-date, the formation of the migmatite complex also pre-date the initial stages of syntaxial uplift implies that the main phase migmatization cannot be the result of late-Himalayan Neogene-aged decompressive melting. All of these fabrics are cut by the garnet-tourmaline bearing leucogranite sheets dated by Zeitler et al (1993) as <10 Ma old.

Discussion.

The prime temptation when studying rocks within the internal zones of an orogenic belt is to ascribe the metamorphism to that orogenic event. Thus, it would appear logical to ascribe the high grade metamorphism and melting within the Nanga Parbat syntaxis, which is the most internal part of the Himalayan orogen exposed anywhere, to be of Tertiary age. The Pb-Pb data presented by Zeitler et al (1993) and Smith et al (1992) have been interpreted by them as suggesting a Neogene age for high grade metamorphism and melting. However, field relationships demonstrate that, although this may be true for the leucogranite sheets which cut the migmatite complex, it is not so for the migmatite complex itself.

It is clear that two melting events have affected the Nanga Parbat region. The first, under granulite facies conditions, pre-dates dyke emplacement and is, at latest, Triassic in age. The second, which is Neogene in age, is most likely related to melting during uplift and unroofing of the syntaxis. This second melt event presents a significant problem: what is the source for the leucogranite melts. Having melted once, and thus being infertile, the migmatite terrain cannot have been the source for the Himalayan leucogranite sheets which cut it, unless Tertiary metamorphism was at higher temperatures than the pre-Tertiary metamorphism, a suggestion excluded by the amphibolite-facies mineralogy of the basic sheets. Here we consider possible source regions for the Neogene-aged melts.

In the absence of extreme temperatures, the rocks currently exposed within the core of the syntaxis, and which had undergone a dehydrative pre-Tertiary melting event, can only have melted a second time if their fertility had been recharged. There are two possible mechanisms by which this may have been achieved. The first is related to the late stages of the main metamorphism and migmatization. The preservation of centimeter-scale leucosomes within the metapelites demonstrates that melt extraction was inefficient. Crystallization of the retained pockets and layers of melt caused some back reaction within the restites. Textural relationships within the Shengus gneisses are consistent with a back reaction such as: $grt + kfs + melt = bt + kya + qtz$.

Similarly, the growth of small muscovite flakes within feldspar and crosscutting biotite may indicate an analogous muscovite generating back reaction. Muscovite is though rarely present in large quantities within the Shengus gneisses. Within the Iskere gneisses, mica content varies. Some are biotite -rich with no muscovite, whereas others contain both biotite and muscovite. Assuming that these migmatitic gneisses have been to the same elevated temperatures as the Shengus gneisses, we infer that the fabric forming muscovite present is the result of a migmatitic back reaction of the type: $bt + als + kfs + melt = ms + pla + qtz$.

The muscovites then recrystallised during early Tertiary simple shear. If high enough temperatures were attained during the Neogene, then some melt could be produced by vapour-absent melting of muscovite produced through

melt related back reactions. However, few of the rocks within the Indus and Astor Gorges contain significant muscovite contents and this process does not appear capable of generating significant melt quantities.

A second mechanism of re-fertilizing the Nanga Parbat gneisses would be by rehydrating them through a process of focussed fluid flow. Some samples contain mats of muscovite, which overprint the peak metamorphic assemblages. These mats reflect the growth of muscovite during the influx of water at temperatures sufficient to destabilise the orthoclase-kyanite present in the peak metamorphic assemblage. It is worth noting that Neogene aged monazites dated by Smith et al (1992) are often contained within fabric parallel (?) muscovites. As the major tectonic fabrics are probably early Tertiary in age, it is difficult to see how they can contain Neogene-aged monazites. However, if the muscovite mats within which the monazites are contained reflect new mineral growth in zones of fluid flow channelised through the dry granulites of the Nanga Parbat massif, rather than a regional scale Neogene-aged prograde metamorphism, this dichotomy can be resolved.

That there are localised pockets of Neogene-aged metamorphism (Smith et al. 1992; Zeitler et al. 1993) is indisputable. Cordierite-bearing low pressure granulites, intruded by cordierite-bearing leucogranites dated by Neogene-aged monazites have been described from the Fairy Meadows area (Zeitler et al 1993; Smith et al 1992). These rocks are not readily explicable in terms of the structure of the whole massif. Similar rocks are not widespread across the syntaxis. They must represent either a suite of the low-pressure rocks imbricated within the main granulite suite, or a localised re-metamorphism of an older higher-pressure granulite terrain. If the latter is correct, the cordierite gneisses may represent a Neogene re-metamorphism associated with locally pervasive fluid flow on the hanging wall of the thrusts developed along the W margin of the syntaxis, along which the syntaxis has been uplifted.

What is the source of the channelised fluids? Due to the continuing northward movement of India, previously unmetamorphosed and thus wet Indian Plate sediments are currently being underthrust beneath the Nanga Parbat syntaxis. Metamorphism of these sediments through dehydration reactions will lead to fluid release and it is likely that at least some of this fluid will pass up through the overlying dry granulites of the Nanga Parbat syntaxis. Thus, at least some of the leucogranite generation may be due to hydration rather than decompression. If metamorphism of these underthrust Indian Plate shelf sediments was at sufficiently high temperatures, then they also provide an alternative source for the leucogranite melts which intrude the Nanga Parbat massif.

It is commonly assumed that leucogranite generation within the Nanga Parbat syntaxis is through decompressive melting. Treloar et al (1991) argued that the uplift recorded within the syntaxis could be explained solely in terms of the folding and thrusting mapped by them and others. This would be consistent with decompressive melting within the upper crustal layers. However, melting in the presence of channelised fluid flow derived from underthrust units does not need decompression. In addition, if the underthrust fertile sediments are the source of the Neogene leucogranite melts, and if these granites are truly decompressive, they provide a constraint on uplift mechanisms for the syntaxis. Thrusting and folding effectively thicken units observed at surface and thus would increase the pressure on the underthrust fertile sediments where melting is inferred to be taking place. If this melting is decompressive, and that needs still to be demonstrated, it follows that syntaxial uplift cannot be accommodated solely in terms of thin skinned thrusting and folding of the upper crust, but needs to be modelled in terms of deep crustal processes, such as delamination, with the upward velocity more than compensating for the extra loading on the melting zone caused by compressional tectonics across the syntaxial arc.

Key words: Deformation, metamorphism, leucogranites, Nanga Parbat, Himalaya.

T/191. Treloar, P.J., Wheeler, J., Potts, G.J. & Rex, D.C. 1991. Structural evolution and asymmetric uplift of the Nanga Parbat syntaxis, Pakistan Himalaya. *Geologisches Rundschau*. 80. 411-428.

Key words: Deformation, structure, metamorphism, Nanga Parbat, Himalaya.

T/192. Treloar, P.J., Wheeler, J., Potts, G.J., Rex, D.C. & Hurford, A.J., 1993. Geochronology of the Indus Gorge and Astor valley sections through the Nanga Parbat syntaxis: Constraints on uplift history. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 79-80.

The Indus Gorge provides a constant altitude east-west section across the north-trending Nanga Parbat syntaxis. The Astor Valley, to the south, provides a second section, this one NW-SE trending, through the syntaxis, although not a constant altitude one. The syntaxis is a structural half window, within the core of which Indian Plate gneisses are updomed from beneath a cover of overthrust volcanics of the Kohistan-Ladakh island arc complex. These sections

provide an opportunity for detailed, structurally constrained, sampling for both P-T-t path analysis and geochronology. Here we present data from these traverses that enable us to constrain the uplift history of the syntaxis. 120 samples were collected for analysis by hornblende and mica Ar-Ar and K-Ar techniques, and by zircon and apatite fission track techniques. When those data of Zeitler (1985), Zeitler and Chamberlain (1989), Smith et al (1992) and George et al (1993) are included we have a copious, closely spaced data set.

A marked break in cooling ages occurs across the western margin of the syntaxis. This margin is marked by the Raikot-Sassi Fault Zone, a complex fault system with an overall oblique sense of displacement that includes both right lateral and thrust type displacements. The data imply that significant displacements have occurred along this zone within the last 1 to 2 Ma.

The eastern margin is marked by neither a significant fault zone nor a marked step in cooling ages. Instead cooling ages gradually decrease westward across the margin into the syntaxis, a decrease explained by exhumation during the growth of a large scale antiformal fold located within the syntaxis.

Within the Indus Gorge section, hornblende and mica Ar-Ar ages are both younger within the western half of the syntaxis than in the eastern half. This is consistent with the recognition of a series of domal structures within the syntaxis not all of which grew synchronously. Within the Indus Gorge section, the data are consistent with the growth of an antiform within the eastern part of the section before 5 Ma ago, and the subsequent growth of a similar structure, at Ca. 3 Ma ago, in the western part of the section. Neither zircon nor apatite ages show this age difference from east to west, indicating that folding may have become of secondary importance to uplift controlled by faulting along the eastern margin after about 2 Ma ago. Locally hornblende and monazite ages indicate $T > 500^{\circ}\text{C}$ as recently as 9-10 Ma and in the case of muscovite Rb-Sr ages as recently as 5 Ma. Some of these very young ages may be due to localized thermal perturbations due to melt emplacement.

Within the Astor Valley section, a different cooling profile is recorded with mica ages increasing towards the west, a pattern shown less well by the fission track ages. The tectonic significance of this variation is, as yet, uncertain.

Although a combination of early folding followed by later oblique slip thrusting along the western margin may explain the uplift and cooling history of the Indus Gorge section, it may be unwise to extrapolate this model without qualification to the rest of the syntaxis, as shown by the data from the Astor Valley. The internal structure of the syntaxis is best modeled as a series of nested domes. Folds within the Indus Gorge plunge south, whereas those within the Astor Valley plunge north. More detailed geochronology is required to demonstrate the extent to which these developed diachronously as well as their temporal relationships to thrusting along the western margin.

Total exhumation and overall uplift rates are difficult to quantify given the vertical telescoping of isotherms due to rapid uplift and unroofing, and the emplacement, as recently as 2 Ma ago, of leucogranite dykes and bodies to high structural levels. However, due to the constant altitude of the Indus Gorge section, the antecedent nature of the river and the magnitude of the unroofing indicated by the cooling history data, we feel confident that exhumation amounts approximately equal bulk uplift amounts. As such, it is hard to escape the conclusion that fold amplification was exponential, or that recent uplift rates have been as high as 6mmyr^{-1} , as suggested by Zeitler (1985).

Key words: Geochronology, structure, Nanga Parbat, Astore, Himalaya.

T/193. Treloar, P.J., Wheeler, J., Potts, G.J., Rex, D.C. & Hurford, A.J., 1995. Geochronology of the Indus Gorge and Astor Valley Sections through the Nanga Parbat Syntaxis: Constraints of Uplift History. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

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Key words: Geochronology, Indus Gorge, Astor Valley, Nanga Parbat Syntaxis,

T/194. Treloar, P.J., Williams, M.P. & Coward, M.P., 1989. Metamorphism and crustal stacking in the north Indian Plate, north Pakistan. *Tectonophysics* 165, 167-184.

The northern part of the Indian Plate in North Pakistan is composed of a number of large-scale crustal nappes, each of which are stratigraphically distinct, and which were stacked late in the main phase of southeasterly directed thrusting associated with the Himalayan event. The major nappes recognised in the Swat to Kaghan area of North Pakistan are the Besham, Swat, Hazara, Banna, Lower Kaghan and Upper Kaghan nappes. Metamorphism was synchronous with early stages of deformation. Within each nappe the metamorphic grade increases upwards, an overall inversion that represents post-metamorphic imbrication within individual nappes, synchronous with the main phase of nappe stacking, rather than a "hot iron" type inversion as described under the MCT in Nepal and India. As a result of this "within-nappe" imbrication each thrust slice within any particular nappe contains rocks of a higher metamorphic grade than those in the slice below, with sharp metamorphic breaks across the imbricating thrusts as well as across the major shears that bound the crustal-scale nappes. Uplift along these imbricating thrusts initiated cooling of the stack. K-Ar mica and hornblende cooling ages imply that much of this uplift was completed by 30 Ma, or within 20 Ma of the collision.

Key words: Metamorphism, tectonics, nappes, Indian Plate.

T/195. Troll, C., 1942. Neue gletscherforschungen in den subtropen der alten und neuen welt (Karakorum und argentinische Anden). *Zeitschrift der Gesellschaft fur Erdkunde zu Berlin*, 1942, 54-65.

Key words: Glaciers, Karakoram, Andes.

T/196. Troll, K., 1938. De Nanga Parbat, als Ziel deutscher Forschung. *Zeitschrift der Gesellschaft fur Erdkunde*, 1(2), 1-2.

Key words: Nanga Parbat, Himalaya.

T/197. Tromp, S., 1954. Preliminary compilation of the stratigraphy of West Pakistan and Baluchistan. *Geologic Mijnbouw, New Series, Jahrbong* 16(5), 130-134.

This compilation contains references to the area of this work.

Key words: Stratigraphy, Baluchistan.

T/198. Tschoepke, R., 1996. How to evaluate mining project economically. Seven examples of the Pakistan mineral industry. *Proceedings, Second SEGMIITE International Conference on Export Oriented Development of Mineral Resources and Mineral Based Industries, Karachi, 1994*, 200-202.

Key words: Economic geology, mining, mineral industry.

T/199. Turi, A.A., Wazir, T.K. & Masood, M.K., 1976. Groundwater irrigation in Bannu District. *M.Sc. Thesis, University of Peshawar*, 73p.

Key words: Hydrology, groundwater, Bannu.

U/1. Uil, H., 1983. (ed.) Technical report on groundwater resources in Domail plain, Bannu and Karak Districts, North West Frontier Province. Report IV-I, 51p. Pakistan-Dutch program, GWI, North West Frontier Province, Water and Power Development Authority, Hydrogeology Directorate, Peshawar and TNO Groundwater Survey, The Netherlands.

Key words: Groundwater, Domail plain, Bannu, Karak, NWFP.

U/2. Ukai, Y. & Kimura, Y., 1965. On the chemical composition of the granitic rocks collected from the Karakoram and Hindu Kush ranges. In: Matsushita, S & Huzita, K. (Eds), *Geology of the Karakoram and Hindukush. Results of the Kyoto University Scientific Expedition to the Karakoram and Hindukush, 1955*, Vol. VII, 121-130. Nippon Printing & Publishing Co., Ltd., Japan.

This is a preliminary, major element, geochemistry of seven granitic rocks from diverse bodies of granitoids. One sample each was collected near Kalam, Diwangar in upper Ushu valley of Swat, Shunji Gol in Ghizar, Urdukas in Baltoro, and upper Hispar, and two between the Indus-Gilgit confluence and Pari. Chemical analyses are accompanied by CIPW norms, Niggli values and cation numbers. Analyses are plotted on Harker diagram and An-Ab-Or triangle. It is "considered that most of these rocks were produced through the granitization of sedimentary rocks".

Key words: Granites, geochemistry, granites, Hindu Kush, Karakoram.

U/3. Ullah, A., 1998. Petrotectonics, petrology and genesis of uranium mineralization of the Siwalik Group of Thatti Nasrati and Shavah Shanwah Area. Ph.D. Thesis, Punjab University, Lahore.

Key words: Petrotectonics, petrology, mineralization, radioactive minerals, Siwaliks, Karak.

U/4. Ullah, H., 1983-85. Geotechnical studies of landslide along Murree-Kohala and Murree-Bhurban Road, District Rawalpindi. M.Sc. Thesis, Punjab University, Lahore, 108p.

The Murree Kohala road one of the most important road of the country which provides facilities of communication between Pakistan and Azad Kashrnir, crossing over the Jhelum river at Kohala. This road is also important for defence point of view. The slopes along the Murree Kohala road are very unstable, especially kassari to Phagwalai village. The condition of the Murree -Kohala road is satisfactory where a good driver can drive every type of vehicle at the speed of 40-50 km/hour, except for the landslide areas. At Murree Kohala road three major slides were selected for study namely Kasseni (K0, K1' K2' K3), Norgali (N1' N2) and Eliot (A1, A2). These are between lower topas to Eliot which are also marked on the map. The second road which join Kohala is starting from Jhikkagali via Burban which meet the Murree Kohala road near phagwani Village. There is also a slide near Kashmiri Bazar which is shown on the map. The project area is lying in the Murree Formation which is mainly composed of Shale, mudstone and sandstone. The detailed geological mapping of the active landslides area were carried out on, the map, sandstone, mudstone and shale with specific symbol on the map.

Key words: Geotechnical, landslides, Rawalpindi.

U/5. Ullah, Z., 1981-83. Geology and petrology of Darel valley (District Diamer) with special emphasis on the petrology of diorites and amphibolites of the area. M.Sc. Thesis, Punjab University, Lahore, 63p.

This thesis presents a geological map of the 30 sq .miles of project area (DAREL) on scale 1" = 1 mile. The project area (Darel) lies in Gilgit Agency, district Diamer. The area is located in the centre of Kohistan. Area is disturbed tectonically, being involved in Himalayan orogeny. The area is composed of igneous and metamorphic rocks. The main rock units in the area are Norite, Diorite, Amphibolites and Granodiorites. Mineralogical description and

petrographic analysis of these rock units are reported in detail. An attempt is made to interpret the petrogenesis of rock types. The Thesis presents a detailed geological and petrological investigation of the project area. Norite and amphibolites represent oceanic crust while Diorite and Granodiorite etc. represent plutonic equivalents of arc. To achieve this goal a period of 45 days was spent at the site during July, August 1984.

Key words: Petrology, diorites, amphibolites, Darel, Diamir, Kohistan.

U/6. Untersteiner, N., 1957a. Glazial-meteorologische untersuchungen im Karakorum. I: Strahlung. Archiv fur Meteorologie, Geophysik und Bioklimatologie, Series B(8), 1-30.

Records of radiation in the ablation area of Chogo Lungma Glacier (Karakorum) show that, in comparison with corresponding conditions in the European Alps, the radiation climate in the Karakorums during summer is characterized by high daily totals of global radiation. This is less due to stronger solar radiation but to a slower decrease of global radiation with increasing cloudiness ($\alpha=0.5$). A relation between the daily sums of global, solar, and sky radiation with cloud amount is given. The short wave radiation balance of firn and bare ice is evaluated from numerous measurements of the albedo. Long wave radiation from the atmosphere is computed from an assumed distribution of temperature and moisture in the free atmosphere by means of Elsasser's diagram, as well as from observed surface values with Ångström's formula, what leads to a good agreement. The outgoing radiation from the glacier's surface is computed according to its temperature. From these data the total radiation balance during the period of observations is derived. By far the greatest, and for its mass balance important, variations of the radiative energy exchange of the glacier is caused by variations of the reflectivity of its surface. Finally, the results of several radiation measurements at higher altitude are given. An estimate of the radiation balance at an altitude of 6.000 to 7.000 m shows that assuming an albedo of 0.75, melting of the snow in this climatic regime (no summer monsoon) seems only possible under rare conditions.

Key words: Glaciers, meteorology, radiation, Karakoram.

U/7. Untersteiner, N., 1957b. Glazial-meteorologische untersuchungen im Karakorum. II: Warmehaushalt. Archiv fur Meteorologie, Geophysik und Bioklimatologie, Series B(8), 137-171.

The present paper deals with further glacial-meteorological observations on Chogo Lungma Glacier carried out during the "Frankfurter Himalaya-Expedition 1955". These observations comprise: ablation, wind velocity at 20, 100, and 300 cm height, temperature and humidity at 20 and 100 cm height, surface temperature, temperature gradient between 20 and 100 cm, precipitation, evaporation, as well as the short and long wave radiative heat exchange at the surface as published in a previous paper. The first series of measurements (Station I, altitude about 4000 m) covers the melting of the remains of winter firn (51 cm) in the course of 6 days. The second series (Station II, altitude about 4300 m) covers the ablation of 120 cm of bare ice with an average albedo of 0,30. Both stations were situated below the firn line on the flat glacier tongue. The daily variation of ablation closely resembles that found in the Alps and indicates a very high percentage of radiative ablation. The glacier wind on Chogo Lungma is exceptionally weak which is probably due to its morphological features (Mustagh-Type). An explanation of the daily course of glacier wind is given by considering the temperature difference between air and ice.

The mean vertical distributions of wind velocity, temperature and humidity may well be represented by logarithmic laws. The vertical flux of perceptible and latent heat are calculated by means of the adiabatic "Austausch" coefficient. To account for stability according to Lettau's formula would necessitate the application of non-logarithmic laws for the temperature and humidity distribution in order to give a constant heat flux. However, the deviations in the lowermost decimetres are small. The mean daily heat economy at Stations I and II is given in Table 6. The correspondence between observed and computed ablation is satisfactory and justifies the methods applied. Radiation balance (long and short wave) contributes 88% over firn and 95% over bare ice to the total ablation. As is to be expected, convective heat supply is of the same order of magnitude as on other temperate glaciers. Ablation by evaporation is negligible. The part of evaporation in the glacial heat economy is discussed in connection with the problems of "nieve de los penitentes". It is shown that, under certain conditions, evaporation may achieve some importance in the thermal budget but that its importance in the mass budget (ablation by evaporation) in the ablation area of temperate glaciers will always be negligible compared to the ablation by melting, due to the great amount of heat required for evaporation. Based upon the small local differences of the heat budget of "sun-cupped" firn an explanation is given of the formation of nieve de los penitentes. The possibilities of simplified measurements of heat

economy, especially on expeditions, are discussed. Finally, the glacial heat budget in high, middle, and lower latitudes is compared, and the predominant importance for glacier shrinkage and advance of summer weather (changes of albedo by temporary snow covers, duration of sunshine) is stressed.

Key words: Glaciers, meteorology, Karakoram.

U/8. Uppal, I.H., 1972. Preliminary account of the Harichand ultramafic complex, Malakand Agency, NWFP, Pakistan. Geological Bulletin, University of Punjab 9, 55-63.

The Harichand ultramafic complex, in the Malakand Agency, covering about 45 square miles, has been mapped for the first time on a scale of 6 inches to 1 mile and is presented here on a reduced scale of 1 inch to 1 mile. The complex constituents large bodies of harzburgite with small conformable outcrops of dunite rock. The harzburgite-dunite bodies are partially surrounded by peridotite rock, which is serpentinized along its contact with the country rocks, consisting of low-grade schists. Two small bodies of metagabbroic rock are present in the metamorphic formation falling within the mapped area. Chromitite at places is associated with dunite, while orthopyroxenite dykes sporadically traverse the area. Preliminary account based on field observations and petrographic studies is given, while the results of details petrological and chemical work will be presented in a later communication.

Key words: Ultramafics, petrography, Harichand, Malakand.

U/9. Uppal, I.H., 1980. Origin of chromite deposits and associate dunite of the Harichand ultramafic complex, Malakand Agency. Contributions to the Geology of Pakistan 1, 113-120.

The Harichand ultramafic complex, also called the Dargai complex, is a large body of ultramafic rocks, peridotites and dunite. There are sizable bodies of chromite pods, lenses and layers. Those associated with the dunite are described in this paper.

The podiform deposits of chromite associated with the dunite bodies ominously exposed in the Hari Chand Complex have been subjected to investigation. Field observations, petrographic and chemical studies of selective specimens show that the chromite & dunite were formed prior to the crystallization of the host rocks in deep magma chamber to make basement layer of the crystal mush. These were later on mobilized and transported upward into the upper part of magma chamber when the main mass of the ultramafic complex solidified.

Key words: Ultramafics, dunite, chromite, petrology, Harichand, Malakand.

U/10. Usman, K. & Ali, L., 1998. Structure and stratigraphy of a part of Kohat-Karak districts south of Lachi, N.W.F.P., Pakistan. M.Sc. Thesis, University of Peshawar, 70p.

Key words: Structure, stratigraphy, Kohat, Karak.

V/1. Valdiya, K.S., 1980. The two intracrustal boundary thrusts of the Himalaya. *Tectonophysics* 66, 323-348.

The series of four different, steeply inclined thrusts which sharply sever the youthful autochthonous Cenozoic sedimentary zone, including the Siwalik, from the mature old Lesser Himalayan subprovince is collectively known as the Main Boundary Thrust (MBT). In the proximity of this thrust in northwestern and eastern sectors, the parautochthonous Lesser Himalayan sedimentary formations are pushed up and their narrow frontal parts split into imbricate sheets with attendant repetition and inversion of lithostratigraphic units. The superficially steeper thrust plane seems to flatten out at depth. The MBT is tectonically and seismically very active at the present time.

The Main Central Thrust (MCT), inclined 30° to 45° northwards, constitutes the real boundary between the Lesser and Great Himalaya. Marking an abrupt change in the style and orientation of structures and in the grade of metamorphism from lower amphibolite facies of the Lesser Himalayan to higher metamorphic facies of the Great Himalayan, the redefined Main Central Thrust lies at a higher level as that originally recognized by A. Heim and A. Gansser. They had recognized this thrust as the contact of the mesozonal metamorphics against the underlying sedimentaries or epimetamorphics. It has now been redesignated as the Munsiri Thrust in Kumaun. It extends northwest in Himachal as the Jutogh Thrust and farther in Kashmir as the Panjal Thrust. In the eastern Himalaya the equivalents of the Munsiri Thrust are known as the Paro Thrust and the Bomdila Thrust. The upper thrust surface in Nepal is recognized as the Main Central Thrust by French and Japanese workers. The easterly extension of the MCT is known as the Khumbu Thrust in eastern Nepal, the Darjeeling Thrust in the Darjeeling-Sikkim region, the Thimpu Thrust in Bhutan and the Sela Thrust in western Arunachal. Significantly, hot springs occur in close proximity to this thrust in Kumaun, Nepal and Bhutan. There are reasons to believe that movement is taking place along the MCT, although seismically it is less active than the MBT.

Key words: Tectonics, MCT, MBT, Himalaya.

V/2. Valdiya, K.S., 1983. Tectonic sections of Himalayan granites. In: Shams, F.A. (ed.), *Granites of Himalayas Karakorum and Hindu Kush*. Institute of Geology, Punjab University, 39-54.

Key words: Tectonics, granites, Himalaya.

V/3. Valdiya, K.S., 1984. Evolution of the Himalaya. *Tectonophysics* 105, 229-248.

The compression and attendant deformation of a thick and vast sedimentary prism formed since Early Riphean times on the northern continental margin of the Indian craton gave rise to the Himalaya mountains as a result of convergence and collision of the Indian and Asian plates. The oceanic trench-sediments, tectonically implanted with sea-floor material and intimately associated with calc-alkaline volcanics in the narrow Sindhu-Tsangpo belt extending from Kohistan through Dras, Leh, Darchen (Mansarovar) to Shigatse and beyond, represent the subduction-island arc complex which developed south of the dynamic southern margin of the Asian continent and was welded to the colliding Indian plate during the late Eocene to Oligocene period. This complex is fringed to the north by a wide zone of Andean-type granitic bodies. The evolution of the Himalayan orogen is closely connected with the development of the present-day Andaman-Nicobar-Indonesia island arc-subduction system in the southeast and the Makran Ranges-Oman Trench in the southwest.

The evolution of the Himalaya was accomplished in four major phases of tectonic upheaval during the late Cretaceous to Palaeocene (Karakoram phase), late Eocene to Oligocene (Malla Johar phase), middle Miocene to Pontian (Sirmurian phase), and late Pliocene to middle Pleistocene (Siwalik phase). While the Karakoram phase marks the convergence of continents and the Malla Johar phase represents the collision and subduction, it was during the Sirmurian upheaval that the main tectonic features developed and the Himalaya acquired its distinctive structural complexion.

Key words: Tectonics, Himalayan evolution, Kohistan-Dras arc.

V/4. Valiullah, M. & Ghanchi, S., 1962. The beryl resources of Pakistan. *The Geologists, Geological Society, Karachi University* 1, 6-8.

Key words: Economic geology, Beryl.

V/5. Vandercammen, A., 1965. Les Spiriferidae de Shogran et Kuragh (Chitral). In: Italian Expeditions to the Karakorum (K2) and Hindu Kush, (A. Desio leader), Scientific Reports IV (1), 67-75 Paleontology-Zoology-Botany. Brill, Leiden.

This paper describes Devonian Spiriferidae from Shogran and Kuragh in Chitral.

Key words: Palaeontology, Italian expedition, Chitral.

V/6. Van Voltan, R., 1962. Magnesite in Pakistan. Proceedings, CENTO Symposium on Industrial Rocks and Minerals, Lahore, 211-215.

Key words: Magnesite, economic geology, Pakistan.

V/7. Venables, S., 1986. Painted Mountains. Hodder and Stoughton, London, 239p.

This is a mountaineering travelogue of the author. The author is a mountaineer and has published several books which describe his travel experience. This, and the following two accounts describe his journey to the specific areas.

Key words: Mountaineering.

V/8. Venables, S., 1986. Siachen sojourn. Mountain 107, 28-33.

This is a description of visit to the Siachen.

Key words: Tourism, Siachen journey.

V/9. Venables, S., 1988. Karakoram odyssey. Mountain 119, 26-31.

The author gives a description of his wanderings in the Karakoram ranges.

Key words: Tourism, Karakoram, Travelogue.

V/10. Verchere, A.M., 1865. Notes to accompany a geological map and section of the Lohra Ghur or Sheen Ghur Range in the District Bannoo, Punjab; with analysis of the lignites. Asiatic Society of Bengal Journal, 34(2), 42-47.

This is a list of plate description accompanying the geological map of the area. It also has description of the samples collected during field visits.

Key words: Geological map, Sheen Ghar, lignite, Bannu, Punjab, India.

V/11. Verchere, A.M., 1867. Geology of Kashmir, the Western Himalaya, and the Afghan Mountains, with a note on the fossil by M.E. Verneuil. Journal of the Asiatic Society Bengal 35, part 1: 89-133, 159-203; part 2: 9-50, 83-115, 201-229.

Shows that the so-called nummulites obtained in the Kashmir valley by Messrs. Vigne and Flemming were crinoid stems. The author considers that the tertiary 'Murree beds' are crushed against the older rocks of the Kajrag range and that the peaks of the latter are composed of porphyry (granite), probably of igneous origin. The lower part of the Kashmir limestone series is classed as of Carboniferous age, and is shown to rest on amygdaloidal and slaty rocks, some of which are considered to be lavas, other trap-ashes more or less altered, and other again unaltered detrital sedimentaries. The higher beds of the limestone series, for which the name Kothair is proposed, are considered to be possibly of Triassic age. The trap is considered to have altered the limestones of part of the Kashmir valley, and is accordingly regarded as intrusive and of post-Carboniferous age.

Key words: Geology, palaeontology, Kashmir, Himalaya, Afghanistan.

V/12. Verma, R.K., 1992. Seismicity, focal mechanism and plate movement along the western margin of the Indian plate. Abstracts, First South Asia Geological Congress, Islamabad, p.44.

Seismically the western margin of the Indian plate extends from the Makran coast in the south (nearly 25° N) to Hindukush (35° N). However the effect of plate collision extends upto north Pamir, S. Tien shan region. Seismically the area which are particularly active are the Kirthar-Sulaiman region, Quetta transverse ranges, Hazara Thrust region, Kohistan region and the North Pamir region. Most of the territory of Pakistan is characterized by strike-slip as well as thrust faulting. This is true to a large extent of the Hindukush and the North Pamir region alos. Over the Hindukush region the seismic zone extends to a depth of nearly 240 km. here a complex system of faulting is also taking place. At a depth of 80-240 the principal stress axis are oriented N to NW as well as S to SE.

Seismically the Hindukush region cannot be explained in term so of a simple plate subduction model. It appears that the lithospheres corresponding to the Indian and the Eurasian plate are moving relative to each other upto a considerable depth.

Key words: Seismicity, plate movement, Indian plate.

V/13. Verma, R.K., 1992. Gravity field in NW Himalaya, Kohistan region and the nature of continental-continental plate collision. Abstracts, First South Asia Geological Congress, Islamabad, p.44.

A Bouguer anomaly map of NW Himalaya, N. Pakistan and parts of Kohistan-Hindukush region has been prepared using all available gravity data. The map shows a pronounce gravity high over the Kohistan region. The gravity field has been interpreted along two profiles. The first extending from Gujranwala to Haramosh massif in NNE-SSW direction and the other from Gujranwala to Ghizar through Kohistan region.

Along the first profile the Moho depth is found to increase from nearly 30 km near the edge of the Indian shield to 77 km underneath the Haramosh massif. Along the second profile a high density intrusive in the upper part of the crust and located close to the Main Mantle Thrust is invoked in order to explain the observed gravity field. The intrusive extends to a depth of nearly 20 km and must have come from the upper mantle.

The nature of isostatic compensation prevailing in the Himalaya will be discussed. The results do not support a simple model of plate subduction along the NW Himalayan front. The role of vertical tectonics in the formation of Himalaya is emphasised.

Key words: Gravity, plate collision, Kohistan, Himalaya.

V/14. Verma, R.K., 1994. Gravity field in NW Himalaya, Kohistan region and the nature of continental-continental plate collision. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 147-152.

Consult the preceding account for further information.

Key words: Gravity, plate collision, Kohistan, Himalaya.

V/15. Verma, R.K. & Gosh, S., 1994. Seismotectonics and nature of plate movement in Hindukush Region. In: Ahmed, R. & Sheikh, A.M. (Eds.), Geology in South Asia--I. Proceedings of the First South Asia Geological Congress, Islamabad, 1992. Hydrocarbon Development Institute of Pakistan, Islamabad, 141-146.

For details consult the following account.

Key words: Seismotectonics, plate movement, Hindukush.

V/16. Verma, R.K., Mukhopadhyay, M. & Bhanja, A.K., 1980. Seismotectonics of the Hindukush and Baluchistan Arc. *Tectonophysics* 66, 301-322.

A seismicity map of that part of the Pakistan-Afghanistan region lying between the latitudes 28° to 38°N and longitudes 66° to 75°E is given using all available data for the period 1890–1970. The earthquakes of magnitude 4.5 and above were considered in the preparation of this map. On the basis of this map, it is observed that the seismicity pattern over the well-known Hindukush region is quite complex. Two prominent, mutually orthogonal, seismicity lineaments, namely the northwestern and the north-eastern trends, characterize the Hindukush area. The northwestern trend appears to extend from the Main Boundary Fault of the Kashmir Himalaya on the southeast to the plains of the Amu Darya in Uzbekistan on the northwest beyond the Hindukush. The Sulaiman and Kirthar ranges of Pakistan are well-defined zones of intermontane seismicity exhibiting north-south alignment.

Thirty-two new focal-mechanism solutions for the above-mentioned region have been determined. These, together with the results obtained by earlier workers, suggest the pre-dominance of strike-slip faulting in the area. The Hazara Mountains, the Sulaiman wrench zone and the Kirthar wrench zone, as well as the supposed extension of the Murray ridge up to the Karachi coast, appear to be mostly undergoing strike-slip movements.

In the Hindukush region, thrust and strike-slip faulting are found to be equally prevalent. Almost all the thrust-type mechanisms belonging to the Hindukush area have both the nodal planes in the NW-SE direction for shallow as well as intermediate depth earthquakes. The dip of P-axes for the events indicating thrust type mechanisms rarely exceeds 35°. The direction of the seismic slip vector obtained through thrust type solutions is always directed towards the northeast. The epicentral pattern together with these results suggest a deep-seated fault zone paralleling the northwesterly seismic zone underneath the Hindukush. This NW-lineament has a preference for thrust faulting, and it appears to extend from the vicinity of the Main Boundary Fault of the Kashmir Himalaya on the southeast of Uzbekistan on the northwest through Hindukush. Almost orthogonal to this NW-seismic zone, there is a NE-seismic lineament in which there is a preference for strike-slip faulting.

The above results are discussed from the point of view of convergence of the Indian and Eurasian plates in the light of plate tectonics theory.

Key words: Seismotectonics, plate movement, Hindukush.

V/17. Verma, R.K., Mukhopadhyay, M. & Roy, B.M., 1977. Seismotectonics of the Himalaya and the continental plate convergence. *Tectonophysics* 42, 319-335.

The relationship between seismicity and tectonics of the northwestern, central and part of the eastern Himalaya lying between longitudes 74–88°E and latitudes 26–35°N has been studied. A seismicity map of the area for the period 1890–1970 is presented. A strain-energy release map of the Himalaya was prepared following the method discussed by Allen et al. (1965). On the basis of this map it is suggested that the Himalaya does not behave as a single unit so far as the seismic activity is concerned. It could be divided appropriately into three different units;

- (1) the Panjab Himalaya;
- (2) the Kumaon Himalaya; and
- (3) the Nepal Himalaya.

It is suggested that the extension of Aravalli structures into the Himalayan regions has played a role in the tectonics of the Kumaon Himalaya, and probably is the cause of the complex nature of seismicity of the region.

In the Kumaon Himalaya the maximum strain-energy release is related to the Main Central Thrust (MCT), whereas in the Panjab as well as in Nepal Himalaya it is related to the activity of the Main Boundary Fault (MBF). The strain-energy release characteristics of the two thrusts show that their mechanisms of storage and release of energy are different. Strain-energy release through the MCT seems to be more uniform as compared to the MBF along which the release of energy has been mostly abrupt, through large magnitude earthquakes.

Focal-mechanism solutions of Himalayan earthquakes located north as well as south of the Indus Suture Zone indicate that the Indian plate is underthrusting the Tibetan plate towards the north, whereas the latter is underthrusting the Indian plate towards the south. P-axes lying to the north as well as south of the Indus Suture Line are shallow dipping. This confirms the view that the present-day seismicity of the area is a result of continental-continental collision and not of lithospheric subduction.

Key words: Seismotectonics, plate movement, plate convergence, Himalaya.

V/18. Verma, R.K., & Sekhar, C.C., 1983. Seismicity of Pakistan and its relationship to faults and lineaments. *Geophysics Research Bulletin*, 21(3), 209-223, Hyderabad.

Key words: Seismicity, faults.

V/19. Verma, R.K. & Sekhar, C.C., 1986. Focal mechanism solutions and nature of plate movements in Pakistan. *Journal of Geodynamics*, 5 (3–4), 331–351.

From the seismic point of view, the territory of Pakistan which lies between latitude 23°–37° N and longitude 61°–75° E is one of the most active zones in the world. The importance of this area lies in terms of movements of the Indian plate with respect to Eurasia on the west. Seismicity, as well as focal mechanism- solutions, throws a considerable light on the nature of forces acting in the area. All the available solutions, along with 12 new ones, have been considered for the present study. Their relationship to major faults in the area is discussed. The majority of the solutions in the central and northern parts show strike-slip faulting with a left-lateral sense of motion, followed by thrust faulting; few show normal faulting. This suggests that the Indian plate is moving with respect to the Eurasian plate along the Chaman fault, Quetta transverse zone, Sulaiman Ranges and the Hazara thrusts region joining the Hazara/Kashmir syntaxis. The orientations of P and T axes have been studied. It is seen that in a large number of cases compressive stress is acting nearly in NNW-SSE to N-S directions. The Hazara thrust region appears to be the most complex. Here, the influence of the Himalayan thrust front is evident to a large extent. The nature of faulting along the Chaman fault and Quetta transverse zone is to some extent similar to that of the San Andreas fault system of California. So far as the energy release is concerned, the maximum energy is being released in the form of strike-slip movements close to the Chaman fault and Quetta transverse ranges.

Key words: Plate movement, tectonics, Hazara.

V/20. Verplanck, P.L., 1986. A field and geochemical study of the boundary between the Nanga Parbat-Haramosh Massif and the Ladakh arc terrane, northern Pakistan. M.Sc. thesis, Oregon State University, 138p.

Key words: Geochemistry, plate boundary, NPHM, Ladakh arc.

V/21. Verplanck, P.L., Snee, L.W. & Lund, K., 1985. The boundary between the Nanga Parbat massif and the Ladakh island arc terrain, north Pakistan: A cross fault on the Main Mantle Thrust. *American Geophysics Union* 66, 1074; Washington.

Key words: Plate boundary, structure, NPHM, Ladakh arc.

V/22. Vicary, M., 1851. On the geology of the upper Punjab and Peshawar. *Geological Society of London, Quaternary Journal* 7, 38-46.

Introductory Remarks by Sir R. I. Murchison. In communicating the enclosed letter from Major Vicary to myself, I beg to observe that he obtained his knowledge in an arduous campaign, which led the British forces into regions ordinarily inaccessible to geologists. Independently of the description of an extensive range of those younger tertiary deposits in the Sewalik hills, Avith the contents of which we have been made acquainted through the letters of our associates Falconer and Cautley, Major Vicary now calls our attention to Palaeozoic fossils derived from the mountains which separate British India from Cabul. It appears that Dr. Falconer had previously obtained possession of fossils establishing this point, and I would now state that when I last visited Edinburgh, the Rev. Dr. Fleming showed me *Producti* and *Sjnriferi* collected by his son Dr. A. Fleming, of the Company's Service, in the vicinity of the salt range at Musakhail on the east bank of the Indus, which seemed to be identical with carboniferous forms well known in the British Isles. Being unaware at that time of any similar discovery, I urged my friend, the Rev. Dr. Fleming, to make his son's researches known to the scientific world, and to compare exactly the species collected in Western India with those of Scotland, with which he is so conversant. Having since shown these fossils to M. de Verneuil, he has identified five out of eight or nine species with forms well known in rocks of this age in other parts

of the world, viz. *Productus Cora*, D Orb. *Orthis crenistria*, Phill. *costatus*, Sow. *Terebratula Royssii*, L'Eveille, and *seve- Flemingii*, Sow. = *P. lobatus*, Sow. and other species of this genus.

Now these fossils have already been known to have an enormous geographical range; the *Productus Cora* occurring in Peru, Spitzbergen, Northern Europe, and the Sierra Morena of Spain; whilst two or three of the other species have an almost equally extensive distribution. The observations of Major Vicary are thus augmented in value by the discoveries of Dr. A. Fleming; for they prove that the palaeozoic rocks have a considerable range in the region of the Indus, a fact hitherto unknown to European geologists.

Key words: Geology, Paleozoic, Siwaliks, Punjab, Peshawar, India.

V/23. Victoria, J.J., 1998. Hydropower - An energy source for the Northern Areas of Pakistan. In: Stellrecht, I. (ed.), *Karakorum-Hindukush-Himalaya: Dynamics of Change*. Culture Area Karakorum, Scientific Studies, 4. Rudiger Koppe, Koln.

Key words: Hydropower, energy resources, Gilgit-Baltistan.

V/24. Vigne, G.T., 1842. *Travelers in Kashmir, Ladakh, Iskardo, etc.* 2nd edition. Colburn.

This is a 500+ pages book about the area. The first few paragraphs from the first chapter are reproduced here.

“At the village of Suru, not far from Bowun, is a well-sculptured figure of Sri, the Indian Ceres, or Lucksmi, as the goddess of plenty, in black marble, and about two feet in length, being the best specimen of the kind that I know of in Kashmir.

Proceeding along the northern side of the Karywah of Islamabad, we arrive at the place where the higher ranges begin to descend upon it; and at this spot alone, near the highest end of the valley, the most ungeological would be convinced of its having once contained a lake, as the remains of beaches formed of shingly conglomerate, are to be seen there deposited in horizontal layers, and resting upon distorted limestone strata. But I have before noticed this place, in my general remarks made upon entering the valley. Close at hand are some small ancient excavations in the limestone-rock, even with the ground, but not displaying any ornamental sculpture: They appear to be made for shelter rather than for any other purpose; at least I was not able to discover one.

Above them is a porch, elevated to the perpendicular face of the rock in which it is cut. The old pathway has been much injured, and I clambered up with some difficulty. Within is a small antechamber, from which a few steps lead into another excavation behind it; but I was deterred from going beyond the entrance, by the stench arising from the innumerable bats that I disturbed, which was rendered absolutely insupportable by the great heat of the weather. The Musalman, I may here remark, says that the bat was originally formed from a piece of clay, which Jesus Christ was accidentally moulding with his fingers, and that God gave it life afterwards, for the sake of its divine maker.

The excavation, is a dark and dismal-looking place, well suited to the purposes and trickery of priestcraft, which I have little doubt from its appearance were in full play within and near it. Perhaps this is the unfathomable cave which Abu Fuzl says is on one side of the springs of Bawun. On the ground, are the ruins of two Hindu temples, of the same shape as the interior building of Martund. The fine strath which I was ascending was the Pergunah of Kahawa, or Kaurah Parah. Kahawa signifies the left, and Parah is a corruption of Pergullah.

Duchin signifies the right, and Duchin Parah, is on the right side of the river Lidur, which flows downwards through the strath, to bear to junctioll with the Jylum, about three miles above Bij Beara. It is a very large river, inferior only to the Veshau, and when swollen with rain or melted snows its flood rushes down towards the plain with great impetuosity.

Harput Nag, or the Bears Spring, may be visited either from or on the way to Eysh Makam. It lies at the extremity of a strath that well deserves its name, being covered with the wildest jungul. I saw a wild cat, and my dogs unharboured a young bear, at which I got a snap shot; but he escaped to the mountains, by shuffling away at a pace I could not have given him credit for. The place is remarkable for its copper-mine, which formerly gave employment to numbers of workmen; but such is the arbitrary and oppressive nature of the Sikh rule that it is not now worked at all. Sher Singh, when governor of the valley, tried all he could to induce the people to resume their labours, but without effect. When compelled to work they will bring the demanded quantity of ore, but take particular care that it could produce little or no metal, and their masters know nothing about the matter. It is useless to attempt to punish them: the unfortunate Kashmirian is quite aware that his wages would probably not be paid, that the produce of his labour will nevertheless be taken, and that the display of a little will be the sure incentive to a demand for more; and these are reasons far more cogent than those that cause a strike amongst European operatives. I entered what I was informed was the principal mine. It extended into the quartzose rock, in a slanting direction, for not more than

twenty-five yards. The interior was much coloured by a nitrate of copper. I procured what purported to be specimens of the ore, but suspect that they were not of the best.”

Key words: Tourism, Kashmir, Ladakh, Skardu, Baltistan.

V/25. Villa, I.M., 1997. High-grade amphibolites in Baltistan: t , T , p , Z , aH_2O , $^{40}Ar/^{39}Ar$, N_{ϕ} . Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 95.

Amphibolites from NW Ladakh Terrain and the Karakorum Metamorphic Complex in N Pakistan record $p \leq 1$ Gpa and $T \leq 700^\circ C$. In metabasites of the Ladakh-Kohistan island arc (Askore amphibolites, Shyok Suture Zone) and in gneisses of the adjoining Karakorum metamorphic complex (Chogo Lungma area, Remendok pluton) and High Himalayan Naga Parbat-Haramosh Massif, amphiboles and micas give Late Miocene-Pliocene ages {Villa et al., Tectonophysics 260 (1996) 201; Villa et al., Schw. Min. Pet. Mitt. 76 (1996) 245}. What is really controlling ages in this high-grade terrain? Temperature? Plotted in a conventional t - T diagram, samples do not define a meaningful family of “cooling paths”. Pressure? No. These amphibolites contain none of the excess Ar typical of eclogites {Tonarini et al., Terra Nova (1993) 13}. Only one gneiss of NPHM contains excess Ar (Ar/Ar biotite plateau=15 Ma, muscovite plateau=9.8 Ma, biotite Rb/Sr=5.7Ma).

Porosity? Dahl {GCA 60(1996) 3687} establishes crystal fields as controlling diffusion in crystals (surprise to so many!). The amphiboles in the metabasites have quite similar composition but ages scatter between 10 and 70 Ma. Resetting of Albian arc volcanics mainly depends on something faster than diffusion. Water? Of course it is known to enhance diffusivity by orders of magnitude. This is why virtually immobile elements such as Pb in zircon can be used as geothermometers. Regional fluid movement is the only way to homogenize Sr over the tens of km diffusion length scale implicitly required if WR Rb/Sr measurements are seen as metamorphic ages. The Rb/Sr data indicate open-system exchange with a fluid. Strain? If looked for, differences between deformed and undeformed muscovites a few meters apart are quite obvious, and correlate with ages. Phase mixtures? from Ar correlation diagrams, multiple generations of phases in the handpicked mineral separates can be diagnosed. Electron microprobe confirms $N(\phi) \geq 2$ where predicted by Ar. The key point is, where a texturally older amphibole or muscovite is still preserved, it also preserves an old age, reinforcing the notion that temperature alone won't reset all minerals. In summary, an age determination by no mean obviously translates into “ T_t point”. For this to happen, one must look at dry static rocks such as the Proterozoic Limpopo belt which exceeded the temperature necessary to erase any inheritance {Kamber et al., J Geol 103 (1995) 493}. In wet, hectic young orogens faster processes, such as recrystallization induced by deformation and fluids, overrun the very sluggish thermal diffusion in resetting mineral ages.

Key words: Amphibolites, Ladakh, Karakorum metamorphic complex, Baltistan.

V/26. Villa, I.M., Lemennicier, Y. & Le Fort, P., 1996. Late Miocene to early Pliocene tectonometamorphism and cooling in south central Karakoram and Indus-Tsangpo Suture, Chomo Lungma areag(NE Pakistan). Tectonophysics 260, 201-214.

The Chogo Lungma glacier is located at the northeastern edge of the Nanga Parbat-Haramosh spur where the Ladakh-Kohistan arc formations are laminated between the Karakorum and High Himalaya units. In the Karakorum metamorphic complex, metamorphism of a pelitic and granitic protolith took place in two tectonometamorphic phases. Isoclinal folds ($\square 700^\circ C$, 1 GPa) were followed by doming ($\square 630$ – $700^\circ C$, 400–750 MPa) in a compressional climax (Lemennicier et al., 1996). One hornblende and two biotites associated to syntectonic magmatism with mantle affinities, contemporaneous of doming, give cooling ages between 3.0 and 7.7 Ma. A muscovite from an orthogneiss in the Karakorum gives an age of 5 Ma. Fast cooling (70–110 K/Ma) has prevailed ever since. Two muscovites from a foliated intrusion emplaced on the thrust of the Ladakh-Kohistan arc over the High Himalaya Crystallines have ages of 8.2 and >9 Ma (despite being collected in the same locality), dating the thrust at just before 9 Ma. All this points to a coeval tectonometamorphism and thrusting in that area during the Tortonian.

Key words: Miocene, Pliocene, metamorphism, tectonics, Karakoram, Indus-Tsangpo suture.

V/27. Villa, I.M., Ruffini, R., Rolfo, F. & Lombardo, B., 1996. Diachronous metamorphism of the Ladakh terrain at the Karakorum-Nanga Parbat-Haramosh junction (NW Baltistan, Pakistan). Schwitz. Mineral. Petrogrog. Mitt. 76, 245-264.

Metamorphic minerals from gneisses, amphibolites and schists of the Himalaya-Ladakh/Kohistan syntaxis in NW Baltistan were dated by $^{39}\text{Ar}/^{40}\text{Ar}$ stepwise heating.

The amphiboles from the Askore Amphibolite unit sampled in the Indus valley give discordant age spectra with step ages ranging from 35 to 70 Ma; we interpret the older step ages as mixtures between relict amphibole cores and new overgrowths. At least in the case of an amphibolite from the NW basal part of the Askore Amphibolite located just above the Main Mantle Thrust, a discordant age spectrum can be quantitatively interpreted using isotope correlations supplemented by petrographic observations and microprobe analyses. The cores retained their Ar during a 600-650°C amphibolite facies overprint. In the Shyok Suture Zone, amphibole ages are much younger, between 9 and 14 Ma. The young radiometric ages are thought to be associated with new amphibole formation along the foot-wall of the Main Karakorum Thrust.

Three biotite ages from the Shyok Suture Zone range between 6 and 8 Ma, similar to that from the NW part of the Askore Amphibolite, while two biotites from the Askore Amphibolite further SE give ages around 35 Ma, very close to the coexisting hornblendes. Biotites from the "Layered Sequence" of the Nanga Parbat-Haramosh Massif contain excess Ar, as shown by comparing $3\text{yAr}/4\text{Ar}$ biotite ages (15 and 27 Ma) with muscovite $3\text{Ar}/4\text{Ar}$ ages (10-12 Ma) and a two-point biotite-plagioclase Rb/Sr age of 5.6 Ma. The Rb/Sr age may point to open-system fluid circulation and/or to Sr inheritance in plagioclase. The muscovites probably date the initial stages of the still-continuing formation of the Nanga Parbat-Haramosh Massif antiform.

The Askore Amphibolite underwent amphibolite metamorphism before 35-40 Ma, followed by rapid exhumation. The Karakorum Metamorphic Complex was thrust over the Shyok Suture Zone between 10-15 Ma, thermally overprinting it. One Askore Amphibolite sample from the basal part of the Ladakh Terrain records a Late Miocene thermal overprint related to the young high-grade metamorphism and penetrative deformation affecting the "Layered Unit" of the Nanga Parbat-Haramosh Massif.

Key words: Metamorphism, tectonic evolution, Ladakh, Himalaya.

V/28. Villa, I.M., Tonarini, S., Oberli, F., Meier, M., Spencer, D.A., Pognante, U. & Ramsay, J.G., 1992. Eocene age of eclogite metamorphism in Pakistan Himalaya. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 94.

High-pressure rocks with an eclogitic assemblage (omphacite-garnet-quartz-rutile) from the Himalaya were first described by Spencer et al. and Pognante & Spencer. A geochronological investigation on two eclogites using the Sm/Nd, Rb/Sr, U/Pb and Ar/Ar methods is presented here. We obtained ages of 49 ± 6 (Sm/Nd on garnet-clinopyroxene pair), 43 ± 1 (Rb/Sr on phengite-clinopyroxene pair), 40 ± 1 (U/Pb on rutile), 91 ± 5 and 82 ± 1 Ma (Ar/Ar isochron on hornblende and plateau on phengite, respectively). The Sm/Nd isotopic system was fully equilibrated during eclogitization and not disturbed since; its mineral ages may date the peak metamorphic conditions ($650\pm 50^\circ\text{C}$ at 13-18 kbar). The Ar/Ar ages indicate that high-pressure minerals may give statistically acceptable but geologically meaningless numerical results. The other three mineral chronometres agree with the post-Cretaceous age proposed on paleomagnetic grounds by Klootwijk et al, for the collision between the Indian and Asian plates. The collision, subduction and the eclogitic metamorphic peak was already completed in the NW Himalaya by 50 Ma, although not in the Central and Eastern Himalaya before this time.

Key words: Eclogites, High-P metamorphism, Eocene, Kaghan, Himalaya.

V/29. Villa, I.M., Zanchi, A. & Gaetani, M., 2001. Rb-Sr dating of the Tirich Mir pluton, NW Pakistan: pre-140 Ma accretion of the Karakoram terrane to the Asian margin. *Journal of Asian Earth Sciences* 19, p.72.

Key words: Rb-Sr dating, plate collision, Tirich Mir pluton.

V/30. Vinassa De Regny, P., 1932. Hydrozoen und korallen aus der ob. Trias des Karakorum. *Wissenschaftliche Ergebnisse der Dr. Trinkler'schen Zentralasien-Expedition*, 2, 192-196. Reimer, Berlin.

Key words: Hydroids, corals, Triassic, Karakoram.

V/31. Vince, K.J. & Treloar, P.J., 1993. Late-stage extension along the Main Mantle Thrust (Pakistan, Himalaya): New field and microstructural evidence. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, p.81.

Recent geochronological work on metamorphic rocks from the Besham area of North Pakistan has yielded evidence of re-activation of the Main Mantle Thrust as a zone of late-stage crustal extension. This has been accommodated in the footwall and hangingwall by displacement along a set of E-W striking normal faults. This trend is roughly parallel to that of the Main Mantle Thrust. Local variations in strike occur as a result of folding of the Main Mantle Thrust into a minor syntaxis around the Besham region. The E-W trending normal faults cut across all the earlier ductile and brittle structures produced by south-verging deformation and are therefore late-stage.

E-W trending south-dipping normal faults in the Indian Plate rocks of the Main Mantle Thrust footwall exhibit topside to the south movement. Extensional fabrics displace the northerly dipping ductile shear fabric of the footwall rocks that were formed as a result of the collision between the Indian plate and Kohistan Island arc although, on a smaller scale, some extension was accommodated by brittle re-activation along fabric surfaces. These can be interpreted either as Riedel shears associated with the earlier south-verging thrusts or, surfaces along which extensional collapse of the entire metamorphic pile occurred. Riedel shears are also associated with a few of the E-W trending faults.

The Kohistan Island arc forms the hangingwall of the Main Mantle Thrust. E-W trending normal faults occurring in the ultramafic rocks can be divided into two groups according to their movement: topside to the south, similar to the footwall and topside to the north. The latter are developed parallel or sub-parallel to the shear fabric of the hangingwall rocks. This is not as well developed as the fabric of the footwall sequence but implies clear north-verging extension. Many minor extensional faults are associated with the larger scale faults in the Kohistan ultramafics.

A second set of normal faults, striking N-S, are associated with the late deformation which folded the Main Mantle Thrust into a minor syntaxis producing an antiform in the Besham region. This east-west directed extension was more pronounced in the hangingwall of the Main Mantle Thrust than in the footwall and is attributed to outer-arc extension of the developing fold.

Key words: Geochronology, microstructure, extension, MMT, Besham.

V/32. Vince, K.J. & Treloar, P.J., 1995. Early-Miocene-aged northward extension along The Main Mantle Thrust, Northwest Himalaya, Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

During the early stages of the Himalayan orogeny rocks of the Kohistan Island Arc were thrust southwards onto the Indian Plate along the Main Mantle Thrust (MMT), a northerly-dipping south-vergent crustal-scale fault zone. As a result, the cover sediments of the Indian Plate were decoupled from the lower-to middle-crustal basement and imbricated along large-scale thrusts. Crustal thickening of the decoupled Indian basement occurred beneath Kohistan by means of internal imbrication, ductile shearing and recumbent folding producing considerable thicknesses of blastomylonites (Treloar et al., 1989). Later thrusts re-imbricated cover and basement rocks and led to further thickening of the Indian Plate as the south-vergent thrusting of Kohistan over the Indian Plate continued. During the phase of thrusting the basement gneisses and granitic lithologies of the Indian Plate developed a strong south-vergent S-C fabric, and were mylonitised in zones of very high shear strains.

However, the presence of high-grade metamorphic rocks on the footwall and low-grade rocks on the hangingwall of the MMT suggests that the crustal-scale fault was later reactivated as a zone of extension. For instance, to the west of the Indus River kyanite-bearing rocks of the Swat Nappe in the footwall of the MMT are in structural contact with blueschist and greenschist facies rocks of the melange sequence (Treloar et al., 1991). To the east of the Indus chlorite-rich metasediments of the Banna Nappe structurally overlie sillimanite grade gneiss at the top of the Hazara Nappe.

Field investigations have illustrated that the mylonitic gneisses and granitic rocks of the Indian Plate immediately below the MMT contain abundant northerly-dipping C' shear surfaces (Platt & Vissers, 1980; Cobbold et al., 1971; Cosgrove, 1976). These ductile shear structures extensionally displace all the earlier south-vergent S-C fabrics in a top-to-the-north sense within the upper 30m of the MMT footwall. However, with increasing depth below the MMT the abundance of the extensional shears decreases rapidly over a relatively narrow zone.

At depths greater than 30m beneath the fault the late-stage deformation is accommodated along brittle transposed mylonitic fabric surfaces which carry N-S trending slicken fibres. Extension fractures and large E-W trending, north-dipping normal faults become progressively more dominant with increasing distance into the footwall of the MMT. However, no evidence for the extensional deformation is observed at depths > 400m beneath the MMT. This indicates either that the late-stage extension was partitioned into a very narrow zone immediately below the fault or, that the zone of ductile shearing was initially much thicker but has since been thinned or cut-out by the later brittle faulting. This is consistent with crustal extension during the transition from ductile to brittle deformation processes, as the ductile extension progressively thinned the crust it allowed cooling to take place which eventually led to brittle extension.

Metamorphic discontinuities also exist within the Indian Plate itself. The north-dipping Banna Shear juxtaposes the low-grade Banna Formation metasediments at the base of the Banna Nappe against the high-grade Mansehra Granite gneiss at the top of the Hazara Nappe. The topside-to-the-north extension has been accommodated along dominantly ductile C' shear surfaces within the gneissic footwall of the fault. As observed within the granitic rocks immediately below the MMT the majority of the northerly-dipping north-vergent ductile extensional shears are concentrated within the top 30-40m of the footwall but are sparse at greater depths.

The north-verging extensional displacements have been accommodated within the low-grade hangingwall of the Banna Shear along north-vergent fold and thrust structures and small-scale conjugate sets of north- and south-dipping normal faults. With increasing distance from the shear zone the extensional structures become progressively more brittle.

Field and laboratory evidence suggests that the Banna Shear either developed contemporaneously with the north-vergent deformation along the MMT or represents the extensional reactivation of a southerly-dipping backthrust which originally thrust low-grade metasediments northwards in association with a phase of brittle imbrication within the Indian Plate. However, there are no late-stage north-vergent structures within the low-grade metasediments which outcrop in the root zone of the proposed backthrust to support the former origin for the Banna Shear.

Microstructural and geochemical investigations have shown that the late-stage ductile C' shears within the footwall rocks of both metamorphic discontinuities developed in association with the retrograde shearing of muscovite and biotite mica during a phase of north-vergent normal displacements. As a result the extensional shears are defined by very fine-grained cataclastic biotites and the growth of new biotite and chlorite. Quartz has undergone dominantly ductile deformation within the granitic and gneissic lithologies. Mica 'fish' show ductile shearing into the C' surfaces at the onset of extension and water brittle fracturing as the deformation continued. Feldspar porphyroclasts underwent dominantly brittle deformation with the formation of sheared and rotated domino fault blocks, which dip to the south. Core and mantle textures around plagioclase porphyroclasts show a lower Anorthite (An) content within the recrystallized mantle, suggesting a retrograde metamorphic event.

On the basis of field criteria, reaction products and microstructural observation, it is likely that late-stage north-vergent extension along the MMT operated under conditions characteristic of greenschist facies metamorphism. Differences in fission track ages exist across the MMT between the footwall and hanging wall rocks. The zircon blocking temperature is recorded as 45Ma in Kohistan and only 20Ma in the Indian Plate. However, the lower temperature apatite ages of 19-16Ma (Zeitler, 1985) contour at the same structural level across the fault. This suggests that the phase of northward extension along the MMT was early Miocene in age, synchronous with north-vergent extension within the main Himalayan chain, where it is believed to have been driven by uplift along the Main Central Thrust (MCT). There is no obvious MCT analogue within the Pakistan Himalaya, The question thus arises as to whether late orogenic extension is a function solely of relatively shallow level thrusting or a result of isostatic adjustment following over thickening of the deep crust.

Key words: Orogeny, tectonics, Eocene, Kohistan island arc, MMT, Himalaya.

V/33. Vince, K.J. & Treloar, P.J., 1996. Miocene, north-vergent extensional displacements along the Main Mantle Thrust, NW Himalaya, Pakistan. *Journal of the Geological Society of London* 153, 677-680.

Structural data from N Pakistan show that early Tertiary, S-vergent structures within the upper part of the Indian Plate and the Himalayan suture zone were overprinted by regionally developed N-vergent extensional structures. Such extension has been suggested, but not previously described from the NW Himalaya. Cooling histories suggest extension was Miocene in age. Extension was most likely the result of isostatic rebound resultant from crustal, or lithospheric, thickening and/or delamination.

Key words: Tectonics, MMT, Miocene, Himalaya.

V/34. Viridi, N.S., 1981. Presence of parallel metamorphic belts in northwest Himalaya - Discussion. *Tectonophysics* 72, 141-146.

Kumar (1978) has recently described two belts of metamorphics from the northwestern Himalaya on the basis of the low pressure-high temperature and high pressure-low to high temperature mineral assemblages. Of the two belts, the southern corresponds to the Central Crystallines while the northern consists of Puga and Sumdo formations. Further it has been suggested (op. cit., p. 126) that the two belts together constitute a pair similar to those observed in California, Japan and Taiwan. Kumar also is not clear in his views on the nature of the Indus Suture Zone. Though firstly (op. cit., p. 122) he regards it as "nothing but a deep mantle-reaching fault" represented by a zone of ophiolites, later, however (p. 130), he describes it as marking the trench at the continental margin along which ocean bed was dragged down, in other words a subduction zone. This "suture" or "deep seated fault" is supposed to separate the Himalaya proper from Tibeto-Karakorum Range of "altogether different geological province". It may be pointed out here that Crawford (1974) was the first to have suggested the Indus Suture to be a deep mantle-reaching fault and not a subduction zone; Kumar, however, has not referred to this work. Geological investigations by the author and others both in Ladakh, Karakorum and the Central Crystallines have shown that the ideas presented in the paper are highly inconsistent with the actual geological set up in the region and the various models proposed to account for the geo-tectonic evolution of the Himalaya (Shankar et al., 1976; Gansser, 1977; Viridi et al., 1977; Viridi, 1980; and Frank et al., 1977). Also the Indus Suture does not separate the Karakorum from the Himalaya but, as will be discussed, it forms an important link between the two.

Key words: Metamorphic belts, Himalaya.

V/35. Viridi, N.S., 1979. On the geodynamic significance of mega lineaments in outer and lesser regions of western Himalaya. *Himalayan Geology* 9, 79-99.

Two types of mega-lineaments one trending NW-SE and conforming to the Himalayan strike and the other transverse to it are observed on the Landsat imagery of the Outer and Lesser regions of the western Himalaya. A majority of these lineaments coincide with known thrusts and faults while the others have exercised a profound control on the topographic features in the area through which they traverse. The NW-SE trending linear have also controlled the limits of sedimentary basins and exercised influence on intensity of deformation during and after the sedimentation. The transverse linears have rotated or dislocated the longitudinal linears and they can be traced southwards through the piedmont zone and probably coincide with deep-seated faults in the basement under the alluvial cover.

Key words: Geodynamics, lineaments, Himalaya.

V/36. Viridi, N.S., 1987. Metamorphic belts in the Indus-Kohistan suture zone and its surroundings: Evolution in space and time. In: Sychanthavong, S.P.H. (ed.), *Crustal Evolution and Orogeny*, 221-248.

The western segment of the Indus-Tsangpo suture zone in Kohistan and Ladakh and the southern margin of the Karakorum exhibits three important metamorphic belts which are more or less continuously traceable from west to east. The northernmost belt, the Pongong-Baltit metamorphic belt forms the basement of the Karakorum and contains older rocks metamorphosed and intruded by granitic batholiths. The regional metamorphism (M₁), probably Late Jurassic to Early Cretaceous, was superimposed by contact metamorphism (M₂) during the Late Cretaceous. Younger events related to the collision of the Indian and the Tibetan plate during the Eocene also affected these rocks, resulting in widespread thrusting and retrogression. The Gilgit-Shyok belt lying farther south consists of metamorphosed sediments, volcanics and tuffs formed in a magmatic arc and the back-arc basin north of the Kohistan-Ladakh magmatic arc. The metamorphism is of the low to medium pressure-medium to high temperature type and varies in intensity from greenschist to amphibolite in Ladakh and from greenschist through amphibolite to pyroxene granulite facies in Kohistan. The prevailing geothermal gradients are high, varying from 30" to 37"C/km and the grade increases due south towards the magmatic arc. South of the magmatic arc in Ladakh, a belt of fore- arc flysch occurs between the Gilgit-Shyok and the Indus-Kohistan belts. However, northwest of Dras in the Deosai and Nanga Parbat regions, the two belts occur in close juxtaposition. The high pressure belt consists of blueschists in Ladakh and blueschists and garnet-granulites in Kohistan. These have been derived from the ophiolitic

melange and the ultrabasic-rocks under high pressure-low temperature to high pressure-high temperature conditions with low geothermal gradients (15° - $18^{\circ}\text{C}/\text{km}$). The high-pressure and low-pressure belts constitute paired metamorphic belts that developed in a Pacific type subduction zone at the southern margin of Tibet during the Cretaceous. A two-stage model for the evolution of these metamorphic belts is proposed.

Key words: Metamorphic belts, Indus-Kohistan Suture zone, Karakoram.

V/37. Viridi, N.S., 1981. Geotectonic evolution of the Indus Suture zone. In: Sinha, A.K. (ed), Contemporary Geoscientific Researchs in Himalayas I, Tectonics, Regional Geology and Biostratigraphy, 131-136.

Key words: Geotectonics, Indus Suture Zone, Himalaya.

V/38. Viridi, N.S., 1992. Cretaceous marginal basins of the Indus-Kohistan collision zone, development and evolution, 157-168. In: A.K. Sinha (ed.), Himalayan orogen and global tectonics. Oxford and IBH, New Delhi.

Key words: Collision, Cretaceous, Indus-Kohistan, Himalaya.

V/39. Visser-Hooft, J., 1926. Among the Karakoram glaciers in 1925. Edward Arnold: London.

Key words: Glaciers, Karakoram.

V/40. Visser, C.F. & Johnson, G.D., 1978. Tectonic control of late Pliocene molasse sedimentation in a portion of the Jhelum Re-entrant, Pakistan. Geol. Rundschau, 67, 15-67.

Several studies have related the cyclic aspect of the sandstone-mudstone repetition in the Siwaliks to complex stream systems. A genetic relationship has been demonstrated between these fluvial cycles and aggrading stream systems of varying sinuosity. The paper covers the flood plain stratigraphy in the Upper Siwaliks of the Potwar. The Markov chain analysis is applied to a portion of the stratigraphy at the Gauss/Maruyama polarity transition in a number of places in the area. From this they derived the principal deposition facies in a region of contemporaneous gluvial deposition. The rocks may have formed in a frequently flooded, sedimentation-dominant flood plain environment. Deep pedogenic overprinting may have occurred much later than the active migration of the stream course.

Key words: Tectonics, sedimentology, Pliocene, Siwaliks molasse, Jhelum.

V/41. Visser, P.C., 1928. Von den Gletschern am Obersten Indus. Zeitschrift fur Gletscharkunde, 16, 169-229.

Key words: Glaciers, Indus.

V/42. Visser, P.C., 1932. Gletcheruberschiebungen im Nubra und Shyok- Gebeit des Karakorums. Zeitschrift fur Gletscharkunde, 20, 29-44.

Key words: Glaciers, Shyok, Karakoram.

V/43. Visser, P.C., 1934. The Karakoram and Turkestan Expeditions of 1929-30. Geographical Journal 84, p821.

Difficult though it may be to give in a limited space an account of an expedition which took more than one and a half year and which not only had a geographical aim, but at the same time had in view the investigation of geological, glaciological, zoological, botanical, and meteorological problems, I will nevertheless try to give in a

narrow compass a synopsis of our third expedition to the mountains of central Asia. This time our object was first of all to explore the as yet unknown regions of the Karakoram and Salto-Karakoram (formerly known as Kailas-Karakoram) lying in the upper course of the Shyok and Nubra rivers. In this part of the Karakoram, which differs entirely from that which we visited in 1925 in Hunza, it looks as if Nature had tried not to compress the greatest possible number of mountain ranges into the smallest possible space, as is the case in Hunza, but just to model them on a wider base, thereby leaving space between the mountains and ranges, as if to show them better. Whoever has admired a Jungfrau or Bernina, a Mont Blanc or Breithorn, will be able to understand that Matterhorns are not always required to make a landscape charming and impressive. In the Salto-Karakoram we found however almost perpendicular granite walls among the highest in the world, and we found mountains which need yield to none as regards beauty and majesty.

Our programme further included the exploration of the tableland, at that time still unmapped, which is situated to the east of the Karakoram Pass and the regions of the Kunlun, which confine it on the north; also observations on the borderlands of the Taklamakan desert. Not only did we intend to map out as carefully as possible the mountains which we had chosen for exploration, but also to *try* to find out something more about the connection of the Karakoram and Aghil mountain ranges and their continuation eastwards.

Key words: Geology, geography, glaciology, zoology, Karakoram, Turkestan.

V/44. Visser, P.C., 1935. Glet cheruberbeobachtungen im Karakorum. Zeitschrift für Gletscharkunde, 22, 22–45.

Key words: Glaciers, Karakoram.

V/45. Visser, P.C. & Visser-Hooft, J. (Eds.), 1935-1940. Karakorum Wissenschaftliche Ergebnisse der Niederländischen Expedition in den Karakoram und die Angrenzenden Gebiete in den Jahren 1922, 1925, 1929-1939, und 1935. E.J. Brill: Leiden. 1938, Volume 2, Glaziologie; 1940, Volume 3, Geologie, Paläontologie und Petrographie.

Key words: Geology, glaciology, palaeontology, petrography, Netherlands Expedition, Karakoram.

V/46. Viterbo, C. & Zanettin, B., 1959a. Caratteri petrografici e chimismo della massa gneissica granitoide affiorante fra Skyo e valle dell Tormik (Karakorum occidentale). Rendiconti della Società Mineralogica Italiana 15, 283-309.

Describes the petrographic characteristics and geochemistry of granitic gneisses of the Skyo and Nubra area.

Key words: Petrography, geochemistry, granitoid, Karakoram.

V/47. Viterbo, C. & Zanettin, B., 1959b. I filoni lamprofirici dell'alto Baltoro (Karakorum). Memorie dell'Accademia Patavina dei Scienze, Lettere ed Arti 71, 1958-1959, 3-39. Padova.

The Baltoro area is essentially occupied by granitic rocks. This paper describes lamprophyric dykes within the area.

Key words: Lamprophyre, Baltoro, Karakoram

V/48. Vogeltanz, R., 1968. Ein seltenes Fossil aus dem Hindukusch. Der Deutscher Alpenverein, Bd. 93, 159–160.

This account gives details about a rare fossil in Hindukush area.

Key words: Palaeontology, fossils, Hindukush.

V/49. Vogeltanz, R., 1970. Receptaculites neptuni (Defrance) from Devonian of Owir An, Chitral, West Pakistan. Record of Geological Survey of Pakistan, Quetta, 19, 4p.

Key words: Palaeontology, Devonian, Chitral, Hindukush.

V/50. Vogeltanz, R., & Diemberger–Sironi, M.A., 1969. Receptaculites Neptuni Defrance aus dem Devon des Hindukusch. Österreichische Akademie der Wissenschaften, mathematisch–naturwissenschaftliche Klasse, Anzeiger, Bd. 105, 100–101.

Key words: Palaeontology, Devonian, Chitral, Hindukush.

V/51. Vokes, H.E., 1935. Unionidae of the Siwalik Series. Connecticut Academy of Arts and Sciences, Memoirs, 9, 37-48.

Key words: Unionidae, Siwaliks.

V/52. Vokes, H.E., 1936. Siwalik Unionidae from the collection of the Second Yale North-Indian Expedition. Geological, Mining and metallurgical Society of India, Quarterly Journals, 8, 133-141.

Key words: Unionidae, Siwaliks.

V/53. Voillot, P., 1994. Der wilde weg zu den aquamarinen. Lapis 19(11), 38-45.

Key words: Gems, aquamarine.

V/54. Völk, H., 1999. Deep-seated mass rock creep along the Karakoram Highway in the middle Indus valley near Chilas, Northern Pakistan, with special focus on the interaction between erosion, valley fill and mass movements. Terra Nostra 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 164-165.

Unexpected sudden landslides along the Karakoram Highway (KKH) are a common and feared phenomenon, but the causes have scarcely been related to processes of persistent rock creep, which are to be presented here. Mass rock creep in motion cannot be experienced by direct observation because of being an extremely slow type of mass movement; the rate of velocity measures only app. < 1-10 mm/a. However the results of these extremely slow rock movements morphologically conspicuous and important from the point of view of engineering geology, especially along glacially eroded valley flanks. It is the change in geotechnical properties, which is linked with rock creep and impairs the stability of valley slopes (Selby 1985; Chigira, 1992; Cruden & Varnes, 1996). Geologically speaking the mountainous region of Chilas is made up of mafic-ultramafic plutonites of a former oceanic island arc, which have entered the geological literature as Chilas Complex of the Sub-Kohistan Arc in the Karakoram (Kazmi & Jan, 1997; Searle & Asif Khan, 1998). Although the Indus valley bottom at Chilas (Middle Indus) only lies at 1030 m asl this trunk valley course of the Indus was glaciated, too, as well as filled up by sediments and deeply eroded several times (Shroder et al., 1993).

Through the enormous incision of both glacier and river processes, which have to compensate for the amazing uplift of the high mountain chains of the Karakoram and the adjacent Nanga Parbat Massive, a deep trough valley with high and steep valley flanks came into being. Mass rock creep in the sense of deep-seated gravitational slope movement (down to 300 m) accompanied by opening of joints, fracturing and dilation, can be observed especially on those places where the Indus river has exposed or undercut the rock flank by recent or subrecent entrenchment. The fluvial disposal of Quaternary valley fill, such as till, gravel, lake deposits etc., deprives the valley slopes on the stoss sides of the river from their support at the footwall. As a consequence the rock walls are progressively failing and exhibiting various phenomena of collapse structures sometimes even reaching the mountain tops and ridges, adjacent to the valley. In the course of our study on mass rock creep in the region of Chilas, app. 8 km up- and downstream of this village, we can distinguish mainly two modes of slope failure:

Plane failures, consisting of several massive rock sheets (slabs) sliding into each other, indicating listric bending of shear planes in the distal part near the slope foot, representing a primary system, resulting in concave slopes.

Toppling failures, consisting of numerous plate-like rock segments near the distal margin of plane rock sheets, representing a secondary system superimposed on the plane failure system (1), resulting in convex slopes. Most geotechnically active joints along which plane failures occur, correspond in position with the regional "layering" of the meta-gabbros dipping towards NE, whereas joints of toppling type steeply dip in the opposite direction (SW) since they are frequently symmetric to the first ones and therefore show the same strike direction. Depending on the respective shear stress in the valley flanks other potentially active joints might also appear enabling the slope to attain general mobility.

Results

The geomorphological result of deep-seated rock creep is a prograding slope foot, thus a narrowing of the valley bottom. Conspicuous fracturing of rocks and opening of joints in outcrops along the KKH must be ascribed to mass rock creep rather than to tectonics. The conclusion must be that probably all events of rockfall are caused and controlled by mass rock creep on the valley flanks. This is particularly important for engineering work along the KKH.

Key words: Deep-seated rocks, geomorphology, Indus valley, KKH.

V/55. Volk, H.R., 2000. Deep-seated mass rock creep along the Karakoram Highway and its geomorphological consequences in the middle Indus valley near Chilas, Northern Pakistan. Geological Bulletin, University of Peshawar 33, 11-27.

Unexpected sudden landslides along the Karakoram Highway (KKH) are a common and feared phenomenon, but the causes have scarcely been related to processes of persistent rock creep, which are to be presented here. Mass rock creep in motion cannot be experienced by direct observation because of being an extremely slow type of mass movement; the rate of velocity measures only - 1-10 mm/a. However the results of these extremely slow rock movements are morphologically conspicuous and important from the point of view of engineering geology, especially along glacially eroded valley flanks as in the case of the Indus valley course in question. Mass rock creep in the sense of deep-seated gravitational slope movement produces irregular slope profiles with trenches accompanied by opening of joints, fracturing and dilation. As a consequence the rock walls are progressively failing and exhibiting various phenomena of collapse structures sometimes even reaching the mountain tops and ridges, adjacent to the valley. In the course of our study on mass rock creep in the region of Chilas, - 8 km up- and downstream of this village, we can distinguish mainly two modes of slope deformation.

1. Toppling movements, consisting of numerous book-like rock segments on the upper slope, rotating out of the slope, representing a primary system, resulting in convex slopes, sections through bulging.
2. Sliding movements, consisting of several massive rock (slabs) slowly gliding downwards upon each other, showing secondary listric bending of shear planes in the distal part near the slope foot, representing a secondary system, resulting in concave slopes. Geologically speaking the mountainous region of Chilas is made up of mafic ultramafic plutonites of a former oceanic island arc, which have entered the geological literature as Chilas Complex of the Kohistan Arc in the Karakoram.

Key words: Deep-seated rocks, geomorphology, Indus valley, KKH.

V/56. Voskresenskiy, I.A., Kravchenko, K.N., Movshovich, E.B. & Sokolov, B.A., 1971. An outline of the geology of Pakistan (in Russian). Nedra, Moscow, 168p. 6 tabs., 61 figs.

Key words: Geology.

V/57. Voskresenskiy, I.A., Kravchenko, K.N. & Sokolov, B.A., 1965. Tectonic subdivision of West Pakistan. 17th All Pakistan Science Conference, Karachi.

This is a brief of the tectonic subdivisions of Pakistan describing the major faults and plates of the country.

Key words: Tectonics.

V/58. Voskresenskiy, I.A., Kravchenko, K.N. & Sokolov, B.A., 1968. The tectonics of West Pakistan. *Geotectonics* 2(2), 93-99.

Key words: MCT, structure, Miocene, Himalaya.

V/59. Vredenburg, E.W., 1907. Note on the distribution of genera *Orthophragmina* and *Lepidocyclina* in the Nummulitic series of Indian Empire. *Geological Survey of India, Records* 35(1), 62-67.

Key words: Palaeontology, India.

V/60. Vredenburg, E.W., 1908. The Cretaceous Orbitoides of India. *Geological Survey of India, Records* 36, 171-213.

Key words: Palaeontology, orbitoids, Cretaceous, India.

V/61. Vredenburg, E.W., 1923. Indian Tertiary gastropoda; No5, fusidae, turbinellidae, chrysodomidae, strepturidae, buccinae, nassidae, collumbellidae, with short diagnoses of new species. *Geological Survey of India, Records* 55(1), 52-77.

Key words: Palaeontology, gastropods, Tertiary.

V/62. Vredenburg, E.W., 1925a. Description of mollusca from Post-Eocene Tertiary formations of Northwestern India; cephalopoda, opisthobranchia, siphonostomatoida. *Geological Survey of India, Memoir* 50(1), 1-350.

Key words: Palaeontology, Eocene, Tertiary formations, India.

V/63. Vredenburg, E.W., 1925b. Description of mollusca from Post-Eocene Tertiary Formations of north-western India; gastropoda (in part) and lamellibranchiate. *Geological Survey of India, Memoir* 50(2), 351-506.

Key words: Palaeontology, Eocene, Tertiary formations, India.

V/64. Vyvyan, M., 1939. A Journey in the Western Karakorum. *Alpine Journal*, 51, 231-242.

The author has passed through the Himalaya and Karakorum. This is his findings during the journey. As this is a travelogue with no abstract. Thus the first few pages from the article are presented here.

The present conventions of Himalayan travel, which is now perhaps in its classic period, somewhat resemble those of Alpine travel in its corresponding stage nearly a century ago. In each case it is usual to explain, if not to justify, being among high mountains by some accomplishment in the way either of practical mountaineering or geographical or scientific investigation, but the subsequent development of Alpine mountaineering inclines one to the belief that these purposes and accomplishments are rather the mould or pattern of mountain experience than the essence of it. This belief is, at any rate, the excuse for the present paper describing a short journey in the western Karakoram last year which has no accomplishments to its credit. Indeed, to return to my comparison, this account will probably read to students of serious Himalayan undertakings much as some 'Narrative of an Excursion to the Aar Glacier' did three quarters of a century ago to those following in contemporary Alpine literature the progress of attempts on the Matterhorn and the triangulations of Adams Reilly.

The plan with which Campbell Secord and I started from England for Gilgit in the first days of June 1938 was to explore the upper basin of the Kunyang Glacier, the first large northern tributary met in ascending the Hispar, and

from it to make, if possible, a pass across the western end of the main Karakoram as the range at this point is sometimes regarded. The outskirts of the western Karakoram are perhaps more familiar to travelers than any other part of the Himalaya, for here roads and settled valleys probably reach nearer than elsewhere in the world to very great mountains. The main range is cut by the Hunza valley and the famous Gilgit road between Kashmir and Sinkiang which follows the river, while its southern fork terminates in the knot of Rakaposhi where the Hunza bends to the S. But although the approaches to these mountains have been frequently visited since Conway's great traverse of the Hispar and Baltoro in 1892, not only his work but that of later high-level explorers such as the W orkmans and the Vissers seems to have been continually hampered by bad weather. - For this reason, mainly, the Kunyang Glacier, dominated by Disteghil Sar (25,868 ft.) and Pumarikish (or Kunjut No. 2, 24,580 ft.) had not been penetrated far enough for the latter mountain to be seen, and the attraction of these recesses led Campbell Secord and myself to follow Colonel Mason's recommendation to visit it. If in exploring the upper basin we could find a col leading to the Malangutti or Yazghil Glaciers, this might be the route between the Hispar and Shimshal valleys which has been reputed to exist among local inhabitants on each side of the range. As it turned out, the party which did reach the northern end of the glacier was not adequate for summit ridge climbing nor equipped for proper surveying. This was the more unfortunate in that the weather was more continually flawless during my brief journeys than I have ever heard of it being among such great mountains; the benevolence of the skies seemed to be a contemptuous gift considering their treatment of our more competent predecessors.

Secord and I came up from Abbottabad in the N.W. Frontier Province via Chilas, a route which is more rapid but gives a longer stretch of the desert Indus valley than the more alpine Kashmir road. Neither of us had been to the Himalaya before and our first sight of great mountains was therefore one of our summer's more important happenings. It fell to us on entering the Indus valley; they were far away to the W. in unadministered tribal territory and looked like broken blue stones. Not till a few days later did 've see high mountains in full white panoply and then there was suddenly the stupendous mass of Nanga Parbat, complicated and alone to the S., and Haramosh and a slice of Rakaposhi (25,550 ft.) to the N. It was this very first revelation of Himalayan decolletes that distracted us from our serious purposes. Looking at them as we lay among long grass in one of the little carpet-like oases that are spread at intervals on the desert shelf above the Indus and its tributaries, we reflected that Kunyang was at least a week of sandy marches further away than the foot of Rakaposhi, and that our feet longed for the more familiar accidents of rock and snow, so 've resolved on a temporary defection. Shortly after we reached Gilgit, therefore, we left on a flying visit to the base of Rakaposhi in order to prospect its N.W. ridge which no one seemed to have approached before, but which looked promising from some R.A.F. photographs in our possession. Crossing the browri surf of the Hunza in a native ferry of inflated skins, whose rowers showed great skill and power, was the only sensational part of this preliminary journey, and then we had one of the most unusual pleasures of mountain travel that of gaining height unexpectedly at the end of the same day. After we had marched through sand which scorches even local porters' feet in the heat of the day, our path wound some 600 ft. up a precipitous gully in what we thought was merely a detour to avoid a cliff jutting out into the river, but reaching the top we found there was no descent. We were in a luscious green alp in the Jaglot valley which we had been making for, and whose main exit seems to be a fairly sheer drop over a cliff which only the Jaglot stream passes on its way to join the Hunza. We camped above Jaglot and the next day we reached the base of our ridge at some 12,500 ft.; we found it at least worth trying and were well on our way down the Hunza valley by nightfall. In fact we were back in Gilgit in 2-1/2 days after leaving it, having covered about 50 miles and, up and down, some 16,000 ft. in that time, travelling alone with packs and two walking ponies for some of the way.

Key words: Karakoram.

W/1. Waagen, W., 1872. Rough section showing the relations of the rocks near Murree (Mari), Punjab. Geological Survey of India, Records 5(1), 15-18.

This note gives a brief description of nummulitic limestone with some shales overlain by reddish sandstone and slates. Presence of main faults is also mentioned. Describe section from Khera Gali to Murree.

Key words: Limestone, shale, sandstone, Murree.

W/2. Waagen, W., 1879. Note on the Attock Slates and their probable geological position. Records of the Geological Survey of India 12(4), 183-185.

The first page of the article: In the "Records of the Geological Survey of India, Vol. XII, pt. 2, there is a paper by Mr. Wynne, entitled "Further notes on the geology of the Upper Punjab," which bears a special interest on account of the general views on the geology of that country. As many of the points treated of in the paper are yet to be considered as open questions, it seems not advisable to pronounce any opinion on them until further materials have been collected, but it may not be useless to notice some points which might be of value towards the elucidation of the questions discussed by Mr. Wynne.

There is before all the age of the "Attock slates." Mr. Wynne is quite right when he considers the evidence upon which the opinion of their being of Silurian age is founded very scanty indeed; and only the absence of any other clue towards the determination of the age of those slates could at the time justify the opinion expressed in our joint memoir on Mount Sirban, that the occurrence of lower Silurian fossils in gravels in the Kabul river, which lay approximately in the strike of the "Attock slates," would make a Silurian age probable also for the latter.

It is very much to be regretted that to the careful search of Mr. Wynne the slates have proved absolutely unfossiliferous up to the present. Yet this sterility in fossils seems not to prevail at all localities. Among the materials which have been most liberally sent to me by the Geological Society of London, there are about a dozen specimens of a *Spirifer*, which bear, however, only the label "Punjab." These specimens are preserved in a black slate, which, if the specimens came really from the Punjab, "and there is no reason why this should be doubted," must have belonged to the Attock slates, as there is no other rock known to me in that part of India which would bear similar petrographical characters, and from which the specimens could have come.

Though these fossils are more or less deformed by oblique pressure, yet the species can without difficulty be determined. All the specimens belong to one and the same species, and cannot be distinguished from *Spirifer keilhavi*, Buch., (8p. Bajah, Salt.). As this species is one of those most characteristic of the carboniferous formation in the Himalaya, and as thus the determination of the age of the rocks from which these fossils came considerably differs from the age hitherto attributed to the Attock slates, it is necessary to be doubly cautious in accepting the current opinion regarding these slates.

The rock in which the fossils are preserved is, as stated above, a black, not very hard slate, such as I have seen to occur at many places in the Attock slates; but there are also outside of the Punjab some localities where similar slates occur. I have myself seen similar slates from the Milam pass which seem also to belong to the carboniferous formation, and seem to be there inferior to white limestones, also full of carboniferous fossils, the latter, however, of a much more recent type. Similar slates have been described by Lydekker from Eishmakam. in Kashmir, whilst at other places in the same territory the carboniferous formation is composed nearly entirely of thick limestones. The slates of Eishmakam have been compared by Lydekker to the "Kiol group" and the limestones to the "Great limestone" of the outer Himalaya. Thus it might be very possible that in the Himalaya the carboniferous formation should present two sub-divisions, one older slaty, and one younger calcareous sub-division. This, however, does not prevent that at many localities the whole formation might be made up of massive limestones.

Key words: Limestone, petrography, palaeontology, stratigraphy, Attock slates.

W/3. Waagen, W., 1884. Section along the Indus from the Peshawar valley to the Salt Range. Records of the Geological Survey of India 17(3), 118-123.

Key words: Mapping, Indus, Peshawar valley, Salt Range.

W/4. Waagen, W., 1887. Die carbone Eis zeit, Karakoram. Geologie Reichsanstalt (Vienna). Jarbusch 37, 143p.

Key words: Ice time, Karakoram.

W/5. Waagen, W. & Wynne, A.B., 1872. The Geology of Mount Sirban, in the Upper Punjab. Memoirs of the Geological Survey of India 9, 331-350.

The paper describes the geology of the area together with the description of the rock and fossils. The following succession in the area has been established.

6.-NUMMULITIC: Thick limestones with some shales-fossils in places.

5.-Cretaceous: a.-Thin-bedded limestones-without fossils apparently, b.-Impure ferruginous sandy limestone, weathering rusty-fossils

4.-Jurassic: Black Spiti shales.

3.-Triassic a.-Thin-bedded limestones and slaty shales, b.-Dolomite, limestone; fossiliferous (Megalodon and other) bes.

2.-BELOW THE TRIAS: Hematite, dolomite, quartzite, sandstone and breccia. Unconformity.

1.-SEMI-CRYSTALLINE: Attock (?) slate.

Key words: Stratigraphy, fossils, geology, Abbottabad.

W/6. Wadia, D.N., 1928a. The geology of the Poonch State (Kashmir) and adjacent portions of the Punjab. Geological Survey of India, Memoir, 51(2), 371-413.

Key words: Geology, mapping, Poonch, Kashmir.

W/7. Wadia, D.N., 1928b. Siwaliks of Potwar and Jammu Hills. Geological Survey of India, Memoirs, 51 (2), 334-362.

Key words: Mapping, siwaliks, Potwar.

W/8. Wadia, D.N., 1929. North Punjab and Kashmir. Geological Survey of India, Records, 62, 152-156.

Key words: Mapping, Kashmir.

W/9. Wadia, D.N., 1930. Hazara-Kashmir syntaxis. Geological Survey of India, Records 63, 1: 129-138.

Key words: Mapping, structure, Hazara-Kashmir syntaxis.

W/10. Wadia, D.N., 1931. The syntaxis of the northwest Himalaya; its rocks, tectonics and orogeny. Records of the Geological Survey of India, Records 65(2), 189-220.

Wadia noted strong folding in the form of a hair-pin bend in the rocks of the Hazara Kashmir area. The bend was called as Hazara-Kashmir Syntaxis. He described the stratigraphy, lithology, tectonics and orogeny of the area. The peculiar syntaxisial bend attracted many geologists in the years to come.

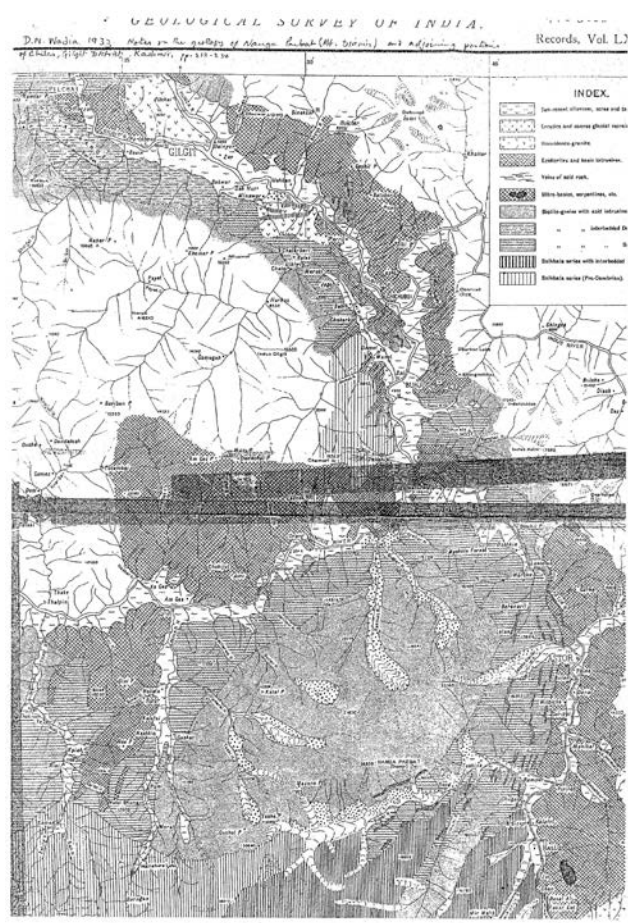
Key words: Mapping, structure, tectonics, Himalaya.

W/11. Wadia, D.N., 1932. The Tertiary geosyncline of north west Punjab and the history of the Quaternary Earth movements and drainage of the Gangetic trough. Geological, Mining, Metallurgical Society of India, Quarterly Journal 4(3), 70-95.

Key words: Structure, Quaternary, drainage, Punjab, India.

W/12. Wadia, D.N., 1933. Notes on the geology of Nanga Parbat (Mt. Diamir) and adjoining portions of Chilas, Gilgit District, Kashmir. Records of the Geological Survey of India 66, 212-234.

Wadia made pioneering studies in the Nanga Parbat – Diamir area. He described gneisses and granitic rocks of the Nanga Parbat as well as their associated metasedimentary rocks. The Chilas-Bunji area rocks were also described by him some of which were called as epidiorites. Further information can be seen in his attached geological below.



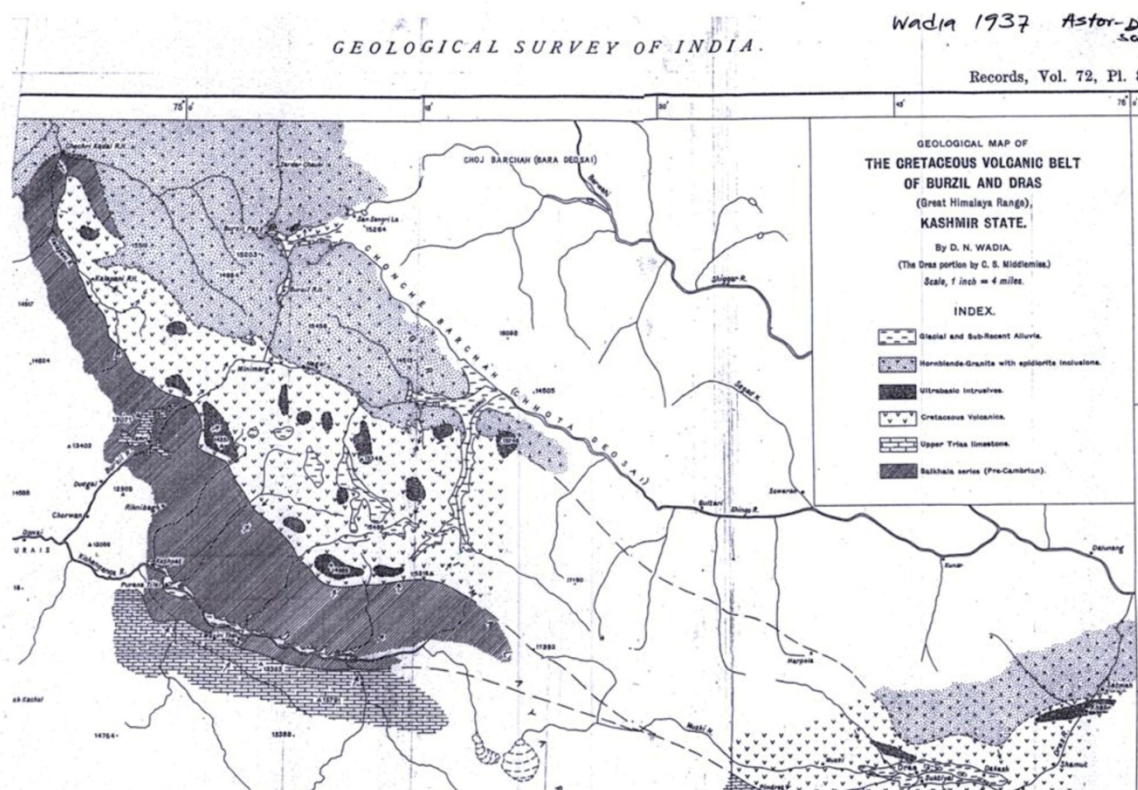
Key words: Igneous rocks, gneisses, Nanga Parbat, Diamir.

W/13. Wadia, D.N., 1934. The Cambrian-Triassic sequence of north-west Kashmir (parts of Muzaffarabad and Bara Mula district). Geological Survey of India, Records 68(2), 121-176.

Key words: Stratigraphy, Cambrian-Triassic, Kashmir.

W/14. Wadia, D.N., 1937a. The Cretaceous volcanic series of Astor-Deosai, Kashmir and its intrusions. Geological Survey of India, Records 72(2), 151-161.

Granitic rocks, a volcanic series, and sedimentary rocks from the south western part of the Deosai plateau and the adjacent Kishan Ganga valley were mapped and briefly described. The complexly folded and some 20 km broad volcanic belt, presumably occupying a synclinal flexure was shown to extend NW to SE toward Dras. Wadia noted that the volcanic series consist of a sequence of well stratified ash beds with some siliceous bands, gritty siliceous toughs, slates (some agglomeritic), agglomerates and flows. The ash beds and agglomerates are each several hundreds meters thick and the volcanic series contains intercalated sediments of Cretaceous age and scattered masses of ultramafic, mafic and granitic rocks.



Key words: Stratigraphy, volcanics, Cretaceous, Astore, Deosai, Kashmir.

W/15. Wadia, D.N., 1937b. An outline of the geological history of India. Indian Science Congress Association, Calcutta, 26p.

This account gives a brief of the geological history of India which includes some parts of present day Pakistan.

Key words: Geological history, maps, India.

W/16. Wadia, D.N., 1938a. The structure of the Himalayas and of the North Indian Foreland. 25th Indian Science Congress, Presidential address, 28p, 1 pl.

Key words: Tectonics, structure, Indian foreland, Himalaya.

W/17. Wadia, D.N., 1938b. Deposits of Ice Age in Kashmir. Geological, Mining, Metallurgical Society of India, Quaternary Journal, 10(4), 191-200.

The only accessible and legible records of the Pleistocene glacial epoch so far studied in India are those met with in the Kashmir Himalayas. A wide extent of the country above the latitude of 33°N and lying between the parallels of 73° and 78°E., especially the parts above an altitude of 6,000 ft. contain abundant proofs of ice-erosion and ice-borne debris covering hill slopes, valleys, cirques, glacial lakes and building terraces and mounds. At lower levels than 5,000 ft. ice-action is likewise indicated by copious occurrences of reassorted moraines, fluvio-glacial drift, lake-deposits and erratics. Many important details and even fundamental data, however, yet remain to be investigated about the Ice-Age in Kashmir and the problem may be said to have only just begun to receive the attention it deserves. Although of late years a large volume of evidence has been obtained proving the importance and extent of the post-Tertiary Ice-Age in Kashmir, precise data of its commencement in terms of the Siwalik sequence, its main fluctuations, or the date of its termination in reference to the Indo-Gangetic alluvial deposits, yet remain to be obtained by long and patient field work. Although, for many parts of Kashmir, the body of evidence is voluminous, no detailed investigation has been possible so far by the Geological Survey of India because of its preoccupation with the more vital stratigraphic and tectonic questions; and their classification and the determination of the sequence of even the major glacial and inter-glacial phases still remain for the future and will supply to the local geologists and naturalists of Kashmir a fascinating occupation. One unique circumstance which has supplied Kashmir Ice-Age with a recording chronometer of its principal episodes is the contemporaneous existence of a great lake, the Karewa lake, which filled the present valley basin of Kashmir, and which in the height of the Pleistocene glacial age must have been no less than 3,000 sq. miles in area. The vicissitudes through which this lake, a true tectonic synclinal basin, with only a single outlet, has passed, the alternations of freezing and non-deposition during the glacial phases and of basin-filling with active deposition during the inter-glacial phases, these alternations going on simultaneously with the intermittent uplift of the Western Himalayas, are registered in the alluvial strata of this lake, designated as the *Karewa Series*. The lake's existence must have been an intermittent one, attaining maximum extent during the warm inter-glacial pauses, succeeded by periods of minima, draining and refilling. Nearly half the area of the present Kashmir valley basin is covered by deposits of the Karewa Series which range in altitude to-day from the level of the Jhelum, 5,200 ft., to over 11,000 ft. on the slopes of the bordering mountains. Both in respect of their horizontal extent and the length of Pleistocene stratigraphic record they represent, the Karewas contain materials for a detailed systematic study of the Ice-Age in the Western Himalayas. Evidence is certain to come to light yielding results in Pleistocene orography, human paleontology and anthropology, besides purely glacial geology. Broadly speaking, four main oscillations of climate have been detected in the glacial cycle of Kashmir, by Dainelli (1913), De Terra (1938) and lately by myself, but it would be premature to try to correlate the Kashmir glacial and interglacial periods with the four main glaciations of the Alpine Ice-Age, nor have sufficient data been yet discovered to allow us to attempt anything more than a broad classification of the glacial formations of Kashmir. The glacial cycle of Kashmir proves to be a highly complex one, displaying varying interrelations of great mountain-building uplift movements, climatic and hydrographic changes, with at least three, or four, advances and retreats of the ice. The deposits formed under these various conditions during the whole glacial period in the Kashmir Himalayas, and which constitute our principal source of information of post-Pliocene geology, may be classified under the following five heads. These are of unequal applicability and reliability for different regions of the mountains, but each class of deposit is of value in throwing light on some particular aspect of the problem:- Moraines of different glaciations at various levels.

Key words: Glaciers, moraines, Pleistocene, Kashmir.

W/18. Wadia, D.N., 1943. The Pliocene Pleistocene boundary in Northwestern India. *Proceedings, National Institute of Sciences, India*, 9(1), 37-42.

Key words: Pliocene, Pleistocene, structure, stratigraphy, India.

W/19. Wadia, D.N., 1951. The transitional passage of Pliocene into the Pleistocene in the Northwestern Sub-Himalayas. *International Geological Congress, 17th Great Britain, Part 11*, 43-84, p107.

Key words: Pliocene, Pleistocene, structure, stratigraphy, India.

W/20. Wadia, D.N., 1957. *Geology of India*. 3rd edition (revised). Macmillan & Co., London, 531p. 19 pls.

This is a revised edition of the very popular and informative book on geology of India by the great Himalayan geologist D.N. Wadia. The book covers all aspects of geology and stratigraphy of the region stretching from Burma to Pakistan. Stratigraphic and lithologic descriptions and mineral deposits have been given, along with a colored map in the pocket.

Key words: Books, geology, stratigraphy,

W/21. Wadia, D.N. & Davies, L.M., 1926. Note on the occurrence of gypsified marl and alveoline-bearing limestone beds in the gypsum zone overlying the salt deposits of Bahadur Khel. Asiatic Society of Bengal, Indian Science Congress, 13th, p.255.

Key words: Sedimentary rocks, limestone, marl, gypsum, Bahadurkhel, Karak, Kohat.

W/22. Wadia, D.N. & Davies, L.M., 1929. The age and origin of the gypsum associated with the salt deposits of Kohat, North West Frontier Province. Mining and Geology Institute, India, Transactions 24, 202-222, Pl. 9 - 14.

Key words: Salt, gypsum, Kohat, NWFP.

W/23. Wadia, D.N. & West, W.D., 1964. Structures of the Himalayas. 22nd International Geological Congress, New Delhi, 1-10.

This is a regional account of the structure and tectonics of the Himalaya. There is a brief description of the Hazara-Kashmir Syntaxis in the context of NW Himalaya, the syntaxis is considered to result from a tongue like projection of the Gondwana massif.

Key words: Structure, Hazara-Kashmir Syntaxis, tectonics, Himalaya.

W/24. Wagner, H.G., 1962. Diamir valley and Diamir glacier (Translated from German). Mitteilungen der Geographischen Gesellschaft Munchen 47, 157-192.

Key words: Glaciers, Diamir.

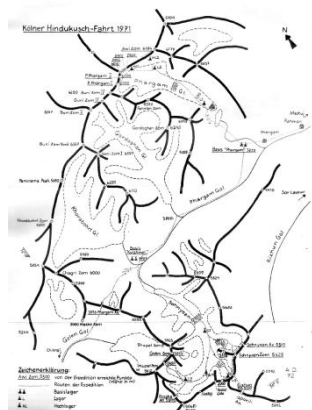
W/25. Wagner, R. & Wachten, A., 1971. Exploration and ascents in the Buni group. Himalayan Journal, 31.

We planned the Kolner Hindu Kush Expedition 1971 on the assumption that sensational discoveries and explorations in large areas of the Hindu Kush could hardly be a target for expeditions in the 'seventies' any more. Besides, for a group of nine climbers, all of amateur status, a too ambitious aim could spell disaster. For this reason we decided on a range which is somewhat away from the spectacular seven-thousanders of the Hindu Kush and had not been explored much; the Buni Zom group in Chitral, south of Buni and Awi, on the Mastuj river. From expedition results in the years 1957, 1965 and 1967, 6 Section Graz ', under the leadership of Dr. Gruber, had worked at sub-dividing the whole Buni Zom group. In 1970 a work was published in which Dr. Gruber differentiates between the North Buni Zom group, situated between Mastuj valley and the Phargam Gol, with the Khorabohrt, Gordoghan and Phargam glaciers and the South Buni Zom group, south and south-west of Phargam Gol, with the mountain areas around the Rizhun, Sohnyoan, Golen, Rinzhoo, Shiak, Shachiokuh, Isporili, etc., glaciers. C The Buni Zom Group in Chitral'—O.A.Z., Vol. 1370; reprinted in #./., Vol. XXX, 1970). Since our team of nine-eight men and one woman-constituted a rather large group, we decided on a double expedition, i.e. division into two groups ; George Holtmann, Herbert Hoven, Christoph Meizka and Albert Wachten were to attempt through a steep climb the difficult-to-reach Phargam glacier and into the untrodden basin to investigate and climb the virgin Awi Zom, the second highest summit of the whole of Buni Zom group; Heinz Dieter Bohme, Anno Diemar, Manfred Heintz, Erika and Robert Wagner had the task to get a clear picture of the Sohnyoan glacier which had been reached for the first time in 1970 by two Japanese groups. Thus we planned to investigate the glaciers which debauched into the

Phargam Gol and which had hardly been given any attention so far. Both groups started from the Phargam Gol with its ideal situation for a Base Camp which was established at 3,987 m. on high ground of the valley at Kulakmali. In order to investigate the approach routes to the Buni Zom group, as also to ease the problem of porters, we set out in separate groups for the Base Camp. The possibility that the Base Camp would be unreachable by one route was also eliminated, and besides the ever-changing composition of the groups helped to overcome and lessen the usual strain of the expedition members. In three mini buses we set out over the route which is to some extent also used by tourists ; through Istanbul, Ankara, Tehran, Kabul, Peshawar and on 4 August we reached Chakdara. Here we parted—one group went in its own conveyance over Saidu to Kalam in the Swat valley; the other group went to Dir and from there on to Chitral by jeeps. The difficulties which the 'Chitral group' expected with the authorities did not occur. After a 70 mile jeep ride through the Mastuj valley up to Miragram, they quickly reached the Base Camp at Kulakmali with the porters and pack animals through Mastuj, Rahman and Phargam. The approach route through Kalam took a few days longer. Besides the collapse of a bridge which hampered our provision of petrol and the difficulties with the authorities, the main problem was to find 40 porters for the loads. In the end the porter team consisted of inhabitants from Kalam and Matiltan in equal proportions. There emerged some unhappy strains of competition between these two teams but we were fortunate to commence the eight-day march through the richly vegetated Ushu Gol over the Kachhikhani An (4,766 m.). After a climb up to a height of 4,805 m., immediate east of the pass, the path leads down north through Sor Laspur and Harchin to Kulakmali. Due to worries and shrinkage in our expedition kitty we had to rearrange the porters in Sor Laspur and Rahman. During the month from mid-August to mid-September our exploration worked out as planned concerning the Sohnyoan and Phargam glacier basins. The settled condition of the glaciers permitted a quick erection of camps in both areas. Each group had the help of two high-altitude porters-Tschapir from Sor Laspur and Seraman from Rahman for the Phargam glacier; Mir Alam from Matiltan (Ushu Gol/ Swat) and Nigaban Shah from Phargam for the Sohnyoan glacier. While the group 'Sohnyoan' began from Kulakmali with the transport of the loads, the other group 'Phargam' erected a further Base with the material which had been already deposited there during the approach march. Besides the rapid glacier stream which descends from the Khorabohrt glacier and which had to be traversed west of the Kulakmali camps, the Sohnyoan group found no difficulties in reaching the Sohnyoan glacier. The glacier which entered the Phargam Gol without any step was reached effortlessly over the western moraine; a steep step between 4,500 m. and 4,650 m. at the foot of the ENE. ridge of the Shupel Zom E. was also easily traversed and thus after ten days all material had been moved from the Base Camp to Camp I (4,700 m.). On account of the huge stone falls along the flanks, the camp was erected in the middle moraine of the glacier. The aim of activities from Camp I for the next 2/3 weeks was the exploration of the routes to the neighbouring valleys, the Rizhun Gol, the Rinzhoh Gol and the Golen Gol as also the possibilities of climbing the boundary walls of the Sohnyoan glacier which showed a prominent salient to the west. For this reason we climbed Pt. 5,625 m. which the Japanese reached in 1970 and which they named 'Sohnyoan Zom'. Once we did this over the north flank and the SW. ridge and another time over the NE. ridge. The climb up the highly glaciated North wall was interesting and not too difficult. The descent though took up much time due to great amount of stone fall so that we were forced into a bivouac at 5,100 m. The descent over the NE. ridge is recommended. A wonderful view offered itself from the lower summit west of the 4 Sohnyoan Zom' which we named 6 Kolon Zom. This flat summit gives an uninterrupted view of the Sohnyoan glacier (9 km. long) beyond the place where it turns north—also an interesting view into the Khorabohrt glacier basin. The result of these climbs showed that the route from the Sohnyoan glacier into Rizhun Gol, either through the north-east pass or the south-west pass, was possible only with the greatest difficulty. The climb of the mighty massif south of the upper Sohnyoan basin seemed possible either over the heavily glaciated north flank or over the rocky ESE. ridge. The last possibility proved objectively too dangerous as we witnessed, after a climb of the pre-summit (Pt. 5,700 m.), the enormous crevasses and dangerous stone falls of the ridge. Investigations into the upper Sohnyoan basin showed that one could reach the Rinzhoh Gol without difficulty over a high saddle (Rinzhoh An, 5,343 m.). On the other hand, a climb of this chain from the west should hardly be considered. There remains the above-mentioned north flank which rises 1,100 m. high from the Sohnyoan glacier towards the eastern corner-stone of the massif which has been shown on the half-inch map of 1954 as Ft. 6,100 m. and which was measured by Gruber from the Khorabohrt glacier as 6,000 m. An attempt was made on this flank but time was against us i we gave up at the steep pure ice passages at the beginning of the second half of the wall. The route for the most favourable climb in this chain was found but it would require the climb of Pt. 6,100 m. and the traversing of the ridge for which we had, in September, no more time. Considerable additions could be made to the map of the northern boundary of the upper Sohnyoan glacier, i.e. to the southern slope of Shupel Zom massif. Contrary to the markings in the half-inch map, the glacier-arm goes direct southward between Shupel Zom West and East and only shortly before it enters the Sohnyoan glacier does it bend towards the east. Over this route we reached the 5,650 m. saddle which we named c Shupel An \ Here we discovered, south of the Shupel Zom E., a summit of 5,810 m. which one ascends by a prominent west ridge. After

climbing this we gave it the name 'Golen Zom' and noted that Shupel An from the Sohnyoan glacier as well as from Golen Gol offers an ideal starting point for the three summits of the Shupel Zom group. We did not attempt to climb the eastern boundary of the lower Sohnyoan glacier since the constant stone fall in the exceedingly broken chain made it appear rather unrewarding. An exception is probably the glacier-arm which descends from Pt. 5,909 m. to Pt. 5,824 m. The Base Camp of the 'Phargam' group is just above Phargam at a height of about 3,300 m. It stands sloping on the moraine in an awkward position. Towards the north one views from here direct into the steep icefalls of the Phargam glacier; the view and the route to Awi Zom (6,484 m.) are yet hidden. The main object of this group was to find a route into the glacier on which no one as yet had set foot; it would be for our own use or it could be of help to any future expeditions. After a march on foot for one and a half hours, at a height of about 3,700 m., a great gorge is formed by the mountains which frame the Phargam glacier. The glacier-tongue plunges over a large rock-fall into the depths; it is impassable as is also the orographic left boundary wall. The only possible ascent is offered by the orographic right rock wall (600 m. height) at the foot of which we erect a provisions depot. The climb now is not difficult; however, one has to be careful about stone falls and we reach the glacier floor at 4,300 m. One hour's advance on to the glacier and then we erect Camp I at 4,584 m. We now transport provisions and equipment from the Base Camp over the steep step to Camp I. From here we view Awi Zom for the first time. Two further crevasses present some difficulties (the first is traversed on the orographic right side and the second on the orographic left) and then we are able to erect Camp II at 5,265 m. in close proximity to the mighty SW. wall of Awi Zom hardly a fortnight after arrival at the Base Camp. Now we can start on its climb. To attempt to climb the deterring SW. wall does not seem advisable and we plan to reach the ridge connecting Awi Zom with Buni Zom so that from there we may attempt the climb over the West ridge. The only possibility to reach this connecting ridge is over a broad sloping rubble band which traverses at the lower end of the SW. wall and ends in a steep groove which leads on to the ridge. At the mercy of the stone falls we cross this strip—we name this crossing 'Crossing of the gods'—and we reach the ridge where we erect at 5,889 m. a high-altitude Camp I. This is the lowest point of the west ridge of Awi Zom. We name the ascending ridge to Buni Zom IV the 'Fairy Tale Ridge' Frightful descents on the Awi Zom west ridge towards our high camp frustrate a climb of the ice-giant. However, the 'Fairy Tale Ridge' with its average height of 6,000 m. offers a demanding and strenuous traverse. We surmount six humps on it which to date have not been mapped, and which no one has yet climbed; the most prominent ones quite close to Buni Zom IV we name: k P. Phargam I and P. Phargam II' (both about 6,000 m.). We return to Camp II. It appears that the only approach to Awi Zom is the above-mentioned SW. wall. A spur runs through the wall and we think it is possible to erect an intermediate camp on it. We keep towards the right (in the direction of the ascent) and in the late afternoon we start (on account of the lessened danger of stone falls) and with the darkness we reach a well-formed saddle on the spur on which we can erect our bivouac tents. But even this place is not absolutely safe of falling stones. From here ascends obliquely to the west ridge, a furrowed snow-field. Next day we cross this snow-field in the morning and also after sunset and now and then some stones fall from the summit wall but they fortunately do not hit us. At about 6,150 m. we at last reach the secure West ridge. Over snow and over rocks we proceed rather effortlessly and reach on 3 September 1971 at 12.45 p.m. the summit of Awi Zom which had not been climbed previously. We would not recommend our route of ascent. Our undertaking had extended up to the last days of summer. Already on the morning of our combined departure from Kulak-mali over Phargam and II to Chitral it was snowing up to the Base Camp.

We were quite aware that we had not returned with any sensational climbs and explorations. Yet, we knew that our stay and work in the Buni Zom area tallied with what we had set out to do. We do hope that the report of our expedition will be a useful addition to the knowledge of this area. [The authors are unduly modest of their achievement, both in climbing activity and exploration. All this is most valuable information and is complementary to the research of Dr. Gruber and other earlier visitors to the area.—Eds.]



KOLNER HINDUKUSH- FAHRT 1971

Key words: Expedition, exploration, Hindukush.

W/26. Wahab-Ud-Din, 1999-2000. Structure, stratigraphy, micropaleontology and petroleum geology of Kotli-Tattapani area, District Kotli, Azad Jammu & Kashmir (Pakistan). M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 217p.

Key words: Structure, stratigraphy, palaeontology, hydrocarbons, Kashmir, Himalaya.

W/27. Wahrenberger, C., 1992. The geology of the Higher Himalaya in upper Kaghan valley, NE Pakistan (Aspects of Metamorphism). Thesis (Diplomarbeit), ETH, Zurich.

Key words: Tectonics, structure, stratigraphy, Kaghan valley, Himalaya.

W/28. Wake, C.P., 1987a. Spatial and temporal variations of snow accumulation in the Central Karakoram, northern Pakistan. M.Sc. Thesis, Wilfred Laurier University, Waterloo, Ontario.

Key words: Glaciers, snow accumulation, Karakoram.

W/29. Wake, C.P., 1987b. Glaciochemical investigation as a tool to determine the spatial variation of snow accumulation in the central Karakoram, Northern Pakistan. *Annals of Glaciology* 13. 279-284.

Between 70 and 80% of the total annual run-off from the upper Indus Basin originates from heavy snowfall and glacierized basins at elevations greater than 3500 m a.s.l. However, very little is known concerning the mountainous headwaters of the Indus. This is especially true with respect to the amount of snowfall in the major source area, the high Karakoram. Recent studies of high-altitude alpine glaciers indicate that geochemical dating techniques can accurately and confidently identify seasonal and annual stratigraphy within snow pits and ice cores, and thus can be used to determine the seasonal and annual rate of snow accumulation. In addition, chemical records can usually be employed to determine sources of precipitation. Six snow pits, each 5- 0 m deep, were investigated in the accumulation zones of the Biafo and Khurdopin Glacier basins. Both accumulation zones are characterized by broad, open basins separated by steep, narrow ridges in which direct precipitation is the dominant form of nourishment. Seasonal stratigraphy is delineated through an analysis of the seasonal variation in the chemical and physical characteristics of the snow-pack. Annual snow accumulation in the Biafo Glacier basin ranges from 0.9 to 1.9 m water equivalent: maximum accumulation occurs in the elevation band 4900-5400 m asl. Roughly one-third of this snow accumulation occurs during the summer.

Key words: Glaciers, chemistry, snow accumulation, Karakoram.

W/30. Wake, C.P., 1987c. Snow accumulation studies in the Central Karakorum, Pakistan. In: Lewis, J., (ed.), *Proceedings of the 44th Eastern Snow Conference*, Frederikton, NB, 19-33.

Key words: Glaciers, chemistry, snow accumulation, Karakoram.

W/31. Wake, C.P. & Searle, M.P., 1993. Rapid advance of the Pumarikish Glacier, Hispar Glacier Basin, Karakoram Himalaya. *Journal of Glaciology*, 39, 204-206.

Pumarikish Glacier is approximately 7 km long and flows south from the main crest of the Karakoram. It is one of the main transverse tributaries feeding into the northern margin of Hispar Glacier, which is 62 km long and flows west from Hispar Pass (5150m) and eventually drains into the Hunza River (Fig.1). Hispar Glacier flows roughly parallel to the southern contact of the Karakoram granite batholith, which corresponds to a belt of mountains with the highest average elevation and the fastest uplift-erosion rates anywhere in Asia (Searle, 1991). Pumarikish Glacier is fed predominantly by avalanches, which originate from the north faces of Pumarikish (7429m) and Khinyang Chhish (7854m) on the northern and western edges of the basin, and from the lower unnamed peaks of the eastern margin. The granite headwall of Pumarikish Glacier is over 2500m from the summit icefields to the upper glacial cirque. The avalanches deposit snow, ice and debris in a small gently sloping basin at 4600-4700m. The lower 4km of Pumarikish Glacier descend gradually from this small accumulation basin to 4000m in a well-defined trough less than 500m wide.

Recorded observations of Pumarikish Glacier are few. Conway traversed and surveyed Hispar Glacier in 1892. From observations of tributaries on the north side of Hispar Glacier, Conway (1894) noted that:

"It is remarkable that whereas the Lak Glacier. has so greatly shrunk of later years, this Chur Glacier [Pumarikish Glacier on our map], its immediate neighbor, and which drains another flank of the selfsame mountains, should, on the contrary, have greatly swollen. It overflows all its moraines and pours in a broken spreading wave on to the surface of the Hispar."

Hayden (1907) made no mention of the north-bank tributaries of Hispar Glacier. Dr Kooncza and Dr Caliat, two surveyors who accompanied the 1908 Workman expedition to Hispar Glacier, found that Pumarikish Glacier was "connected by terraces" to the main body of Hispar Glacier (Workman and Workman, 1910). Their map shows a relatively direct crossing of Pumarikish Glacier at the snout. The map produced by Eric Shipton's Karakoram Expedition of 1939 (Mott, 1950) also shows an apparently straightforward crossing of the snout. No account was mentioned of difficulties encountered while crossing this glacier. No mention was made of Pumarikish Glacier in published reviews by Mason (1930), Hewitt (1969), Mercer (1975) or Mayewski and Jeslike (1979).

Our own observations of the glacier began on 19 August 1985 when it was crossed during a reconnaissance of the Hispar Glacier Basin as part of the Snow and Ice Hydrology Project. At that time, the glacier was easy to cross. There was a well-marked path on both lateral moraines and across the glacier used by shepherds to bring their yaks to summer pastures further up the margin of Hispar Glacier. The surface of the glacier showed only mild undulations and was covered in debris which ranged in size from large boulders to silt and mud. The surface was several tens of metres below the top of the lateral moraines. The appearance of the glacier had changed little when it was crossed on 8 August 1987 en route to Hispar Pass. However, by 29 June 1988, the snout of the glacier had thickened by at least 20m. The surface was still debris-covered but now also showed large debris-covered hillocks and deep valleys. There was no path or obvious route across the glacier. The eastern margin of the glacier was defined by a vertical ice cliff 1520 in high which descended to a narrow defile bordered on the far side by the lateral moraine. Steps had to be cut in the ice and the porters were belayed down this section. The upper surface of the glacier was approx. 10-20m below the top of the lateral moraine (Fig.2a).

Further observations were made during July and August 1989, when a base camp was established at Bitanmal, 3 km west of Pumarikish Glacier. The snout of Pumarikish Glacier had thickened so dramatically that the upper surface of the glacier was 16-22m above the top of the lateral moraine (Figs.2b and 3). The glacier had also advanced 1 km, reaching almost the middle of the 2-2.5km wide Hispar Glacier (Fig.4). The entire length of Pumarikish Glacier was now heavily crevassed and impossible to cross at any point (Fig.5). The regular path up to Hispar Pass was now cut off and to continue up-glacier it was necessary to circumnavigate the advancing snout by travelling out into the middle of Hispar Glacier and around the front of the Pumarikish Glacier ice. This diversion added about 4-6h on to the journey. The pastures along the ablation valley beside Hispar Glacier upstream of Pumarikish Glacier were cut off, and the Hispar yaks now grazed mostly at Bitanmal. A brief reconnaissance up Pumarikish Glacier failed to reveal any snow, ice and/or rock deposits which would have been indicative of a major avalanche or landslide.

It is clear from Conway's observations in 1892 that the upper level of the glacier surface was above the top of the lateral moraines so that ice flowed over them, and that Pumarikish ice flowed well out on to Hispar Glacier. Furthermore, Conway's observation that Khiang Glacier had thinned in the years prior to 1892 indicates that the advance and thickening of Pumarikish Glacier was an isolated event and not characteristic for the north-bank tributaries of Hispar Glacier. The swollen nature of Pumarikish Glacier described by Conway appears strikingly similar to our observations during the summer of 1989, suggesting that the glacier had experienced at least two periods of rapid advance separated by approximately 100 years.

Several glaciers in the Karakoram have been known to surge in the past (Hewitt, 1969; Gardner and Hewitt, 1990). The majority of documented surging glaciers in the Karakoram are concentrated along the main range. In the summer of 1989, Pumarikish Glacier exhibited features characteristic of a glacier in surge: rapid advance of the snout unrelated to activity of nearby glaciers, exceptional rates of advance and the formation of new surface features. In addition, Pumarikish Glacier displays basin-morphology features described by Hewitt (1969) as characteristic of surging glaciers in the Karakoram: medium size for the region, nourishment predominantly via avalanching, and steep tributary glaciers and snow avalanches which supply relatively small, low-angle accumulation zones. While the observational record of Pumarikish Glacier over time is limited, the morphological changes and repetitive nature of rapid advances over the past century, combined with basin morphology which is characteristic of surging glaciers in this region, suggest that Pumarikish Glacier can be added to the list of documented surging glaciers in the Karakoram.

Key words: Glacier advance, Pumarikish, Hispar, Himalaya, Karakoram.

W/32. Walton, J.L.W., 1984. Special techniques for surveying on mountain terrain. In: Miller, K.J., (ed.), *The International Karakoram Project*, 1, Cambridge University Press.

At some stage in almost all land surveying projects a network of fixed or "control" points has to be set up. When the area being studied involves moving terrain, such as a glacier, special survey techniques have to be used either to eliminate errors incurred by the moving control points, or to actually determine their velocity. This paper contains a review of a number of these special techniques ranging from simple "by eye" approximations to complex methods requiring extensive computer facilities. Some of these techniques may be applied to problems involving infinitesimal velocities such as the tectonic plate movement studies planned for the 1980 international Karakoram Project.

Key words: Survey, tectonics, Karakoram.

W/33. Wang, W., Huang, M. & Chen, J., 1984. A surging advance of Balt glacier, Karakoram mountains. In: Miller, K.J., (ed.), *The International Karakoram Project*, 1, 76-83. Cambridge University Press.

In November 1977, it was discovered that the Balt Bare Glacier's terminus had moved downwards 1.6-km since 1974. This movement took place mainly in 1976. During the investigation in October 1978, it was found that the terminus had further advanced a distance of 0.4-km but had begun to thin. The glacier terminus, 2.5-km in length, was surveyed and mapped at a scale of 1:5000 and a short-term measurement of surface velocity and temperature on the glacier was taken. We believe that the temperature in the surveyed section is high, and at melting point on its bottom. When the thickness and the basal sliding velocity of the glacier are estimated, one would consider that basal sliding was the dominant mechanism of the surge. It was predicted that the glacier would be thinner in the near future and that this surging advance would arrest.

Key words: Glacier advance, Balt, Karakoram.

W/34. Wang, Y., Peng, Q. & Feng, Y., 1980. The cartographic methods of the map of the Batura Glacier. In: Shi, Y. (ed.), *Professional Papers on the Batura Glacier in the Karakoram Mountains*. Science Press, Beijing.

Key words: Mapping, Batura glacier, Karakoram

W/35. WAPDA (Water And Power Development Authority, Pakistan), 1962. 1961 snow surveys. WAPDA, Lahore.

For more than 50 years, Water and Power Development Authority (WAPDA) has spearheaded investigations in Water Resources, Water Logging & Salinity, Engineering Geology, Reservoir Engineering, Dam-site Investigation, Hydropower, etc., in Pakistan. In several of the projects, WAPDA also involved technically skilled personnel and specialized organizations from abroad. A wealth of data in the form of reports is available in WAPDA Headquarters in Lahore and in its Regional Offices. These data are not freely available, but can be accessed through proper channel by those engaged in academic and applied research. In the following are given the titles and key words of a number of these reports under the name WAPDA. Others, having authorships, are given in appropriate places. We would like also to mention that there are many more unpublished reports of WAPDA that might be of interest to geoscientists.

Key words: Mapping, snow survey.

W/36. WAPDA, 1965. Reconnaissance report of Kabul-Swat-Chitral Basin. Appendix A. Directorate of Planning and Investigation, Lahore.

See WAPDA, 1962.

Key words: Reconnaissance, Kabul, Swat, Chitral.

W/37. WAPDA, 1970. 1968 Annual report of rivers and climatological data of West Pakistan, 1, 309p.

See WAPDA, 1962.

Key words: Rivers, climate data, West Pakistan.

W/38. WAPDA, 1976. Sediment appraisal of West Pakistan Rivers, 1966-1975: Surface Water Hydrology Project, Lahore.

See WAPDA, 1962.

Key words: Sediments load, rivers.

W/39. WAPDA, 1979. Sediment appraisal of West Pakistan Rivers, 1960-1972: Surface Water Hydrology Project, Lahore.

See WAPDA, 1962.

Key words: Sediments load, rivers.

W/40. WAPDA, 1989. Snow and ice hydrology project, upper Indus Basin-Karakoram Himalaya. Final Report. Wilfried-Laurier University, Waterloo, Ontario.

See WAPDA, 1962.

Key words: Snow, hydrology, Indus basin, Karakoram, Himalaya.

W/41. WAPDA, DAMES & MOORE, 1986. Mineral sector development study, N.W.F.P., Pakistan. Report submitted to Ministry of Planning and Development, Government of Pakistan, Islamabad, 73p.

Key words: Mineral development, NWFP.

W/42. WAPDA, Dams Monitoring Organization, 1967. Memorandum on the geology of Khanpur Main Dam. Dams Monitoring Organization, Report, 11p.

See WAPDA, 1962.

Key words: Engineering Geology, Khanpur Dam, Haripur

W/43. WAPDA, Dams Monitoring Organization, WAPDA, 1979. Warsak power house slide area, Geological Report. Dams Monitoring Organization, Report, 15p.

See WAPDA, 1962.

Key words: Engineering geology, Warsak Dam, Peshawar

W/44. WAPDA, Dams Monitoring Organization, WAPDA, 1980. Memorandum on the geology of spillway. Dams Monitoring Organization, Report, 11p.

See WAPDA, 1962.

Key words: Engineering geology.

W/45. WAPDA Dams Monitoring Organization, WAPDA, 1981. Stability of hill slopes. Dams Monitoring Organization, Report, 22p.

Key words: Engineering geology, slope stability.

W/46. WAPDA Dams Monitoring Organization, WAPDA, 1981. Cracks in power station buildings, Volume I, additional investigation and exploratory works. Dams Monitoring Organization, Report 143, 14p.

Key words: Engineering geology, Warsak Dam, Peshawar

W/47. WAPDA Dams Monitoring Organization, WAPDA, 1981. Warsak dam cracks in power station buildings, Volume II, exploratory drilling. Dams Monitoring Organization, Report, 143, 21p.

Key words: Engineering Geology, Warsak Dam, Peshawar.

W/48. WAPDA Dams Monitoring Organization, WAPDA, 1981. Khanpur dam faults across spillway and its probable extension under the dam. Dams Monitoring Organization, Report 157, 7p.

Key words: Engineering Geology, structure, Khanpur Dam, Haripur.

W/49. WAPDA Dams Monitoring Organization, WAPDA, 1982. Sedimentation in Tarbela dam reservoir, exploration and testing of sediments. IM-E-151, 42p.

Key words: Sedimentology, Tarbela Dam

W/50. WAPDA Dams Monitoring Organization, WAPDA, 1983. Analysis of the consequences of potential flow slides of sediments at Tarbela dam. Volume I and II, IM-E-162.

Key words: Sedimentology, Engineering Geology, Tarbela Dam

W/51. WAPDA 2001. Booklet on hydrogeological map of Pakistan, scale 1:250,000. Hydrogeology Directorate, WAPDA Lahore.

This 22 page booklet comprises introduction, hydrogeological maps, hydrogeological setup of Pakistan, physiography, groundwater potential in Pakistan, groundwater potential in Baluchistan, Hydrogeological investigations in Punjab, Hydrogeological investigations in N.W.F.P., Hydrogeological investigations in Sind, conclusions and recommendations, and bibliography.

Key words: Hydrogeology, groundwater maps.

W/52. Waqarullah, A.F. & Ahmad, A., 2000. One dimensional (1-D) basin modeling of north-eastern portion of Kohat region, N.W.F.P., M.Sc. Thesis, University of Peshawar, 55p.

Key words: Basin modeling, Kohat.

W/53. Warner, L.F., 1993. Variable denudation of the Nanga Parbat-Haramosh massif: A fission-track study of the Tato valley, Pakistan. B.S. Thesis, Leigh University, Bethlehem, Pa.

Key words: Denudation, Geochronology, Fission Track dating, Nanga Parbat, Himalaya.

W/54. Warraich, M.Y., Zafar, M., Hassan, S., Aslam, A., Ahmad, M.N., Ali, M., Karim, T., Naka, T. & Herayama, J., 1993. Geology of the northwestern part of Abbottabad quadrangle, Abbottabad, Hazara Division. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 7, 5-15.

Geology of the northwestern part of Abbottabad quadrangle, Abbottabad has been described. The area is occupied by, from bottom to top, Abbottabad formation (Early Cambrian) and Hazira formation unconformably overlain by the Samana Suk formation (Jurassic), and Cretaceous Chichali and Kawagarh formations. Brief descriptions of the rocks are given together with a colored geological map and seven colored field photographs. The Abbottabad formation is represented by Saraban Dolomite member which is divided into Lower, Middle and Upper units.

Key words: Stratigraphy, geology, Abbottabad, Hazara.

W/55. Wartho, J.A., 1991. Argon isotope systematics and mineralogy of metamorphic hornblendes from the Karakoram. Unpublished Ph.D. dissertation, The University of Leeds, Department of Earth Sciences, 255p.

Key words: Mineralogy, geochemistry, Ar isotopes, metamorphism, hornblende, Karakoram.

W/56. Wartho, J.A., Dodson, M.H., Rex, D.C. & Guise, P.G., 1991. Mechanisms of Ar release from Himalayan metamorphic amphiboles. *American Mineralogist* 76. 1446-1448.

Changes in hornblende samples that occur during stepwise $^{39}\text{Ar}/^{40}\text{Ar}$ analysis were studied experimentally and mineralogically. A complex succession of reactions was seen (hornblende - oxyhornblende - clinopyroxene-structured phase - fine-grained reaction products + glasses) in the temperature range 750-1300°C. The release of Ar from hornblende in the vacuum furnace appeared to occur by fundamentally different processes from those resulting in Ar loss during metamorphism. Simple diffusional interpretations of the release patterns are, therefore, not capable

of revealing the thermal history of samples. In principle, some useful information may be obtained if long-standing fractures and other defects control both natural Ar loss and mineral reactions within the laboratory.

Key words: Geochemistry, Ar isotopes, metamorphism, amphibole, Himalaya.

W/57. Wartho, J.A., Rex, D.C. & Guise, P.G., 1996. Excess argon in amphiboles linked to greenschist facies alteration in the Kamila Amphibolite Belt, Kohistan Island Arc system, northern Pakistan: insights from $^{40}\text{Ar}/^{39}\text{Ar}$ step-heating and acid leaching experiments. *Geological Magazine*, 133, 595-609.

A mineralogical and $^{40}\text{Ar}/^{39}\text{Ar}$ study of 13 amphibole samples in the Kamila Amphibolite Belt and Kamila Shear Zone in northern Pakistan has found a correlation between the degree of greenschist facies alteration and quantity of excess ^{40}Ar . Additionally, there is a north-south divide with amphibole samples from the northern region showing larger degrees of green schist facies alteration, brittle deformation, and excess ^{40}Ar incorporation compared to the predominantly plastically deformed, less altered, amphibole samples from the Kamila Shear Zone in the south. Acid leaching of two amphiboles from the Kamila Amphibolite Belt indicates that a large proportion of the excess ^{40}Ar is correlated with later greenschist facies alteration phases, and can be easily removed by acid etching, thus revealing acceptable regional $^{40}\text{Ar}/^{39}\text{Ar}$ plateau ages.

Key words: Geochemistry, Ar isotopes, greenschists, Kamila amphibolite, Kohistan arc.

W/58. Warwick, P.D. & Hussain, F., 1990. Coal fields of Punjab, North-West Frontier Province and Azad Kashmir. In: Kazmi, A. H. & Siddiqi, R. A. (eds.), *Significance of Coal Resources of Pakistan*. Geological Survey of Pakistan, Quetta, 15-26.

Key words: Geology, hydrocarbons, coal, NWFP, Azad Kashmir, Punjab.

W/59. Warwick, P.D. & Shakoar, T., 1988. Preliminary report on coal deposits of the Salt Range area, north-central Pakistan. US Geological Survey Project Report PK-88, 333p.

Key words: Geology, hydrocarbons, coal, Salt Range.

W/60. Warwick, P.D. & Wardlaw, B.R., 1992. Paleocene-Eocene Stratigraphy in Northern Pakistan: Depositional and Structural Implications. 7th Himalaya-Karakoram-Tibet International Workshop.

The Paleocene-Eocene strata of northern Pakistan are found in a northeast-trending trough that is well preserved south of the Main Boundary Thrust (MBT) but is structurally disrupted to the north of the thrust (fig. 1). The depositional trough south of the MBT can be reconstructed along a northwest-southeast cross section from lithofacies of the upper Paleocene Lockhart Limestone and associated Hangu and Patala Formations, the upper part of the lower Eocene Panoba Shale, and the uppermost lower Eocene Kuldana Formation. The Lockhart Limestone was deposited throughout most of the trough and is predominately red algal nodules in skeletal mudstones to packstones in the northwest (Hangu area), foram muds in skeletal mudstones to wackestones (packstones rare) in a central area (Makarwal), and foram-dasyclad sands in skeletal wackestones and packstones (mudstones rare) in the southeast (Salt Range). The southeastern facies of the Lockhart Limestone shows a gradual facies change shoreward to clastics that are indistinguishable from the underlying Hangu Formation and the overlying Patala Formation. During the deposition of the upper part of the Panoba Shale and equivalents, deltaic sands and muds are in the northwest, marls and shales in a central area, and nodular-bedded carbonates in the southeast. The Kuldana Formation is represented by red beds in the northwest and northeast (northern Potwar) and by evaporites and various marine units in the central area (Karak, north of Makarwal). North of the MBT, but south of Khairabad Thrust, where only the foram mud facies is present in the Lockhart Limestone, three sequences are recognized: Hangu missing below, Lockhart, and a Patala marl and shale sequence above, Hangu missing below, Lockhart, and Patala red beds above, and Hangu below (mostly mudstones rather than sandstone as it is south of the MET), Lockhart, and Patala red beds above. The Patala red beds north of the MBT indicate probable terrestrial and marginal marine

deposition during the upper Paleocene-lowermost Eocene, well before the generally widespread, younger Kuldana was deposited south of the MBT.

It appears the "red" Patala is generally present in structurally higher thrust plates north of the MET, suggesting that sequences and are not on the same thrust plate as mapped. The structurally juxtaposed stratigraphies north of the MBT are significantly different than those south of the MBT and are composed of marginal marine to terrestrial. Study Area in sediments that probably represent northern Pakistan. A general shoaling area at the northern end of the Paleocene-Eocene trough that presaged the continental collision.

Key words: Stratigraphy, Paleocene, Eocene, structure, North Pakistan.

W/61. Washburn, A.L., 1939. Karakoram glaciology. *American Journal of Science* 237, 138-146.

Key words: Glaciology, glaciers, Karakoram.

W/62. Wasson, R.J., 1979. Stratified debris slope deposits in the Hindu Kush, Pakistan. *Zeitschrift für Geomorphologie* 23, 301-320.

Key words: Debris flow, debris deposits, Chitral, Hindukush.

W/63. Wazir, M.Y. & Masood, Allauddin, 1983. Petrology of part of North Waziristan Agency, including Khaderkhel, Datta Khel, Kaniro-Ghamanzar Khel and Dagan areas, NWFP., Pakistan. M.Sc. Thesis, Peshawar University, 80p.

Key words: Petrology, mapping, North Waziristan.

W/64. Weerth, A., 1991. Neu mineralfunde aus den berühmten Pakistani shen edelsteinpegmatiten. *Lapis* 16(1), 36-37.

Key words: Gems, pegmatite, Pakistan.

W/65. Weerth, A., 1991. Neufunde aus dem Himalaya und Karakorum. *Lapis* 16(10), 45-46.

Key words: New mineral finds, Himalaya, Karakoram.

W/66. Weerth, A., 1992. Die aktuellen mineralfunde aus dem bereich des Hunza-Tals in Nord-Pakistan. *Lapis* 17(10), 38-44.

Key words: Minerals, Hunza.

W/67. Weerth, A., 1994. Krieg und steine. Ein aktueller situationsbericht über neufunde aus Pakistan und Afghanistan. *Lapis* 19(10), 27-30.

Key words: Gems, Afghanistan, Pakistan.

W/68. Weerth, A., 1997. Alpine Neuheiten aus dem Karakorum. *Lapis* 22, 13-22.

Describes newly discovered gemstones from the Karakoram Mountains.

Key words: Karakorum.

W/69. Weerth, A., 1988. Edelsteinvorkommen im schatten der achttausender: Beshreibung der mineralvorkommen im norden Pakistans. Lapis 13, 11-28.

Describes the general geology and other information on localities of various gem minerals and collectable specimens in northern Pakistan.

Key words: Gems,

W/70. Weinberg, R.F., Dunlap, W.J. & Whitehouse, M., 2000. New field, structural and geochronological data from the Shyok and Nubra valleys, northern Ladakh: linking Kohistan to Tibet. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya. Geological Society, London, Special Publication 170, 253-275.

The Nubra-Shyok confluence in northern Ladakh is a key area for understanding the tectonic evolution of NW Himalaya and provides the basis for linking the geology of Pakistan to that of Tibet. The geology of the confluence area has been the subject of much speculation centered mainly on the existence of ophiolites and their regional significance. These ophiolites are thought to represent the eastward extension of the Shyok Suture Zone (SSZ), which separates the Dras island arc from the southern margin of Eurasia, and which was overprinted by movement along the Khalsar Thrust (often thought to represent the eastern continuation of the Main Karakoram Thrust). The geology of the area is relatively complex and the little information available has hampered regional geological correlations. The Khalsar Thrust (KT) and the dextral Karakoram Fault (KF), two regional tectonic features of NW Himalaya, merge at the confluence defining a triple point and three block; the Ladakh block to the south, the Saltoro block to the northwest, and the Karakoram block to the northeast. Close to the triple point, the KF changes strike and movement direction. Movement vector analysis of the triple point indicates that the KT and the two parts of the KF could have moved contemporaneously, and allows prediction of the movement vectors across the faults. The KT and KF shear preferentially volcano-sedimentary rocks of the Shyok and Nubra formations, respectively. Contrary to previous interpretations, these sheared rocks do not represent disrupted ophiolites. Regional tectonic reconstructions, however, require suturing between the Ladakh block and Eurasia and the strike of the SSZ in Baltistan suggest that the suture zone might crop out north of the KT, either along the southern slopes of the Saltoro Range or further north along the Saltoro valley. In the few outcrops of the Saltoro block we were able to visit, we found no evidence of ophiolitic rocks. Instead we found outcrops of the calc-alkaline Tirit batholith. Although our observations do not confirm the presence of the suture-related rocks in the southern Saltoro block, this possibility cannot be ruled out. Zircons from a sample of Tirit granite (U-Pb ion-microprobe age) yielded an age centered at 68 ± 1 Ma. The similar range of modal composition and age of the Tirit and Ladakh batholiths suggest that they are part of the same magmatic event. This result and a number of other observations indicate that the post-75 Ma geology of the Ladakh and Saltoro blocks is similar. Thus, if there is a suture zone in the southern Saltoro block, suturing must have occurred before 75 Ma, as concluded by others along the same tectonic boundary to the west in Pakistan. The KF represents a much younger terrane boundary, juxtaposing rocks of the Ladakh and Saltoro blocks to those of the Karakoram terrane. Rocks related to suturing of continents were not found along the KF. Karakoram leucogranites cropping out in the southern part of the Karakoram terrane yielded a U-Pb zircon age centered at 15.0 ± 0.4 Ma (2σ). Because these leucogranites were not found south of the KF, this fault must have initiated after leucogranite intrusion and must therefore be younger than 15 Ma old. At the confluence the KF cuts across the regional rocks sequence than can be followed from Kohistan into Baltistan and into the confluence area. Movement on the fault displaces the sequence by approximately 150 km to southern Tibet was the regional rock sequence could be regained.

Key words: Structure, geochronology, Shyok, Nubra valleys, Shyok suture, Karakoram fault, Ladakh, Kohistan, Tibet.

W/71. Wells, N.A., 1984. Marine and continental sedimentation in the early Cenozoic Kohat Basin and adjacent northwestern Indo-Pakistan. Ph.D. dissertation, University of Michigan, 465p.

Key words: Sedimentation, continental, Cenozoic, Kohat basin.

W/72. Wells, N.A. & Gingerich, P.D., 1983. Review of Eocene Anthracobunidae (Mammalia, Proboscidea) with a new genus and species, *Jozaria Palustris* from the Kuldana Formation of Kohat (Pakistan). University of Michigan, contributions from the Museum of Paleontology, 26, 117-139.

Anthracobune and its primitive bunodont-bilophodont herbivorous allies from the Eocene of Indo-Pakistan are grouped together in a new family, Anthracobunidae. Anthracobunids are interpreted as basal "tethytheres" that are probably broadly ancestral to proboscideans, sirenians, and desmostylians. The family includes five genera and species: *Anthracobune pinfoldi* Pilgrim, 1940; *Lammidhania wardi* (Pilgrim, 1940); *Pilgrimella pilgrimi* Dehm and Oettingen-Spielberg, 1958; *Ishatherium subathuensis* Sahni and Kumar, 1980; and *Jozaria palustris* (new genus and species). Anthracobunidae may be ancestral to Moeritheriidae among primitive proboscideans and Prorastomidae/Protosirenidae among primitive sirenians; they resemble both groups in size and general cheek tooth morphology, and they appear earlier in the fossil record. Anthracobunids are primitive in having four premolars and in lacking the tusks and specialized rostra seen in moeritheriids and protosirenids. Desmostylia may also be derived from Anthracobunidae. *Jozaria* appears to have fed on soft aquatic vegetation in brackish to freshwater marshes. Some *Pilgrimella* and *Ishatherium* specimens have been found in marine deposits. These observations are consistent with the postulated amphibious habits of moeritheres and the shallow-water littoral-marine habitats of sirenians and desmostylians.

Key words: Palaeontology, mammals, Eocene, Kuldana Formation, Kohat.

W/73. Wells, N.A. & Gingerich, P.D., 1987. Paleoenvironmental interpretation of Paleogene strata near Kotli, Azad Kashmir, Northeastern Pakistan. *Kashmir Journal of Geology* 5, 23-42.

In the Kotli area of east central Pakistan, the Subathu Formation was deposited by a single cycle of transgression and regression during the early Eocene. The marine Subathu section, which is developed on a pre-Eocene bauxite, records the successive passage of a coastal coal swamp; a very muddy shoreline; shallow and highly turbid but quiet offshore waters depositing unfossiliferous green mud and organic debris; clear and probably deeper but still occasionally turbid wear over fetid muds and marls beyond the coastal turbid zone; progressively shallower water depositing shales and higher energy limestone; an oyster bank; a delta-related submergent sand-bar complex; and a back-bar bay or lagoon that trapped river muds. Finally, progradation of a brackish coastal marsh across the bay is inferred from the succeeding slowly accumulated and completely pedogenized onshore clays. The topmost marine shale is inferred to correlate with a regional regression at the end of the early Eocene.

Key words: Paleoenvironments, Paleogene, Azad Kashmir.

W/74. Werdin, J., 1998. Gletscherverbreitung und-dynamik im Hunza-Karakorum. Thesis (Diplomarbeit), Geographisches Institut, Universitat Bonn.

Key words: Glaciers, Hunza, Karakoram.

W/75. Wessels, W., 1997. Myocitodontinae from the Miocene of Pakistan. *Koninklijke Nederlandse Akademie van Wetenschap, Proceedings, Series B*, 99, 253-312.

Key words: Palaeontology, Miocene, Pakistan.

W/76. Wessels, W., Bruijn, H.D., Hussain, S.T. & Leinders, J.J.M., 1982. Fossil rodents from the Chinji Formation, Banda Daud Shah, Kohat, Pakistan. *Koninklijke Nederlandse Akademie Van Wetenschap, Proceedings, Series B*, 85, 337-364.

Key words: Fossils, rodents, Chinji Formation, siwaliks, Karak, Kohat.

W/77. Wessels, W., Unay, E. & Tobien, H., 1987. Correlation of some Miocene faunas from northern Africa, Turkey and Pakistan by means of Myocricetodontinae. Koninklijke Nederlandse Akadademie van Wetenschap, Proceeding, Series B, 90, 65-82.

Key words: Palaeontology, Miocene, Africa, Turkey, Pakistan, siwaliks.

W/78. West, R.M., 1980. Middle Eocene large mammal assemblage with Tethyan affinities, Ganda Kas region, Pakistan. *Journal of Paleontology* 54, 508-533.

A new collection of fossil mammals from the vicinity of Ganda Kas, along the southern edge of the Kala Chitta hills, Pakistan, provides new insights into the Paleogene faunas of southern Asia. Nineteen genera are now known from Ganda Kas, one described here as new. In addition, several taxa are referred to the Cetacea, *Khirtharia* is returned to the Helohyidae and shown to be a senior synonym of *Bunodentus*, and *Pilgrimella pilgrimi* is a junior synonym of *Anthracobune pinfoldi* which is a tethythere closely allied to the Moeritheriidae. The excellent new material of *Khirtharia*, *Anthracobune* and *Lammidhania* allows more complete description of their dentitions and, in the case of *Khirtharia*, the skull, than was previously possible. The abundance and diversity of cetaceans and tethytheres at Ganda Kas suggests marked affinities of South Asian faunas with the other major Tethyan Eocene assemblage at Fayum, Egypt. Other affinities are with eastern Asia through the brontotheres and artiodactyls. *Lammidhania* is retained in the Anthracotheriidae, although it surely is atypical and may, when the upper dentition is known, belong elsewhere. The fossil mammals from Ganda Kas fit well with the coastal environment postulated for Kuldana and Kohat Formation rocks.

Key words: Palaeontology, mammals, Eocene, Kalachitta Range.

W/79. West, R.M., 1981. Plio-Pleistocene fossil vertebrate and biostratigraphy of Bhattani and Marwat Ranges, northwest Pakistan. Neogene-Quaternary boundary, Proceedings, Field Conference, India, 211-216. Geological Survey of India.

Key words: Vertebrate palaeontology, biostratigraphy, Plio-Pleistocene, Bhattani Range, Marwat Range.

W/80. West, R.M. & Lukacs, J.R., 1979. Geology and vertebrate-fossil localities, Tertiary Continental rocks, Kala Chitta Hills, Attock District, Pakistan. *Contribution in Biology and Geology* 26, Milwaukee Public Museum Press, 20p.

Key words: Palaeontology, vertebrate fossils, Tertiary, Kalachitta Range, Attock.

W/81. West, W.D., 1931. Hazara Simla Hills correlations. Geological Survey of India, Record 65, 125-132.

Key words: Stratigraphy, Hazara, Simla.

W/82. Whalley, W.B., 1984. High altitude rock weathering processes. In: Miller, K.J. (eds.), *The International Karakoram Project volume 1*, Cambridge University Press.

High altitude rock weathering is poorly understood both in terms of processes involved and rates of activity. As well as freeze-thaw activity which produces small blocks, larger scale rock falls appear to be common. In addition, chemical processes are probably more important at high altitude than has been generally realized. This chemical weathering can take place in either cracks or on the surface to give sand and silt-sized particles (grus). Rock surface rinds, as a form of desert varnish, appear to form where special conditions operate, although these environmental parameters are not yet elucidated. Other places show grain by grain disintegration due to weathering in micro-cracks. The varnish rinds are of complex chemical composition and show preferential enrichment of Mn and Fe over the parent rock. A variety of techniques have been used to investigate these crusts. Examples are shown

of scanning electron micrographs and Mossbauer spectroscopy which suggest formation of haematite and a gel form of $\text{Fe}(\text{OH})_3$. The form of Mn concentration is not yet known but appears to be in small nodules (1 – 2 μm diameter) on the varnish surface.

Key words: Weathering, Karakoram.

W/83. Whalley, W.B., McGreevy, J.P. & Ferguson, R.I., 1984. Rock temperature observations and chemical weathering in the Hunza region, Karakoram: Preliminary data. In: Miller, K.J. (eds.), *The International Karakoram Project 2*, 616-633. Cambridge University Press.

Air, rock surface, 5 cm deep and crack temperatures were recorded around a variety of rock types at various altitudes in the Hunza Valley in July/August 1980. Clear sky and cloudy conditions were compared. Under clear skies rock surfaces can exceed air temperatures by as much 24°C with actual rock temperatures around 40°C even at 4250m. Cloudy conditions showed smaller excess. Rock surface minima reached nearly 5°C below air temperatures under clear skies but were about the same under cloudy skies. Rock cooling rate vary considerably according to cloud cover and rock color. At 4400m the effects of chemical weathering are significant in rock breakdown. Desert varnish is rare above 3000m.

Key words: Weathering, rock temperature, chemistry, Hunza, Karakoram.

W/84. Wheeler, J., Murdie, R., Potte, G.J., Prior, D.J., Treloar, P., Butler, R.H.W.H., George, M., Harris, N.B.W. & Jones, C., 1991. Structure of northern Nanga Parbat syntaxis and its relation to the Kohistan arc. Abstract Volume, 6th Himalaya-Karakoram-Tibet workshop, Auris, France, 95-96.

The Nanga Parbat syntaxis of Pakistan is a region of basement gneiss belonging to the Indian continental plate, structurally overlain by amphibolites of the Kohistan Island Arc which were emplaced along a complex set of faults, the Main Mantle Thrust (MMT). In turn, these arc rocks are bounded to the north in the Hunza region by Asian plate metasediments, the contact being the Northern Suture. The relation between the MMT and the Northern Suture, where they approach each other in an area north of the Indus gorge, is critical to understanding the relation between the formation of the Nanga Parbat syntaxis and possible late movements on the two major sutures.

They are three lithotectonic units identified within the northern part of the syntaxis. The Iskere Unit, found on the west side, consists of migmatic orthogneiss yielding Proterozoic ages. The Shengus Unit occurs on the east side of the syntaxis in the Indus gorge and further south, and contains metapelites and calc-silicate rocks, again sometimes migmatic. In the north and northeast, immediately underlying the MMT, is the Layered Unit. This is strikingly banded on the scale of 100s of metres, consisting of biotite gneiss alternating with thick sheets of orthogneiss, sometimes garnetiferous. Sheets of marble, and boudinaged sheets of amphibolite, are common.

The Shengus and Iskere units contain sheets of amphibolite, sometimes discordant to the banding in the surrounding gneisses, and inferred to be original basic dykes. The age of these is not certain; though both dykes and gneisses share a dominant N-S trending stretching lineation, and the dykes are frequently foliated parallel to their margins. Dykes were encountered in two areas.

In the Indus gorge, field relation suggests that the dykes were less ductile than gneiss during the post-dyke deformation. The main shape fabric in dykes and gneiss, and the north-south lineation, are Himalayan in age and relate to initial emplacement of the Kohistan Arc over the Indian Plate. This main fabric is folded into a broad antiform trending NNE, slightly oblique to the lineation.

Further N near the village Iskere, dykes are arched into an antiform with a roughly N-S axis and intrude the magmatites of the Iskere Unit. The dykes are foliated, but foliation in the gneiss is poorly developed and usually N-S subvertical. The migmatites were thus relatively ridged during folding, with dykes as "easily slip" horizons accommodating flexure whilst the gneiss form a crude axial-planar fabric.

A contact interpreted as the MMT is well displayed in mountain side to the N and E of the Iskere, where it separates epidotitic banded greenschist and amphibolites from the gneiss of the layered unit. Banding in both units appears parallel to the contact. Where it is seen further S, bounding the E side of the syntaxis in the Indus gorge, the contact is vertical and the foliations on the both side is concordant. In contrast, on the W side of the syntaxis, at Sassi and further N, it is heavily modified by ductile and brittle dip-slip and oblique-slip movement.

At least 1-2 km of Kohistan amphibolites is seen above the MMT north of Iskere: these are upper-arc rock. However, glacial rubble includes abundant pale green phyllites with garbenschiefer amphiboles. This distinctive

lithology is characteristic of metasediments of the Asian Plate, and possibly the Kohistan amphibolites are roofed by these rocks. This would imply that the “Northern Suture” is not a strait subvertical join here, as it is further west in the Hunza area, but a N-dipping contact. Tourmaline pegmatites showing little deformation are present throughout the syntaxis. In addition larger granitic sheets are common and, NW of Iskere, an undeformed 2-mica leucogranite intrudes syntaxis rocks.

Key words: Structure, Nanga Parbat, MMT, Kohistan arc, Himalaya.

W/85. Wheeler, J., Potts, G.J. & Treloar, P., 1990. Asymmetric structure and uplift of the Nanga Parbat syntaxis, Pakistan Himalayas. In: Abstract volume, 5th Himalaya-Karakoram-Tibet Workshop, Milano, 64.

The syntaxis is an anomalous N-S trending structure in which the Main Mantle Thrust (MMT) in an internal part of the Himalayan belt has been warped up to expose Indian Plate continental gneisses in its footwall, rimmed by ophiolitic material of the Kohistan Island Arc in the hangingwall. We studied a transect across the syntaxis in the Indus gorge to constrain its structural evolution. On the East Side, the MMT is vertical but there are no penetrative fabrics of syntaxis age, the main fabric being interpreted as of MMT age. Crossing an antiformal core region, the steep West margin contains fabrics with steep stretching lineations and shear bands indicating down-to-West movement along this margin. This uplift was accompanied by passive rotation in the East, but active shearing on the West margin. We suggest that the syntaxis formed above a deep detachment propagating westwards, perhaps a consequence of gravity spreading in the main Himalayan chain. Sticking on this led to large-scale buckle folding in metasediments now found in the east half of the syntaxis. Subsequent shortening in orthogneisses in the west was accomplished along a shear zone steeping upwards, giving overall tilting of the existing structures. Thus we predict asymmetric uplift ages due both to a west-propagating locus of uplift and to large-scale tilting of the partly formed syntaxis along a curved shear zone.

Key words: Structure, Nanga Parbat, MMT, Himalaya.

W/86. Wheeler, J. Treloar, P.J. & Potts, G.J., 1995a. Structural and metamorphic evolution of the Nanga Parbat syntaxis, Pakistan Himalayas on the Indus Gorge transect: the importance of early events. *Geological Journal* 30, 349-371.

For details consult the following account.

Key words: Structure, Nanga Parbat, metamorphic evolution, Indus gorge, Himalaya.

W/87. Wheeler, J., Treloar, P.J. & Potts, G.J., 1995b. Structural and Metamorphic Evolution of the Nanga Parbat Syntaxis: The Importance of Pre-Himalayan Events. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Nanga Parbat syntaxis remains a focus of scientific attention in the Pakistan Himalaya due to the rapid exhumation rates inferred for its recent history. Young fission track ages (Zeitler, 1985), recent overthrusting of Indus gorge gravels by the syntaxis gneisses (Butler and Prior, 1988), and apparently very young migmatites (Zeitler et al, 1993) have all been linked to large uplift rates with accompanying rapid erosion and perhaps tectonic exhumation. However, these basement gneisses, in common with other basement complexes in young orogens, have certainly be subject to a prolonged history, not all of which relates to the Tertiary plate collision which created the present orogen. The nearest parts of the Indian foreland exposed south of the Himalayas consist of Proterozoic gneisses, and Proterozoic zircon ages (amongst others) have been reported from the Indus gorge. The task of distinguishing recent structures and metamorphic assemblages (related to the Tertiary Himalayan history) from much older features is not trivial. In this contribution we present a summary of a detailed structural and metamorphic study of the Nanga Parbat syntaxis along the Indus gorge transect. We show how the kyanite-bearing migmatites, common in the gneisses of the Indus gorge, are pre-Himalayan: their genesis does not, therefore, relate either to the Himalayan burial/exhumation cycle or to the genesis of Himalayan granites. In contrast, the gross structure and main fabric preserved in the syntaxis is Himalayan. The gneisses in the gorge form a diverse array of ortho- and paragneisses with many textural variations. A crude subdivision into “Iskere” granitoid orthogneiss in the west, and “Shengus” paragneiss in the east is, however, sufficient to illustrate the main features (c.f. Chamberlain et

al., 1989). Most of the gneisses carry strong mineral shape fabrics and also banding, sometimes clearly migmatitic. An additional key group of rocks are sheets of amphibolite on the m- to 10 m scale. We first describe structural features as investigated in the field, and then summarise the metamorphic history of the syntaxis gneisses.

Structural history

Usually, mineral shape fabrics and banding are parallel in the gneisses. The planar composite fabric appears to define a large, tight antiformal closure in the east half of the syntaxis, and a more open closure on the west side (Fig. 1). Where gneisses are adjacent to interleavings of Ladakh island arc amphibolites on the eastern margin, LS fabrics in the two units are parallel. Since the Ladakh fabrics relate to Himalayan events, we infer that the shape fabrics in the gneisses do also. Thus, the eastern margin is the Main Mantle Thrust, rotated but otherwise unmodified. Omitting much detailed complexity (Wheeler et al., submitted), lineations throughout the syntaxis are roughly N-S and inferred to be Himalayan. The large tight antiform postdates the lineations but, as the fold axis is subparallel to them, they were not severely steepened. It is likely that the antiform affected the whole nappe pile of syntaxis gneisses and Ladakh-Kohistan island arc amphibolites, as Fig. 1 suggests.

The amphibolite sheets within the gneisses commonly carry the same LS fabric, with N-S lineation, as the adjacent gneisses. However, in some places it can be seen that the margins of the sheets truncate migmatitic banding in the gneisses. Moreover, no evidence for migmatisation of the amphibolite sheets has been observed, even when they are within intensely strained and migmatised gneisses. These two key observations show that migmatisation predated the intrusion of discordant basic sheets which now form the amphibolite sheets. This relationship is commonly obscured by subsequent deformation at amphibolite facies, which formed LS fabrics in both gneisses and basic sheets and transposed earlier structures, giving the illusion that banding and mineral shape fabrics relate to the same deformation event. There is no record of Tertiary basic magmatism within the Indian plate gneisses in the Himalayan chain or in the foreland. We infer that the basic sheets are pre-Tertiary - they may be part of the Panjal Trap magmatic event, and therefore Permian. The migmatisation of the gneisses, being still earlier than this, is therefore unrelated to the Tertiary Himalayan collision. The main fabric, often transposing migmatitic banding into parallelism with other features, is Himalayan in age.

Metamorphic history

The Shengus paragneisses contain several assemblages, but a "typical" assemblage is as follows: garnet-kyanite-orthoclase-biotite-plagioclase-quartz-accessories. Garnet and orthoclase both form porphyroclasts with irregular outlines. Garnet is commonly rimmed by a corona of biotite and kyanite. The edges of such coronas are commonly streaked out into a strong shape fabric defined by quartz ribbons, aligned biotite and blades of kyanite, and streaks of polycrystalline orthoclase. The occurrence of kyanite + orthoclase shows that muscovite, which must have been present in this metapelite originally, broke down by dehydration or dehydration melting. The occurrence of garnet + orthoclase is diagnostic of more extreme conditions. Figure 2, the petrogenetic grid of Vielzeuf & Holloway (1988) shows that these two phases can only be produced on a prograde path by a biotite dehydration melting reaction above 800°C: specifically, $\text{biotite} + \text{Al-silicate} + \text{plagioclase} + \text{quartz} = \text{garnet} + \text{orthoclase} + \text{melt}$. PT estimates using the garnet-biotite geothermometer (Ferry and Spear, 1978) and the garnet-kyanite-plagioclase-quartz geobarometer (Kozior and Newton, 1988) also indicate these extreme temperatures, although substantial post-peak resetting has modified the relevant phase compositions. Inclusions of sillimanite in garnet show that this reaction happened in the sillimanite stability field on the prograde path. The kyanite-biotite coronas are best explained by partial back-reaction of melt with garnet and orthoclase: the reverse of the above reaction, but in the kyanite stability field. These reactions, involving melt, were part of the migmatisation event. Subsequent deformation involved the recrystallisation of the biotite-kyanite coronas and other phases, but no further reaction. As argued in the structural section, this was a Himalayan event, probably much later than the partial melting reactions and corona development which relate to the migmatisation. Sporadic late sillimanite and muscovite (due to ingress of small amounts of water in the sillimanite stability field) are the only new Himalayan phases to be developed in the gneisses. This metamorphic history is summarised in Fig. 2. The Iskere orthogneisses show differences to the Shengus gneisses which are not due merely to bulk chemical differences. A typical Iskere gneiss assemblage is orthoclase-biotite-muscovite-plagioclase-quartz-accessories. Assemblages including garnet and/or kyanite also occur, but never with orthoclase. Biotite and muscovite are typically strongly foliated. It would appear, then, that muscovite never broke down in these rocks, and they never experienced the same temperatures as the Shengus gneisses: yet, since in the field migmatitic textures are common, this poses a problem. Wet melting is one possibility, but we prefer a model in which the Iskere gneisses did undergo substantial melting, perhaps at conditions comparable to those in the Shengus gneisses during migmatisation. Then, melt segregated on a small scale, but remained in chemical "communication" with the restite, enabling melt to back-react thoroughly as the migmatite complex cooled. Such a process would recreate the subsolidus amphibolite facies assemblage: any grain-scale reaction textures could then have been destroyed by the later Himalayan deformation, which gave rise to the two-mica shape fabric. Thus, we suggest that

the Iskere gneisses followed the same PT path as the Shengus gneisses during migmatisation, but that large-scale melt loss from the Iskere migmatites was insignificant, leading to complete back-reaction. The Shengus gneisses lost substantial melt, so that back-reaction was incomplete and the granulite-facies restite assemblage was preserved.

In summary, a significant part of the Indus gorge syntaxis history relates to pre-Himalayan events, specifically a migmatisation episode. This produced the banding still seen in the gneisses, although any accompanying shape fabrics have been obliterated. The migmatisation caused partial melting in all rock types at temperatures above 800 °C. Melt loss was limited, so that back-reaction was important during cooling of the migmatite complex. Subsequently, a swarm of basic sheets intruded the complex. During the Himalayan collision, the gneisses and basic sheets were intensely deformed at amphibolite facies, but there is no evidence for any further partial melting. Thus, these kyanite migmatites differ not only in grade but also in age from the reputedly Himalayan cordierite migmatites found further south. The pre-Himalayan inheritance of the basement gneisses cannot be ignored in any model for the Himalayan evolution of the Nanga Parbat syntaxis.

Key words: Structure, Nanga Parbat, MMT, Himalaya.

W/88. White, M.G., 1966. Copper, lead, zinc, antimony and arsenic in West Pakistan. US Geological Survey/Geological Survey of Pakistan, (IR) PK-4, 39p.

Copper localities that merit geological investigation are found in the western Chagai district, in North Waziristan agency and in the Salt Range in Mianwali and Sarrgodha Districts. No high-grade deposits have been reported from these areas and if deposits are developed they will likely be low-grade, high-tonnage, disseminated deposits. Those localities reported from Chitral State are too remote and inaccessible to be of interest now. All lead localities found to date are of minor importance; there has been small production at one locality in Chagai District and in the southern part of the Hazara District. Zinc, antimony, and arsenic are sparse in Pakistan and no important localities of these metals are reported. No base metals are reported in East Pakistan.

Key words: Economic geology, base metals, Pakistan.

W/89. Whittington, A., 1995. The Thermal Evolution of Nanga Parbat, Northern Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The Nanga Parbat - Haramosh Massif (NPHM) is a tongue of underthrust Indian Plate Precambrian basement exposed for 100 km protruding northwards into the Asian Plate, at the western end of the Himalaya. Geochronological studies over the past decade have shown that the whole massif has been exhumed exceedingly rapidly (up to 7 mm/y) over the past 5 Ma. In addition, Ar-Ar dating linked with detailed structural studies has shown that the recent exhumation is most rapid on the western margin, due to a combination of thrust and transpressive strike-slip faulting. This study concentrates on the southern part of the massif, around Nanga Parbat (8125m). Here recent structures related to rapid Pliocene & Pleistocene exhumation can be observed overprinting older Main Mantle Thrust structures associated with collision and initial crustal thickening. The present study relates the various stages of metamorphism and magmatism to the structural history and tectonics of Nanga Parbat. Preliminary Ar-Ar analyses on pelitic gneisses have yielded ages of 1.8 to 2.0 Ma for muscovite, and 2.3 to 3.1 Ma for biotite. The older biotite ages imply the presence of excess argon, so that the closure ages recorded are absolute maxima. These maximum muscovite ages of 2.0 Ma imply a minimum average cooling rate of 165°C/m.y. over the past two million years. For an arbitrary geothermal gradient of 40°C/km this represents an average exhumation rate of >4 mm/y. Initial results of thermal modeling shows that rapid exhumation can lead to very high near-surface geothermal gradients, and that the pronounced topography around Nanga Parbat may produce non-horizontal isotherms. The assumptions of horizontal isotherms and modest geothermal gradients are made in calculating exhumation rates from fission track data, and there may be significant over-estimation of these rates in the literature. The aim of future work is to integrate the results of various other techniques into a more detailed thermal model for the evolution of this part of the massif.

Key words: Structure, Precambrian basement, thermal evolution, NPHM, Himalaya.

W/90. Whittington, A. & Harris, N., 1995. Anatexis of the Nanga Parbat Massif, Northern Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

An unusual thermal history of the Nanga Parbat-Haramosh Massif (NPHM) is indicated both by anatectic leucogranites of unusually young age (< 10 Ma) and by the recognition of even younger cordierite-spinel anatectic melts hitherto unknown to the Himalayan orogen. The NPHM forms a northward kink in the suture (MMT) between the Indian Plate and Kohistan Island Arc at the western end of the Himalaya. A combination of thrust and transpressive strike-slip faulting has resulted in unusually rapid exhumation rates (~ 7 mm/yr) of the western margin of the massif over the past 5 Ma^{1,2}. Recent compressional structures related to this rapid exhumation can be observed overprinting older MMT structures associated with collision and initial crustal thickening. Basement lithologies from the NPHM have undergone a complex thermal history involving at least three phases of anatexis. Migmatitic pelitic gneisses with anatectic leucosomes are cross-cut by amphibolitic sheets, probably of pre-Himalayan age³. These migmatites are intruded by tourmaline-two mica leucogranite dykes and plutons which are syn-tectonic with respect to exhumation structures. The NPHM leucogranites are similar in major-element geochemistry to High Himalayan leucogranites (intruded at ~ 20 Ma) exposed along the length of the Himalaya⁴, even though much younger ages (2.3 - 7 Ma) are indicated by ionprobe studies of accessory phases from NPHM intrusives⁵. Trace element abundances differ from those of High Himalayan leucogranites in that Rb/Sr ratios are significantly higher as are concentrations of Y, U and Th. Ba abundances are lower in the NPHM intrusions. Such variations suggest low degree partial melts from a pelitic source of unusually radiogenic character. Melting could be induced by a combination of high internal heat production and by rapid exhumation under vapour-absent conditions. Leucogranite emplacement was post-dated by local anatexis forming granitic pods, rarely more than 50 cm in diameter, within kink bands and shear zones. Both peritectic cordierite and spinel have been observed suggesting that biotite breakdown has occurred under fluid-present conditions, presumably due to local fluid ingress along structurally favourable channels. Further studies of such melts may constrain the behaviour of crustal fluids following rapid exhumation of the massif.

Key words: Leucogranites, crustal anatexis, NPHM, Himalaya.

W/91. Whittington, A., Harris, N.B.W., Ayres, M.W. & Foster, G., 2000. Tracing the origins of the western Himalay: an isotopic comparison of the Nanga Parbat massif and Zaskar Himalaya. In: Khan, M. A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 201-218.

New Sr and Nd isotope data for basement gneisses and leucogranites are presented from two contrasting areas of the western Himalaya; the Nanga Parbat-Haramosh massif (NPHM) and Zaskar. Sr-isotope systematics of metapelites and anatectic migmatites from the Zaskar Himalaya are characterized by ϵ_{Sr} of 515-930, typical of the High Himalayan Crystalline unit as exposed for more 2000 km along strike. Moreover, Zaskar leucogranites are typical of the belt of Early Miocene granites intruding the High Himalayan Crystalline across the orogen (mean $\epsilon_{\text{Sr}} = 834$). In contrast, the NPHM leucogranites show an elevated average ϵ_{Sr} of 2400, and basement samples show a wide range in ϵ_{Sr} from 1850 to 8150. Errochrons for the metasedimentary gneisses indicate isotopic homogenization of the basement at c. 500 Ma for the Zaskar samples compared with c. 1800 Ma from the NPHM, confirming that the two terrains have experienced contrasting pre-Himalayan histories. Nd isotopic data from the NPHM indicate model ages from 2300 to 2800 Ma, indicating the mean crustal formation ages of the protoliths from which the sediments were derived. A compilation of published Nd data from the Himalaya indicates average protolith formation ages of 2640 ± 220 Ma for the Lesser Himalaya lithologies, compared with 1940 ± 270 Ma for High Himalaya unit. Gneissic lithologies from Zaskar and the NPHM have previously been correlated with the High Himalayan Crystalline Series, since both display high-grade Himalayan metamorphism and are intruded by syn-to post-tectonic tourmaline-bearing leucogranites. Isotopic systematics in the Zaskar region confirms this correlation. In contrast, the NPHM basement rocks are better correlated with Lesser Himalayan lithologies, exposed south of the Main Central Thrust. We conclude that the NPHM represents either a lower structural level of the Lesser Himalaya Series, or its protolith.

Key words: Basement gneisses, leucogranites, Sr and Nd isotopes, NPHM, Zaskar, Himalaya.

W/92. Whittington, A., Harris, N. & Butler, R., 1996. Field and analytical constraints on thermal evolution of the Nanga Parbat Massif, Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona (USA), 168-169.

In this contribution, a multidisciplinary approach elucidates the thermal and magmatic history of a rapidly exhuming terrane in the Western Himalaya. Inverse modeling allows investigation of the P-T-t path for exposed rocks from collision to exhumation constrained by geochronologic and thermobarometric data. We specifically address the problem of melt formation by considering the interaction between transient geotherms and fluid infiltration during rapid exhumation. The Nanga Parbat Syntaxis, or Nanga Parbat-Haramosh Massif (NPHM), forms a northward kink in the suture between the Indian Plate and Kohistan Island Arc at the western end of the Himalaya. A combination of thrust and transpressive strike-slip faulting has resulted in unusually young cooling rates on the western margin of the massif over the past 5 Ma (1). Recent compressional structures related to this rapid exhumation can be observed overprinting older Main Mantle Thrust (MMT) structures associated with collision and initial crustal thickening (2). The Tato Valley which runs north from the peak of Nanga Parbat to the Indus Valley at Raikot Bridge is particularly problematic for geochronological and thermal modeling studies due to (i) its exceptionally high cooling rates, interpreted to indicate rapid and increasing exhumation rates of 7mm/year (1) and (ii) its unparalleled topography of 7 km vertical relief over a horizontal distance of 21 km. The basement Indian Plate lithologies exposed in the massif have a polymetamorphic history, as indicated by pre-Himalayan amphibolite dykes cross-cutting some migmatitic fabric. Small tourmaline leucogranite plutons and sheets show sharp cross-cutting relations and are undeformed except in shear zones related to recent exhumation. All fabrics and units are overprinted in the core of the massif by cordierite-bearing granitic pods, which form preferentially in small conjugate shears with kinematics consistent with vertical stretching. Thermobarometric data from equilibrium pelitic assemblages suggest peak metamorphic conditions of $700 \pm 60^\circ\text{C}$ and $4.4 \pm 0.6\text{ kbar}$ (3). Some assemblages record higher pressures of about 6kbar at similar temperatures, suggesting a near-isothermal decompression path during exhumation. Published U/Pb ages on accessory minerals suggest that this is latest episode of high-grade metamorphism is Pliocene in age, broadly coeval with formation of the leucogranites (4,5). In present day study, $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology has been used to determine the exhumation path of these rocks, and while excess argon renders biotite ages only useful as upper limits to the timing of closure, muscovite ages suggest that these rocks cooled through about 445°C as recently as 1.8 Ma. Geochemical constraints indicate an origin for the leucogranites by fluid-absent muscovite breakdown (decompression melting) during exhumation. Accessory phase thermometry calculations indicate that melting occurred at temperatures of $710 \pm 10^\circ\text{C}$, consistent with such a fluid-absent melting reaction. Sr-isotope systematics can be used to find the precise crustal source of the granites. Data from leucogranite plutons define a narrow range of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios between 0.87 and 0.90. Samples of basement gneisses from the massif define a much broader field from 0.77 to 1.25. This wide range of isotopic ratios suggests that pervasive fluid infiltration through the basement has not occurred, and confirms that lithologies are available in the massif with sufficiently radiogenic Sr to source the granite plutons. The likely source was geochemically similar to metapelites within the outcropping gneisses but lay at greater depth than lithologies exposed at present erosional levels. The most recent melt-forming episode, associated with melting of metapelites and local formation of pneumatolytic cordierite-granite pods, resulted from biotite breakdown during infiltration of an aqueous fluid along small shear zones. The combination of geochronologic and thermobarometric results provides powerful constraints on thermal models of the evolution of the NPHM between 50 Ma and the present day. Further limits can be imposed by structural arguments which bracket total exhumation since 50 Ma as between about 30 and 35 km, and the absence of large melt volumes exposed at the surface which indicates that fertile levels of NPHM crust did not cross the vapour-absent biotite solidus for pelitic assemblages. One-dimensional thermal models indicate that the unusually young cooling ages from this area do not necessarily imply extreme or rapidly increasing exhumation rates, because the advection of heat resulting from rapid exhumation leads to a steepened near-surface geotherm. The most important control on the present-day thermal structure of the NPHM appears to be the thermal structure resulting from obduction of the Kohistan Arc some 50 million years age. Transient geotherms calculated for the past 10 Ma can only be reconciled with published geochronological and thermobarometric studies if exhumation rates lay in the range of 3 to 4 mm/year, still considerably greater than exhumation rates determined from the main Himalayan orogen. Exhumation paths fitted to the cooling age data and calculated P-T fields require leucogranite formation at realistic depths (sources 2 to 5 km below present levels of exposure) times (2 to 8 Ma). Multidisciplinary approaches on samples from a restricted spatial area allow a well-constrained thermal and metamorphic history to be inferred. At Nanga Parbat the complex magmatic history is controlled by both the evolving thermal structure, involving relaxation of transient geotherms and recent telescoping of isotherms due to rapid exhumation, and fluid infiltration at moderate depths (<10-15 km).

Key words: Thermal evolution, NPHM, Himalaya.

W/93. Whittington, A.G., 1996. Exhumation overrated at Nanga Parbat, northern Pakistan. *Tectonophysics* 260, 215-226.

New $^{40}\text{Ar}/^{39}\text{Ar}$ laserprobe and thermobarometric data from the Nanga Parbat-Haramosh Massif (NPHM) in northern Pakistan provide important constraints on thermal models of the evolving geotherm of the massif. Simple thermal models indicate that the unusually young cooling ages from this area do not necessarily imply extreme exhumation rates of about 7 mm/y, because the advection of heat resulting from rapid exhumation leads to a steepened near-surface geotherm. The most important control on the present-day thermal structure of the NPHM appears to be the thermal structure resulting from obduction of the Kohistan Arc some 50 m.y. ago. Transient geotherms calculated for the past 10 Ma can only be reconciled with published geochronological and thermobarometric studies if exhumation rates lay in the range of 3 to 4 mm/y, still considerably greater than exhumation rates determined from the main Himalayan orogen.

Key words: Geochronology, Ar-Ar dates, thermal evolution, NPHM, geothermometry, Himalaya.

W/94. Whittington, A.G., 1997. The thermal, metamorphic and magmatic evolution of a rapidly exhuming terrane: the Nanga Parbat massif, northern Pakistan. Ph.D. thesis. Open University, Milton Keynes.

Key words: Metamorphism, magmatism, thermal evolution, Nang Parbat, Himalaya.

W/95. Whittington, A.G., Foster, G.L., Harris, N.B.W. & Ayres, M.W., 1999. Lithostratigraphic correlation in the western Himalaya-an isotopic approach. *Geology* 7, 585-588.

We present the results of a whole-rock Nd isotopic study of two contrasting regions of the western Himalaya, using the neodymium model age approach on the scale of a single orogen. High-grade metasedimentary rocks from Zaskar yield model ages (TDM) that are similar to those of the High Himalayan Crystalline Series (TDM = 1.2–2.0 Ga; ϵNd = –6 to –16) and distinct from values from the Lesser Himalaya (TDM = 2.3–3.4 Ga; ϵNd = –18 to –27). Hence these two lithological sequences can be recognized for 2000 km along the strike of the orogen. Data for the basement of the Nanga Parbat massif at the western extremity of the Himalaya (TDM = 2.3–2.8 Ga; ϵNd = –18 to –30) suggest that these rocks are not equivalent to the High Himalaya, as previously supposed, but have affinities with the Lesser Himalaya. A thin metasedimentary cover sequence on the margins of the Nanga Parbat massif is isotopically indistinguishable from the High Himalaya (TDM = 1.6–1.8 Ga; ϵNd = –10 to –14). The prior misidentification of the provenance of the massif stems from its high metamorphic grade, characteristic of the High Himalaya, but in this case related to the unique Neogene history of the Nanga Parbat massif, which has exhumed a higher-grade equivalent of the Lesser Himalaya that is not seen elsewhere.

Key words: Lithostratigraphy, High Himalayan Crystallines, Lesser Himalaya, Nanga Parbat, Zaskar.

W/96. Whittington, A.G., Harris, N.B.W., Ayres, M.W. & Foster, G.L., 1998. Where did Nanga Parbat come from? *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 211-212.

The Nanga Parbat-Haramosh Massif (NPHM) is the most northerly exposure of Indian Plate basement, and forms a syntaxial loop at the northwestern end of the Himalayan orogen. It is bounded to the north by the Main Mantle Thrust (MMT), locally overprinted by more recent strike-slip and reverse faults that separate the NPHM from the Kohistan-Ladakh island arc terrane. The NPHM has long been considered to be a westward extension of the Higher Himalayan Crystalline Unit (HHC), which outcrops further east in the main orogen, in part because of its similarly high metamorphic grade, and in part because both the HHC and NPHM host tourmaline-bearing leucogranite bodies of Eocene age or younger. The leucogranites from both regions have similar geochemistry, indicating generation from a pelitic source by vapour-absent "decompression" melting (Harris and Inger, 1992). However, several discrepancies have become apparent in recent years between the P-T-t path followed by the NPHM and HHC terranes. For example, leucogranites at Nanga Parbat have crystallisation ages as young as 1 Ma (Zeitler and Chamberlain, 1991), compared to typical ages of 18 to 22 Ma for Higher Himalayan leucogranites (Harrison et al., 1997). Geochronological studies have revealed that Nanga Parbat is currently being exhumed at a rate of at least 3

mm/y (Whittington, 1996), that has resulted in an elevated geothermal gradient and exceptional topography, thus promoting vigorous fluid flux throughout the massif. These factors have in turn led to a second melting episode, generating small cordierite-bearing restitic assemblages localised in shear zones that are not observed in the main orogen (Whittington et al., 1998). Thus the timing of both exhumation and anatexis at Nanga Parbat differs from that seen in the central Himalayan orogen. Isotopic systematics of rocks of the NPHM and the HHC in Zaskar, the nearest outcrop of HHC to the NPHM, suggest different histories for the two terranes. NPHM leucogranites are exceptionally radiogenic, with ($^{87}\text{Sr}/^{86}\text{Sr}$) ratios of about 0.877 and ϵNd of -23 (present day), compared with ($^{87}\text{Sr}/^{86}\text{Sr}$) ratios of 0.74 to 0.78 and ϵNd of -13 to -17 for High Himalayan leucogranites from Zaskar (Ayres, 1997). When plotted on an errorchron diagram, Nanga Parbat basement lithologies display a trend corresponding to between 2100 and 2400 Ma, while Zaskar rocks display a trend corresponding to about 500 Ma, for both Rb-Sr and Sm-Nd systems. Supporting evidence Proterozoic events from the NPHM terrane comes from amphibolite sheets which cross-cut the oldest gneissic fabrics are characterised by Nd model age of 2200-2400 Ma; (ii) previously published zircon core ages from the NPHM cluster around 1850 Ma for the Iskere gneiss, and 500 and 2500 Ma for the Shengus gneiss (Zeitler et al., 1989; Zeitler et al., 1993). Thus isotopic evidence suggests that the NPHM basement is much older than the HHC unit, and the two cannot be correlated. These results pose the question of whether the NPHM basement unit is unique to this area, exposed locally by the exceptional exhumation history of Nanga Parbat, or does it outcrop elsewhere in the Himalayan orogen? Lesser Himalayan lithologies, exposed in the footwall of the MCT in the main orogen, are comprised of a metasedimentary succession, but have attained a much lower metamorphic grade. Published zircon ages from the Lesser Himalaya (1870 to 2600 Ma, Parrish and Hodges, 1996) are quite distinct from those found in the HHC unit (800 to 1000 Ma, *ibid.*), but match ages from the NPHM. While Himalayan-age granite magmatism is unknown in the Lesser Himalaya, the abundance of pelitic lithologies makes this sequence a fertile source, and the Nanga Parbat leucogranites reproduce the isotope systematics that would be expected if these rocks were melted during decompression. Cambro-Ordovician granites do occur in the Lesser Himalaya, and the leucogneisses found in the southern NPHM may represent their metamorphosed equivalents. An orogenic event of this age may also explain the presence of 500 Ma ages in some zircon cores from the Shengus gneiss, but clearly did not result in isotopic homogenisation on a bulk-rock scale. Hence in answer to the question, where did Nanga Parbat come from, it is possible that the c. 30 km of erosion experienced by Nanga Parbat in the past 10 Ma has exposed Lesser Himalayan basement rocks through the Kohistan island arc terrane. This raises a further question, what happened to the HHC rocks overlying the Lesser Himalayan sequence? Work in progress on the margins of the NPHM that seeks to address this question (Foster et al., this volume) is further complicated by the lack of a well-defined MCT in northern Pakistan, in contrast to the relatively uniform stratigraphy seen in the main orogen.

Key words: Higher Himalayan Crystallines, NPHM, Indian plate, Himalaya.

W/97. Whittington, A.G., Harris, N.B.W. & Baker, J., 1998. Low pressure crustal anatexis: the significance of spinel and cordierite from metapelitic assemblages at Nanga Parbat, northern Pakistan. In: Treloar, P.J. & O'Brien, P. (Eds.), *What Drives Metamorphism and Metamorphic Reactions?* Geological Society, London, Special Publications 138, 183-198.

Key words: Crustal anatexis, metapelites, NPHM.

W/98. Whittington, A.G., Harris, N.B.W. & Butler, R.W.H., 1999. Contrasting anatectic styles at Nanga Parbat, northern Pakistan. In: Macfarlane, A., Sorkhabi, R.B. & Quade, J., (eds) *Himalaya and Tibet: Mountain root to mountain tops*. Geological Society of America, Special Papers 328, 129-144.

Tourmaline-bearing two-mica granite plutons and sheets intruding the basement lithologies of the Nanga Parbat-Haramosh massif represent the youngest known occurrence of High Himalayan leucogranite magmatism. Trace-element modeling using Rb, Sr, and Ba indicates an origin by vapor-absent muscovite melting. Accessory phase modeling suggest that anatexis occurred at temperatures of $\sim 720^\circ\text{C}$, and therefore depths of 20-25 km. The source of one such intrusion (the Tato pluton) is considered to be metapelitic gneiss similar to that cropping out in the massif, and isotopically distinct from the source of the Miocene Himalayan leucogranites. Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of ~ 0.88 for the Tato pluton compare with 0.74-0.78 for Miocene granites intruded into the central Himalayan orogen.

Subsequent to, or coeval with, leucogranite emplacement, small cordierite-bearing leucosomes have been generated in ductile shear zones within the interior of the massif. These are geochemically variable, but are consistently characterized by strong depletion in high field strength elements and other incompatible trace elements. Petrographic and geochemical constraints indicate that at least some seam may be restitic, following localized incongruent melting of biotite in the presence of a fluid yielding a high melt fraction ($F \sim 0.5$). Other seams may be wholly or partly subsolidus in nature. Thermo-barometric data from these seams indicate that channelled fluid migration within the massif occurred at pressures <400 Mpa and temperatures of about 630°C. Geochemical constraints on contrasting granitic rocks from the interior of the Nanga Parbat-Haramosh massif chart a changing regime from fluid-absent anatexis in the mid-crust (~20 km depth) to fluid infiltration during ductile deformation in the upper crust (~10 km depth). These findings are consistent with the rapid exhumation of the massif with more modest exhumation rate around the margins.

Key words: Crustal anatexis, trace element modeling, Sr isotopes, NPHM.

W/99. Whittington, A.G., Kelley, S.P. & Harris, N.B.W., 1998. Fluid flow in the Nanga Parbat-Haramosh Massif: the use and interpretation of argon isotopes. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 210-211.

An extensive dataset of 175 $^{40}\text{Ar}/^{39}\text{Ar}$ analyses of mica separates are presented from the Nanga Parbat-Haramosh Massif, an actively deforming syntaxial region that forms the western Himalaya. Three critical areas were selected for sampling in order to distinguish genuine spatial and temporal patterns of cooling from the spurious effects caused by inherited excess argon. The majority of ages are interpreted as recording regional cooling due to rapid exhumation within the last 10 Ma. Younger ages of less than 1 Ma from leucogranite sheets and plutons approximate to intrusion ages, and support field evidence for magma emplacement into relatively cool country rocks by fracture flow rather than by diapirism. The widespread occurrence of "excess" argon, i.e. gas of unknown composition trapped at the time of closure, results in anomalously old ages that require multiple total fusion analyses of single grains to determine the true ages of geological events. The use of isotope correlation diagrams for multiple analyses enables some confidence to be placed in the resulting age, and the composition of non-radiogenic argon trapped at the time of closure may be used as a tracer of fluid pathways. In the interior of the massif, incorporation of excess argon suggests the presence of magmatic and/or metamorphic fluids at depth, while in the Liachar Shear zone on the western margin of the massif, the incorporation of argon with an atmospheric composition suggests circulation of meteoric fluids at shallower levels.

Key words: Fluid flow, Ar isotopes, NPHM

W/100. Wiche, K., 1960. Researches of climatic geomorphology in the Western Karakoram. Deutscher Geographentag Berlin 1959, Tagungsbericht und Wissenschaftliche Abhandlungen; Wiesbaden.

Key words: Geomorphology, Climate, western Karakoram.

W/101. Williams, M.P., 1989. The geology of the Besham area, north Pakistan: deformation and imbrication in the footwall of the Main Mantle Thrust. Geological Bulletin, University of Peshawar 22, 65-82.

The gneisses, granites and metasediments of the northern exposed margin of the Indian plate in the Besham antiform consist of a Precambrian crystalline basement with younger sedimentary cover. These were metamorphosed during the main fabric-forming event of the Himalayan orogeny, a ductile simple shear dominated deformation of the footwall of the MMT during southward overthrusting of the Kohistan Arc. Deformation intensity and ductility decrease southwards. Subsequent thrusting brought together internally imbricated blocks, which have different deformation/metamorphic histories. High-grade rocks thrust over low-grade rocks within each block define an inverted metamorphic gradient produced by post-metamorphic thrusting. Major cross folding producing the Besham antiform, plus brittle faults are expressions of the later N-W directed backthrusting and E-W compression and uplift of the Besham area.

Key words: Structural geology, deformation, metamorphism, Besham, Swat.

W/102. Williams, M.P., Treloar, P.J. & Coward, M.P., 1988. More evidence of pre-Himalayan orogenesis in northern Pakistan. *Geological Magazine* 125, 651-652.

As this article doesn't contain an abstract, and is a correspondence to other authors, giving more details about the pre-Himalayan orogenesis of the northern Pakistan.

Key words: Pre-Himalayan orogenies, deformation, Besham, Swat.

W/103. Willis, B.J., 1991. Evolution of Miocene fluvial systems in Chinji area, Potwar Plateau, northern Pakistan, Ph.D. dissertation, State University of New York, Binghamton, 297p.

For more information, see Willis (1993b).

Key words: Fluvial system, Miocene, Chingi, siwaliks.

W/104. Willis, B.J. 1993a. Ancient river systems in the Himalayan foredeep, Chinji village area, northern Pakistan. *Sedimentary Geology*, 88, 1-76.

The Miocene Chinji and Nagri Formations (Siwalik Group) of northern Pakistan record ancient fluvial environments in the Himalayan foredeep basin. Excellent exposures on the Potwar Plateau (Chinji Village area) allowed detailed documentation of the geometry and stacking of sediment bodies that comprise these strata, and of variation of large-scale bedding geometry, grain size, sedimentary structures and paleocurrent orientations within such bodies. Major sandstone bodies are tens of meters thick and are continuous along strike for many kilometers. They are composed internally of interconnected channel belt deposits, each of which contain several storeys (channel bar and fill deposits). Individual storeys, defined by inclined bedsets dipping down to a major basal erosion surface at up to 11°, are only 5 to 15 m thick within the Chinji Formation but can be up to 30 m thick within the Nagri Formation. Bedsets within storeys reflect sediment accreted during individual flood events. Along-strike variation of bedsets within storeys and the stacking patterns of storeys within channel belt deposits reflect changes in the channel bed through time due to the growth of bars, migration of channels, and channel cutoff. Generally, braided channel patterns are indicated by the relatively large number of storeys within individual channel belt deposits exposed perpendicular to paleoflow, abundant evidence for channel bar superposition due to channel switching, local evidence for mid-channel bars, dominance of coarse-grained channel fills, and low paleocurrent variations. Paleochannel reconstructions from storeys exposed within the Chinji Formation indicate that individual channel segments generally had widths of 80–200 m, maximum depths of 4–13 m, wavelengths of 1.6–2 km and discharges of 400–800 m³/s. Full channel belt widths (1–2 km) estimated from exposures perpendicular to paleoflow, and evidence for 2–3 coeval channels within channel belts, indicate full channel discharges of 1500–2000 m³/s. Larger channel segments reconstructed from the Nagri Formation had widths of 200–400 m, maximum depths of 15–30 m, wavelengths of 3–5 km, and discharges of 3000–5000 m³/s. As Nagri Formation channel systems were also clearly braided, full channel dimensions and discharge estimates are probably at least a factor of two greater than for individual channel segments (i.e. order of 10,000 m³/s).

Strata between major sandstone bodies are dominated by lobate and wedge-shaped bodies (crevasse splay and levee deposits), minor channel-form bodies (deposits of minor floodplain channels), laminated mudstone bodies (lake deposits) and paleosols. These strata are arranged into meters to 10 m thick stratified sequences that were rapidly deposited, bounded by well developed paleosols recording periods when deposition rates were low. The thickness and grain size of such paleosol bounded sequences are not directly related to the proximity of a major channel deposit along strike. Instead, such sequences within overbank deposits appear to reflect local progradation of splays and levees into low areas on the floodplain.

Key words: Fluvial system, Chingi Formation, Nagri Formation, siwaliks.

W/105. Willis, B.J., 1993b. Evolution of Miocene fluvial systems in the Himalayan foredeep through a two kilometer-thick succession in northern Pakistan. *Sedimentary Geology*, 88, 77-121.

Sedimentological variations through a kilometer-thick coarsening-upward succession in the Miocene Himalayan foredeep basin (fluvial Chinji and Nagri Formations of the Siwalik Group) are documented in the Chinji Village area on the Potwar Plateau of northern Pakistan. From the Chinji Formation upwards into the Nagri Formation: (1) the proportion of major sandstone bodies increase relative to mudstone-dominated beds; (2) average thickness and mean grainsize of channel deposits increase; (3) sediment aggradation rates increase; (4) there is a reported change in sediment provenience; (5) paleocurrents are generally to the southeast and vary little upsection; and (6) paleosols are more distinct lower in the section where there is also more evidence of ponding of water on the floodplain. Smaller-scale (100 m thick) cyclic variations in the proportion of major channel sandstone bodies also occur in both formations.

In the modern Himalayan Basin, sediment dispersal away from the mountain belt is associated with: (1) major rivers that flow along the basin axis; (2) large rivers that drain substantial areas of the mountain belt and deposit low relief sediment fans extending hundreds of kilometers into the basin; and (3) smaller rivers in fan and interfan areas that drain local areas and carry finer sediment loads. Sediment variations through the Chinji-Nagri Formation boundary can be related to a shifting of depositional environments within such fan and interfan areas. Major basin-axial rivers are not exposed in this area. It appears that kilometer-thick upsection variations in these deposits record the progradation of the sediment fan formed by a large river system (river discharge on the order of 104 m³/s) over the floodplain of a smaller river system (river discharge on the order of 103 m³/s).

Large-scale vertical sediment variations over hundreds of meters to kilometers appear to reflect changes in the basin subsidence and the rate of sediment input to the basin over time scales on the order of 105–106 years. Upsection variations can not easily be related to climatic change or eustatic variations in sea level. The most likely explanation for upsection changes is tectonism. Deposition rates and shifting positions of river systems within the basin responded more quickly to changes in basin subsidence rate, whereas increases in the proportion of sandstone bodies and increases in floodplain slopes lagged behind. Deposit variations in the Siwalik Group clearly record variations between different-scale river systems delivering sediment to the basin as well as the overall basin evolution.

Key words: Fluvial system, Chinji Formation, Nagri Formation, siwaliks.

W/106. Willis, B.J. & Behrensmeyer, A.K., 1995. Fluvial systems in Siwalik Miocene and Wyoming Paleogene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 115, 13-35.

The 3 km thick Miocene Siwalik Group (Himalayan foredeep in northern Pakistan) and the 2 km thick Paleogene Fort Union/Willwood formations (Bighorn Basin in Wyoming) both preserve long records of fluvial deposition adjacent to rising mountain belts. Depositional environments and associated habitats change across large basins along with changing physiography and with the location of different river systems that may have varied greatly in patterns of channel deposition and the drainage of adjacent floodplain areas. Deposits exposed in these two basins provide very different records of shifting paleoenvironments and patterns of basin filling. These differences reflect distinct patterns and scales of depositional environments. The nature of the exposures, and the types of sedimentologic studies that have been carried out in each basin.

The Siwalik Group fills a basin that extended at least 1000 km along its axis and 150–250 km away from the mountain front. Comparison of Siwalik deposits and modern drainages in the Himalayan foredeep suggests the ancient Siwalik basin was filled by large rivers that deposited low gradient sediment fans covering areas on the order of 1000 km², and by smaller intrafan rivers with more poorly drained floodplains. Despite the scale of these river systems relative to Siwalik exposures in Pakistan, transitions between different systems have been recognized. Deposits of coeval river systems in the Siwalik Basin show pronounced differences in alluvial architecture, the character of overbank deposits, and the abundance and taphonomy of organic remains.

In contrast, the Bighorn Basin in Wyoming is a relatively small intermontane foreland basin extending 200 km along its axis and about 80 km across. Bighorn Basin strata were deposited by a river that flowed south to north along the basin axis and by smaller rivers that flowed transverse to the basin axis. Much of this basin is exposed and thus it is possible to reconstruct changing patterns of deposition and environments through time in more detail than in the Siwalik Basin. These patterns indicate changes in basin-wide drainage conditions and environments through time, but there are also important differences among coeval strata.

Upsection shifts in environments and vertebrate faunas within both the Siwalik and Bighorn Basins may reflect tectonic or climatic forcing, but this comparison emphasizes the importance of recognizing deposits from different contemporaneous river systems before inferring such large-scale controls on paleoecological change through time.

Key words: Fluvial systems, siwalik, Miocene, Wyoming Paleogene.

W/107. Willis, B.J. & Behrensmeyer, A.K., 1996. Architecture of Miocene overbank deposits in northern Pakistan. *Journal of Sedimentary Research, Section B-Stratigraphy & Global Studies* 65, 403-407.

The paper presents a description and analysis of the architecture of ancient overbank deposits from the Miocene Chinji Formation of northern Pakistan (see also Behrensmeyer, 1987, Willis, 1993a). The authors described meters-thick paleosol bounded sequences that are defined by an alternation of relatively mature paleosols and stratified deposits with a lesser degree of pedogenesis. They asserted that the mature paleosols represent relatively long periods of very low deposition rate, whereas the stratified deposits represent relatively short periods of high deposition rate. They proposed and evaluated five end-member hypotheses for the origin of the paleosol-bounded sequences. It is concluded that the stratified deposits were formed by local rapid filling of low areas on the flood plain, independently of the position of major channels: such filling may have been a more or less continuous process, or may have been a short-lived event associated with river-channel avulsion. They specifically dismissed the possibility that the nature of the stratified deposits was related to the proximity of major channels and the growth of alluvial ridges. They also dismissed the possibility that paleosol-bounded sequences could have been related to regional variations in sediment supply and deposition rate, or to valley incision and filling.

Key words: Overbank sedimentation, Miocene, siwaliks.

W/108. Wilson, W.E., 1984. What's new in mineral? *Mineralogical Record* 15(1), 43-46.

Gives many worldwide mineral discoveries. From Haramosh in the Gilgit-Skardu area of northern Pakistan reports large crystals and aggregates of aquamarine.

Key words: Mineral discoveries, gemstones, Haramosh, Gilgit, Skardu.

W/109. Windley, B.F., 1981. Phanerozoic granulites. *Journal of the Geological Society, London*, 138, 745-751.

Granulites can form at every stage of the Wilson cycle: during plate accretion (Mid-Atlantic Ridge), in active plate margins of island-arc and Andean type (Ivrea Zone, main complex in Kohistan in the Karakorums), in the roots of Andean-type batholiths (Coast Range Complex, British Columbia; Santa Lucia Range of California), during the closure of a marginal basin (Aracena belt, Spain), during Himalayan-type collision (Jijal Complex in the Karakorums of N Pakistan and at l'Agly in the Pyrenees) and during post-tectonic intrusion at depth (São Paulo, Brazil). Himalayan-type orogenic belts may, in principle, contain any of such granulites. The majority of granulites form along active plate margins in the roots of magmatic arcs, which are the main sites of crustal growth in the Phanerozoic. Layered stratiform complexes, formed largely by cumulate processes, are common in Phanerozoic granulites (Kohistan, Ivrea, Calabria in Italy, Cabo Ortegal in NW Spain, Brittany and N Pyrenees). Their granulite-grade parageneses may have formed during cooling from an igneous temperature, or during superimposed metamorphism. Variations in the types of granulites may help in understanding how different types of lower continental crust are constructed.

Key words: Granulites, Jijal complex, Chilas, Kohistan.

W/110. Windley, B.F., 1983. Metamorphism and tectonics of the Himalaya. *Geological Society London Journal* 140, 849-865.

Metamorphism connected with the main growth and deformation stages of the Himalaya ranges from mid-Cretaceous to the Quaternary. Northward subduction gave rise in the early to mid-Cretaceous to an island arc complex with greenschists, amphibolites, granulites and blueschists in the W (Kohistan-Ladakh) and an Andean-type margin with greenschist-amphibolite grade metamorphism in the E (India and Tibet). Ophiolitic nappes were thrust southwards over the Indian continental margin in the Palaeogene during the final stages of closure of the southern arm of Tethys. The Indus-Zangbo Suture bifurcates westwards and between the two sutures lies the Kohistan-Ladakh island arc which was converted to an Andean-type arc in the Palaeocene-Eocene. The Karakorum Range underwent northward subduction at least during the late Cretaceous to give rise to a complex and prominent calc-alkaline batholith. Post-collisional southward thrusting of crustal slabs over the Indian continental margin took

place in the early Miocene with production of high-grade metamorphism, inverted isogrades and crustal melt granites. Later southward thrusting in the Pliocene to Quaternary gave rise to localized low-grade recrystallization against the thrusts.

Key words: Metamorphism, tectonics, Karakoram, Himalaya.

W/111. Windley, B.F., 1984. *The Evolving Continents*. Wiley, New York, 399p.

In this highly popular book there is a brief summary of the geology and tectonics of northern Pakistan.

Key words: Tectonics, continents, magma genesis, metamorphism, mineralization..

W/112. Windley, B.F., 1985. Geochemical and time constraints on the evolution of the Kohistan arc-batholith, Pakistan. Abstract Volume, 1st Himalayan Workshop, Department of Geology, University of Leicester.

The Kohistan arc-batholith went through three stages of growth. New Rb-Sr isochron dates are by M.G. Petterson, an ³⁹Ar/⁴⁰Ar date is by D. Rex and geochemical data are by I. Luff and M.G. Petterson. We do not know when the island arc began to form. The Yasin Group Sediments which were deposited in intra-arc basins (C. Pudsey) contain Albian-Aptian faunas. The arc pluton consist of a bimodal suite of low-K tonalitic and high-K diorite gneisses, one of which has a Rb/Sr age of 102±12 Ma. The overlying Chalt Volcanics comprises pillowed primitive basaltic tholeiites succeeded by andesites, dacites and rhyolites, typical of many mature island arcs. The Chilas Complex consisting of norites and layered cumulates formed by deep-level fractionation (dominated by orthopyroxene precipitation) from the magma, which gave rise to the island arc. All these rocks were deformed by major fold structures, which are correlated with the formation of the Northern Suture, after which the island arc was intruded by an Andean-type calc-alkaline batholith on the northern active continental margin of Tethys. The first expression of the I-type batholith was the intrusion of a swarm of NE-SW trending hornblende diorite dykes, one of which has a ³⁹Ar/⁴⁰Ar hornblende age of 75 Ma. The main constituent of the batholith is a suite of medium-K intrusions emplaced throughout its evolution, which ranges from gabbro to granite, though the dominant rock type is granodiorite. In the Gilgit area this suite is intruded by high-K diorite plutons. Two plutons near Gilgit have Rb-Sr isochron ages of 54±4 Ma and 40±6 Ma. Limited Sr-isotope data indicate a dominantly mantle source for the batholith and trace element patterns are typical of subduction-related magmas. The Dir-Utror Group of calc-alkaline lavas (and sediments with Eocene fossils) are probably remnants of the volcanic cover of the batholith. Following formation of the Indus Suture in the Eocene, the batholith was intruded by an intense swarm of layered aplite-pegmatite, S-type granite, sheets at 34±14 Ma and 29±8Ma, as a results of partial melting of the island arc crust thickened tectonically and/or by magmatic accretion or of the underplated Indian below the arc.

Key words: Geochemistry, evolution, Kohistan arc batholith, Himalaya.

W/113. Windley, B.F., 1988. Tectonic framework of the Himalaya, Karakoram and Tibet, and problems of their evolution. *Philosophical Transactions of the Royal Society, London*, A326, 3-16.

The Himalaya, the Karakoram and Tibet were assembled by the successive accretion to Asia of continental and arc terranes during the Mesozoic and early Tertiary. The Jinsha and Banggong Sutures in Tibet join continental terranes separated from Gondwana. Ophiolites were obducted onto the shelf of southern Tibet in the Jurassic before the formation of the Banggong Suture. The Kohistan--Ladakh Terrane contains an island arc that was accreted in the late Cretaceous on the Shyok Suture and consequently evolved into an Andean-type batholith. Further east this Trans-Himalayan batholith developed on the southern active margin of Tibet without the prior development of an island arc. Ophiolites were obducted onto the shelf of India in the late Cretaceous to Lower Palaeocene before the closing of Tethys and the formation of the Indus--Yarlung Zangbo Suture at about 50 Ma. Post-collisional northward indentation of India at ca. 5 cm per year since the Eocene has reformed this accreted terrane collage; palaeomagnetic evidence suggests this indentation has given rise to some 2000 km of intracontinental shortening. Expressions of this shortening are the uplift of mid-crustal gneisses in the Karakoram on a late-Tertiary breakback thrust, folding of Palaeogene redbeds in Tibet, south-directed thrust imbrication of the foreland and shelf of the Indian Plate, north-directed back-thrusts along the Indus Suture Zone, post-Miocene spreading and uplift of

thickened Tibet, giving rise to N-S extensional faults, and strike-slip faults, which allowed eastward escape of Tibetan fault blocks.

Key words: Tectonics, Himalaya, Karakoram, Tibet.

W/114. Windley, B.F., Coward, M.P. & Jan, M.Q., 1986. The geology and tectonic evolution of the Karakoram-Kohistan range of the Himalaya of N. Pakistan. In: Huang, J.Q. (ed.), *Proceedings of Symposium on Mesozoic and Cenozoic Geology. 60th Anniv. Volume Geological Society of China*, 455-467.

The Indus suture in northern Pakistan splits into two branches that bring rocks of diverse nature in contact. The exact position of the northern suture is uncertain. North of it pelitic and calcareous rocks show a rapid northward increase in grade of metamorphism; in the sillimanite zone they are intruded by the Tertiary calc-alkaline Karakoram batholith. Sedimentary rocks to the north of the batholith are mostly Palaeozoic in age and are dominated by pelites, calcareous and arenaceous rocks, and extend to the Chinese border. The southern suture, with associated high-pressure granulites, meta-ultramafics and blueschists, is bordered on the south by rocks of the Indian plate consisting of a basement of late Precambrian pelites intruded by Cambrian granites and overlain by a cover of Mesozoic carbonates and shales which, with its basement, was highly folded, thrust and metamorphosed up to sillimanite grade during the Tertiary.

Between the two sutures occur rocks of the Kohistan sequence belonging to a mid-Cretaceous island arc (formed during northward subduction) which is represented by (north to south): tightly folded pillow-bearing basic volcanics and sediments; foliated tonalites and diorites; the Chilas complex which is a stratiform cumulate body over 300 km long and 8 km thick; an amphibolitic belt of mixed lithologies; and the Jijal complex which is a 200 km² tectonic wedge of high-pressure mafic granulites and chromite-layered ultramafics. The Chilas complex was folded by an F1 isoclinal anticline (and metamorphosed in the granulite facies) and the upper part of the Kohistan arc by a major F2 syncline; both folds formed during collision of the arc with the Indian plate in the early Eocene. The arc was upthrust on a ramp during the collision so that it is now subvertical, providing a remarkable section through the crust. The Kohistan sequence became an Andean-type arc in the Eocene (during southward subduction) when calc-alkaline plutonics and volcanics were intruded and extruded. Several plate tectonic models are evaluated for the production of the Karakoram batholith and the northern suture. Factually, the Kohistan sequence (and its eastern extension in Ladakh) is a double arc with an intervening period of collision (Coward et al., 1984). From the Chinese border to the Karakoram batholith is a thick sequence of low-grade fossiliferous sediments, mostly slates, phyllites, dolomites, limestones and sandstones, ranging from Devonian to early Cretaceous (Desio and Martina, 1971; Tahirkheli, 1979). The structural history of this sequence of deformed sediments is unknown.

The Karakoram batholith (> 350 km long and 10 km wide) consists of a complex sequence of intrusions which can be broadly divided into two groups: early large plutons of foliated biotite or hornblende-granodiorite, adamellite and quartz diorite were intruded by small intrusions and sheets of undeformed leucogranite with rare garnet and tourmaline, adamellite, and pegmatite and aplite with tourmaline, garnet and beryl. Preliminary data suggest the granodiorites and granites have K/Ar ages in the range 65-5 Ma (Blasi et al., 1980; D. Rex, pers. comm.). Broughton (1981) found from a chemical (XRF and microprobe) study of these rocks that they represent two distinct petrogenetic groups. The more mafic granodiorites, tonalites and diorites have a calc-alkaline chemistry and are diopside normative and contain modal hornblende, sphene, more calcic plagioclase and magnetite $\pm$ ilmenite, in contrast to the more alkali-rich leuco-granites which are corundum normative and contain modal garnet and tourmaline and ilmenite as an opaque phase.

South of the Karakoram batholith there is a meta-pelitic sequence which shows a marked southward decrease in grade via closely spaced isograds. Sillimanite schists in the north pass via garnet-staurolite schists, garnet-chloritoid phyllites to chloritoid slates and chlorite-biotite slates at Chalt. Chloritoid schists occur in the same tectonic position in the Skardu area (Zanettin, 1964). Adjacent to the batholith there is a 4 km wide belt of corundum-bearing marbles with complex sulphide mineralisation which crystallised at 600-700 °C and 7 kb fluid pressure (Okrusch et al., 1976).

Key words: Tectonics, continents, Karakoram, Kohistan.

W/115. Winslow, D.M., Chamberlain, C.P. & Zeitler, P.K., 1995. Metamorphism and melting of the lithosphere due to rapid denudation, Pakistan Himalaya. *Journal of Geology* 103, 395-408.

The Nanga Parbat-Haramosh Massif of the western Himalaya has undergone a complex metamorphic and tectonometamorphic history over the past 1.8 Ga. metamorphism in the Tato region is characterized by a Barrovian type metamorphism by partial melting and recrystallization along shear zones during nearly isothermal decompression while the massif was still at temperature $>550^{\circ}\text{C}$. mineralogical and textural evidence for this path includes garnet zoning pattern, late-stage migmatization, abundant cordierite both in schists and leucogranite dikes, replacement of high-pressure assemblages by low-pressure assemblages, and abundant low-density inclusions. Thermobarometry on the nonmigmatized gneisses reveals conditions of $540\text{--}740^{\circ}\text{C}$ at $7.1\text{--}13.1\text{ Kbar}$. Thermobarometry in the migmatized rocks reveals final equilibration at $608\text{--}675^{\circ}\text{C}$ at $3.9\text{--}6.8\text{ Kbar}$. Early fluid inclusions occur in quartz inclusions within garnet porphyroblasts that grew during decompression. The last fluid inclusions to be trapped occur in microfractures that locally crosscut several grain boundaries and, hence, record conditions after quartz grain boundary migration ceased. Examination of all the petrologic and fluid inclusion data conclusively show a very rapid denudation event late in the collisional process. Rapid denudation resulted in the advection of isotherms to shallow crustal levels causing an elevated geotherm ($\sim 60^{\circ}\text{C/km}$) in the upper crust, metamorphism along zones, and partial melting of the crust at depths of ca. 22 km.

Key words: Metamorphism, lithosphere, denudation, Himalaya.

W/116. Winslow, D.W., Zeitler, P.K. & Chamberlain, C.P., 1993. Characterization of Neogene metamorphism in the polymetamorphic Nanga Parbat syntax, Pakistan, Himalaya. Abstracts with Program, Annual Meeting of the Geological Society of America, p. A-123.

Pelitic units metamorphosed under upper amphibolite-lower granulite facies conditions record the complex tectonometamorphic history of the Nanga Parbat Syntax (NPS) with peak metamorphic conditions of 145°C and 7.1 kbar . The NPS is an extension of Indian basement which has undergone rapid exhumation over the past 10 Ma resulting in its exhumation from beneath the Kohistan paleoisland arc terranes. Recent geochronologic work indicates that the massif has experienced extensive metamorphic and igneous activity coincident with rapid exhumation. Here we report petrologic and thermobarometric evidence for polymetamorphic history within the NPS.

The first example is from a shear zone found just south of Talo village along the Raikot valley. The shear zone which has been brought to the surface along the associated brittle fault, contains the assemblage $\text{met} + \text{biotite} + \text{sillimanite} + \text{plagioclase} + \text{cordierite} + \text{K-feldspar} + \text{rutile} + \text{ilm.}$ Ca X-ray maps of Ca-Mn-Mg-Fe in garnet reveal a complex porphyroblast growth history. Ca and to lesser degree Mg , Mn and Fe record an early zoned euhedral garnet with compositions mirroring presumed paleocrystal faces. This growth was followed by the growth of homogeneous garnet and later resorption of the garnet characterized by a Mn enriched rim as well as physical replacement of garnet by biotite. Thermobarometry including biotite, matrix biotite and biotite in contact with the rim of the garnet yields an increasing P-T path from 814 to $845 \pm 50^{\circ}\text{C}$ at P of 6.8 and $7.1 \pm 1\text{ kbar}$ respectively for the zoned euhedral core followed by new garnet growth at temperatures of $688 \pm 50^{\circ}\text{C}$ and P of 6.1 kbar .

The second example is a shear zone located in the Diamir traverse 3 km from the Raikot fault and may be a ductile shear associated with earlier movement along the Raikot fault. Within the mylonite are relict porphyroclasts of garnet. The garnets are almost completely replaced by cordierite, biotite and plagioclase. Garnet-biotite in contact yield final equilibration temperature of 555°C at 2.2 kbar . While garnet cores and biotite yield temperatures of 670°C at 2.2 kbar .

Cation zoning, petrography and thermobarometry suggests a complex tectonometamorphic history for the southern portion of the NPS. An early M1 metamorphism which overgrows a relict foliation is characterized by an increasing P-T path consistent with loading of the Indian plate by the Kohistan island arc terrane. Within the past 10 My , M1 was overprinted by a distinctively lower temperature lower pressure M2 metamorphism initiated as rocks recrystallized during decompression. Migmatization was probably coincident with this phase. This was followed by further decompression characterized by resorption of plagioclase and growth of $\text{Fe-rich cordierite}$ at the expense of garnet as rapid denudation perturbed isotherms.

Key words: Neogene metamorphism, NPHM, Himalaya.

W/117. Winslow, D.M., Zeitler, P.K. & Chamberlain, C.P., 1993a. Combined $^{40}\text{Ar}/^{39}\text{Ar}$ biotite cooling ages and fluid inclusion data from Nanga Parbat (Pakistan Himalaya). An indication of the depth to paleoisotherms with time. EOS 74, p.301.

Key words: Geochronology, Ar-Ar dating, cooling history, fluid inclusion, NPHM, Himalaya.

W/118. Winslow, D.M., Zeitler, P.K. & Chamberlain, C.P., 1994a. Petrology, thermo-chronology, and fluid inclusions: Implications for the denudation and metamorphic history of the Nanga Parbat region, Pakistan. EOS 75, p.186.

Key words: Petrology, thermo-chronology, fluid inclusion, denudation, metamorphic history, NPHM.

W/119. Winslow, D.M., Zeitler, P.K. & Chamberlain, C.P., 1994b. Differential cooling within the Nanga Parbat Massif, Pakistan Himalaya: Implications for syntaxial development. Geological Society of America, Abstracts with Programs 26(7), A-136.

Key words: Petrology, chronology, Fluid inclusion, Cooling history, NPHM.

W/120. Winslow, D.M., Zeitler, P.K., Chamberlain, C.P. & Hollister, L.S., 1994. Direct evidence for a steep geotherm under conditions of rapid denudation, western Himalaya, Pakistan. Geology 22, 1075-1078.

Recent fluid-inclusion and $^{40}\text{Ar}/^{39}\text{Ar}$ cooling-age data show that currently exposed basement rocks in the Raikhot glacier valley of the Nanga Parbat-Haramosh massif, Pakistan Himalaya, were at temperatures of 350 ± 50 °C at depths of 6 ± 2 km (hydrostatic pressure correction). These data imply the presence of a steep thermal gradient in the upper crust at 1 Ma (29-100 °C/km) and denudation rates over the past 1.0 m.y. of 3-6 mm/yr, providing independent corroboration of previous estimates of rapid denudation at Nanga Parbat (4.5 mm/yr over 3.3 m.y.). Our data provide direct documentation of near-surface compaction of isotherms under conditions of rapid denudation, a result that has long been supported by thermal modeling.

Key words: Geothermometry, Rapid denudation, Ar-Ar dating, Fluid inclusions, NPHM.

W/121. Winslow, D.M., Zeitler, P.K., Chamberlain, C.P. & Williams, I.S., 1996. Geochronological constraints on syntaxial development in the Nanga Parbat region, Pakistan. Tectonics 15, 1292-1308.

$^{40}\text{Ar}/^{39}\text{Ar}$ data (hornblende, biotite, muscovite, and K-feldspar) and U/Pb data (zircons) were obtained from the Nanga Parbat-Haramosh Massif (NPHM), NW Pakistan, along three transects in the southern regions of the NPHM. We have based our interpretations on our new data as well as geochronologic dates from previous studies in the northern regions of the massif. Geochronologic data show that the NPHM has experienced exceptionally high denudation and cooling rates over the past 10 m.y. U/Pb ages determined through sensitive high-resolution ion microprobe (SHRIMP) "depth-profiling" experiments on metamorphic zircons and conventional U/Pb monazite dates suggest that the timing of metamorphism varied across the massif. In addition, we have documented that the massif has experienced postmetamorphic, differential cooling both along and across strike. Thermochronologic data on currently exposed surface rocks suggest that cooling occurred more recently and at greater rates in the south-central regions of the massif (representing deeper crustal levels) than along the margins and northern regions of the massif. Within the Tato region, cooling following peak metamorphic temperatures of 600°–700 °C was as high as 140 °C/m.y. following partial melting of pelitic units. Biotites from this area record plateau ages of 0.9 ± 0.1 Ma. Along the Astor and Indus gorges, cooling was less rapid (approximately 70°–80°C/m.y.) following peak metamorphism as indicated by U/Pb monazite ages of 6–8 Ma and $^{40}\text{Ar}/^{39}\text{Ar}$ muscovite cooling ages of 2.2–3.4 Ma. Cooling over the last 3 m.y. occurred at rates of 100°–140 °C/m.y. The overall cooling age pattern within the massif is interpreted syntaxial growth through the development of north plunging antiforms prior to 3 Ma, followed by reverse faulting along east dipping fault zones. Along the Raikot River transect the biotite cooling age pattern is consistent with the folding of isotherms during folding of the foliation surfaces. The age pattern was disrupted at 1 Ma due to faulting along the Raikot and Tato faults.

Key words: Chronology, metamorphism, NPHM, Himalaya.

W/122. Wissman, H. Von., 1959. The present day glacier cover and snowline in high Asia: *Abhandlungen der Akademie der Wissenschaften und der Literatur. Mathematisch-Naturwissenschaftliche Klasse, Heft 14*, 1101-1436 (in German). 335p

Key words: Glaciers, snowline, Asia.

W/123. Wood, R.M., 1985. A science of mountains. In Miller, K.J., *The International Karakoram Project, Volume 2*. Cambridge University Press.

This article considers the beginnings of the science of mountains and the role of the IKP in the integration of several disciplines concerned with that science. The hope is expressed that IKP may help stimulate more projects to further that integration towards a more unified approach to the study of earth sciences.

Key words: Orogeny, Kohistan arc, Himalaya.

W/124. Workman, F.B., 1899. Ascent of the Biafo Glacier and Hispar Pass: Two Pioneer ascents in the Karakoram. *Scottish Geographical Magazine* 15, 523-526.

This is a narrative of the earliest visit to the central Karakoram Biafo glacier and the Hispar pass housing another great glacier of this name. General information on the geography of the area is also given.

Key words: Glaciers, Biafo glacier, Hispar Pass, Karakoram.

W/125. Workman, F.B., 1901. Amid the snows of Baltistan. *Scottish Geographical Magazine* 17, 74-86.

Key words: Snow, Glacier, Baltistan.

W/126. Workman, F.B., 1904a. Ascent of the Great Chogo Lungma Glacier. *Apalachia*, 10.

Key words: Glacier, Chogo Lungma, Karakoram..

W/127. Workman, F.B., 1904b. Explorations des glaciers du Karakorum. *La Geographie* 9, 23-34.

Key words: Glacier, Karakoram.

W/128. Workman, F.B., 1905. From Srinagar to the sources of the Chogo Lungma Glaciers. *Geographical Journal* 25, 245-268.

Key words: Glaciers, Chogo Lungma, Srinagar.

W/129. Workman, F.B., 1908. Further Explorations in the Hunza Nagar and Hispar Glacier. *Geographical Journal* 32, 495-496.

Key words: Exploration, glaciers, Hispar, Nagar, Hunza.

W/130. Workman, F.B., 1910a. The Hispar Glacier. Its tributaries and mountains. *Geographical Journal* 35, 23-29.

The Hispar glacier is one of the longest of the Karakoram glaciers that ends into the Hunza River near Ganesh. The glacier is some 60 km long and is fed by many smaller glaciers of the central Karakoram. This paper provides details of the Hispar glacier, its tributaries and catchment area.

Key words: Glaciers, Hispar, Hunza, Nagar.

W/131. Workman, F.B., 1910b. The Hispar Glacier: Prominent features of its structure. *Geographical Journal* 35, 115-132.

Consult the preceeding account for further information.

Key words: Glaciers, Hispar.

W/132. Workman, F.B., 1913a. Expedition zum Siachen oder Rose-Gletscher im Karakoram im Jahre. *Mitteilungen Geografische Gesellschaft* 56, 61-65.

Key words: Glaciers, Siachen, Karakoram.

W/133. Workman, F.B., 1913b. Some notes on my 1912 expedition to the Siachen or Rose glacier, Eastern Karakoram. *Scottish Geographical Magazine* 29, 13-17.

Key words: Glaciers, Siachin, Karakoram.

W/134. Workman, F.B., 1914. The exploration of the Siachen or Rose Glacier, Eastern Karakoram. *Geographical Journal* 43(2), 117-148.

Key words: Glaciers, Siachin, Karakoram.

W/135. Workman, F.B. & Workman, W.H., 1901. In the ice-world of the Himalaya: Among the peaks and passes of Ladakh, Nubra, Suru and Baltistan. Fisher Unwin, London.

Key words: Glaciers, Snow, Ladakh, Nubra, Suru, Baltistan, Karakoram.

W/136. Workman, F.B. & Workman, W.H., 1908. Ice-bound Heights of the Mustagh. An account of two seasons of Pioneer Explorations and high climbing in the Baltistan Himalaya. Constable, London.

Key words: Glaciers, Mustagh, Baltistan, Karakoram.

W/137. Workman, F.B. & Workman, W.H., 1917. Two summers in the ice-wild of eastern Karakoram. The Exploration of nineteen hundred square miles of mountain and glacier. Fisher Unwin, London.

The authors spent two summers exploring 1900 km² area of the eastern part of the Karakorum Range. The area is one of the most glaciated on earth. Descriptions have been given of the ice cover of the area with emphasis on various glaciers.

Key words: Glaciers, Eastern Karakoram.

W/138. Workman, W.H., 1910. The tongue of the Hasanabad Glacier in 1908. *Geographical Journal*, 36, 194-196.

Here is a copy of the account from WH Workman: In the 'Records of the Geological Survey of India,' vol. 35, p. 135, Mr. H. H. Hayden calls attention to the story of the rapid advance of the Hasanabad glacier, which he obtained from the Mir and the Wazir of Hunza, according to which the glacier advanced several miles in the course of two and a half months, though it was said to be stationary when he observed its tongue in August, 1906. It was also said to have made a similar advance on a former occasion, of which the time was not specified, after which it retreated rapidly. In the course of the expedition of Mrs. Bullock Workman and myself to the Hispar region in the summer of 1908, before reaching Nagar we camped at Dadimal, about 6 miles distant from the Hasanabad nala. Being so near to it, I decided to devote a day to a visit to the tongue of the Hasanabad glacier, to see whether any change had occurred in its position or condition since Mr. Hayden had observed it two years previously. Accordingly, accompanied by a servant and a coolie to carry my instruments, I started early the next morning to walk the 6 miles that lay between our camp and it. On my arrival at the mouth of the nala about 10 a.m., I was met by the Wazir of Hunza, the medical officer of the Aliabad Dispensary, and a dozen attendants, dispatched by the Mir of Hunza to take me in charge and conduct me to Mr. Hayden's stations. They presented the Mir's compliments, together with a cordial invitation to our party to visit Hunza, of which, owing to other arrangements, we were unable to avail ourselves. After I had rested a short time, and quenched my thirst from a basket of delicious mulberries the Mir had thoughtfully sent over, the whole party went up the nala to the tongue of the glacier, first visiting Mr. Hayden's first station, just west of the extremity of the tongue. This was a huge granite boulder, with Mr. Hayden's inscription upon it in black letters as fresh and bright as if made the preceding day. We climbed to the top of the boulder, which was large enough to accommodate several persons. From here, station 2, marked on the

THE TONGUE OF THE HASANABAD GLACIER IN 1908. 195 rock-face of the mountain-wall opposite on the east side of the nala, could easily be seen, and the lettering on it read with the field-glass. A tripod was set up at the central point of the boulder-top, for use in sighting and photographing. A line sighted from this to station 2 passed directly over the extremity of the tongue, thus showing that, at the end of two years that had elapsed since Mr. Hayden's observation, the tongue remained in the exact position in which he found it. There was also no evidence, from the debris at the extremity, that it had moved either way during that time, one of my photographs of this portion being an almost exact reproduction of Mr. Hayden's, even the same boulders and debris-formations being seen in both. In other respects the tongue was not essentially altered in its appearance as shown in Mr. Hayden's admirable photographs. The steep, rough talus leading up to the Gamkin irrigation-canal, above which Mr. Hayden's station 3 was located, was next ascended, and the spot found where the boulder forming the station had rested, but the boulder itself was not there. It had slid down the slope to a point, below the canal, some 60 feet from its former position, where it was lying partially embedded in sand. Photographs were taken from here, as well as from station 1. The inspection being completed, the party returned to the mouth of the nala. The Wazir added nothing to the statements previously made about the glacial movement. We bade one another adieu about noon, after which I returned to Dadimal. The day was warm, the solar thermometer at 12.30 indicating 196°5' Fahr. I am not aware that the Hasanabad glacier has ever been explored by a European, or that its length is known. Its nala, as far as I could see into it, is narrow, and high snow-peaks tower above its upper portion. If, as seems probable, its length is not great, and its reservoir is large as compared with the size of the trunk, and the mountains enclosing its upper end descend sharply to it, a season or two of heavy snowfall would be likely to cause such an accumulation of snow in the reservoir as might easily induce a sudden augmentation of pressure, which would drive the trunk rapidly down the narrow nala. The last rapid advance would appear from the account to have taken place in the summer of 1903, after the stormy seasons of 1902 and 1903 in this region, when I also noticed a similar advance of a large branch of the Chogo Lungma descending sharply from the snowy Haramash mountains, which crowded the Chogo Lungma trunk bodily over for a considerable distance against its left lateral moraines, from which, in 1902, it stood well removed. The same cause might have been active on the former occasion, when the Hasanabad glacier advanced, and then retreated quickly. If the conditions I have mentioned as probable are the ones actually existing, an equilibrium of pressure having been established by the advance after stormy seasons, in succeeding seasons, without unusual or with less than the average snowfall, the tongue.

Key words: Glaciers, Hasanabad, Hunza.

W/139. Workman, W.H., 1913. Features of Karakoram Glaciers connected with pressure, especially of affluents. *Zeitschrift für Gletscherkunde und Glazialgeologie*, 8, 23-30.

Key words: Glaciers, Karakoram.

W/140. Workman, W.H., 1914. Physical characteristics of the Siachen Basin and Glacier system. *The Geographical Journal* 43, 273-292.

The first few paragraphs of the article: The term "glacier" is not sufficiently comprehensive to designate accurately the immense and, in arrangement, complicated bodies of snow, neve and ice collected in the great rock-basin extending north-west from the source of the Nubra River to Peak 23 (Hidden peak), 78.4 kilom. (49 miles), with an east and west average width for a considerable distance of 32 kilom. (20 miles), and having an area, approximately, of 2400 sq. kilom. (over 900 square miles).

The basin is crossed in various directions by many glaciers of the first order and innumerable lesser ones, fed by snow precipitated upon the mountains and slopes of its watershed, all converging on a great central trunk averaging 4 kilom. (2*5 miles) in width, that stretches the length of the basin in a north-west by south-east direction and discharges from its tongue water derived from the snow collected in all parts of this extensive region to give birth to the Nubra river. This central trunk with its multitude of affluents resembling a river-system is more fittingly styled the Siachen glacier-system. The four other great karakoram glaciers, as well as many smaller but by no means insignificant ones, are fashioned on the same plan. This type is peculiar to the Karakoram, being conditioned on the configuration of its valleys and the arrangement of its peaks. For this reason, as well as on account of certain structural features referable to existing conditions, all these glaciers merit the designation of glacier- systems or glaciers of the Karakoram type. The Siachen basin is separated by its enclosing walls, on the east, from an unexplored region containing the Remo basin, with which the Siachen probably communicates by an ice-covered pass, possibly two, leading from the head of the Tarim Shehr affluent, and further north a group of snow mountains discovered by us from the east Siachen head that give rise to a large glacier, apparently the Urdok, running north-west into Chinese Turkestan; at the north end, from a glacier-basin leading north-east from the Gasherbrum massif; and on the west from the Baltoro, Kabery (Kondus), Sher-pi-gang, Dong Dong, Bilaphond, and Chumik basins, with glacier-passes connecting with the Bilaphond and Kabery, the last first discovered and crossed by our expedition in 1912. The enclosing barriers of the Siachen consist of granite, gneiss, crystal- line schists, slates and shales, sandstones, amorphous and crystalline limestones, and conglomerates, with some igneous intrusions. These rocks alternate with one another at short intervals, and are in places intimately intermingled and interfolded. They are extensively foliated, friable, and easily disintegrated by frost and weathering. Even the granites, largely of the biotite variety, are divided into small sections by joints crossing one another, and intersected by bands of quartz, feldspar, s'chists, and shales, in consequence of which they split up easily into frag? ments. The physical condition of the gneiss and crystalline schists would suggest to the ordinary observer that they were formed largely by metamorphosis of sedimentary deposits. But whether this be the fact, or whether it be that they originated as primary granites and were afterwards metamorphosed by folding, they are brittle, and present in the one case an immature appearance as if incompletely developed, or in the other a decadent one, as if the original structure had been overwrought and dis- organized by strain and violence in the upheaval of the great ranges of which they form constituents. This fragile condition of the rocks accounts for the irregular, jagged outlines of the mountains of the region, especially of the granite peaks, many of which are greatly serrated, and for the vast detritus-deposits that load the glaciers and play an important role in the development of their structural features. Owing to the amount of snow covering the mountains and the staining and weathering of the visible rock-surfaces, it is often difficult, even from a short distance, to distinguish the character of the rocks composing a mountain, so that the observer, particularly if he is not a trained geologist, may well be in doubt as to what formation lies before him. The shales and slates, the latter largely of very dark color, are the most easily distinguished. The north-east wall of the Siachen trunk resembles in structure and extent that which, with an unbroken length of 63 kilom. (39 miles), forms the upper portions of the southern Hispar and western Biafo barriers.* Starting at the north-east head, it extends west 4*8 kilom. (3 miles), then turns south-east and continues on 22 kilom. (14 miles) to the Tarim Shehr affluent. Here it turns east and forms the north wall of the Tarim Shehr for 27 kilom. (17 miles) to its sources, making a continuous, unbroken wall 53 kilom. (33 miles) long. The upper 20 kilom. (12 miles) of this wall is, and the remainder appears to be, a part of the main watershed between Turkestan and the Indus, and as such it probably continues on from the head of Tarim Shehr tributary to the Karakoram pass. A second portion continuing around as the south wall of the Tarim Shehr glacier and extending west to the Tarim Shehr promontory there turns south-east and forms the remaining portion of the north-east wall of the trunk to its end, having a length of 53 Kilm. (33 miles). Stated in another way, the north-east Siachen wall stretches from the north head of the trunk south-east in a nearly straight line for some 72 kilom. (45 miles), being pierced only by one small and two large affluents. The south-west boundary of the upper half of the trunk can scarcely be called a wall. It consists of numerous mountains of irregular outlines, scattered about in an irregular manner, enclosing vast reservoirs of snow and ice that communicate with the

majba glacier by large secondary glaciers, the whole forming an ice-bound labyrinth that defies description. Still, the mountains and affluents stand in such relation to the main glacier that lines drawn from one headland to another suffice to mark the limits of its bed with sufficient accuracy. From the Peak 36 tributary to the tongue, a fairly continuous wall exists which is pierced by several large affluents. The structure of these walls may be stated in general terms as follows: The mountains enclosing the Indira Col and the north-east col, at the northern extremity, are composed of slates and shales, light and dark in colour with, possibly, some limestones. Thence down the north-east wall to within about 6 kilom. (4 miles) of the Tarim Shehr opening mostly of light coloured limestones and shales with some conglomerates and at least one igneous intrusion. The limestones are strongly in evidence in the moraines fed by this section. The rocks are soft and the peaks and ridges broken and jagged in outline. From a point shortly north-west of Teram Kangri, the wall and its peaks, including that summit, quite to their tops, forming the north barrier of Tarim Shehr glacier to its end, appear to be the same. The same is true of the visible rocks on the south side of Tarim Shehr glacier, though some of the ice-covered peaks at its upper end must contain granite and gneiss, as much debris of this character appears in the moraines of that side. On the extremity of Tarim Shehr promontory, most of which is composed of brown shale, granite crops out over a considerable area. Thence, beginning with Junction mountain, 6353 metres (20,840 feet), rising above the promontory, ascended by us in 1911, down to the great bend, some 25 kilom. (16 miles), the mountains are of dark brown and black slate with occasional sections of lighter colour broken into jagged points and cleft by deep, ragged ravines. The only granite noticed in situ in the whole length of this wall was at Tarim Shehr promontory. From our camps on moraines opposite this wall, the view toward it was most forbidding. The foreground was occupied by the huge black hillock-moraine coming from the Tarim Shehr affluent, the towering hillocks of which, resembling vast heaps of coal piled up at random in a Cyclopean coalyard, shut out from sight the white ice of the glacier beyond, while the background was formed by the succession of black peaks hard in outline and destitute of grace, rendered more desolate by contrast with the snow capping their tops, the whole constituting as sombre and depressing a landscape as could well be imagined, far eclipsing the most fantastic conceptions of Boecklin and casting an uncanny shadow over the soul. On the south-west side of the trunk a similar variety of formation occurs, but granite is more and limestone less in evidence. The last three peaks of the King George V. group ending the massive mountain-tongue, interposed between the heads of the Baltoro and Siachen glaciers, which form 11 kilom. (7 miles) of the upper south-west Siachen wall, appear to be mainly composed of granite and gneiss, though on an eastern spur and near its south-east extremity the granite passes over suddenly without discontinuity of outline into black slate. South of this tongue at the entrance of the upper western tributary into the Siachen, the Hawk, a graceful pointed spire of granite, soars from a circle of black slate peaks and ridges to an altitude of 6768 metres (22,200 feet). From this peak downward for 35 kilom. (22 miles) to the great bend, the south-west wall is largely, if not wholly, composed of sedimentary rocks, prominent among which are black slates. Just at the bend, two elevations, the ends of spurs descending from Peak 8, have the appearance of granite.

Key words: Glaciers, Siachen.

W/141. Workman, W.H. & Workman, F.B., 1911. *The Call of the Snowy Hispar. A narrative of Exploration and mountaineering on the northern frontier of India.* Constable, London.

Key words: Glaciers, Hispar, India.

W/142. Wriggins, S.H., 1980. *Karakoram Highway--500 miles of men against glaciers.* Orientations 11, 20-25.

Key words: Glaciers, KKH, Karakoram.

W/143. Wynne, A.B., 1879a. *A geological reconnaissance from the Indus at Kushalgarh to the Kurram at Thul on the Afghan frontier.* Geological Survey of India, Records, 12 (2), 100-114.

Key words: Reconnaissance, Indus, Kurram, Kohat, Afghan Frontier.

W/144. Wynne, A.B., 1879b. *On the continuation of the road section from Murree to Abbottabad.* Records of the Geological Survey of India 12(4), 208-210.

Key words: Geology, Murree, Abbottabad.

W/145. Wynne, A.B., 1880a. On the distribution and identification of the Palaeozoic rocks of the northern Punjab. *Geological Magazine*, Decade, 2, 7(7), 313-317.

Speculation having been rather freely applied to the identification of these rocks, I beg to offer a few notes upon the subject, the facts regarding which I have described in a paper already published. (a note by the author about the article).

Key words: Paleozoic, Punjab.

W/146. Wynne, A. B., 1880b. On the Trans-Indus extension of the Punjab Salt Range. *Geological Survey of India, Memoirs*, 17 (2) 211-305, 6pls.

Key words: Trans-Indus, Salt Range, Punjab.

W/147. Wynne, A.B., 1882. Further note on the connexion between the Hazara and the Kashmir series. *Records of the Geological Survey of India* 15(3), 163-169.

Gives a summary of the views entertained as to the correlation of the rock-groups of the Hazara area with those of Kashmir.

Key words: Stratigraphy, Hazara, Kashmir.

W/148. Wyss, R., 1940. *Geologie. Mit Beiträgen von Dr. Carl Renz und Dr. Manfred Reichel. Wiss Ergebn. Niederland Expedition Karakorum angegr. Geb. Jhr 1922-35.* Brill, Leiden.

This gives information on the geological studies performed during the Karakoram expedition. Further information is not available with the authors.

Key words: Karakoram expedition.

W/149. Wyss, R., Renz, H.H. & Reichel, M., 1940. *Geologie des Karakorum.* Brill, Leiden.

Wyss took part in the 1925 Netherlands Expedition to the western Karakoram. In this account, he describes various aspects of geology, such as stratigraphy, magmatism, sedimentary deposits, etc.

Key words: Geology, structure, Netherland Karakoram Expedition, western Karakoram.

Y/1. Yafeng, S. & Xiangsong, Z., 1984. Some studies of the Batura glacier in the Karakoram mountains. In: Miller, K.J. (Eds.), *The International Karakoram Project, Volume 1*. Cambridge University Press.

In 1974 and 1975, using terrestrial stereophotogrammetry, the Glacier Investigation Group of China made a survey of the Batura Glacier drainage area and drew a 1:60,000 map. A glacial inventory has been accomplished and much data on morphological measurements obtained. The Batura Glacier has some continental-type characteristics but there are number of maritime features; we call the Batura “a complex type glacier”. According to our forecast, the glacier will advance another 180-240 m but in the 1990’s it will once again be on the decline.

Key words: Glaciers, Batura, Karakoram.

Y/2. Yafeng, S. & Wenyingt, W., 1980. Research on Snow Cover in China and the Avalanche Phenomena of Batura Glacier in Pakistan. *Journal of Glaciology*, 6(94).

This paper summarizes the state of research in China on snow cover, snow-drift control, and avalanche defences, and also reports the results of observations of avalanching above Batura Glacier, Pakistan, during two expeditions.

Key words: Glaciers, avalanche, Batura, Karakoram.

Y/3. Yamin, F., 1981-83. Geology and petrology of Tangir valley (District Diamer) with special emphasis on the mineralogy/petrology of the intrusives. M.Sc. Thesis, Punjab University, Lahore, 143p.

Tangir covers 351 square kilometers area located between Kohistan in the South and Yasin in the North. According to plate tectonic concept it lies in between Indo-Pakistan and Eurasian plates comprising a part of Kohistan Island arc. The particular project area is mapped on a scale of 1:62500. In the thesis, an attempt is made to introduce the detailed Geology of the area. Bulk geological sequence of the area is consisted of Norite, Diorite, Amphibolite, Granodiorite and granite which is obducted on to the Paleozoic rocks of Indo-Pakistan plate in the South and subducted under the Eurasian plate towards the North. The Northern part of the area is in contact with Yasin Group which is volcanic. So Tangir area constitutes the lower sequence of Kohistan Complex.

Key words: Geology, petrology, igneous rocks, amphibolites, Tangir, Diamir.

Y/4. Yammoto, H., 1993. Contrasting metamorphic P-T-time paths of the Kohistan granulites and tectonics of the western Himalayas. *Geological Society London Journal* 150, 843-856.

In the Swat-Indus Kohistan area, lower crustal rocks of the Kohistan arc including amphibolites, granulites and ultramafic rocks are widely exposed. Detailed petrological-structural studies reveal that the Chilas-Jijal metamorphic complex comprises essentially intermediate- to high-pressure granulites with a granulite/amphibolite transition controlled by extensive retrograde metamorphism and ductile deformation. Contrasting patterns of compositional zoning in garnet and orthopyroxene suggest complicated P-T paths in the granulites. Geothermobarometry based on garnet-bearing granulites identify two distinct P-T-time paths: a high-pressure anticlockwise path of the Jijal complex and a low-pressure retrograde path of the Chilas complex. These P-T-time paths represent the evolution of middle to lower crustal rocks of the Kohistan arc. The anticlockwise P-T-time path combined with published isotopic ages reveals that: (i) the high pressure granulite facies metamorphism is related to the Kohistan-Asia collision and (ii) the crust of the Kohistan arc had been thickened at least 55 km before the India-Asia collision.

Key words: Tectonics, P-T-t paths, Chilas complex, Jijal complex, Kohistan.

Y/5. Yamamoto, H. & Nakamura, E., 1996. Sm-Nd dating of garnet granulites from the Kohistan Complex, northern Pakistan. *Journal of the Geological Society, London*, 153, 965-969.

Sm-Nd mineral-isochron ages of garnet granulites in the southern part of the Kohistan complex are determined. The 91.0 ± 6.3 Ma age is obtained from a granulite body of the Jijal complex at Pattan and the 69.5 ± 9.3 Ma age is obtained from a granulite body of the Chilas complex at Zambil. These ages indicate that the granulite bodies at Pattan and at Zambil had cooled to below upper amphibolite facies by about 90 Ma and about 70 Ma respectively.

The time of cooling of the granulite of the Jijal complex is comparable to the time-lapse of the Asia–Kohistan collision (102–75 Ma), although that of the Chilas complex is probably younger than the Asia–Kohistan collision and certainly older than the Asia–India collision (c50 Ma).

Key words: Geochronology, Sm-Nd dating, granulites, Jijal, Kohistan.

Y/6. Yamamoto, H. & Nakamura, E., 1998. Sm-Nd dating of superposed replacements in mafic granulites of the Jijal Complex, Northern Pakistan. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 216–218.

The northern part of the Jijal complex (NJC) in the Kohistan arc is a rare example of the lower crust of an island arc. Two stages of replacement under the granulite facies conditions are observed in mafic to ultramafic rocks of the NJC. In the earlier stage, garnet clinopyroxene granulite (garnet+clinopyroxene+plagioclase+quartz) replaced two-pyroxene granulite (orthopyroxene +clinopyroxene ± hornblende + plagioclase ± quartz) and patches of relict, the two-pyroxene granulite, were left in the garnet-clinopyroxene granulite. In the later stage, many pod- and lens-shaped bodies of garnet hornblende (garnet+hornblende +clinopyroxene) replaced the garnet-clinopyroxene granulite. The two-pyroxene granulite and the garnet-clinopyroxene granulite are nearly equivalent in chemical composition and distinct from the garnet hornblende.

Sm-Nd isotopic systems have been studied in these three rock types. Samples for dating were collected from roadside sections along the Karakoram Highway around lat. 35°07' N and long. 73°00' E (near the Pattan village). Whole rock and mineral isochrons define the following ages: 118 ± 12 Ma for KU66A (two-pyroxene granulite), 94.0 ± 4.7 Ma for PD6B (garnet-clinopyroxene granulite), and 83 ± 10 Ma for PDI5B (garnet hornblende). Errors in ages are quoted as 2 σ . The age of KU66A shows that the protolith of two-pyroxene granulite had been formed before the Kohistan-Asia collision, which is dated between 102 and 85 Ma [1, 2]. The age of PD6B agrees with a 91.0 ± 6.3 Ma Sm-Nd age of KU66 (the garnet-clinopyroxene granulite from the same outcrop of KU66A in this study) in an earlier report [31]. All the above ages are consistent with relative order of the formation of the three rock types. The earlier replacement took place before c. 90 Ma (PD6B, KU66) and the later probably before c. 80 Ma (PDI5B). The result implies that these events in the NJC are related to the Kohistan-Asia collision.

Key words: Geochronology, Sm-Nd dating, granulites, Jijal, Kohistan.

Y/7. Yamamoto, H. & Nakamura, E., 2000. Timing of magmatic and metamorphic events in the Jijal complex of the Kohistan arc deduced from Sm-Nd dating of mafic granulites. In: Khan, M.A., Treloar, P.J., Searle, M.P. & Jan, M.Q. (Eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 313–319.

Mafic to ultramafic granulites in the northeastern part of the Jijal complex include two-pyroxene granulite, garnet-clinopyroxene granulite and garnet hornblende. Field and textural relations indicate that two-pyroxene granulite is a relict left after formation of the garnet-clinopyroxene granulite and garnet hornblende was an originally intrusive rock, which dissected the protoliths of mafic granulites. Sm-Nd mineral isochron ages of 118 ± 12 Ma, 94.0 ± 4.7 Ma and 83 ± 10 Ma were determined for two-pyroxene granulite, garnet-clinopyroxene granulite and garnet hornblende respectively. These ages, together with previously reported chronological data, led to the following tectonic implications: (1) crystallization of the granulite protoliths predates, or is coeval with, the tectonic accretion of the Kohistan arc to the Asian continent; (2) crustal thickening related to the accretion was probably responsible for the high-pressure granulite-facies metamorphism in the Jijal complex; (3) formation of the garnet hornblende assemblage was probably after crystallization of garnet-clinopyroxene granulite.

Key words: Geochronology, granulites, Jijal, Kohistan.

Y/8. Yamamoto, H. & Yoshino, T., 1998. Superposition of replacements in the mafic granulites of Jijal complex of the Kohistan arc, northern Pakistan: dehydration and rehydration within deep arc crust. *Lithos* 43, 219–234.

Key words: Granulites, Jijal, Kohistan.

Y/9. Yaqoob, M., 1978-80. Geological mapping of Tarbela Dam. M.Sc. Thesis, Institute of Geology, Punjab University, Lahore, 142p.

Key words: Geology, structures, dams, Tarbela.

Y/10. Yaqub, H.M., 1973. Geological mapping and investigation of Chalt damsite, northwest Karakoram, Gilgit Agency. M.Sc. Thesis, Punjab University, Lahore.

Key words: Geology, structures, Chalt damsite, Gilgit, Karakoram.

Y/11. Yar, M., 1997-98. Geological mapping and hydrogeological studies of Rawalakot area (District Ponch) A.K. with special emphasis on microbiological study of water. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 56p.

Geologically, the area under study is situated Lesser Himalayas Precambrian to recent rocks are exposed. Most of the area is covered by thick vegetation and rangelands. Samples were collected from springs, wells and streams for pollutants and bacterial study. The source of pollutants is faecal marked by the coliform organisms. Septic tanks, uncontrolled disposed off liquid and solid waste by the community, disposed off solid and liquid wastes from C.M.H and the fine sediments from Murree Formation contaminated the water as a whole. The rainwater flow through Murree Formation and the dissolution of carbonate and bicarbonate and other minerals from Murree Formation and the soils are also effected the water quality. The toxic metals like lead, zinc, copper and manganese coming into the water through aluminum pipes, or from the fitting used for the pipes. All the above sources arise the health based problems to the community in Rawlakot area. The diseases like enteric fever, typhoid, dysentery, diarrhea, cholera, abdominal pains and gastric enteric, brain hemorrhage and heart problems are water borne common infections in community. From the results it has been concluded that the drinking water from the springs, wells and streams are mostly at intermediate to high risk.

Key words: Mapping, hydrogeology, Rawlakot, Azad Kashmir.

Y/12. Yaseen, C.M., 1995-96. Structure, stratigraphy, micropaleontology and petrography of Darthian, Narota & Karwal areas, Districts Haripur, Hazara (NWFP), Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 95p.

The Darthian, Narota and Karwali area are part of Attock-Hazara fold-and-thrust belt of the northwest Himalaya of Pakistan. The lithographic units exposed in the area are mainly sedimentary in nature and range in age from Mesozoic to Cenozoic. The area is deformed by folding and faulting during the Tertiary-Himalayan collision. The Early Cretaceous Lumshiwal Formation has conformable contact with the overlying Late Cretaceous Kawagarh Formation. The presence of glauconite in the Lumshiwal Formation reveals that the formation was deposited in marine condition during regressive as well as transgressive phases. The Late Cretaceous subduction of the Indian plate below the Kohistan Island arc caused the deepening of the Tethyan shelf in the subduction zone and initiated the deep marine deposition of the Kawagarh Formation. The contact between Kawagarh Formation and Early Paleocene Hangu Formation is marked by break in deposition which is evidenced by the presence of laterite/haematite and sandstone. The abrupt change in facies from deep water marine environment of Kawagarh Formation to terrestrial deposition of Hangu Formation indicates the initial Early Paleocene collision of the Indian Plate and Kohistan Island arc. The Lower Tertiary sequence exposed in the area is Early to Late Paleocene Lockhart limestone, Late Paleocene Patala Formation, Early Eocene Margalla Hill Limestone, Early Eocene Chorgali Formation and Early to Middle Eocene Kuldana Formation. The Lower Tertiary sequence marks the complete cycle of transgression and regression of the Tethyan Sea. The presence of early Paleocene to Late Eocene foraminiferal assemblage like globorotalia, globogorina, lockharia, assilina and nummulites in the limestones and shales of the Lower Tertiary sequence show the tropical sub-tropical open sea upper slope to outer shelf environments. The Kuldana Formation is composed of marine limestone, continental variegated clay, shales and evaporitic gypsiferous bands. These variegated lithologies show that the Early to Middle Eocene Kuldana.

Key words: Structure, stratigraphy, palaeontology, petrography, Haripur.

Y/13. Yasin, A.R., 1982-84. Structural studies of Chinarkot-Galidada Area, District Mansehra. M.Sc. Thesis, Punjab University, Lahore, 87p.

The landforms bear a specific relationship with geological structures and the climate which can be worked out by qualitative as well as quantitative analysis of the topographic map. The most predominant lithologies of the project area are garnet mica schists, and Susalgali granite gneiss. The rocks of the project area have been classified into eight lithologic units for the sake of mapping purposes at a scale of 7 Cm. to a kilometer. Mesoscopic deformational structures are well exhibited in the project area including both planner and linear structures. The rocks have been folded isoclinally and later being refolded into open folds. The area is traversed by a shear zone, the Chalundri fault and is divisible into two structural domains. The area is deformed by different deformation phases, among which three are recognized on mesoscopic as well as microscopic scale and area is characterized by heterogeneous deformation. The rocks have been folded isoclinally and later being refolded into open folds. The area lies in the core zone of the regional synformal structure of the Mansehra Complex which has experienced metamorphism in Barrovian style. The project area has been metamorphosed up to garnet grade with local contact metamorphic effects along the contacts of granites.

Key words: Structure, granite gneiss, Metapelites, Mansehra.

Y/14. Yasin, M.M., Agha, M.A. & Khattak, Z., 1976. Groundwater appraisal of Haripur plain. M.Sc. Thesis, University of Peshawar, 65p.

Key words: Groundwater, Haripur, Hazara.

Y/15. Yasir, A., 1988-90. The geology and petrology of Jijal and Pattan layered ultramafics-mafic complexes in the vicinity of Jijal & Duber with special emphasis on petrogenesis of these complexes. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 90p.

The project area covers about 368 sq. Km. located in the vicinity of Jijal & Duber, District Kohistan. The work has involved geological mapping of the area on a scale of 1:50,000 of toposheet No. 43 A/16 of Survey of Pakistan. This thesis deals with the geology, petrography and petrogenesis of the Jijal and Pattan complexes in particular and the relation of these complexes with other complexes of Kohistan Arc complex has also been discussed.

The geological sequence of Jijal complex consists of ultramafic and mafic cumulates. The ultramafic cumulates are divided into dunite, wehrlite, websterite, garnet-pyroxenite and garnet-hornblendite, whereas mafic cumulates are garnet gabbro. The geological sequence of Pattan complex also consist of ultramafic and mafic cumulates. The ultramafic cumulates are chromite, dunite and (meta) wehrlite, whereas mafic cumulates are divided into two pyroxene gabbro and two pyroxene-quartz-diorite. Field evidences suggest that Pattan complex was emplaced along pre-existing metamorphosed kayal cumulate complex. The top of the Pattan complex is marked by a spectacular, intrusive polymagmatic breccia. In Duber and NW of Duber Pattan complex is overthrust onto the Jijal complex, which is also a layered cumulate complex. While in Pattan area and SE of Pattan there is a faulted (strike slip) contact between Pattan complex and Jijal complex. The Jijal complex is southernmost, layered ultramafic-mafic cumulate complex of the Kohistan-Ladakh tectonic province. The Main Mantle Thrust (MMT) is the southern boundary of the Jijal complex, which interns is the southern boundary of Kohistan Arc complex. The Main Mantle Thrust (MMT) Duber Thrust Fault wedges out Jijal complex NW of Duber near Chert. On the other hand Main Mantle Thrust and Pattan Fault (strike slip fault) wedges out the Jijal complex on the eastern side near Pashto. The Jijal and Pattan complexes are generated by precipitation from subduction generated, hydrous, low K, picritic high Mg tholeiitic magmas and there is a strong possibility of finding economic metallic mineral deposits with in these layered cumulate complexes.

Key words: Petrology, ultramafics, Jijal complex, Pattan complex, Kohistan.

Y/16. Yasir, M. & Anwar, M.K., 2000. General geology of northeastern Peshawar Basin, south and southeast of Swabi area. M.Sc. Thesis, University of Peshawar.

Key words: Geology, Peshawar basin, Swabi

Y/17. Yeats, R.S., 1982. Neotectonic setting of the southern Himalaya, Northern Pakistan. Abstracts with Programs, Geological Society of America 14, p.650.

Key words: Neotectonics, Himalaya.

Y/18. Yeats, R.S., 1993. Earthquake Hazard of the Himalayan Front. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, p.55.

Great earthquakes of $M > 8$ struck the Himalayan front of India and Nepal in 1897, 1905, 1934, and 1950, leaving seismic gaps between the 1934 and 1905 earthquakes and west of the 1905 shock that were only partially filled by earthquakes in 1803, 1833, 1869, and 1991. None of these great earthquakes has any documented surface rupture, although the 1905 event was accompanied by growth of folds at the Himalayan front.

However, there is abundant evidence of young folding and faulting, including back-thrusting, and these structures must be the surface expression of a décollement moving unmetamorphosed strata over the Indian shield. Beneath much of the Sub-Himalaya, the décollement is too shallow and thus too weak to generate $M > 8$ earthquakes, and the source must then be farther north, perhaps as far north as directly beneath the MCT, where the décollement may enter basement rocks. A major problem is the geological evidence for earthquake segment boundaries. These may follow Indian-shield discontinuities like the Hardwar Ridge and may be expressed at the surface by changes in tectonic style from imbricate thrusting to blind thrusting and development of duns. A second problem is the absence of evidence for great earthquakes prior to 1897. Civilized societies in the plains south of the Himalaya apparently did not record great events for the preceding 2000 years. On the other hand, the Taxila earthquake of A.D.25 in the northern Potwar Plateau of Pakistan may have been a great earthquake, and seismic risk to northern Pakistan may be as great as it is farther east despite the presence of Precambrian salt at the décollement farther south. The absence of Precambrian salt in Hazara and in ranges around the Peshawar basin suggests that the Precambrian salt basin terminates northward in the Himalayan foothills and therefore does not lessen seismic risk in Pakistan.

Key words: Hazards, earthquake, India, Nepal, Himalaya.

Y/19. Yeats, R.S. & Hussain, A., 1982. Zone of Late Quaternary deformation in the southern Peshawar Basin, Pakistan. In: Malinconico, L.L. & Lillee, R.J. (Eds.), Tectonics of Western Himalaya. Geological Society of America, Special Paper, 232, 265-274.

Four left-stepping pressure ridges extend for nearly 60 km parallel and close to the southern margin of the Peshawar basin, cutting diagonally across older imbricate thrust structures of the Attock-Cherat Range. Lacustrine, fluvial, and alluvial-fan deposits dated at 2.8 to 0.6 Ma are strongly folded, faulted, and eroded prior to deposition of alluvial-fan gravels, which are themselves cut by east-northeast-trending faults with their north sides up thrown. The pressure ridges postdate some of the fan drainage but deflect other drainage. The east-northeast-trending faults are high-angle and accompanied by Instrumental seismicity; there is no evidence for strike-slip except for the enechelon distribution of the ridges and low-angle slickensides on one of the faults.

Alluvial-fan and fluvial sediments are folded and faulted at Tarbela Dam, 40 km east-northeast of the easternmost pressure ridge, and the base of Indus River gravels is apparently displaced by a reverse fault with the northwest side up. Farther north, a fault adjacent to Tarbela Lake has left lateral displacement. Additional lineation and south facing scarps occur throughout the Attock-Cherat Range, and Jurassic limestone is faulted over gravels at the western end of the Nizampur basin. We interpret these features as part of a broad zone of deformation involving seismogenic crust; direction of slip is south-southwest. There is no evidence of surface rupture in this zone during Holocene time.

Key words: Peshawar basin, Late Quaternary, deformation.

Y/20. Yeats, R.S. & Hussain, A., 1987. Timing of structural events in the Himalayan foothills of north-western Pakistan. Geological Society of America Bulletin 99, 161-175.

The Attock-Cherat Range forms the southern boundary of the Peshawar basin and includes rocks transitional between metasediments of the Lesser Himalaya and foreland-basin strata to the south. The Attock-Cherat Range comprises three fault-bounded structural blocks which are, from north to south, (1) Precambrian metaclastic strata overlain by unfossiliferous limestone which is itself apparently overlain by Paleozoic strata with the contact not

exposed; (2) unfossiliferous flysch of Precambrian(?) age overlain by Cretaceous and Paleogene marine strata and Murree red beds at least in part of early Miocene age; and (3) unfossiliferous limestone, argillite, and quartzite correlated in part to Paleozoic strata in the Peshawar basin, overlain by a Tertiary sequence generally similar to that in block 2. Farther south, in the Kala Chitta Range, strata of Triassic to Eocene age occur in south-verging folds and thin thrust sheets. The similarity of the Tertiary sequences in the Kala Chitta Range and in blocks 2 and 3 demonstrates that the pre-Tertiary sequences were juxtaposed by faults prior to deposition of the Paleocene Lockhart Limestone. This may coincide with initial contact of the west-northwest-facing passive margin of India with Eurasia or nearby microplates. Major late Tertiary imbricate thrusting and folding took place prior to uplift of the Attock-Cherat Range and to deposition of Peshawar intermontane basin fill of Pliocene-Pleistocene age. The Peshawar basin formed as the Kala Chitta Range was faulted south on the Main Boundary thrust (MBT), forcing Siwalik foreland basins still farther south. Late Quaternary deformation in the southern Peshawar basin occurred along a seismically active zone of *en echelon*, stepped-left faulted pressure ridges that may reflect a subsurface ramp on the older MBT.

Key words: Structure, Himalayan foothills, Attock-Cherat Range.

Y/21. Yeats, R.S. & Hussain, A., 1989. Stratigraphy and structural events around the southern margin of Peshawar basin, Pakistan. Geological Bulletin, University of Peshawar 22, 45-54.

The Peshawar intermontane basin is superimposed on the fold-thrust belt at the southern margin of the 'Pakistan Himalayas. In the southern part of the basin the first Ordovician rocks were identified near Nowshera on the basis of discovery of trilobite trace fossils and consequently the Paleozoic stratigraphy of the area has been revised and modified. The Attock-Cherat Range forms the southern boundary of the Peshawar basin and includes rocks transitional between metasediments of Lesser Himalaya and foreland basin strata of Kala Chitta Range to the south. The range is dominated by slate, less metamorphosed argillaceous and arenaceous strata and subordinate limestone of Precambrian to Paleozoic age. These rocks are unconformably overlain by a thin cover of Jurassic, Cretaceous? Paleocene, Eocene and Miocene rocks. The structural events close to the Peshawar basin are recognized in pre-Paleocene, pre-Pliocene and late Quaternary times. The Peshawar basin formed as the Kala Chitta Range was faulted south on the Main Boundary Thrust (MBT) pushing the Siwalik foreland basin still further south. Evidence for active tectonics is found in four left-stepping *en-echelon* pressure ridges formed within Peshawar basin parallel to its southern margin.

Key words: Structure, stratigraphy, Peshawar basin.

Y/22. Yeats, R.S. & Hussain, A., 1993. Geology of the Himalayan foothills from the perspective of the Attock-Cherat Range. Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, p.56.

The Attock-Cherat Range contains boundaries between very different pre-Mesozoic terranes. South of the Hissartang thrust, the Kala Chitta Range and Potwar Plateau foreland fold-thrust belt comprises an unmetamorphosed Phanerozoic sequence with Ordovician to Carboniferous missing; Indian-shield rocks are overlain by Eocambrian evaporites. This correlates easily with subsurface cratonic rocks of the Punjab plains south of the Salt Range. North of the Khairabad (Panjal) thrust, late Precambrian continental-margin elastics (Manki Slate, Tanawal Quartzite) are overlain by a relatively complete Paleozoic and Mesozoic section which does not correlate well with the shield but is similar to sequences in Kashmir and Afghanistan. These strata are metamorphosed and intruded by granitic rocks, and they can be mapped northward across the Peshawar basin and Swat to the suture zone (MMT). Between the Khairabad and Hissartang thrusts are two problematical thrust plates. The northern plate is dominated by a late Precambrian flysch sequence (argillite, sandstone, and rare limestone, very weakly metamorphosed) named the Dakhner Formation; this is traced NE into the Hazara Formation. The Dakhner resembles the more highly metamorphosed Manki Slate farther north, but it lacks counterparts to the Tanawal Quartzite, Shahkotbala Limestone, Uch Khattak Limestone, and Shekhai Limestone characteristic of the Precambrian north of the Khairabad thrust. The fossiliferous Lower Paleozoic sequence overlying the Precambrian of the Peshawar basin is absent south of the Khairabad thrust, where the Dakhner is overlain directly by Paleocene strata and locally by Jurassic or Cretaceous rocks. Similar relationships are seen in the Kherimar Hills and Hazara. The southern thrust sheet consists of Darwaza Limestone, Hissartang Quartzite and associated redbeds, and Inzari Limestone overlain by Paleocene. The Darwaza to Inzari sequence lacks fossils and does not correlate easily with

the lower Paleozoic of the Peshawar basin or with any other sequence, including that of the Salt Range. The Mesozoic and Tertiary of these thrust sheets correlate with the fold-thrust belt to the south even though the older rocks do not, indicating that the Dakhner, Darwaza-Inzari, and Kala Chitta sequences were juxtaposed in pre-Paleocene and possibly pre-Jurassic time. The lack of evidence for Eocene collision suggests that the major encounter of the Attock-Cherat Range was between India and one or more microplates, and this encounter may have been largely strike slip on the western margin of the Indian plate.

Key words: Structure, Attock-Cherat, Himalayan foothills.

Y/23. Yeats, R.S. & Lawrence, R.D., 1984. Tectonics of the Himalayan Thrust Belt in Northern Pakistan. In: Haq, B.U. & Milliman, J.D. (eds.), *Marine geology and oceanography of Arabian Sea and Coastal Pakistan*. Van Nostrand Reinhold, New York, 177-198.

Key words: Tectonics, Himalayan Thrust belt.

Y/24. Yielding, G., Ahmad, S., Davison, I., Jackson, J.A., Khattak, R., Khurshid, A., King, G.C.P. & Zuo, L.B., 1984. A microearthquake survey in the Karakoram. In: Miller, K.J. (ed.), *The International Karakoram Project, Volume 2*, 150-169. Cambridge University Press.

A portable seismic network was operated in the Karakoram area of northern Pakistan for over two months during the summer of 1980. The principal objectives were to record possible subcrustal earthquakes beneath the Karakoram Range, and to monitor crustal activity throughout northernmost Pakistan. Of the 371 earthquake locations presented here, about two-third lie in the Hindu Kush intermediate-depth seismic zone. One intermediate-depth earthquake (at a depth of about 140-km) was recorded from beneath the Karakoram Mountains. Shallow crustal activity also occurs in the Karakoram Range, with events recorded from near the northwest end of the Karakoram Fault and near a number of smaller lineaments in Baltistan. Seismicity in Kohistan appears to be largely confined to the upper crust, though occasional earthquakes at 65-km depth (approximately the base of the crust) occur beneath areas of higher topography (Nanga Parbat, Rakaposhi). An area close to the Hamran (1972) and Darel (1981) earthquakes showed intense activity in depth range 0-20 km, similar to that involved in the main shocks themselves.

Key words: Seismicity, earthquakes, Karakoram.

Y/25. Yin, J., 1992. Carboniferous sedimentary environment and tectonic setting in the western Kunlun and adjacent regions. In: Zheng, D., Zhang, Q. & Pan, Y. (eds.), *Proceedings of International Symposium on the Karakoram and Kunlun Mountains*, 130-142. China Meteorological Press, Beijing.

This is a sedimentological account of the Carboniferous lithofacies zones in the Kunlun and adjoining areas. The deposits can be classified into mobile, sub-stable and stable types. The Early Carboniferous deposits of the mobile-type located at central belt of sedimentary basin are characterized by thick volcanic-sedimentary rock assemblages (>6000 m). The Late Carboniferous of the same belt are composed of shelf platform type sediments (<200 m). Meanwhile, the lithofacies zones belonging to sub-stable and stable type deposits occurred on both sides of the mobile type deposits belt. Regionally, the contact between Upper and Lower Carboniferous strata is conformable or disconformable. It is reasonable to presume that the sedimentary environments and tectonics settings for Early and Late Carboniferous in the studied area may be referred to as a rift and post-rift basins, respectively.

While the paper deals with areas outside the geographic limits of Pakistan, it includes a regional geological map that extends up to Punjab foredeep and is reproduced here.

Key words: Carboniferous, environment, rift basin, Kunlun, northern Pakistan.

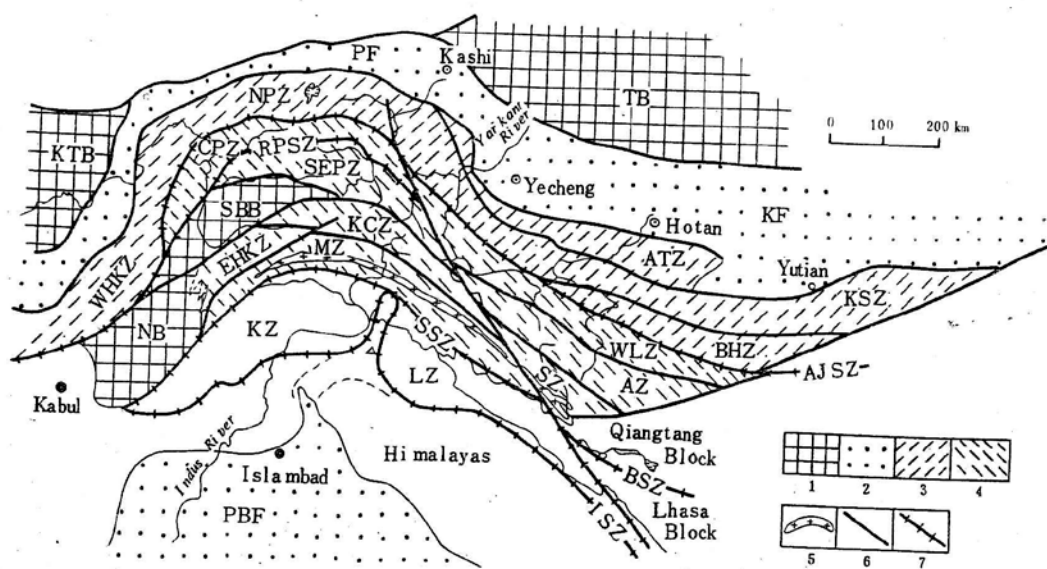


FIG.1

Schematic tectonic map of the Pamir-Western Kunlun-Karakorum regions
(Modified from Desio, 1979 and Belyaevsky, 1976)

1. Block/Massif; 2. Foredeep; 3. The Kunlun Folded System; 4. The Karakorum Folded System; 5. The Karakorum Axial Batholith; 6. Fault; 7. Suture zone. KTB: Karam-Kadjik block; SBB: South Badakhshan block; NB: Nuristan Block; TB: Tarim block; PF: Pamir foredeep; KF: Kunlun deep; PBF: Punjab foredeep. WHKZ: West Hindu Kush zone; NPZ: North Pamir zone; ATZ: Akaizi-Tekelikitag zone; KSZ: Kudi-subashi zone; BHZ: Bayan Har zone (Karatag mountain). CPZ: Central Pamir zone; SEPZ: Southeast Pamir zone; KCZ: Kara Chukur zone; MZ: Muztagh zone; EHKZ: East Hindu Kush zone; WLZ: West Loqzun zone; AZ: Aghil zone; SZ: Saser zone. KZ: Kohistan zone. LZ: Ladakh zone. AISZ: Akbaital-Jinsha River suture zone; SSZ: shayok/Northern suture zone; ISZ: Indus/southern suture zone.

Y/26. Yin, J. & Bian Q., (Chief Compilers), 1996. Geological map of the Karakorum-Western Kunlun and adjacent regions. In: Pan Yusheng (ed.), Geological Evolution of the Karakorum and Kunlun Mountains. Seismological Press, Beijing, 288p.

This volume deals with stratigraphy and paleontology, characteristics of sedimentary rocks, ophiolites, geochemistry of granitic rocks, geophysics and regional geologic evolution and tectonics of the mountain region to the north of Pakistan border. The geological map, however, gives information on area as far to south as Nanga Parbat. There are brief descriptions in Chinese and English.

Key words: Mapping, stratigraphy, palaeontology, ophiolites, Karakoram.

Y/27. Yoshida, M., 1996a. Paleomagnetic synthesis of three phases collision in the Himalaya-Karakoram belt and surrounding terranes. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geoscience Lab, GSP, Islamabad, 23-26.

It has been widely accepted that the Himalaya-Karakoram ranges were shaped by a crustal deformation caused by the collision of the Indian subcontinent with the Eurasian continent. In the northwestern part of the Himalaya-Karakoram belt, this continent- continent collision is not simple because (1) the Kohistan-Ladakh arcs were captured between the two colliding continental blocks, Indian and Eurasia continents, and (2) on the west, the Himalaya-

Karakoram belt adjoins the Afghan block bordered by the Chaman strike-slip faults zone, which caused a complicated oblique-collisional tectonic setting of the region (Figure 1).

(1) Suturing around the Kohistan-Ladakh Arcs

The paleo-latitudinal changes for the Kohistan arc, northwestern part of Indian subcontinent (northern Pakistan), and Eurasian continent since mid-Cretaceous time are illustrated in the Figure 2.

MKT Suturing: The paleo-position of Kohistan arc in mid-Cretaceous time is estimated to be around the equatorial zone (Zaman and Torii, 1996). The paleomagnetic direction of mid-Cretaceous Kohistan rocks is quite similar to that of Cretaceous components maintained by the rocks in the immediate northern block belonging to the Eurasian continent (Klootwijk et al., 1994; Zaman and Torii, 1996), which indicates the paleo-position of the Kohistan arc at the mid-Cretaceous time was very close to the southern margin of the Eurasian continent. The Main Karakoram Thrust zone (Northern Suture or Shyok Suture zone) had been probably already sutured. The mid-Cretaceous landmass extended from the Kohistan arc to the Karakoram block (= southern marginal terrane of Eurasian continent) was, however, considerably distant from the Eurasian inland terranes, Tadjikistan and Tarim basins. Its latitudinal discrepancy is more than 20° (2,000 km+) despite only 2°-4° gap (several hundred kilometers) is given in present geographic frame, which suggests a remarkable crustal shortening (intra-continental subduction) along terrane-boundaries took place within the Eurasian continent. Figure 1: Geotectonic frame of the Himalaya-Karakoram collision belt and surrounding terranes (boundaries based on Jacob and Quittmeyer, 1979), and the triple collision zone.

MMT Suturing: In northern Pakistan, the India-Eurasia collision is represented by the suturing along the Main Mantle Thrust (MMT) between the Kohistan and subcontinent. According to the compilation of paleomagnetic data (paleo-latitudes), the northward movement of the subcontinent is very rapid up to around the Late Paleocene (ca.58Ma) but after that the rate of movement suddenly slowed (Figure 2). Then the discrepancy of paleo-latitudes between the northwestern margin of subcontinent and the Kohistan arc (Ahmad and Yoshida, this volume) exhibits very small in Middle Eocene time (ca.45Ma), which suggests a completion of MMT suturing. Similar evidence has been found in the paleomagnetic data of deep-sea sediments accumulated on the Indian oceanic crust (Klootwijk et al., 1992). These sudden slowdowns in the northward motion of subcontinent are probably caused by an 'initial collision' without complete suturing along the MMT. Continuous underthrusting ('subduction' within continental crust) might occurred along the MMT suture zone in Paleocene-Eocene time. This may provoke an immense deformation of the crust of Kohistan arc including tectonic rotations and formed a structural frame of the Himalaya-Karakoram collision belt in northern Pakistan. (2) Oblique Collision between India and the Afghan Block Paleomagnetic data is sparsely known in the Afghan block which is of fused micro-continent terranes such as Helmand, Lut and Kabul blocks. Paleomagnetic data obtained from the Chagai and Raskoh volcanic arcs, southern part of the Afghan block mark its paleo-position in Paleogene time. The India-Afghan suturing is considered to be an oblique collision in Pliocene (Treloar and Izatt, 1993). The collision corresponds to a reorganization of arc-subduction system around the Afghan block which is represented by the calc-alkaline volcanism in the Sultan arc since the Gilbert Chron (Akram and Yoshida, 1996). The tectonic rotation within the block after the India-Afghan collision is also unveiled by the paleomagnetic data.

(3) Triple Collision Zone

The Himalaya-Karakoram collision belt is therefore characterized as a triple collision zone. Three phases of collision (Treloar and Izatt, 1993) can be, at least, recognized in and around the Himalaya-Karakoram collision belt, northwestern Pakistan since Cretaceous time. The first collision is represented by the MKT (or Shyok) suturing occurred in the Early (?) Cretaceous. The second collision is India-Eurasia collision which occurred along MMT (Indus-Tsangpo) suture at Late Paleocene-Middle Eocene time. The third one is the oblique collision between the collage of India-Kohistan terranes and the Afghan block. On the basis of currently-available paleomagnetic data, terrane-scale displacement and tectonics of this triple collision zone will be synthesized.

Key words: Paleomagnetism, collision, Himalaya, Karakoram.

Y/28. Yoshida, M., 1996b. Multi-disciplinary study of late Quaternary Loess-paleosol deposits in Haro river area, Attock district, Punjab, Pakistan- An Overview. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 14, 71-75.

This is an introduction to the Loess-paleosol deposits studied by several groups of the geoscience laboratory. The various contributions are listed in appropriate places.

Key words: Loess-paleosol deposits, Late quaternary, Attock.

Y/29. Yoshida, M., & Ahmad, M.N., 1995a. Paleomagnetism of oolitic ironstone bed in Hazara District, Northern Pakistan: Cretaceous–Tertiary Paleo–laterite in northwestern Lesser Himalaya. Nepal Geological Society Journal (Special Issue), 12, p.14.

Key words: Paleomagnetism, Cretaceous, Tertiary, Laterite, Hazara, Himalaya.

Y/30. Yoshida, M. & Ahmad, M.N., 1995b. Rock magnetic properties and Paleomagnetism of oolitic iron stone, Hazara District, northern Pakistan. In: Khadim, I.M. & Yoshida, M. (eds.), Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad, 13, 59-79.

Chamosite-hematite type oolitic ironstone, the Langrial iron ore, is distributed in Hazara District, northwestern margin of Indo-Pakistan Subcontinent which is situated in the northwestern part of the Lesser Himalayan Belt. The ironstone bed is assumed to be a palm-laterite formed during Cretaceous -Tertiary (K-T) time. The oolitic ironstone bed induces a geomagnetic anomaly with a maximum anomalous intensity of c.500nT; and no meaningful anomaly pattern was observed by VLF-EM survey. The oolitic ironstone shows rather small magnetic susceptibility and relative weak NRM intensity but very hard coercivity. Ferromagnetic properties of the rock are mainly derived from hematite grains which possess two remanence component: the overprint component (Declination=83.6°, Inclination=27.7°) and the characteristic remanence component (DecWon=298.5°, Inclination=19.8°). The directions of these remanence components suggest two-phase clockwise tectonic rotation of the terrain after the acquisition of each remanent magnetization. The characteristic component probably indicates paleomagnetic direction during the formation of oolitic ironstone which is inferred to be a lateritization and erosion processes at Cretaceous-Tertiary (K-T) boundary time in the southern hemisphere. The overprint component which passed a reversal test was possibly a thermo-viscous remanent magnetization (TVRM) acquired by long-term burial heating due to a subsidence of the terrain in the northern hemisphere.

Key words: Paleomagnetism, ironstone, Hazara.

Y/31. Yoshida, M., Ahmad, M.N., Ali, M. & Khadim, I. M., 1993. Paleomagnetic study of Kalam volcanics, upper Swat valley, northern Pakistan. 1993 Fall Mtg. The Society of Geomagnetism and Earth Planetary, and Space Sciences (SGEPSS), Abstract C 12, P1–08.

Key words: Paleomagnetism, volcanics, Kalam, Swat.

Y/32. Yoshida, M., & Fujiwara, Y. 1994a. Rock magnetic studies in Pakistan. In: Magnetic approaches to Geological Sciences, Part III. (Yoshida, M. & Fujiwara, Y. eds.,) Geoscience Labs. Geological Survey of Pakistan, Islamabad.

Rock magnetic study in Pakistan has been attempted on the rocks in the northern area for structural and geomagnetic analyses. Here, selected typical studies: rock magnetic studies in Hazara-Kashmir Syntaxis (Bassart et al, 1990), AMS studies on Jijal and Chilas complexes (recent studies by Geoscience labs. Project), and magnetic susceptibility study in northern Pakistan, are reviewed.

Key words: Magnetic studies, Hazara-Kashmir.

Y/33. Yoshida, M., & Fujiwara, Y. 1994b. Paleomagnetic studies on Siwaliks in Pakistan. In: Magnetic approaches to Geological Sciences, Part III (M. Yoshida & Y. Fujiwara, eds.), Geoscience labs. Geological Survey of Pakistan, Islamabad.

The Siwaliks of the Potwar Plateau, northern Pakistan, present the best example of a continuous sequence of paleomagnetically well-dated terrestrial deposits spanning most of the Neogene. In this work, magnetostratigraphy and some environmental analyses of Siwaliks are reviewed.

Key words: Paleomagnetism, magnetostratigraphy, Siwaliks, Potwar Plateau.

Y/34. Yoshida, M., & Fujiwara, Y. 1994c. Paleomagnetic studies in Pakistan. In: Magnetic approaches to Geological Sciences, Part III (M. Yoshida & Y. Fujiwara, Eds.), Geoscience labs. Geological Survey of Pakistan.

Palaeomagnetic studies in Pakistan and its adjacent area have been carried out in various fields: paleogeography, continental drift, crustal deformation, magnetostratigraphy, and tectonic interpretation in the late Proterozoic and the Phanerozoic. Here, previous achievements except on the Siwaliks (see Y/30) are summarized and recent studies by the Geoscience Labs project are discussed.

Key words: Paleomagnetism, magnetostratigraphy, tectonics, Proterozoic, Phanerozoic.

Y/35. Yoshida, M., Karim, T. & Zafar, M., 1996. Thorium–232 decay series anomaly in natural Gamma–ray spectra of Haro river Loess–Paleosol deposits, Attock district, Punjab. Geological Survey of Pakistan, Proceedings Geoscience Colloquium, 14, 129–138.

Late Quaternary loess-paleosol sequence of Ham river sections, Attock, Punjab, exhibits a spectral gamma-ray anomaly in the energy window t (2.45-2.79MeV) which represents the thorium-232 (^{232}Th) decay series. The horizons showing high Th anomaly are probably enriched in Th-bearing minerals such as monazite. The anomalous horizons also coincide with the beds of Au concentration which is of placer origin. It suggests that the spectral gamma-ray method can be applicable to explore placer gold in the area.

Key words: Paleosole, Quaternary, Thorium²³² decay, Attock.

Y/36. Yoshida, M., Khan, I.H. & Ahmad, M.N., 1996. Rock magnetic interpretation on the origin of Paleogene oolitic iron stone, Langrial iron ore, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 116-119.

Key words: Paleomagnetic properties, ironstone, oolitic, Hazara.

Y/37. Yoshida, M., Mononobe, S. & Karim, T., 1992. Thermomagnetic properties of Iron Titan oxides in the “hematite band”, Abbottabad area (a short note). Geological Survey of Pakistan, Proceedings of Geoscience Colloquium 3, 23-27.

This account gives thermomagnetic properties of the Fe-Ti oxides in oolitic hematite band at the K-T Boundary near Bagnoter, Abbottabad.

Key words: Thermomagnetism, haematite, Abbottabad, Hazara.

Y/38. Yoshida, M., Zaman, H. & Ahmad, M.N., 1996. Paleoposition of Kohistan arc and surrounding terrane since Cretaceous time: the paleomagnetic constraints. In: Kausar, A.B. & Yajima, J. (eds.), Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc. Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad 15, 83-101.

Paleomagnetic data recently obtained from the rock units in Kohistan arc show considerably low paleo-latitude at early Tertiary and mid-Cretaceous times. Paleomagnetic data of the Indo-Pakistan subcontinent, paleo-latitude data of Indian deep-sea sediments, and sea-floor spreading data of the Indian Ocean have detailed the southern limit of the Kohistan arc for the past 80 m.y. Paleomagnetic data from the Tadzhikistan and Tarim basins of Eurasian continent blocks, also reveal the northern limit of the arc and lateral displacement of southern continental margin.

Analysis of the combined paleolatitude-age profiles for these terranes (Figure 6) indicates paleomagnetic constraints on paleoposition of the Kohistan arc and its collision timing.

Key words: Paleomagnetism, Cretaceous, Kohistan arc.

Y/39. Yoshida, M., Zaman, H., Khadim, I.M., Ahmad, M.N. & Akram, H., 1997. Paleoposition of the Himalaya-Karakoram belt and surrounding terranes since Cretaceous: Paleomagnetic reconstruction of three phases collision history. In: Khadim, I.M., Zaman, H. & Yoshida, M. (Eds.), *Paleomagnetism of Collision Belts*. Geoscience Laboratory, GSP, Islamabad, 49-72.

Paleomagnetic data recently obtained from Pakistan have made conceivable a history of three phases collision of the Himalaya-Karakoram collision belt and surrounding terranes since Cretaceous time. The early Cretaceous was the time of suturing between the Kohistan arc and the Asian continent. At that time Indo-Pakistan subcontinent was located far in the southern hemisphere and the southern margin of the Asian continent spread out around equatorial region. The southern margin of Asian continental block was continuously shifting northward during the Cretaceous period after the Asia-Kohistan collision. The Paleocene was the main collisional stage between the Indo-Pakistan subcontinent and Kohistan-Asia blocks. The collision caused gigantic deformation and crustal shortening in and around the Himalaya-Karakoram collision belt. Most of ophiolite blocks around the subcontinent (peri-Indian suture) were obducted during this stage of time. Suturing between Indian subcontinent and Asia-Kohistan block was followed by the oblique collision between Indian subcontinent and Afghan block to the west, which provoked large-scale counterclockwise rotation by the late Eocene to early Oligocene. Thus, analysis of the combined paleolatitude-age profiles and paleomagnetic investigation of the tectonic deformation for these terranes document the geohistory of three phases collisions of the Himalaya-Karakoram collision belt: the first phase Asia-Kohistan collision (along the Shyok Suture) in the early Cretaceous, the second phase Kohistan-India collision (along the Indus-Tsangpo Suture) in the Paleocene, and the third phase India-Afghan block (along the Chaman Strike-Slip Fault) collision in the late Eocene-early Oligocene.

Key words: Paleomagnetism, Cretaceous, Karakoram, Kohistan arc.

Y/40. Yoshino, T., 1998. Magmatic underplating of the lower crust of the Kohistan arc (N. Pakistan) deduced from Al-zoning in clinopyroxene and plagioclase. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 220-221.

The Kohistan complex, lying in the north-western part of the Himalaya, has been considered as a Cretaceous magmatic island arc, namely the Kohistan arc. The complex displays a widely exposed lower crustal section composed of metabasic rocks (amphibolites, pyroxene granulites and garnet granulites) with gabbroic origin. Because the lower crust of the Kohistan arc commonly has a mafic composition derived from gabbroic magma, magmatic underplating should be considered as a crustal generation mechanism. During the period of subduction-related magmatism, the underplated materials at middle to deep crustal level could subsequently undergo metamorphism under high-T conditions corresponding to upper amphibolite to granulite facies. Hence metabasites derived from a gabbroic protolith of the lower crust might preserve information of the metamorphism after cooling from magmatic temperature. Metamorphic P-T paths of the rocks would provide a constraint on the overall history of crustal evolution.

The lower crustal part of the Kohistan arc is divided into three geological units: the Jijal complex, the Kamila amphibolite belt and the Chilas complex, from south to north. Yamamoto. proposed a tectonic thickening model on the basis of two contrasting P-T paths of garnet-bearing granulites in the Chilas and Jijal complexes. The P-T path of the Chilas complex involved approximately isobaric cooling at relatively low-pressure conditions, whereas that of the Jijal complex showed anti-clockwise path at higher-pressure conditions. Such anti-clockwise P-T paths may reflect crustal thickening due to magmatic underplating or accretion in the crust. It is insufficient, however, to consider models for these P-T paths, because the P-T path for rocks of the Kamila amphibolite belt, which is sandwiched by the Chilas and Jijal complexes, has not documented well. To understand the evolutionary process of the lower crust of the Kohistan arc, determination of P-T paths of the Kamila amphibolite belt is needed.

The lower crustal rocks of the Kohistan complex (northern Pakistan) are mostly composed of metabasic rocks such as pyroxene granulites, garnet granulites and amphibolites that were originally gabbros. P-T trajectories of the relic

two-pyroxene granulites, which are the protolith of the amphibolites within the Kamila amphibolite belt have been investigated. Aluminous pyroxene retains igneous texture such as exsolution lamellae developed at core. The significant amount of Al in clinopyroxene is buffered by breakdown reactions of plagioclase accompanied by film-like quartz as a product at grain boundaries between plagioclase and clinopyroxene. Distinct Al-zoning profiles are preserved in pyroxene with exsolution lamellae at core and plagioclase adjacent to clinopyroxene in pyroxene granulites. In the northern part of the Kamila amphibolite belt, Al-contents in clinopyroxene increase toward the rim and abruptly decrease at the outer rim, and anorthite contents in plagioclase decrease toward the rim and abruptly increase near the grain boundary between plagioclase and clinopyroxene. In the southern part of the Kamila amphibolite belt, Al-contents in clinopyroxene and anorthite contents in plagioclase simply increase toward margin of the grain. The anorthite zoning in plagioclase is in agreement with the zoning profiles of Ca-tschermaks and jadeite components inferred from variations of Al, Na, Ti and Fe³⁺ in clinopyroxene. Assuming that the growth surface between them was in equilibrium, geothermobarometry based on Al-zoning in clinopyroxene coexisting with plagioclase indicates that metamorphic pressures significantly increase with increasing temperature under granulite facies metamorphism. The peak of granulite facies metamorphism occurred at conditions of about 800 °C and 800-1100 MPa. These prograde P-T paths represent a crustal thickening process of the Kohistan arc during the Early to Middle Cretaceous. The crustal thickening of the Kohistan arc was caused by accretion of basaltic magma at mid-crustal depth.

Key words: Magmatism, mineral chemistry, Cretaceous, Kohistan arc.

Y/41. Yoshino, T., Yamamoto, H., Okudaira, T. & Toriumi, M., 1998. Crustal thickening of the lower crust of the Kohistan arc (N.Pakistan) deduced from Al zoning in clinopyroxene and plagioclase. *Metamorphic Geology* 16, 729-748.

The lower-crustal rocks of the Kohistan complex (northern Pakistan) are mostly composed of metabasic rocks such as pyroxene granulites, garnet granulites and amphibolites. We have investigated P-T trajectories of the relic two-pyroxene granulites, which are the protolith of the amphibolites within the Kamila amphibolite belt. Aluminous pyroxene retains igneous textures such as exsolution lamellae developed in the core. The significant amount of Al in clinopyroxene is buffered by breakdown reactions of plagioclase accompanied by film-like quartz as a product at grain boundaries between plagioclase and clinopyroxene. Distinct Al zoning profiles are preserved in pyroxene with exsolution lamellae in the Kamila amphibolite belt, Al in clinopyroxene increases towards the rim and abruptly decreases at the outer rim, and anorthite in plagioclase decreases toward the rim and abruptly increases near the grain boundary between plagioclase and clinopyroxene. In the southern part of the Kamila amphibolite belt, Al in clinopyroxene and anorthite in plagioclase simply increase towards the margins of the grains. The anorthite zoning in anorthite in plagioclase simply increase towards the margins of the grains. The anorthite zoning plagioclase is in agreement with zoning profiles of Ca-Tschermaks and jadeite components inferred from variations of Al, Na, Ti and Fe³⁺ in clinopyroxene. Assuming that the growth surface between them was in equilibrium, geothermobarometry based on Al zoning in clinopyroxene coexisting with plagioclase indicates that metamorphic pressures significantly increased with increasing temperature under granulite facies metamorphism. The peak of granulite facies metamorphism occurred at conditions of about 800 °C and 800-1100 Mpa. These prograde P-T paths represent a crustal thickening of the process of the Kohistan arc during the Early to Middle Cretaceous. The crustal thickening of the Kohistan arc was caused by accretion of basaltic magma at mid-crustal depths.

Key words: Crustal thickening, granulites, amphibolites, mineral chemistry, Kohistan arc.

Y/42. Young, G.J., 1982. Glaciological Data Report GD 12 - Glacial Hydrology. World Data Center-A for Glaciology [Snow and Ice], Boulder, Colorado. 133p.

Key words: Glaciology, hydrology.

Y/43. Young, G.J. & Hewitt, K., 1993. Glaciohydrological features of the Karakoram Himalaya: measurement possibilities and constraints. In: Young, G.J., (ed.), *Snow and Glacier Hydrology*. International Symposium, Kathmandu, Nepal, 16-21 November 1992. Proceedings. International Association of Hydrological Sciences. IAHS/AISH Publication. 218: 273-283.

Key words: Glaciology, Hydrology, Karakoram.

Y/44. Young, G.J. & Schmok, J., 1989. Ice loss in the ablation area of a Himalayan Glacier: studies on Miar Glacier, Karakoram Mountains, Pakistan. *Annals of Glaciology* 13, 289-293.

One of the main aims of the Snow and Ice Hydrology Project, a joint Canada-Pakistan endeavor, is to estimate ice loss in the ablation areas of glaciers in order to predict with greater confidence stream flow in the headwaters of the Indus River. To this end, Miar Glacier, located in the central Karakoram Range, north of Gilgit, was intensively studied during the summers of 1986 and 1987. Measurements of glacier mass balance by the monitoring of accumulation and ablation at stake locations is very difficult in the Himalayan environment. It is usually almost impossible to reach elevations above the equilibrium line without major effort, and always very difficult once there to make meaningful measurements; the ablation areas are often heavily crevassed and/or debris-covered, and this poses difficult sampling problems. The method used in this study was to monitor annual surface movement on a cross-profile as near as possible to the equilibrium line. The measurements, obtained in conjunction with depth soundings made on the same profile, allow the annual ice flux through the cross-profile to be calculated. If an approximately steady-state glacier is assumed, it would be expected that this flux would be roughly equivalent to the rate of ice loss below the profile. The movements of wooden stakes drilled into the glacier were monitored throughout each of the summers and, since two of the stakes survived the intervening winter, this allowed calculation of annual movement. Distances between the crests of ogives were also surveyed, providing an independent assessment of glacier movement. Depth measurements by radio-echo sounder were successfully made in the summer of 1987, showing maximum ice depths of 550 m. The annual ice flux through the transverse profile was estimated as $5.67 \times 10^7 \text{ m}^3$, which corresponds to a mean annual ice loss from the glacier surface below the profile of 8.10 m of ice.

Key words: Glaciology, hydrology, ablation, Miar glacier, Indus River, Karakoram.

Y/45. Young, H.L., 1964. Geohydrology of Naranji area, West Pakistan. Preliminary Report 3, Water and Soil Investigation Department Publication 32, Hydrogeology Directorate, WAPDA, North West Frontier Province, Peshawar.

Key words: Geohydrology, Naranji, Peshawar.

Y/46. Young, H.L. & Naqavi, S.A.H., 1964. Geohydrology of the Dharmrah Kas area, Preliminary Report 9, Water and Soil Investigation Department Publication 37, Hydrogeology Directorate, WAPDA, North West Frontier Province, Peshawar.

Key words: Geohydrology.

Y/47. Younghusband, F.E., 1895. Chitral, Hunza and the Hindu Kush. *Geographical Journal*, London. 5(5), 409 – 422

As this article does not have an abstract, the first few paragraphs are reproduced here: It is with a good deal of compunction that I address you on these states of the Hindu Kush which are to form the subject of my lecture to-night, for I feel that the honour of doing so should have fallen on others than myself. I was not the first, by many, to explore and open up these states. Many had gone before me, and all that I could do was to follow in the steps of these first pioneers, and carry on the work which they had commenced. Poor Hayward, the first intrepid Englishman who pushed his way into these mountain recesses, never returned to tell the tale of what he saws for he was cruelly murdered in Yasin in 1870. But Biddulph, the first to visit Chitral and the first to visit Hunza, might well have borne the privilege which is now falling to me. And Macnair, Sir William Lockhart and the members of his mission Mr. Ney Elias, Colonel Durand, Dr. Robertson, Captain Tyler, E.E., were all my predecessors, and could have told a more interesting tale than mine of how they found these primitive, picturesque hill-men at their very first touch with the outside world. But while I cannot lay claim to your attention as the first to visit this interesting region, I can, at least, ask it as the last to do so. It has been my privilege to represent the British Government in both Hunza and Chitral, and it is only a few months ago that I returned from the latter place, after a stay of more than two years

among these little states of the Hindu Kush. Before, however, proceeding to any description of these it is necessary for me to put clearly before you the reasons why these regions should especially interest you. These are many. There are, first, the political and military reasons. Here is the point where, as the title of Mr. Linight's remarkably interesting book runs, 'Three Empires Meet.' The Indian, the Russian, and the Chinese empires all meet here, and where three such empires meet the eyes of the people who inhabit them must naturally be turned. To the members of a scientific society, however, such considerations may possibly not have much weight. These would require some deeper attraction than the mere political boundaries of different races. To such the Hindu Kush affords the highest interest; for we have here mountain ranges of colossal height and only of recent years explored, and races of people of a very primitive type, who, shut up for centuries in their mountain fastnesses, have preserved intact much of their original type of manners and customs. I was brought up a soldier, and became a "political," as we are called in India, my interests were therefore more purely military and political rather than scientific; but as it was a part - the main part, I may say - of my duties to study the character and nature both of the people and the country, I shall hope that some of the impressions I formed of them may prove interesting to you. The country I am to describe to you, then, is that lying immediately north of Kashmir and south of the Pamirs, which is drained by water flowing into the Indus, and comprises the states of Hunza, Nagar, and Chitral. It is an entirely mountainous country, with never a stretch of plain more than 3 or 4 miles in length. The valleys are all deeply cut, and even the longest mountains are 13,000 or 14,000 feet in height, while some rise to 25,000. The nature of the mountains will best be gathered from the lantern slides I propose to show you. Except in the lower part of Chitral and in occasional secluded side valleys, they are perfectly bare. In some parts one may travel for March after March without seeing a sign of a tree outside the valley bottoms, and the barren character of these hills has much to do with their forms and with that of the valleys. What we see here are great masses of rocky mountains, their summits in the loftier regions clothed in snow and ice, but in most parts bare, and their bases always so. On these rocks the sun in summer beats down with a force which makes them so hot it is impossible to keep one's hand on them without burning it; and in winter come frosts reaching below zero Fahrenheit, which freezes the draining of the snow and rain in the crevices of the rocks, and breaks them off by the same process as water swollen into ice bursts up our water pipes. Owing to the extremes of temperature, the rocks in all this region are very loose, so when the snow melts off them at the close of winter and still more so when a storm of rain or a cloud-burst falls upon these mountains, the whole of their sides is washed of their loose debris, which comes pouring down a liquid stream of mud and stones and boulders into the gorges, and there piles itself up till, by the pressure of weight from behind it is forced out into the more open main valley and then spreads itself out in one of those alluvial fans, or cones of deposition which occur in all mountainous countries, but which are seen in these dry lofty regions of the Hindu Kush in their fullest development. These are one of the most characteristic features of this country, and it is for this reason that I direct your attention to them. The traveller here sees in the distance some big snowy peak, but the greater part of the scene around him is of bare hillside, and the valley bottoms, which to traverse are simply a succession of these alluvial fans separated here and there by some huge rocky bluff, but often running one into the other in a continuous stretch. The climate of these regions is one of extreme. At Chitral (5000 feet) the maximum I registered was 100°, and at Gilgit (4800 feet) Dr. Roberts recorded a maximum of 110°. These temperatures were in the cultivated parts, where the vegetation makes it cooler. In the bare open valley, where the sun comes with full force on the rocks, it must be certainly greater. As to the minimum, in Chitral in February (I have no January records) the lowest reading was 15°, and in Mastuj (7800 feet) 5° below zero. In Gilgit it is not so cold; the thermometer there does not appear to fall below 20°. The air over most of the region is extremely dry and the rainfall very small. Nearly all the moisture from the monsoons, which break over the plains of India, is precipitated on the outer ranges of mountains before reaching these remote valleys; and, though not so dry as the countries east and north for a certain amount of moisture seems to come up the funnel of the Indus valley to Gilgit and Hunza, and over the Bajaur hills to Lower Chitral - the rainfall on the whole is very slight, and the climate dry and healthy.

Key words: Geography, climate, Chitral, Hindulush, Hunza.

Y/48. Younghusband, F.E., 1896. *The Heart of a Continent*. Murray, London. Reprinted 1984, Oxford University Press, Oxford, 409p.

Key words: Books, Continents.

Y/49. Yousaf, M., 1970. Gravity survey of Kohat Area. M.Sc. Thesis Institute of Geology, Punjab University, Lahore, 87p.

The gravity survey of Kohat area has been conducted in Collaboration with Gravity Party III of Oil and Gas Development Corporation, for the purpose of oil prospecting. A network of 562 ordinary gravity stations and 15 gravity base stations covering an area of about 5000 sq. Km was accomplished. The survey consisted of geodetic work and gravity observations carried out with a Russian transit theodolite and Wordon gravimeter respectively. The results of the survey are shown on a Bouguer anomaly map on the scale of 1: 250,000 which show a number of positive and negative anomalies both qualitative and quantitative analysis of this map has been done.

Key words: Gravity survey, Kohat.

Y/50. Yousaf, M., 1979-81. Lithostructural mapping of Khanpur Dam Project Area with special reference to the engineering geological problems at the dam site. Punjab University, Lahore.

Key words: Hydrology, engineering geology, Khanpur dam, Haripur.

Y/51. Yousaf, M., 1987-89. The geology and petrology of Jijal and Patan complexes southeast of Indus River in southern Kohistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 80p.

The project area lies in some parts of Kohistan and Mansehra districts, covering about 150 sq. kms area, including south easterly sides of Jijal and Patan complexes, starting from Karakoram highway spreading up to Pashto village. The work has evolved geological mapping of the area on a scale of 1:50,000. This thesis deals with the geological, petrographical and petrogenetical studies of the Jijal and Patan complexes and their relation with Kayal complex. The project area lies in the frontal part of the Kohistan island arc which covers about 36,000 sq Km area, structurally bounded by sutures named as Main Mantle thrust (MMT) and Main Karakoram thrust (MKT) on its southern and northern sides respectively. The Kohistan arc is intruded by a large number of basic complexes starting from a very primitive Dasu complex up to Jijal complex along with a Kohistan batholith which was intruded at last. Previously, the metamorphosed mafic complexes have been lumped together as an undifferentiated mass called Kamila amphibolite. Now we under the guidance of our supervisors have divided the Kamila amphibolite into three complexes starting from very older Dasu complex down to Kayal complex and last emplaced Patan complex. Dasu complex is the oldest pluton which is highly metamorphosed, intruded in the island arc. Dasu complex is underplated by another pluton the Kayal complex which is metamorphosed upto amphibolite facies grade, but less metamorphosed as compared to Dasu complex. Again Kayal complex is being underplated by another pluton which least metamorphosed last emplaced Patan complex. Patan complex is in turn underplated by a highly metamorphosed Jijal complex which is being obducted into the Indian plate. The geological rock sequences of the area consist of ultramafic and mafic associations. The ultramafic association of the Patan complex is overlain by a thick mafic unit which grades into two pyroxene diorite at top and gabbro-norite at base. The ultramafic portion of the Patan complex is discovered by us for the first time which is well exposed in north western side of Indus River (in Duber stream) and is sliced off in south eastern side due to strike slip Patan fault. The ultramafic association of the Jijal complex consists of cyclic units of dunite/wehrlite-websterite-hornblende clinopyroxenite –garnet clinopyroxenite. The mafic association of Jijal complex consists of a massive garnet gabbroic unit of about 7 Km. Both Jijal and Patan complexes are interlinked by a strike-slip fault named as Patan fault. The field evidences reveal that both Patan and Jijal complexes are well layered intrusions emplaced in the frontal part of the island arc by underplating, phenomenon, among which Jijal complex is least metamorphosed. Both complexes were formed from two different cycles of magma which was hydrous, low K, picritic-high Mg tholeiitic in nature (Loucks, 1990).

Key words: Petrology, ultramafics, Jijal, Patan, MMT, Kohistan.

Y/52. Yousafzai, A.K., 1997. Geology of Shamoza area in part of Bajawar Agency and Lower Dir: Implications for extensions of collision zone. M.Sc. Thesis, University of Peshawar, 46p.

Key words: Indus suture, petrology, Shamoza, Bajaur, Dir.

Y/53. Yousafzai, I.J.K., Badshah, M.A., Shah, A.A. & Ahmad, B., 1975. Petrography of the ultramafics and related rocks of Pashto and Barai area, Northeast of Shergarh-Sar Allai Kohistan Hazara. M.Sc. Thesis, University of Peshawar, 31p.

Key words: Petrology, ultramafics, MMT, Allai, Kohistan.

Y/54. Yusuf, S.M., 1961. Mineral position of Pakistan. CENTO Conference on minerals, Ankara, 28-44.

Key words: Minerals, statistics.

Z/1. Zafar, M., Akram, H. & Yoshida, M., 1996. Major elements composition of Haro river Loess-paleosol deposits, Attock district, Punjab, Pakistan. *Proceedings Geoscience colloquium*, 14, 117-123.

The variation of chemical composition of the loess-paleosol deposits reveals that Fe, K, Al, and Mg contents are relatively high in the paleosol horizons than rest of the loess sequence, whereas Ca content is relatively low. Elemental ratios of $\text{SiO}_2/\text{Al}_2\text{O}_3$, and $\text{SiO}_2/\text{Fe}_2\text{O}_3$ generally decrease at paleosol horizons. These characteristics of chemical composition resemble to loess-paleosol deposits in Kashmir and China, it is applicable to identify paleosol horizon as well as paleoenvironmental condition in the area

Key words: Geochemistry, loess-paleosol deposits, Attock.

Z/2. Zafar, M., Murata, M., Khan, T., Ozawa, H. & Nishimura, H., 1998. Major and trace element composition of post-collisional, peraluminous Garam Chashma granite in Trans-Himalaya, northwestern Pakistan. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 221-222.

Garam Chashma granite belongs to a suit of granitoids of the Asian continental plate in the Hindu Kush Range (Trans Himalaya), northwestern Pakistan. It is located about 30-km northwest of Chitral and northern suture covering an area of about 300-km². The Garam Chashma granite is a discordant and leucocratic rock, which intruded into pelitic metasediments and amphibolites formed during Barrovian type metamorphism that took place between 40-25 Ma ago. A comparative age of 28-12 Ma has been suggested for the Garam Chashma granite which is same as for some of the Higher Himalaya leucogranites. Petrographically, the major rock forming minerals include quartz, plagioclase, K-feldspar, muscovite and biotite with subordinate garnet and tourmaline. Ratio of muscovite to biotite is not constant. All accessory mineral cordierite has also been reported in the area. Grain size ranges from fine to coarse grained. Texturally the rocks are massive, however, slight to moderate foliation marked usually by muscovite and biotite, especially near the contact of intrusion can be observed. Aplitic and pegmatitic veins/dikes localising minerals such as garnet and tourmaline are widely spread through out the pluton. A total of about 72 rock samples were collected from the Garam Chashma area. Major and trace components (Ce, Cr, Nb, Ni, Pb, Rb, Sr, Th, Y, Zr, and Ba) were analyzed using X-ray fluorescence spectrometer. On the ternary discrimination diagram, for S and I-type granites, oxide mole values of Al-Na-K, Ca and Fe+Mg predominantly plots on the S-type field suggesting sedimentary source for the Garam Chashma pluton. The silica concentration variation range is very small (71.91-76.08 wt %). A/CNK ratio is greater than 1 thereby conforming the peraluminous nature of the pluton. Almost all the major elements when plotted against silica, show some sort of depletion trend with increasing silica, whereas Na shows an enrichment trend. Minor depletion trend of K may represent an early formation of K-feldspar along with ferromagnesian minerals during crystallization history of the pluton. Depleting patterns of Ba, Nb, Sr, Ti, and P, commonly found in subduction related magmatism, are observed. Decreasing K/Rb ratios in K/Rb versus Rb plot may be attributed to the fractionation of feldspars.

Furthermore, a chemical compositional comparison based on major and trace elements with two pre-collisional granitoid bodies named Tirichmir and Kafiristan in Trans Himalaya, located NE and SE of the Garam Chashma respectively, is also performed. Silica concentration ranges for Tirichmir (65.96-72.02 wt %) and Kafiristan (64.26-75.72) are higher than that of the Garam Chashma pluton, because of their predominant granodioritic nature. A/CNK plots reveal peraluminous and meta-peraluminous characteristics of Tirichmir and Kafiristan plutons respectively. In Si versus K plot, potassium shows an enrichment trend in Tirichmir and Kafiristan plutons when compared to Garam Chashma. Ca and Fe concentrations are higher than those for the Garam Chashma pluton because of the presence of more mafic minerals. However, higher Ca and Fe concentrations and lower Mg concentration in the Kafiristan pluton than the Tirichmir pluton, are probably due to the higher concentrations of hornblende in the former. Pb, Rb, Y, Th and Zr concentrations show enrichment in mafic fractions of both the granitoids. A positive correlation of Ba and Sr represents fractionation of mineral phases such as plagioclase and K-feldspar of the Garam Chashma pluton and hornblende, feldspars and biotite of the Tirichmir and Kafiristan pluton.

Key words: Geochemistry, peraluminous granite, Garam Chashma, Chitral, Hindukush.

Z/3. Zafar, M., Murata, M., Khan, T., Ozawa, H., & Nishimura, H., 2000a. K-Ar biotite ages from Miocene post-collisional Garam Chashma leucogranite, eastern Hindu Kush Range (Trans-Himalayas), northwestern Pakistan. *Journal of Mineralogical and Petrological Sciences*, 95, 101-106.

Key words: Geochronology, K-Ar dating, Leucogranite, Garam Chashma, Chitral, Hindukush.

Z/4. Zafar, M., Murata, M., Khan, T., Ozawa, H., & Nishimura, H., 2000b. Major and trace elements composition of post-collisional, prealuminous Garam–Chashma granite in Trans–Himalaya, northwestern Pakistan. *Journal of Mineralogical and Petrological Sciences*, 95, 173–181.

Key words: Geochemistry, Peraluminous granite, Garam Chashma, Chitral, Hindukush

Z/5. Zaheer, B., 1990-91. Structure, stratigraphy and petrography of the western limb of the Hazara-Kashmir Syntaxis, Garhi Habibullah-Shinkari area, Northern Pakistan. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 105p.

The Garhi Habibullah-Shinkari area lies along the western limb of the major northwest plunging antiformal structure known as the Hazara-Kashmir syntaxis. The 293 km² area has been mapped in this study. The western limb of the Hazara-Kashmir syntaxis has been divided into four fault-bounded tectonostratigraphic zones. These are named as the Muzaffarabad-Balakot zone, the Garhi Habibullah-Abbottabad zone, the Panjal zone and the Mansehra zone. These zones belong to different tectonic and stratigraphic provinces which have been juxtaposed during the Himalayan thrusting. The Muzaffarabad-Balakot zone lies to the east of Main boundary fault. This zone constitutes late Proterozoic to Cenozoic sequence. This sequence is involved in the Muzaffarabad-Balakot southwestward overturned anticline. The late Proterozoic Dogra formation forms the core of the Muzaffarabad-Balakot anticline. The Dogra formation is unconformably overlain by the early Cambrian Muzaffarabad formation. The Ordovician (?) Yadgar formation disconformably overlies the Muzaffarabad formation. The Yadgar formation is unconformably overlain by the Paleocene-Eocene sequence which includes the Hangu Formation, Lockhart Formation, Patala Formation and Margala Hill Limestone. This was followed by the late Eocene Kuldana and Miocene Murree molasses. The most of the Paleocene to Miocene sequence along the overturned limb of the Muzaffarabad-Balakot anticline is faulted.

The Garhi Habibullah-Abbottabad zone lies between the Main boundary fault and Garhi Habibullah fault. This zone is involved in the Garhi Habibullah syncline. The Cambrian Abbottabad group lies in the core and Hazara formation along the limbs of the anticline. In the Garhi Habibullah syncline, the late Proterozoic Hazara formation is unconformably overlain by the Cambrian Abbottabad group of rocks. The Jurassic sequence has been eroded from the core of the syncline due to later Himalayan uplift.

The Panjal zone lies between the Garhi Habibullah fault and Panjal fault. The Panjal zone includes the late Proterozoic to Triassic rocks which are involved in the Tarkot anticline and Doga syncline. In this zone the Carboniferous Chushal formation unconformably overlies the late Proterozoic Hazara formation and grades into the Permo-Triassic panjal formation. These rocks are metamorphosed up to lower green schist facies metamorphism. The Mansehra zone lies west of Panjal fault. It includes the late Proterozoic Hazara and Tanol formations and intrusive Cambrian Mansehra granite. The grade of metamorphism varies from chlorite-grade in the south to staurolite-grade in the north.

The Panjal and Mansehra zones are intruded by Permian mafic dikes and sills of basalts and dolerites. These basalts and dolerites are fresh but at places show weak Himalayan metamorphic effects. The sedimentary, metamorphic and igneous rocks of these zones are classified by petrographic studies.

The rocks of these zones have been affected by multiple pre-Himalayan and Himalayan deformational events. Four deformational events have been recognized as D₁, D₂, D₃ and D₄ deformations. D₁ Hazran deformation is restricted to the late Proterozoic sequence. D₂ deformation produced a barrovian type metamorphism which produced lower-greenschist to amphibolite facies metamorphism in the Panjal and Mansehra zones. The effect of D₂ deformation is weak or absent in Garhi Habibullah and Muzaffarabad-Balakot zones. D₃ deformational event produced southeast-directed folds and thrusts in Mansehra, Panjal and Garhi Habibullah zones. Whereas D₃ deformational event in the Muzaffarabad-Balakot zone produced southeast-directed folds and thrusts. The backsteepening and late extensional folding in all of the four zones occurred in the later phase of D₃ deformation. However, the D₄ deformational event is related to the northwest plunging antiformal and synformal structures which are related to the formation of the Hazara-Kashmir syntaxis.

Key words: Structure, stratigraphy, petrography, Hazara-Kashmir Syntaxis.

Z/6. Zaheer, M.A., 1983. Catalogue of publications of Geoscientific Organisations by National Geodata Centre, Islamabad. Geological Survey of Pakistan, Information Release 208.

As the title indicates, this contribution is a directory of publications of geosciences organizations of Pakistan.

Key words: Geosciences publications.

Z/7. Zaheer, M.A. & Mirza, M.A., 1983. Geoscience Abstracts of Pakistan. Geological Survey of Pakistan, Information Release 207.

This is a list of abstracts related to various meetings and conferences in geological sciences, up to the year 1982.

Key words: Geoscience abstracts.

Z/8. Zahid, M. & Moon, C.J., 1998. Genesis of stratabound scheelite mineralisation Chitral, Northern Pakistan. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 222-223.

Tungsten mineralisation lies within the Asian plate approximately 50-km to the north-west of Main Karakoram Thrust, which marks the suture zone between the Kohistan complex (Northern Pakistan) and Asian plate. Arkari Formation hosts the stratabound tungsten mineralisation at Miniki Gol, Chitral. This Formation is dominantly composed of garnet mica schist, phyllite, calc-silicate quartzite, marble and tourmalinite. Tungsten mineralisation is mainly represented by scheelite in the study area. Scheelite has been found in various rock types but is mainly concentrated in calc-silicate quartzite and subordinate tourmalinite. It occurs as discontinuous patches, stringers and conformable small veins within calc-silicate quartzite and thus can be classed as stratabound type.

Miniki Gol area has undergone at least two phases of deformation and metamorphism which are related to continent-arc collisions during the Cretaceous and Eocene respectively. The Miniki Gol metasediments are intruded by leucogranites emplaced after the culmination of amphibolite facies metamorphism. This felsic intrusion seems to be contemporaneous with the second phase of deformation.

Both the continuity and distribution of scheelite mineralisation appear to be influenced by the internal structure in the calc-silicate quartzite and tourmalinite. Scheelite in these rocks has partitioned along both overprint penetrative foliation and crenulation foliation. The concentration of some scheelite grains in hinges of the kink folds suggests that these foliation planes probably have acted as loci for the epigenetic mineralising fluids. The presence of scheelite grains within the cross-cutting quartz veins also suggests a post-granitic enrichment of the tungsten mineralisation.

The occurrence of calcic-amphibole (hornblende-actinolite), clinozoisite, titanite, calcite, anorthite, grossular garnet, diopside and scheelite fairly coordinates with the skarn mineral assemblage. Except for diopside and grossular garnet, these mineral compositions appear to show a consistent and common trend through out the deposits. This also establishes a genetic relationship between scheelite mineralisation and Miniki Gol leucogranite.

The high concentration of Zr, Hf, Be, Th, U, Ga, Nb, Y, Sn and W in scheelite-bearing calc-silicate quartzite compared to the unmineralised calc-silicate quartzite, psammite and schist implies a hydrothermal activity at the Miniki Gol area. Moreover, the consistency of the fluid inclusions both within leucogranite and calc-silicate rock also signify a genetic link between the scheelite mineralisation and the possible post-magmatic hydrothermal fluids.

Key words: Scheelite mineralization, economic geology, stratabound deposits, metapelites, Chitral.

Z/9. Zahid, M. & Moon, C.J., 1999a. P-T estimates of the calc-silicate rocks and the associated scheelite mineralization from the Miniki Gol, Chitral, N. Pakistan. Geological Bulletin, University of Peshawar, 32, 1-11.

Co-existing calcic-amphibole and plagioclase have been used to obtain pressure-temperature estimates from the calc-silicate rocks at Miniki Gol, Chitral, N. Pakistan. The Miniki Gol calc-silicate rocks are located within the Hindu Kush range, approximately 50 km to the northwest of the Northern suture zone. Jurassic Arkari Formation hosts the calc-silicate rock, composed of clinozoisite, quartz, calcic amphibole, plagioclase, chlorite, biotite, calcite, sphene, garnet and scheelite.

A pair of coexisting ferro-tschermakitic hornblende and anorthite from scheelite bearing calc-silicate quartzite and a pair of andesine and magnesio-hornblende from barren calc-silicate quartzite were selected for P-T estimates. These pairs have apparently formed under equilibrium conditions. The tschermakitic hornblende anorthite pair yields a temperature range of 600-650°C whereas the andesine and magnesio-hornblende pair

gives a temperature range between $530 \pm 20^{\circ}\text{C}$ and $490 \pm 20^{\circ}\text{C}$. These temperatures are compatible with those of the upper amphibolite facies and greenschist facies metamorphism, respectively.

A general agreement was also observed when these estimates were checked with the criteria described for the correlation of temperature with increase in TiO , Na_2O and Al_2O_3 , from actinolite to tschermakite. The chemistry of the tschermakitic amphibole indicates that the calc-silicate rock has formed at a pressure below 5 kbar. Keeping in view the variation of chemical composition (Al_2O_3 , content) in calcic-amphibole associated with scheelite grains, it can be suggested that scheelite crystallised in a temperature range of 550°C - 400°C .

Key words: Geothermobarometry, calc-silicates, scheelite mineralization, Chitral, Hindukush.

Z/10. Zahid, M. & Moon, C.J., 1999b. Genesis of tourmalinite from Chitral, Northern Pakistan. Geological Bulletin, University of Peshawar 32, 77-87.

Miniki Gol scheelite-bearing tourmalinite occurs within the Jurassic Arkari Formation. The Arkari Formation is located near the Pak-Afghan border within the Eastern Hindu Kush and is composed of garnet mica schist, phyllite, marble, mica quartzite, calc-silicate quartzite and subordinate tourmalinite. The extension of tourmalinite is very limited and has been identified at three locations within the mica schist. Tourmalinite is dominantly composed of tourmaline, spessartine-rich garnet, quartz and scheelite. Tourmaline reaches up to 80% by volume in some tourmalinites. The chemical composition of tourmaline and garnet of the tourmalinite fairly corresponds with those of the nearby exposed leucogranite. The values of K₂O, MnO, Zn, Rb and Ba of Miniki Go1 tourmalinite, are not markedly different from the associated schist and thus cannot be considered as siliceous chemical precipitates (exhalites). The limited extension of the tourmalinite is also inconsistent with the occurrence of exhalites. The lack of Sb, Hg, Ag, F and P in the tourmalinite also rules out the possibility of the exhalative activity in the study area. A linear relationship between LREE and elements of obvious igneous origin such as Zr, Hf and Be in the tourmalinite indicates a post-magmatic metasomatic activity. The Miniki Go1 leucogranite can be considered as potential source for the extreme enrichment of boron in the tourmalinite.

Key words: Tourmaline, scheelite, metasomatism, Chitral, Hindukush.

Z/11. Zaka, K.J., Bajwa, N.A. & Pervaiz, K., 1998. Landslide hazard zonation in the Hindukush Mountains at Golen Gol hydropower project, Chitral-A terrain evaluation approach. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, p.224.

Mitigation of disasters can be successful only when detailed knowledge is obtained about the expected frequency, character and magnitude of natural phenomena which may cause disaster in an area. The zonation of hazard must be the basis for any hazard mitigation project. To map such zones, a terrain classification map (TCM) has been prepared assuming slope as basic element. A land use map (LUM) was prepared using aerial photographs. A combination of TCM and LUM provides fair assessment of slope, vegetation, geology /structure and land use. Five hazard prone zones have been identified i.e. old stable landslides, old active landslides, recently active landslides and potential land slide zones. The interpretation of TCM, lineament map and engineering geological map leads to the conclusion that the area of thrusts and ridges are more prone to land sliding.

Key words: Landslide, hazard, hydropower, Hindukush.

Z/12. Zaka, K.J., Baloch, I.H. & Chaudhry, M.N., 1997. Provenance, alkali, aggregate reaction (A.A.R) and inservice behaviour of NW Himalayan gravels and sands in cement concrete at Terbala and Warsak Dams Pakistan. Geological Bulletin, Punjab University 31 & 32, 53-68.

For further information, consult the following summarized account of this paper.

Key words: Alkali aggregate, gravels, sands, cement concrete, Indus.

Z/13. Zaka, K.J. & Chaudhry, M.N., 1995. Provenance, alkali, aggregate reaction (A.A.R) and inservice behaviour of NW Himalayan gravels and sands in cement concrete at Terbala and Warsak Dams Pakistan. Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The NW Himalaya in Pakistan from which the gravel and sand of Indus River and its major tributaries are derived is geologically very complex. The mountain chains comprising this area have been formed by India Eurasia collision initiating at ca 65 m.y. with the Kohistan-Ladakh Island Arc trapped in between. The Indian plate at the leading edge is composed of Higher Himalayan S-type granitoids, migmatites and a sequence of high grade calc-pelites, marbles, pelites and psammites with layers of amphibolites. Granitoid, migmatite, carbonate, amphibolite and hard schists derived from these blocks are innocuous. Extensive mylonites have developed along Main Central Thrust, Indus Suture Zone and Thakot Fault and rarely within the Higher Himalayan crystallines (HHC). Quartz rich clasts of mylonites derived from these zones contain highly strained quartz with anomalous optics and are potentially deleterious.

The Lesser Himalaya to the south of the Higher Himalayan Block is composed of a northern metamorphic-igneous zone comprised predominantly of porphyritic S-type cordierite granitoids, pelites and psammites. The southern sedimentary zone is comprised of pelites and psammites and a sequence of unmetamorphosed shelf carbonates with minor sandstone and shale horizons. The granitoid, hard schist and medium to high-grade psammites of metamorphic zone are innocuous. Slates, phyllites and graywackes in lower greenschist facies are potentially deleterious. Carbonate and sandstone clasts from the sedimentary part are innocuous. However chert clasts from this zone are potentially deleterious. The Balakot Mylonite Zone (B.M.Z) and Oghi Shear Zone (O.S.Z) yield deleterious strained quartz rich clasts. Microfractured quartz clasts derived from Hazara slate and Tanawal Formation of pelite psammite character from Lesser Himalaya are also potentially deleterious since they contain cryptocrystalline quartz along fracture cleavage developed during the second major deformation phase. The Kohistan Island Arc is composed of high grade amphibolites, acid to intermediate volcanics and I-type granitoids ranging in composition from granite to diorite and minor chert, volcanogenic arenites, carbonates, pelites and marl. The Kohistan terrain yields slightly reconstituted acid to intermediate ferro to cryptocrystalline volcanics, pyroclasts and volcanogenic chert/chalcedony and arenites metamorphosed to a very low grade. These are again potentially deleterious. I-type granitoids and amphibolites are innocuous.

A gabbro-norite batholith also occurs in this terrain. The huge batholith variously interpreted as having been formed under a spreading center (Ghazanfar et.al. 1991), as a core batholith to the Kohistan Island Arc (Jan, 1980) or formed due to rifting of a mature arc or under a back arc spreading center (Khan et.al. 1992) is composed of about 95% gabbro-norite, 1% ultramafics and 3% diorites and tonalites. The clasts derived from this source are innocuous.

The Kohistan Arc is bounded by two suture zones the northern of which is known as the Main Karakoram Thrust (MKT) while the southern branch is known as the Indus suture zone or the Main Mantle Thrust (MMT). The suture is composed of pillow lavas, peridotite and dunite cumulates, harzburgite tectonites, bedded cherts, volcanogenic chalcedonic cherts and flysch. The two suture zones contribute only small quantities of deleterious clasts derived from bedded/ribbon chert and other flyschoid sediments. The Karakoram Plate to the north of MKT is composed of a basement S-type granitoid complex overlain by high grade pelite, psammites, marbles and calc-pelites. This in turn is overlain by a sequence of slates and low grade carbonates. Only small quantities of potentially deleterious volcanics and low grade meta-argillites are contributed by this terrain.

The sand and gravel derived from this complex terrain has so far exhibited excellent physical characteristics. But these have shown alarming petrographic and chemical behaviour in concrete. A controversy has therefore continued over the past one decade as to the actual causes of deleterious deterioration in parts of already placed concrete.

In Tarbela and Warsak Dams natural sand and gravel from the river bed of Indus and Kabul were used respectively. In case of Tarbela the coarse aggregates is composed on the average of amphibolitic/foliated diorite 27.6%, granodiorite/granite 16.1%, greywacke group 13.7%, quartzite/micaceous quartzite 13.0%, schist/subschist 7.4%, acid to intermediate volcanics 6.8%, phyllite 5.5%, carbonates 4.2%, garnet amphibolite 2.4%, basic volcanics 2.2%, diabase 0.9% and chert 0.2%. The fine aggregates are composed of quartz/quartzite/micaceous quartzite 30.5%, granite/granodiorite 20.2%, amphibolite/foliated diorite 10.7%, feldspar 10.0%, micas 5.8%, greywacke group 5.3%, amphibole 4.6%, schist 4.0%, phyllite/slate 3.3%, iron ore 1.3%, epidote 1.3%, carbonates 1.2%, volcanics 0.6%, garnet 0.3%, sphene 0.3%, chert 0.2%, tourmaline 0.2%, apatite 0.1%, zircon 0.1%. These were considered non-deleterious and were used with ordinary portland cement having ~ alkali level ranging from 0.9% to 1.03%. Although the exact composition of cement used for construction of Warsak Dam is not known yet the record of analysis available show that the total alkalis level ranged from 0.9% to 1.20%.

The aggregates used in construction of Tarbela Dam contain large amounts of slightly metamorphosed acid to intermediate volcanics, argillites, microfractured quartzites, greywacke and a little chert. Although these aggregates contain large quantities of potentially deleterious rock types yet they were presumably regarded safe either because their parent rocks had undergone metamorphism or on the grounds that they had large quantities of mildly reactive rock types and therefore, would not develop deleterious reaction. It was only after twelve years of completion that A.A.R was confirmed in concrete structures of the dam (Chaudhry and Zaka 1994).

Similar type of aggregates were used for the construction of Warsak Dam. The coarse aggregates are composed of schist 11.6%, phyllite/slate 8.8%, amphibolite/amphibole gneiss 23.0%, quartzite 20.9%, granite/granite gneiss 21.5%, microfractured and strained quartzite 7.8%, acid to intermediate volcanics with microcrystalline matter 2.6%, limestone 3.0%, chert 0.8%. The fine aggregates are composed of quartz 35.2%, amphibole 12.3%, plagioclase/albite 7.9%, amphibolite/amphibole gneiss 7.0%, orthoclase/microcline 6.4%, quartzite 5.2%, schist 3.5%, granite/granite gneiss 4.1%, phyllite/slate 2.0%, magnetite 1.3%, biotite 2.6%, strained quartz 3.5%, microfractured and strained quartz 2.7%, muscovite 1.0%, chlorite 0.6%, limonite 0.8%, garnet 0.5%, acid to intermediate volcanic with microcrystalline matter 1.1%, limestone 1.6%, sphene 0.2%, chert + microcrystalline quartz 0.5%, tourmaline Tr. Warsak Dam civil structures have undergone deterioration due to A.A.R especially the Power House installations. The rock types, which are directly responsible for deleterious reactions, are microfractured quartzite, phyllite/slate, and partially reconstituted merrocryalline acid to intermediate metavolcanics and a little chert.

The aggregates were considered safe by earlier works on the grounds that the deleterious rock types like argillites, greywackes, quartzite and acid to intermediate volcanics had undergone metamorphism. We suggest that these rocks have been reconstituted in very low-grade metamorphic zone (Winkler, 1976) or prehnite-pumpellyite to lower greenschist facies. As such the reactive silica phases and phyllosilicates have not been reconstituted completely to innocuous mineral phases. We further suggest that such rocks are rendered innocuous only when metamorphosed to biotite grade on an equivalent reaction in greenschist facies. In phyllosilicate bearing rocks it is characterized by the transformation of illite to structurally well ordered micas or equivalent transformations.

The presumption that a large quantity of reactive rock types in Indus aggregate may render it innocuous is not proved. While Pessimism can be applied to gravel composed predominantly of one rock type (flint gravel of U.K. or France from London or Paris Basins) the same is difficult to extrapolate for polymit gravels with a variety of reactive rock types unless prolonged experimentation furnishes a justification. alkali, aggregate reaction (A.A.R) and inservice behaviour of NW Himalayan gravels and sands in cement concrete.

Key words: Alkali aggregate, gravels, sands, cement concrete, Indus.

Z/14. Zakir, S. & Shaheen, F., 2001. Monitoring of groundwater quality in Gadoon Amazai Industrial Estate, NWFP, Pakistan. Abstracts, 4th Pakistan Geological Congress, Islamabad, p.48.

Industrial effluents are potential source of water pollution. The lack of in-plant control measures, discharge of untreated wastewater through open drainage system and the lack of implementation of existing regulation remain serious threats to the quality of surface and ground waters. The present study was carried out to evaluate the pollution load of ground water contamination in the Gadoon Amazai Industrial Estate (GAIE). A total of 21 samples were collected from GAIE during three months from five tube wells, one hand pump and one dug well and analysed for biological oxygen demand, chloride, electrical conductivity, nitrate-nitrogen, sulphate and sulphide. The overall result showed that the concentrations of all the parameters were within the permissible limits as recommended by World Health Organization (WHO). These industries are however, the potential sources of ground water pollution. Immediate implementation of on site control measures, treatment plants and awareness of the industrialists are suggested as futuristic measures for saving the ground water from the expected industrial pollution.

Key words: Groundwater, pollution, Gadoon-Amazai, Swabi.

Z/15. Zaleha, M.J., 1997a. Fluvial and lacustrine palaeoenvironments of the Miocene Siwalik Group, Khaur area, northern Pakistan. *Sedimentology* 44, 349-368.

The Miocene Siwalik Group (upsection, the Chinji, Nagri, and Dhok Pathan Formations) in northern Pakistan records fluvial and lacustrine environments within the Himalayan foreland basin. Thick (5 m to tens of metres) sandstones are composed of channel bar and fill deposits of low-sinuosity (1.08–1.19), single-channel meandering and braided rivers which formed large, low-gradient sediment fans (or 'megafans'). River flow was dominantly toward the south-east and likely perennial. Palaeohydraulic reconstructions indicate that Chinji and Dhok Pathan rivers were small relative to Nagri rivers. Bankfull channel depths of Chinji and Dhok Pathan rivers were generally ≤ 15 m, and up to 33 m for Nagri rivers. Widths of channel segments (including single channels of meandering rivers and individual channels around braid bars) were 320–710 m for Chinji rivers, 320–1050 m for Nagri rivers, and 270–340 m for Dhok Pathan rivers. Mean channel bed slopes were on the order of 0.000056–0.00011. Bankfull discharges of channel segments for Chinji and Dhok Pathan rivers were generally 700–800 m³s⁻¹, with full river discharges possibly up to 2400 m³s⁻¹. Bankfull discharges of channel

segments for Nagri rivers were generally 1800–3500 m³s⁻¹, with discharges of some larger channel segments possibly on the order of 9000–32 000 m³s⁻¹. Full river discharges of some of the largest Nagri braided rivers may have been twice these values.

Thin (decimetres to a few metres) sandstones represent deposits of levees, crevasse channels and splays, floodplain channels, and large sheet floods. Laminated mudstones represent floodplain and lacustrine deposits. Lakes were both perennial and short-lived, and likely less than 10 m deep with maximum fetches on the order of a few tens of kilometres. Trace fossils and body fossils within all facies indicate the former existence of terrestrial vertebrates, molluscs (bivalves and gastropods), arthropods (including insects), worms, aquatic fauna (e.g. fish, turtles, crocodiles), trees, bushes, grasses, and aquatic flora. Palaeoenvironmental reconstructions are consistent with previous palaeoclimatic interpretations of monsoonal conditions.

Key words: Sedimentary deposits, fluvial, Siwaliks, Potwar.

Z/16. Zaleha, M.J., 1997b. Intra- and extra-basinal controls on fluvial deposition in the Miocene Indo-Gangetic foreland basin, northern Pakistan. *Sedimentology* 44, 369-390.

Key words: Deposition, foreland basin, Miocene, Siwaliks.

Z/17. Zaman, H., 1993. Geology, tectonics and paleomagnetism in northern Pakistan and the field program in Chitral. *Proceedings of Geoscience Colloquium, Geoscience Lab, GSP, Islamabad* 7, 34-43.

Geology and tectonics of northern Pakistan are briefly described together with an overview of paleomagnetism in Ladakh and Chitral. Preliminary paleomagnetic results from the Cretaceous-Paleogene Red Beds of Chitral (collected by Zaman et al) are given in an appendix. The data suggest low latitude for Chitral area in Cretaceous – Paleogene time. It is also inferred that Chitral area was not originally a part of Eurasia.

Key words: Tectonics, Paleomagnetism, Chitral, Hindukush.

Z/18. Zaman, H., & Torii, M., 1995a. Preliminary result of paleomagnetism from the Cretaceous red beds of the eastern Hindu Kush, Chitral, Pakistan. *Autumn Meeting. Geomagnetism Soc., Earth Planet. Space Science. (SGEPSS), Kyoto, Japan. Abst.,* 22–24.

For additional information, see Zaman and Torii, 1996a and 1996b.

Key words: Paleomagnetism, red beds, Chitral, Hindukush.

Z/19. Zaman, H. & Torii, M., 1995b. Preliminary results of paleomagnetism from the Cretaceous red beds of the eastern Hindukush, Chitral, Pakistan. In: Khadim, I.M. & Yoshida, M. (eds.), *Rock Magnetism and Paleomagnetism. Recent Progress in Pakistan, Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad)* 13, 137-147.

For additional information, see Zaman and Torii, 1996a and 1996b.

Key words: Paleomagnetism, red beds, Cretaceous, Chitral.

Z/20. Zaman, H., & Torii, M., 1996a. Paleomagnetic study of the Cretaceous red beds from the eastern Hindu Kush Range, northern Pakistan: Paleoreconstruction of the Kohistan–Karakoram composite unit before India–Asia collision. *International Seminar on Paleomagnetic Studies in Himalaya–Karakoram collision belt. Geological Survey of Pakistan. Geoscience Labs. Extended Abstracts,* 1-4

In order to study the tectonic displacement of the Kohistan–Karakoram region, we collected more than 350 paleomagnetic samples in two field trips from the Chitral district of northwestern Pakistan (35° 28' to 36° 16' N, 71° 44' to 72° 20' E). In the first phase of sampling Devonian to Cretaceous sedimentary, volcanic and plutonic rocks were sampled from the Kohistan and Karakoram terranes. In the second phase of samplings, mid-Cretaceous red beds were exclusively sampled from Drosh-Shishi area of Kohistan terrane. Here we report paleomagnetic results obtained from the mid-Cretaceous red beds of Drosh-Shishi and Buni areas.

On the basis of paleomagnetic results, thermal rather than alternating field demagnetization allowed the separation of multi-components magnetization. As shown in the Figure 1 (a, b, c), most of the samples (except

that of Northern Suture zone in Figure 1d) revealed three components of magnetization. The most unstable A component was broken down between 200° and 500°C. In the geographic coordinates the site mean direction for the A component ($D = 15.0^\circ$, $I = 54.2^\circ$) is close to the present field direction of the sampling area, indicating a recent origin for this component. An intermediate component (B) was separated from 300° to 660°C. Tilt-corrected mean direction for the B component from all three formations gave a mean direction ($D = 284.2^\circ$, $I = 1.0^\circ$) with northwestward declination and very shallow positive inclination. The omnipresence of this partially overprinted remanence across the Northern Suture zone is probably related to the time of temperature enhancement after the India-Asia collision, indicating that thermochemical remanent magnetization is responsible for the acquisition of B component. The direction obtained from the B component is nearly consistent with the previously reported characteristic direction (interpreted as a remagnetization) from the adjacent area (Klootwijk et al., 1994). The equatorial to low northern paleolatitude (-0.5° to 0.5°) from the B component is in good support to the Klootwijk et al. (1994) interpretation, that initial India-Asia contact was established at, or before the Cretaceous-Tertiary (KT) boundary at equatorial to low northern paleolatitudes.

Figure 1: Orthogonal projections and intensity plots of thermal demagnetization in the stratigraphic coordinates. Solid (open) symbols indicate projection onto the horizontal (vertical) plane. (a) Reshun Formation (b) Punt Formation (c) Drosh Formation (d) Northern Suture zone. The temperature range for the most stable characteristic remanent magnetization (0 is found to be variable from one locality to another, and is generally unblocked between 600° and 685°C. The mid-Cretaceous ChRM direction obtained from the C component is clearly divided into two separate groups. Group of sites from the Purit Formation gave a characteristic direction ($D = 311.2^\circ$, $I = -4.4^\circ$, $k = 12.4$, $\alpha_{95} = 17.8^\circ$) with northwestward declination and very shallow negative inclination. Dual polarity, very high coercivity and unblocking temperatures, positive fold and conglomerate tests all satisfies the condition that the ChRM of the Purit Formation was acquired before folding, and most likely as a depositional remanent magnetization. Comparison of mean declination from the Purit Formation group with the Cretaceous apparent polar wander paths (Besse and Courtillot, 1991) indicate a counterclockwise rotation of about 66° and 15° relative to Eurasia and India, respectively. The counterclockwise rotation is consistent with the regional structure of the Hindukush-Pamir-Karakoram syntaxial bend. The mean ChRM direction obtained from the Reshun and Drosh formations is, $D = 79.1^\circ$, $I = -4.7^\circ$, $k = 28.3$, $\alpha_{95} = 12.8^\circ$. Positive fold test, high unblocking temperature and relatively low coercivity suggests that the ChRM of Drosh Formation was acquired before folding, and most likely as a chemical remanent magnetization. In contrast to the Purit Formation, the northeastward mean declination from the Reshun and Drosh formations indicates that the sampling area experienced a clockwise rotation of about 62° and 113° with respect to Eurasia and India, respectively. This unusual clockwise rotation is not consistent with the regional superstructure, and is probably related to the local tectonic movement caused by the rotation of thrust sheets along the Northern Suture zone.

The paleolatitudes obtained from mean inclinations are 2.2° and 2.3° for the Purit and Reshun+Drosh formations, respectively. By comparing these paleoposition of the Kohistan-Karakoram area with the present day latitude (-35° N), implying that over 3500 km of crustal shortening was taken place since mid-Cretaceous time, of which more than 90% postdated the India-Asia collision (Figure 2). The shortened crust was most likely consumed by continental underthrusting, intercontinental thrusting with internal deformation and lateral extrusion along major and minor faults (Molnar and Tapponier, 1975). About 3° paleolatitudinal difference between B and C components indicates that the study area was pushed northward about 300 km from the time of red bed deposition to that of India-Asia collision (Figure 2). The displacement of the sampling area between two acquisition points is acceptable in the sense, that during the said period oceanic part of the subducting Indian Plate was pushing forward the Kohistan-Karakoram terranes towards north. The ChRM directions from the Reshun and Drosh formations are nearly consistent, which probably indicate that these two formations could be placed on the same platform, at the north side of the suture zone. In this case a faulted boundary between the Purit and Drosh formations cannot be ruled out, most likely under the cover of Shishi River. The mid-Cretaceous inclination values (Figure 2: Comparison of the paleolatitudes obtained from the intermediate B and C components with the Cretaceous paleogeographic reconstruction of Asia (redrawn from Chen et al., 1993)). It is indicated that more than 3500 km of crustal shortening was taken place after the ChRM acquisition at equatorial paleolatitude, and more than 90% of 11 postdated the acquisition of B component (probably related to India-Asia collision). obtained across the Northern Suture zone are almost identical, which indicates that suturing has been completed at the time of ChRM acquisition. This is in good agreement with the geochronological results from North Pakistan, which date the age of suturing at 102-85 Ma (Treloar et al., 1989).

Key words: Paleomagnetism, red beds, Cretaceous, Chitral.

Z/21. Zaman, H. & Torii, M., 1996b. Paleoposition of the Kohistan-Karakoram composite unit: A paleomagnetic study of the Cretaceous red beds from the eastern Hindukush Range of Northern Pakistan. Abstract volume, 11th Himalaya-Karakoram-Tibet Workshop, Flagstaff, Arizona, 175-176.

In order to study the tectonic deformation of the Eastern Hindukush region, we collected paleomagnetic samples within Chitral district of northwestern Pakistan ($35^{\circ} 28'$ to $36^{\circ} 16'$, $71^{\circ} 44'$ to $72^{\circ} 20'$). During two field trips, more than 350 hand samples of Devonian to Cretaceous sedimentary, volcanic and plutonic rocks were collected at 20 localities. Here we report paleomagnetic results obtained from the Mid-Cretaceous red beds of Drosh-Shishi and Buni areas (Purit and Drosh Formations from Drosh-Shishi area and Reshun Formation from Buni area; by Pudsey et al., 1985).

The rock magnetic parameters indicate that magnetic minerals are variable from one formation to another. The dominant magnetic carrier identified in the samples of the Purit Formation is a high temperature hematite. In the samples of the Drosh Formation two kinds of magnetic minerals are present, that is a dominant hematite and subordinate magnetite. The ratios of magnetic minerals are changing in the sample of Reshun Formation, where hematite and goethite are dominant in the red mudstone and pebble conglomerates respectively. On the basis of paleomagnetic results, thermal demagnetization allowed the separation of multi-components magnetization. Most of the samples revealed three components of magnetization (except two sites from the Northern Suture). A recent field component (A) was removed between 200° and 500°C . An intermediate thermal stability component (B) was separated from 300° to 660°C . The temperature range for the characteristic remnant magnetization (ChRM) component (C) is found to be variable from one locality to another, and is generally unblocked between 600° and 685°C . In the geographic coordinates the site mean direction for component A ($D=15.0^{\circ}$, $I=54.2^{\circ}$) is nearly similar to the present field direction of the sampling area, indicating a recent origin for this component. Tilt corrected intermediate component (B) from all three formation gave a mean direction ($D=284.2^{\circ}$, $I=1.0^{\circ}$, $k=7.9$, $a95=18.3^{\circ}$) with northwestward declination and very shallow positive inclination. A uniform presence of this secondary magnetization across Northern Suture indicates that it was probably acquired at the time of India-Asia collision. The direction obtained from component B is nearly consistent with the previously reported characteristic direction (interpreted as a secondary remagnetization) from the adjacent area (Klootwijk et al., 1994). The Mid-Cretaceous ChRM direction obtained from C component (thirteen sites) is clearly divided into two separate groups. Group of sites from the Purit Formation gave a characteristic direction ($D=311.2^{\circ}$, $I=4.4^{\circ}$, $k=12.4$, $a95=17.8^{\circ}$) with northwestward declination and very shallow negative inclination. The corresponding pole for the Purit Formation is located at 31°S , 133°E . The mean ChRM direction obtained from the Reshun and Drosh Formations is, $D=79.1^{\circ}$, $I=4.7^{\circ}$, $k=28.3$, $a95=2.8^{\circ}$, with corresponding pole position at 7°N , 169°E . In both cases the positive fold test indicates that the ChRM component was acquired before folding, and is most likely the primary magnetization.

Comparison of mean declination from the Purit Formation group with the Cretaceous apparent polar wander paths (Besse and Courtillot, 1991) indicate a counterclockwise rotation (Kohistan block) of about 66° and 15° relative to Eurasia and India, respectively. The counterclockwise rotation is consistent with the regional structure of the Hindukush-Pamir-Karakoram syntaxial bend. In contrast the northeastward mean declination from the Reshun and Drosh Formations indicate that the sampling area experienced a clockwise rotation of about 62° and 113° with respect to Eurasia and India, respectively. This unusual clockwise rotation is probably related to the local tectonic movement caused by the rotation of thrust sheets along the Northern Suture Zone. The paleolatitudes obtained from mean inclinations are 2.2 and 2.3°S for the Purit Formation and Reshun + Drosh Formations, respectively. By comparing this paleoposition of the Kohistan-Karakoram composite unit with the present day latitude ($\sim 35^{\circ}\text{N}$), implying that over 3500 km of crustal shortening was taken place since Mid-Cretaceous time, of which more than 90% postdate the India-Asia collision. The ChRM directions from the Reshun and Drosh Formations are nearly consistent, which probably indicate that these two formations could be placed on the same platform, at the north side of the suture zone. In this case a faulted boundary between the Purit and Drosh Formations cannot be ruled out, most likely under the cover of Shishi River. The Mid-Cretaceous inclination values obtained across the Northern Suture are almost identical, which indicates that suturing has been completed (or near to completion) at the time of ChRM acquisition. This is good agreement with the geochronological results from North Pakistan, which date the age of suturing at 102-85 Ma (Treloar et al., 1989).

Key words: Paleomagnetism, Paleoposition, Kohistan, Chitral, Hindukush.

Z/22. Zaman, H. & Torii, M., 1996c. Rock magnetism of the mid-Cretaceous red beds from the Kohistan and Karakoram terranes, northern Pakistan. Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 102-105.

We report rock magnetic results obtained from the mid-Cretaceous red beds samples, collected from the eastern Hindukush ranges of northern Pakistan. Most of the rock magnetic samples were collected from the Purit, Drosh and Reshun formations, while two localities were sampled from the Northern Suture Zone. The Reshun

Formation of the Karakoram Plate side is a group of rocks including polymict pebble and cobble conglomerates, red calcareous shale and pale gray micritic limestone lies below the Reshun Fault and above Chitral slate or Darkot Group of sediments. On the basis petrographic work (Pudsey, 1986), it is suggested that fluvial sediments of the Reshun Formation was largely derived from the volcanic arc. The red beds of Drosh-Shishi area is lying just south of the Northern Suture zone within the Kohistan terrane, and is divided into three different rock units. In case of Purit Formation, red calcareous shale with abundant calcite veins is the most dominant rock type, while conglomerates and sandstone constitutes about one third of the formation in the lower half overlying the Purit Formation is the Drosh Formation, which is a sequence of thickly-bedded andesitic volcanics. Some thin red calcareous shales are interbedded with the lava flows. The overlying unit of Northern Suture zone consists mainly of dark-gray limestone interbedded with black phyllite and black calcareous shale (Pudsey, 1986).

Rock magnetic properties indicate that magnetic minerals are variable from one formation to another. From thermomagnetic analysis and low temperature measurements it is determined that hematite is the dominant magnetic carrier in the samples of Purit Formation (Figure 1c, d). Furthermore very high coercivity and unblocking temperature indicates that the hematite grains are probably detrital in origin, which in turn is the carrier of characteristic remanent magnetization (ChRM) in the red beds of Purit Formation. From the paleomagnetic components studies it is further indicated that some low thermal stability hematite is also present as a secondary magnetic mineral by comparing with the paleomagnetic results, it is suggested that low temperature hematite is responsible for the acquisition of B component (secondary remagnetization), and is probably related to the time of temperature enhancement after the India-Asia collision, indicating that thennochemical processes are responsible for the production of secondary magnetic minerals. This idea can fairly be compared with the temperature increase above 300°C deduced from zircon resetting at 55-68 Ma from the adjacent area (Zeitler, 1985). The ratio of magnetic minerals are changing in the samples of Reshun Formation, where hematite and goethite are dominant in the red mudstones and pebble conglomerates, respectively (Figure 1a, b). This probably indicates that the source and depositional environment of the existing magnetic minerals were different for the red mudstones and conglomerate beds.

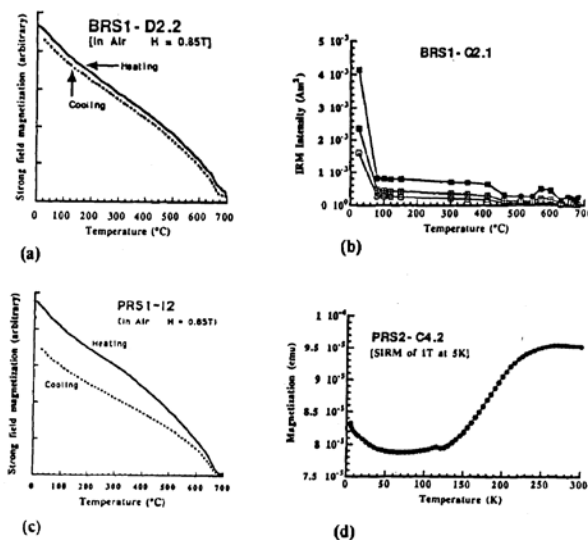


Figure 1: Results of the rock magnetic study for the samples of Reshun (BRS 1.D2.2 and BRS 142-1) and Punt (PRSI-I2 and PRS-CJ-) formations (a and c) Strong field thermomagnetic analysis in air (b) Thermal demagnetization of a three components IRM produced by magnetizing the sample in a field of 1.3, 0.4 and 0.12 T successively along three Werent axes. (d) SIRM of 1 Tesla was imparted at 5 K and then heated up to 300 k

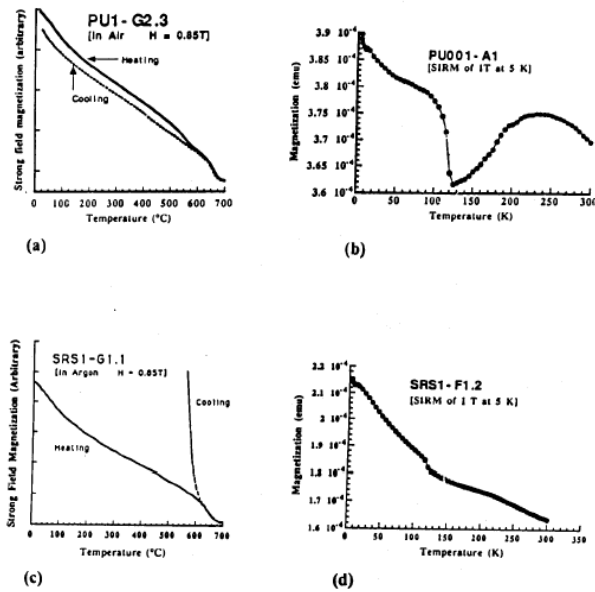


Figure 2: Results of the rock magnetic study for the samples of Drosh Formation (PU1-G2.3 and PU0 I-A1),an Northern Suture Zone (SRS1-G1.1 and SRS1-F1.2) (a and c) Strong field thermomagnetic analysis in air an argon. respxtnclly (band d) SIRM of 1 Tesla was imparted at 5 K and then heated up to 300 K.

In the samples of the Drosh Formation two kinds of magnetic minerals are present, that is a dominant hematite and subordinate magnetite (Figure 2a, b). As evident from the field observation, the red beds of Drosh Formation is thinly interbedded with the andesitic volcanics Here the source of red beds deposition is probably shared by the volcanic ashes and other fine sediments from the surrounding volcanic rocks, which could result in the possible presence of very fine grained magnetic minerals (Superparamagnetic and Single Domain magnetite grains). As described by Turner (1981) that in some cases the original sediments may have been rich in magnetite, but after progressive diagenesis (including oxidation of magnetite) very fine magnetite could be replaced by hematite. It is therefore predicted that the hematite of Drosh Formation was formed by martitization or hydrothermal alterations of the preexisting detrital magnetite, while the subordinate magnetite was probably recrystallized as a result of temperature enhancement after the India-Asia collision. By comparing with the palaeomagnetic results of the same samples it is suggested that hematite is the carrier of ChRM, and secondary remagnetization component (B) is carried by magnetite. The magnetic mineralogy in the samples of Northern Suture Zone is shared by hematite, magnetite and probably iron sulfides. On the basis of rock magnetic characteristics the dominant magnetic carrier is the low coercivity and low temperature hematite (Figure 2c). From low temperature measurements the verway transition of magnetite is very clearly determined, while the presence of hematite is very poorly shown (Figure 2d). This behaviour around the Morin transition zone of hematite (the decreasing change in the remanence with increasing temperature) may reflects the presence of the superparamagnetic grains, which unblocked near the room temperature (Hunt et al., 1995). Unstability of the magnetic minerals in the samples of Northern Suture zone is also indicated from the paleomagnetic results, where the direction of the ChRM is identical with the present Earth's field direction in the sampling area

Key words: Paleomagnetism, Paleoposition, Kohistan, Chitral, Hindukush

Z/23. Zaman, H. & Torii, M., 1996d. Rock magnetism of the mid-Cretaceous red beds from the northwestern margin of Kohistan island arc, northern Pakistan. In: Kausar, A.B. & Yajima, J. (eds.), *Geology, Geochemistry, Economic Geology and Rock Magnetism of the Kohistan Arc*. Proceedings of Geoscience Colloquium (Geoscience Lab, GSP, Islamabad) 15, 207-232.

We report rock magnetic results obtained from the mid-Cretaceous red beds samples, collected from the northern margin of Kohistan island arc, northern Pakistan. Rock magnetic parameters indicates that magnetic minerals are variable from one formation to another. Detrital hematite is the dominant magnetic carrier in the samples of the Purit Formation, while low stability hematite is probably the carrier of secondary magnetization. In the samples of the bosh Formation two kinds of magnetic minerals are present, that is a dominant hematite and subordinate magnetite. Hematite here is probably formed by the in-situ oxidation of pre-existing detrital magnetite, suggesting the magnetization origin as a chemical. The magnetic mineralogy in the samples of

Northern Suture Zone is shared by hematite, magnetite and probably iron sulfides. Unstability of the remanence in the samples of Northern Suture Zone is probably due to the presence of superparamagnetic hematite grains.

Key words: Paleomagnetism, Paleoposition, Kohistan,

Z/24. Zaman, H. & Torii, M., 1997. Rock magnetism of the mid-Cretaceous red beds from Kohistan and Karakoram blocks, northern Pakistan. In: Khadim, I.M., Zaman, H. & Yoshida, M. (eds.), *Paleomagnetism of Collision Belts*. Geoscience Laboratory, GSP, Islamabad, 13-33.

Rock magnetic studies were carried out in order to identify the remanence carrying minerals in the mid-Cretaceous red bed rocks from the Eastern Hindukush mountains, northern Pakistan. Rock magnetic properties indicate that remanence carrying minerals are variable from one formation to another. In the samples of the Purit Formation detrital specular hematite is the dominant carrier of characteristic remanent magnetization (ChRM), while low stability pigmentary hematite is responsible for the acquisition of secondary magnetization. Two kinds of magnetic minerals are present in the samples of the Bosh Formation, i.e., a dominant hematite and a subordinate magnetite. This hematite was probably formed by the in situ oxidation of pre-existing detrital magnetite, suggesting the ChRM origin as a chemical, while magnetite is the alteration product attributed to India-Asia collision. The magnetic mineralogy in the samples of the Northern Suture Zone (NSZ) is shared by hematite, magnetite and probably iron sulfides. Recently acquired ChRM in the samples of NSZ is probably due to the presence of ultrafine hematite grains. The ratio of magnetic minerals are changing in the samples of the Reshun Formation, where detrital hematite is dominant in the red mudstone and goethite in pebble sandstone. Here detrital and pigmentary hematite are responsible for the acquisition of ChRM and intermediate component of magnetization, respectively. In some samples, the presence of magnetite is also indicated by the isothermal remanent magnetization methods.

Key words: Paleomagnetism, collision belts, Kohistan, Chitral, Hindukush.

Z/25. Zaman, H. & Torii, M., 1999a. Palaeomagnetic study of Cretaceous red beds from the eastern Hindukush ranges, northern Pakistan: Palaeoreconstruction of the Kohistan-Karakoram composite unit before India-Asia collision. *Extended Abstracts, International Seminar on Paleomagnetic Studies in Himalaya-Karakoram Collision Belt and Surrounding Continents*, November 20-21, 1996, Islamabad. Geosciences Lab, GSP, Islamabad, 1-4.

For details, consult Zaman and Torii, 1996b and 1999b.

Key words: Paleomagnetism, red beds, Kohistan, Chitral, Hindukush.

Z/26. Zaman, H. & Torii, M., 1999b. Palaeomagnetic study of Cretaceous red beds from the eastern Hindukush ranges, northern Pakistan: Palaeoreconstruction of the Kohistan-Karakoram composite unit before the India-Asia collision. *Geophysical Journal International* 136, 719-738.

We report palaeomagnetic results obtained from Cretaceous red bed sample, collected from the eastern Hindukush mountains, northern Pakistan. Rock magnetic studies revealed specular haematite as the dominant remanence carrier, while pigmentary haematite, magnetic and goethite are responsible for the acquisition of secondary magnetizations. Thermal treatment generally revealed three components of magnetizations. The most unstable component (A) was removed between 200 °C and 500 °C, which corresponds to the local present field direction. The intermediate component (B) was generally separated between 200 °C and 600 °C. The omnipresence of this complex secondary component across the Northern Suture Zone suggests that movement of chemically active orogenic fluids at, or slightly before, the time of the India-Asia collision was probably responsible for the authigenic remagnetization processes. The characteristic component (C) was generally unblocked between 600 °C and 685 °C. The characteristic directions from 12 sites fall into two groups. The sites from the Purit Formation give a tilt-corrected mean direction of $D=311.20$, $I=4.40$, $K=12.4$, $\alpha_{95}=17.80$, indicating a counter-clockwise rotation of about 660 and 150 relative to Eurasia and India, respectively. The tilt-corrected mean direction for the Reshun and Drosh formation is $D=263.00$, $I=2.20$, $K=52.7$, $\alpha_{95}=10.60$ which indicates that the sampling area experienced a counter-clockwise rotation of about 1140 and 630 with respect to Eurasia and India, respectively. In both cases the palaeomagnetic rotation is consistent with the regional superstructure of the Hindukush-Pamir-Karakoram syntaxial bend. The difference in rotation between these two groups is probably due to local tectonic movement caused by the net rotation of thrust sheets along the Northern

Suture Zone. The palaeolatitudes calculated for Purit and Reshun+Drosh formations are 2.20S and 1.10N, respectively. This indicates that about 4000km of convergence has taken place since the mid-Cretaceous, of which about 90 per cent post-dates the India-Asia collision. The Late Cretaceous, inclination values across the Northern Suture Zone are almost identical, which indicates that suturing had been completed at the time of ChRM acquisition.

Key words: Paleomagnetism, Kohistan, Chitral, Hindukush

Z/27. Zaman, H., Torii, M., Yoshida, M. & Karim, T., 1994. Preliminary paleomagnetic results from the Cretaceous–Paleogene red beds of Chitral area, northern Pakistan. 1994, Spring Meetingg. Geomagnetism Soc., Earth and Planet. Space Science, (SGEPSS), Abstract volume.

For more information, consult Zaman and Torii, 1996b.

Key words: Paleomagnetism, red beds, Cretaceous-Paleogene, Chitral, Hindukush

Z/28. Zaman, H., Yoshida, M., Khadim, I.M., Ahmad, M.N. & Akram, H., 1998. Paleomagnetism of the Himalaya–Karakoram belt and surrounding terranes since Jurassic: Implications for three phase collision history. In: Gondwana's Paleomagnetism. Geological Society of India, Special Publication.

Key words: Paleomagnetism, Jurassic-Tertiary, Karakoram, Himalaya.

Z/29. Zaman, M., 1967-68. The geology of the Kiwai-Paras Area, Lower Kaghan Valley, (District Hazara), West Pakistan. M.Sc. Thesis, Punjab University, Lahore, 94p.

Key words: Geology, Kaghan, Mansehra.

Z/30. Zaman, M., 1974. Geology of the raw material available in North West Frontier Province. M.Sc. Thesis, Peshawar University, 66p.

Key words: Raw material, geology, NWFP.

Z/31. Zaman, M.Q., 1961. Exploration and development of petroleum in Pakistan. Natural Resources 1(1), 33-41.

Key words: Hydrocarbon, exploration.

Z/32. Zaman, R., 1988-90. Geology and structure of Kotli-Nikial-Khuiratta area Kotli A.J.K. with special emphasis on Himalayan Frontal Thrust and related structures. M.Sc. Thesis, University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan, 115p.

Geological and structural mapping of Kotli-Nikial-Khuiratta area of about 300 square km was carried on 1:50,000 scale of toposheet No's 43 K/2, 43 K/3, 43 G/11 and 43 G/15 of survey of Pakistan. The lithostratigraphic units described range in age from Pre-Cambrian to Pleistocene and consist mainly of sedimentary rocks. The Pre-Cambrian rock formation is Dogra Slate and Cambrian rock unit is Sirban Formation.

In this area apart from Lower Cambrian, all the formations of Paleozoic and Mesozoic are missing. Either they were not deposited or were weathered to form Bauxite/Fireclay representing an unconformity of a big gap. In the Tertiary period, Patala Formation, Margala Hill Limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy. The rocks are folded and faulted comprising the major and minor structures of the area. The major folds of the area are khuiratta-Kohali anticline (11pp/325pp), Devigarh-Palana anticline (04pp/313p), Tattapani-Karela anticline (6pp/116pp) and Khad-Bahni syncline (6pp/228pp). The major fault is the Himalayan Frontal Thrust with minor thrust like Gala Thrust and Khad Thrust. Deformational events and stereographic projection of the area have been interpreted. The tectonic setup has been also discussed. About eighty five rock samples were taken from the field and carried back to the

laboratory for petrographic studies. In the field of economic geology, a number of deposits including Fireclay, Bauxite, Coal, Limestone, Chalk and Dolomite are of economic interest.

Key words: Geology, structure, Himalayan Frontal Thrust, Azad Kashmir.

Z/33. Zaman, R.S. & Saeed, U., 1979. Development of land and groundwater resources in Kurram Gambila Road, District Bannu. M.Sc. Thesis, University of Peshawar, 63p.

Key words: Land resources, groundwater, Bannu.

Z/34. Zaman, S. & Hashim, M., 1983. The structures, stratigraphy and statistical studies of Siwalik group of area north of Taba Nala, Mianwali District, Punjab. M.Sc. Thesis, University of Peshawar, 111p.

Key words: Structure, stratigraphy, Siwaliks, Mianwali.

Z/35. Zaman, W. & Rehman, N., 1990. Geological investigations of Bhal Syedon (Fateh Jhang) Well No. 2 with special reference to drill cutting analysis. M.Sc. Thesis, University of Peshawar, 144p.

Key words: Geology, well log, hydrocarbon, Fatehjang, Attock.

Z/36. Zanchi, A., 1992. Structural Evolution of the Karakoram Sedimentary cover: preliminary data. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 101.

Preliminary field structural analyses and reconnaissance mapping of the north Karakorum sedimentary cover has been carried out in the Chapursan and Shimshal valleys north of the axial batholith, on the basis of previous stratigraphic reconstructions (Gaetani et al., 1990).

In the Chapursan Valley the structure of the sedimentary cover consists of a complex and polyphasic stack of embricated and locally verticalized Permian to Jurassic thrust sheets, also including the discordant Tupop conglomerates, Cretaceous in age. The oldest deformational event is outlined by an E-W striking belt composed of verticalized and tectonized sediments belonging to the Permian-Jurassic sequences, overlain by the Cretaceous Tupop Formation with a sharp stratigraphical unconformity. Compressional events subsequent to Tupop deposition produced the main stack of thrust sheets, including strongly deformed and folded slices of Tupop. In the Chapursan Valley slip vectors along thrust planes and fold axes indicate a northward direction of transport, whereas NW-SE trending fold axes due to northeastward transport have been mainly observed in the Shimshal valley. The north vergent structure is widely crossed by successive breakback thrusting, evident along the northern side of the Chapursan valley (Northern fault of Gaetani et al., 1990), and along the contact between the sedimentary cover and the axial batholith outcropping in the Yaskuk Glacier area.

The last recognized tectonic phase is the activation of an important set of E-W sinistral strike-slip faults, causing further steepening of previously embricated thrust sheets. These faults may be interpreted as a consequence of a NW-SE directed simple-shear, probably due to deformation along major NW-SE dextral strike-slip faults, as the Misgar dextral strike-slip fault. The sedimentary cover of the north Karakoram is deformed under anchimetamorphic conditions in the Chapursan valley, while sericite to muscovite phyllites of low-grade outcrop in the Shimshal valley. Near the Shimshal Pass andalusite and biotite have been detected in phyllites at the contact aureole of large previously unknown granitic bodies. Cataclasis is mostly evident along thrust planes and strike-slip faults, thus showing brittle conditions of deformation.

Key words: Sedimentary cover, stratigraphy, petrology, structure, Hunza, Gilgit, Karakoram.

Z/37. Zanchi, A., 1992. Structural history of the north Karakorum terran in the upper Hunza valley, Pakistan. In: Zheng, d., Zhang, Q. & Pan, Y. (eds.), Proceedings of international symposium on the Karakorum and Kunlun mountains. China Meteorological Press, Beijing, 143-151.

The sedimentary cover of the north Karakorum terrain is composed of three main structural units: Gujhal, Sost and Misgar Units characterized by different stratigraphic and tectonic evolution. Fold and thrust surfaces

generally trend E-W in the Sost and Misgar Units, whereas they are clearly NW-SE in the Gujhal Unit. Several deformation events have been recognized. A mid-Cretaceous event is testified by the folded succession cropping out below the Cretaceous Tupop and Darband Formations in the Sost Unit. Mid-Cretaceous granodioritic intrusives, some of which have been dated at about 100 Ma, crossing previously formed schistosity, have been observed along the contact between the Gujhal Unit and the Karakorum Axial Batholith, in the Misgar Unit and the Karakorum Axial Batholith, and in the Misgar Unit, indicating a widespread orogenic event. Important post-Cretaceous thrusting is testified by the deformation of the Cretaceous sediments and also by stacking of Eocene intrusives in the Yashkuk area. North vergent tectonic transport seems to be followed in time by south vergent active, and are due to the prosecution of indentation phenomena between India and Eurasia.

Key words: Structure, Hunza valley, Karakorum.

Z/38. Zanchi, A., 1993a. Structural evolution of the North Karakoram cover, north Pakistan. In: Treloar, P.J. & Searle, M.P. (Eds.), *Himalayan Tectonics*. Geological Society of London, Special Publications 74, 21-38.

The oldest deformational structures recognized in the Karakoram sedimentary cover north of the Karakoram Axial Batholith (KAB) consist of an E-W deformed belt composed of Permian-early Cretaceous sediments. This belt is overlain with a stratigraphical unconformity by the Cretaceous Tupop conglomerates and subsequent Late Cretaceous marine sediments. In the Chapursan Valley a complex and polyphase antiformal stack consisting of a Permian to Cretaceous succession was recognized. Post-Cretaceous northward and northeastward directions of transport are shown by slip vectors along thrust planes and by fold axes in the Chapursan Valley, whereas NW-SE-trending folds due to northeastward transport were observed in the Shimshal Valley. The north-vergent structure is crossed by successive north-dipping thrusts along the northern side of the Chapursan Valley and along the contact between the sedimentary cover and the northern continuation of the KAB.

The last tectonic phase recognized in the Chapursan Valley caused the activation of an important set of E-W-orientated sinistral strike-slip faults. In the Shimshal Valley, large E-W sinistral and NW-SE dextral faults are present as well, and may be interpreted as a consequence of a NW-SE-directed simple-shear due to deformation along major NW-SE dextral strike-slip faults.

The sedimentary cover of the Karakoram was deformed under anchimetamorphic conditions in the Chapursan Valley, whereas sericite to muscovite low-grade metapelites with occurrence of chloritoid, epidote and biotite are present in the lower Shimshal Valley. Near the Shimshal Pass, andalusite, garnet, muscovite and biotite were found in phyllites at the contact aureole of an important belt of large previously unknown granitic bodies.

Key words: Sedimentary cover, structure, Hunza, Gilgit, Karakoram.

Z/39. Zanchi, A., 1993b. Structural history of the sedimentary cover of the North Karakoram terrane in the upper Hunza valley (Pakistan). Abstract, Volume, 8th Himalaya-Karakoram-Tibet Workshop, Vienna, 82.

The Karakoram terrane belongs to the peri-Gondwanian blocks rifted from Gondwana during Permian and accreted along the southern Eurasian margin before collision with the Indian plate. The Karakoram block is located between two major suture zones: the Shyok Suture Zone to the South and the Rushan-Pshart suture to the North.

The Karakoram microplate includes a thick sedimentary cover, which is mainly Paleozoic in the western termination and Permian to Cretaceous in the central and eastern area. In the Hunza valley the cover consists of a thick pile of poorly metamorphic Permian-Cretaceous sediments cropping out north of the Karakoram Axial Batholith (KAB).

The sedimentary cover of the North Karakoram terrain is composed of three main structural units: the Gujhal, Sost and Misgar Units characterized by different stratigraphic and tectonic evolution. Folds and thrust surfaces generally trend E-W in the Sost and Misgar Units, whereas they are clearly NW-SE in the Gujhal Unit.

Several deformational events have been recognized on the basis of structural and geological analyses. A "mid-Cretaceous event" is testified by the folded succession cropping out below the Cretaceous Tupop and Darband Formations in the Sost Unit. Mid-Cretaceous granodioritic intrusives, some of which have been dated at about 100 Ma, crossing previously formed schistosity, have been observed in the region. Important post-Cretaceous thrusting is testified by the deformation of the Cretaceous sediments and also by stacking of Eocene intrusives in the Yashkuk area. North vergent tectonic transport seems to be followed in time by south vergent thrust motion. Complex strike-slip faults are successively active, and are due to the prosecution of indentation phenomena between India and Eurasia. Metamorphic conditions range between very low and low grade, which is reached in the deepest part of the Gujhal Unit. Andalusite is generally widespread around the intrusives, indicating low-

pressure conditions, Field work was carried out in during two field seasons (1991-1992), leading to the preparation of a preliminary geological map which is presented in the poster section. Three main geological transects from the KAB to the Misgar Unit have been reconstructed: 1) from Shimshal village to the Khunjerab pass through the Doesam and Chapchingal Pir, 2) along the Hunza and nearby valleys (Shikarjerab, Abgarch and Khudabad valleys) and along the Yaskuk glacier and the western part of the Chapursan Valley.

Key words: Sedimentary cover, structure, Hunza, Gilgit, Karakoram.

Z/40. Zanchi, A., 1994. Structure evolution of Hunza Karakorum. Proceedings of the International Symposium on the Karakorum and Kunlun Mountains, 31-43. Meteorological Institute, Beijing.

Key words: Structure, Hunza, Karakoram.

Z/41. Zanchi, A., Angiolini, L., De Amicis, M., Gaetani, M. & Le Fort, P., 1999. The new digital geological map of Central-Western Karakorum. Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 187.

The new map of central-western Karakorum, presented in a preliminary version at the XII Himalayan Workshop held in Rome in 1997, has been completed and is now available in a digital format (ArcInfo covers). The mapped area (fig. 1) includes the sedimentary cover of the North Karakoram Terrain and the northern portion of the Karakorum central granitoid belt. The latter has been almost entirely mapped by P. Le Fort and represents the original base of the geological map recently published at 1:250,000 scale by Le Fort & Gaetani (1998). The new map summarizes the fieldwork carried out in Central Karakoram during the last years. Due to the lack of reliable topographic maps at the time of the fieldwork, mapping was directly performed using copies of three high resolution Spot images (panchromatic image with a pixel size of 10m) which have been printed at a 1:50,000 scale. The eastern part of the study area, from Lashkargaz to Babagundi Ziarat (Chapursan Valley) has been redrawn using the digital Spot image as a base after georeference and correction by a Geographic Information System (ILWIS 2.1). As far as concern the area located west of Lashkargaz, Spot images were available only in a photographic format and thus an automatic correction of the deformed images was not possible. The geological map has thus been redrawn on the 1:100,000 Russian map of the world, enlarged at a 1:50,000 scale, which represents a very precise and updated (1987) topographic base with contour intervals at 40 m. Due to the good quality of the topographic informations provided by this map together with the analysis of the panchromatic images, we have extended the map out of the boundaries of the area directly surveyed, over large part of the Afghan watershed region.

The database related to the map includes three topological levels of information:

- polygons, including about 8,000 geological units:

- lines, representing linear elements as faults, thrust lithological boundaries, etc. subdivided in about 30 layers. Topographical informations directly derived from the available cartography are also included within this database points, which represent the location of mesoscopic structural observations, sample locations, position of stratigraphic sections, etc. The new version of Fieldlog 3.1 (Geological Survey of Canada, 1998), a relational database which works in strict connection with Autocad 13-14 has been used for this purpose. Through Fieldlog, all kinds of structural data and informations related to the collected samples may be easily managed and represented in the digital map.

The final scale of publication will be 1:150,000, in order to fit the previous map of the Central Eastern Karakorum (Zanchi & Gaetani, 1994). The map represents an important step in the understanding of the geological structure of the region.

Key words: Digital map, Karakoram.

Z/42. Zanchi, A. & Gaetani, M., 1994. Introduction to the geological map of the north Karakorum terrain from the Chapursan valley to the Shimshal pass 1:150,000 scale. *Rivista Italiana de Paleontologia i Stratigrafia* 100, 125-136.

Key words: Geological map, North Karakoram, Gilgit.

Z/43. Zanchi, A., Gaetani, M., Angiolini, L., De Amicis, M. & Poli, S., 1997. The 1:150,000 new digital geological map of the North Karakoram terrane from the Chapursan

valley to Morich Gol (Northern Pakistan). Abstract volume, 12th Himalaya-Karakorum-Tibet International Workshop, Rome, Italy, 239-240.

Between August and September 1996 we crossed the sedimentary cover of the North Karakorum Terrain, from the Hunza valley to Chitral passing through the Chillinji, Karambar and Shah Jinali passes. One of the main purpose of the expedition was to produce a geological map of the whole area, according to the stratigraphic and structural framework established during previous work and to the new observations performed in 1996.

Due to the lack of reliable topographic maps, field mapping was directly realized on pancromatic Spot images printed at a 1:50,000 scale. Correction and georeferencing of the images was obtained with current GIS software (ILWIS 1.4 ITC-Netherlands). Lithological boundaries, major tectonic structures and other topographic informations were digitized in a vector format on separate layers above the georeferenced images leading to a high level of precision. Data concerning mesoscopic structural observations and sampling were included using Fieldlog, a special multirelational database developed by the Geological Survey of Canada for mapping purposes. Finally, polygonization and map production was performed with standard ARC-INFO software.

Three preliminary sketches of our new map are presented in the poster. The first map includes the area between the upper Chapursan valley and the Chillinji (Karambar) region. From north to south we crossed the western prosecution of the Sost Unit (Zanchi & Gaetani, 1994) which is bounded to the south by the Upper Hunza Fault. South of this post-Cretaceous north-vergent thrust the Permian to Mesozoic Guhjal Unit of the Hunza Valley is tectonically associated with the Tas Kupruk Unit, and with a complete Ordovician to Permian section of the Paleozoic, (Gaetani et al., 1996). Complex superposed folding in part post-dating thrust stacking were recognized around Chillinji.

The second area is located north of the Karambar pass, where a poorly deformed Late Carboniferous succession was recognized on the basis of brachiopods assemblages (Angiolini et al., this vol.).

The third sector includes the area from the Shah Jinali pass to the Morich Gol in the Chitral region. From the Shah Jinali pass to the west we crossed from SW to NE the western prosecution of the Tas Kupruk Unit, the Paleozoic Lun Slates (Devonian), a narrow belt of metabasites (plagioclase-hornblende amphibolites) including small amounts of serpentinites with olivine and pyroxene relics, marbles with biotite-sillimanite metapelites, and finally the Late Paleozoic-Mesozoic carbonatic Atark Unit. Complex superposed folding and sinistral strike-slip shearing are characteristic of the structural framework of this area. The amphibolite-serpentinite belt represents the easternmost prosecution of similar complexes described by Buchroithner and Gamerith (1986) in the Arkari and Tirich Gols and may represent the remnant of a suture zone now coincident with the Tirich Mir Fault Zone, separating the Karakoram Block from the East Hindu Kush block. According to available data, the intrusion of the mid-Cretaceous Tirich Mir pluton post-dates the emplacement of the amphibolitic belt. Pre-Late Cretaceous suturing between Karakoram and Hindu Kush is also enhanced by the occurrence of Reshun-like conglomerates in the Atark unit, which suggest a common history for the two blocks since that period.

It is worth noting that, although mapped more than 10 years ago by the Austrian teams, and despite its structural importance, the presence of these basic and ultrabasic rocks was completely ignored in the new 1996 map of North Pakistan compiled by Searle and Khan (1996).

Key words: Digital map, Tectonics, Chapursan, Karakoram.

Z/44. Zanchi, A., Gaetani, M., Angiolini, L., De Amicis, M. & Sironi, M., 2001. The 1:100.000 Geological map of Western-Central North Karakoram terrain (Northern areas, Pakistan). *Journal of Asian Earth Sciences* 19, p.79.

Key words: Mapping, Karakoram.

Z/45. Zanchi, A., Gaetani, M. & Poli, S., 1997. The Rich Gol metamorphic complex: evidence of separation between Hindu Kush and Karakoram (Pakistan). *Comptes Rendus del' Academie des Sciences Paris, Sciences de la terre et des planètes* 325, 877-882.

The westernmost part of the Karakorum belt and its prosecution along East Hindu Kush includes: 1) the southern portion of the Tash Kupruk Unit; 2) the Shah Jinali Phyllites; 3) the Rich Gol Metamorphic Complex (RGMC), a narrow belt of high-grade metabasites with serpentinites and metapelites, which forms a narrow strip along the Tirich Mir Fault, separating the Atark Unit (Hindu Kush?) from Karakorum metasediments. The RGMC may represent the easternmost part of similar complexes described around the Tirich Mir and may be linked to the boundary between Karakorum and East Hindu Kush.

Key words: Metamorphism, Hindu Kush, Karakoram.

Z/46. Zanchi, A. & Gritti, D., 1995. Multistage Structural Evolution of Northern Karakoram (Pakistan). Abstract Volume, 10th Himalaya-Karakoram-Tibet Workshop, (ETH Zurich) Switzerland.

The structural setting of the sedimentary cover of the Karakorum (fig. 1) is well exposed in the uppermost Hunza Valley, where several expeditions were carried out (Gaetani et al., 1990; Zanchi, 1993; Gaetani, 1994). General mapping and structural analysis were extensively performed in the Kundil, Borom, Shikarjerab and Abgarch side valleys located around Sost, where some of the most intriguing structures of the belt are exposed (fig.2). The mid-Cretaceous unconformity described by Gaetani et al. (1990) is exposed above Khudabad in the Borom and Kundil valleys in the southern part of the Sost Unit. Here the mid-Cretaceous deformed belt is covered by the Tupo Conglomerate and by the Late Cretaceous.

Below the unconformity folded limestones show E-W trending folds with subvertical axial planes; transposition and the slaty cleavage developed in the folded Jurassic marls and slates belonging to the deformed belt.

Along the top of the Borom and Kundil valleys thrust sheets of the Sost Unit override the Late Cretaceous sediments as well as the thrust sheet of the Guhjal Unit. E-W trending drag folds showing northward tectonic transport are present belt in the Darband Formation along thrust planes of the Sost Units. NW-SE folds and thrust planes developed in the the Guhjal Unit (fig.3), which also override the Cretaceous sediments along the Upper Hunza Fault, the major tectonic boundary between the Sost and Gubjal Units.

South-vergent thrust stacking was active along the northern part of Sost Unit and lead to the formation of a complex em. antiformal stack with strong lateral geometrical variations. Whereas in the Yashkuk Glacier area the western prosecution of the Sost Unit mostly records north-verging thrust stacking (Zanchi, 1993), around Sost south-vergent thrust sheets are dominant. In the Borom valley a large part of the Permian to Triassic successions show large be overturned concentric folds, indicating south vergent motion. Further east the same succession is tectonically reduced with intensive thickening of the Gircha Formation due to development of tight folds with subvertical axial planes and ring reverse faults.

The northern flank of the antiformal stack, which is overthrust by the Misgar Slates moving along the south-vergent Northern Fault, is crossed by the Misgar Fault Zone north of Sost, fonning a complex system of WNW-ESE trending tectonic flakes due to very intensive folding and at least partly successive strike-slip motion. The fault zone was identified by Gaetani et al., (1990) and located in the sedimentary thrust sheets of the Sost Unit; these authors indicated dextral motion on the basis of the displacement shown by the tectonic boundary between the Misgar and Sost Unit along the Northern Fault. Ogasawara (1992) also indicated dextral movements along a mylonitic shear zone developed around 60 Ma in the Misgar area near the Misgar Fault of Gaetani et al. (1990) and also including mylonitic metagranitoids intruded in the Misgar Unit. A few data collected along the Misgar Fault of Gaetani indicate complex and polyphasic fault motions along the structure. Complex reverse faulting, dextral and sinistral strike-slip movements were observed along the Karakorum Highway and in the Shikarjerab valley. Oblique dextral-reversal components indicated by calc-mylonites along thrust surfaces slightly south of the Misgar Fault Zone also indicate that transpression might be partly coeval with the embrication of the northern side of the stack.

The Misgar Fault Zone seems to be the westward prosecution of important dextral en echelon strike-slip faults observed in the upper part of the Skimshal. The steeply dipping E-W thrust surfaces of the central and southern part of the Sost stack are generally remobilized by sinistral strike-slip faults. During this phase microfolds with subvertical axes and conjugated kink bands developed in the slates of the unit, deforming previous foliations.

Dextral movements along major WNW-ESE to NW-SE fault zones (Misgar Fault) and possibly coeval pervasive sinistral movements along inherited E-W faults may be due to post-collisional dextral shearing active along the right corner of the Indian Indenter in extreme conditions of deformation. Coeval movements along mechanically unfavourable fault planes may be explained by strain accommodation in discrete domains bounded by E-W faults occurring along a mayor dextral fault zone. Activation of sinistral motions along E-W faults is probably due to the importance of inherited structures, represented by high-angle reverse faults formed during previous compressional phases.

Key words: Structure, metamorphism, Hunza, Karakoram.

Z/47. Zanchi, A. & Gritti, D., 1996. Multistage structural evolution of Northern Karakoram (Hunza region, Pakistan). *Tectonophysics*, 260, 145-165.

Detailed mapping and structural work in Upper Hunza Valley, Pakistan, have enlightened the tectonics and the structural evolution of the sedimentary cover of Northern Karakorum. This includes the Northern Sedimentary Belt (NSB) with the Guhjal and Sost Units (Permian-Cretaceous), cropping out north of the Karakorum Axial Batholith (KAB); the NSB is bounded to the north by the Misgar Unit, consisting of slates of unknown age. In the Sost Unit a mid-Cretaceous deformed belt is sealed with a strong angular unconformity by the Late

Cretaceous formations. Folds within the mid-Cretaceous belt possibly indicate north-vergent transport. Stacking of NE- to N-vergent thrust sheets postdates the deposition of Cretaceous sediments, which are largely included within tectonic slices developed along the southern flank of the Sost stack. The southern part of the stack is in turn intruded by the Palaeogene Kuk pluton belonging to the Batura Unit of the KAB.

S- to SSE-vergent thrusting was successively active, stacking steep north-dipping thrust sheets along the northern side of the Sost Unit, forming a complex antiformal stack, well exposed around Sost. High angle pure dip-slip reverse and oblique dextral motions are recorded by fault-slip data and calc-mylonites along major faults, forming a transpressive fault zone close to the contact between the Sost and Misgar Units. During this stage, the Misgar Unit was thrust southward above the Sost Unit along the Northern Fault. Prosecution of dextral motion was also active afterwards along the boundary between the two units. The importance of wrench tectonics is also indicated by widespread activation of E-W sinistral strike-slip faults in the whole study area, generally moving along pre-existent fault planes.

Key words: Structure, Hunza, Karakoram.

Z/48. Zanchi, A., Poli, S., Fumagalli, P. & Gaetani, M., 1999. Mantle peridotites along the Tirich Mir Fault (NW-Pakistan): Pre-mid Cretaceous accretion of the Karakorum terrane?. *Terra Nostra* 99 (Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany), 186.

Mesozoic progressive accretion of Perigondwanan terranes along the southern margin of Eurasia, before the collision of the Indian plate, has been so far recognized by several authors, even if the structural relationships, number, identity and evolution of these blocks are still poorly known. In Pakistan, the Main Mantle Thrust marks the boundary between India and the Mesozoic Kohistan arc, whilst the Northern Suture separates Kohistan from the Karakoram, which was located along the southern margin of the Mega Lhasa.

Ultramafic bodies, along with melanges or syntectonic sediments, have been so far largely used as a marker of sutures or major fault zones between the different terranes, although well documented mantle peridotites are rare. Our recent discovery of a narrow, but more than 150 km long, belt of deformed mafic and ultramafic sandwiched between East Hindu Kush and Karakoram (Zanchi et al., 1997) along the Tirich Mir Fault, Chitral, NW-Pakistan provides a strong argument for the location of the northwestern boundary of Karakoram, as previously suggested merely on the basis of paleogeographic reconstructions (Gaetani, 1997).

In 1996 and 1997 during two field expeditions, we have found a narrow belt of amphibolites, metagabbros, peridotites, gneisses, and quartzites, here named the Tirich Boundary Zone, (TBZ) extending from the Shah Jinali Pass to the Barum valley. North of the Shah Jinali Pass, the TBZ disappears along the Tirich Mir Fault, which prosecutes northward along the Yarkhun

Valley into Afghanistan, merging into a complex system of south-vergent thrusts which form the northern boundary of the Karakoram. West of the Tirich Mir, the same rocks still occur in the Sunitz, Arkari and Lutko valleys. From the Lutko valley the belt extends westward into the poorly known mountains of Nuristan, Afghanistan. Well-preserved spinel lherzolites and harzburgites (loss on ignition 1-3 wt0/o) have been found in the Tirich Gol, in the Barum valley, and in the Arkari Gol, whereas schistose serpentinites predominate in the Rich Gol. Whole-rock analyses show high MgO contents, coupled to low CaO, Al₂O₃, Na₂O and TiO concentrations that indicate the depleted signature of TBZ peridotites. The depleted character is further confirmed by the mineral chemistry of olivine, clinopyroxene, orthopyroxene and spinel. Microstructural and petrological features unequivocally indicate a mantle origin for these ultramafic bodies, equilibrated at temperatures ranging from 1000°C to 1100°C on the basis of currently available geothermometers. Peridotites are tectonically coupled to partially metamorphosed igneous bodies, which includes a whole range of rocks from hornblende gabbros, to cumulitic hornblendites to quartz-diorites. Metamorphic rocks lying south of the ultramafic-mafic complex mainly consist of quartzites, amphibolites and garnet-sillimanite (kyanite)-biotite gneisses and mica schists, locally displaying k-feldspar and migmatitic textures. Widespread greenschist facies reequilibration affect most units.

The high temperature attained by metasediments, by the mafic suite and by the peridotitic bodies, and the common reequilibration path through amphibolite to greenschist facies conditions suggest an early arrangement of the TBZ sequence, even though all current contacts are always of tectonic origin. Absence of an ophiolitic sequence s.s., relatively low temperatures of equilibration for lherzolites and harzburgites, along with coupling with a deep crustal sequence might suggest a sub-continental character of the TBZ peridotites. Therefore, this belt might represent a fragmented crust-mantle boundary developed either on a passive continental margin or along a zone of attenuated continental crust.

The mid-Cretaceous Tirich Mir Pluton intrudes this belt, clearly post-dating magmatism, metamorphism and deformation of the unit, which may be related to an early collision of the Karakoram terrane with the southern section of the Pamir belts (Pashkov and Budanov, 1990; Gaetani et al., 1993).

Key words: Tectonics, structural geology, peridotite, Tirich Mir fault, Chitral, Hindukush.

Z/49. Zanchi, A., Poli, S., Fumagalli, P. & Gaetani, M., 2000. Mantle exhumation along the Tirich Mir Fault Zone, NW Pakistan: pre-mid-Cretaceous accretion of the Karakoram terrane to the Asian margin. In: Khan, M.A[sif], Treloar, P.J., Searle, M.P. & Jan, M.Q. (eds.), *Tectonics of the Nanga Parbat Syntaxis and the Western Himalaya*. Geological Society, London, Special Publication 170, 237-252.

The left-lateral strike-slip Tirich Mir Fault, Chitral, NW Pakistan, is associated with a belt of peridotites, metagabbros and gneisses named the Tirich Boundary Zone (TBZ), separating the Late Paleozoic-Mesozoic units of the East Hindu Kush from the Paleozoic successions of the Karakoram block. These rocks were metamorphosed up to upper amphibolite facies conditions, followed by a greenschist facies overprinting, and then thrust on to very low-grade metasediments; they were finally intruded at shallow levels by the mid-Cretaceous Tirich Mir pluton. Ultramafic rocks along the fault zone include well-preserved spinel lherzolites and harzburgites (Tirich Gol, Barum valley, Arkari Gol), whereas schistose serpentinites occur in the Rich Gol. Whole-rock analyses and mineral chemistry of olivine, clinopyroxene, orthopyroxene and spinel from these peridotites show a depleted signature. Microstructural and petrological features suggest a mantle origin for these ultramafic bodies, which equilibrated at temperatures ranging from 100-1100°C, peridotites are faulted against partially metamorphosed igneous bodies including hornblende-gabbros, hornblende-gabbros, hornblende cumulates and quartz-diorites. Metamorphic rocks of the TPZ, which lay south of the ultramafic-mafic complex, include quartzites, amphibolites, garnet-sillimanite ($\pm$ kyanite $\pm$ K-feldspar)-biotite gneisses and mica schists, locally displaying migmatitic textures.

A sub-continental character of the peridotites indicated by low temperatures of equilibration and by the presence of a deep crustal sequence. These characters along with the absence of an ophiolitic sequence may suggest that the TBZ represent a fragmented crust-mantle boundary developed along a zone of attenuated continental crust. The TBZ is interpreted as a sheared lithospheric section of a Jurassic-Early Cretaceous orogenic complex, formed as a consequence of the accretion of the Karakoram terrane to the southern side of the Pamir belts, which were progressively accreted to the Asian margin.

Key words: Tectonics, structural geology, petrology, Tirich Mir fault, Chitral, Hindukush.

Z/50. Zanettin, B., 1955. Italian Karakorum Expeditions 1953–55, notes on the petrography of the area extending from the Haramosh Group to the Kosar Gunge Group (northern side of the Indus Baltistan). *La Ricerca Scientifica*, anno 26, No. 11.

Key words: Petrography, Haramosh, Baltistan.

Z/51. Zanettin, B., 1956. Notizie petrografiche sull territorio compreso fra i gruppi dell'Haramosh e del Koser Gunge (versante settentrionale dell'Indo Balti). *La Ricerca Scientifica* 26, 3394-3404.

Key words: Petrography, Haramosh, Baltistan.

Z/52. Zanettin, B., 1957. Motivi petrografici essenziali osservati nella regione centrale dell'Indo Karakorum. *Rendiconti della Società Mineralogica Italiana* 13, 397-411.

Key words: Petrography, Central Karakoram.

Z/53. Zanettin, B., 1961. Motivi petrologici petrogenetici nel Karakorum Centro-Meridionale. *Institute of Geology & Mineralogy, Padova University, Memoir* 3, 1–41

Key words: Petrology, Petrogenesis, Central Karakoram

Z/54. Zanettin, B., 1964a. Tertiary granitic masses of diverse origins in the south-central Karakorum. 22nd International Geological Congress 11, 514-530.

Key words: Petrography, petrology, Tertiary granites, south-Central Karakoram.

Z/55. Zanettin, B., 1964b. Geology and petrology of the Haramosh Mangu Gosor area. Italian Expedition to the Karakorum (K2) and Hindu Kush, (Leader A. Desio). Scien. Report III, vol. I, Brill. Leiden, 253p.

Key words: Geology, petrography, granitoids, Haramosh, Mango Gosor, Karakoram.

Z/56. Zanettin, B., 1964c. Molteplicità de processi nella genesi de masse grantiche terziarie nel Caracorum Centro-Meridionale. Consiglio Nazionale de Ricerche, Centro de Studi per la petrografia e la geologia, 3-20.

Key words: Tertiary granitoids, Modes of genesis, Central Karakoram.

Z/57. Zanettin, B. & Callegari, E., 1960. Chimismo di rocce vulvaniche e plutoniche del Karakorum Centro–Meridionale. Instt. Geol. Min., Padova University, Memoirs, 21, 3 - 38.

Zanettin made substantial contribution to the petrography and petrology of igneous rocks of the western and central Karakoram range. In this paper the authors gave details of the geochemistry of volcanic and plutonic rocks of the central Karakoram.

Key words: Geochemistry, volcanic, plutonic rocks, Central Karakoram.

Z/58. Zaninetti, L. & Bronnimann, P., 1975. Triassic Foraminifera from Pakistan. Rivista Italiana di Paleontologia e Stratigrafia, 81(3), 257-280.

The Landu Nala bed, Surghar Range, Pakistan, has 2 Triassic microfossiliferous intervals. The 1st, containing Endothyrales and Meandrosira pusilla, is attributed to the Lower Anisian. This calcarenitic unit is situated between the subadjacent Khatkiara sandstones and the dolomitic Kingriali formation. The latter formation, constituting the 2nd interval, contains Involutina comparable to those of Espahk formation (Iran). The probable age of the microfauna is Ladinian. At the base of the Samana Suk bed, Samana Range, Pakistan, an important association of Triassic Foraminifera, especially Involutinidae, was identified. Compared to the microfauna of the Espahk limestone, this association seems younger than that of the Kingriali formation in the Landu Nala bed. The age for the Samana Suk bed is estimated at Middle to Upper Triassic (Ladinian to Carnian).

Key words: Palaeontology, Foraminifera, Triassic.

Z/59. Zanin Buri, C., 1965. A new Permian epimastopora (calcareous alga) from Hunza valley (Western Karakorum). In: Desio, A. (ed.), Italian Expeditions to the Karakorum and Hindu Kush. Scientific Report 4(1), 79-88. Brill, Leiden.

While examining samples coming from a section made in the Permian of Hunza vally (right side of Chapursan river: on the way to Khudabad-raminj) during Prof. A. Desio's expedition, I recognized the presence of an algal form belonging to Epimastopora, unknown until now in this region. The specimens we examined have been taken from the samples of Girch formation with a thickness of 6000 m, whose upper part is formed by brown and black arenaceous layers with small interpositions of dolomitic limestone, while lower part is formed by light – coloured quartz – sandstones. Our specimens are coming from the calcareous layers in between the inferior and superior member of the formation.

Epimastopora forms are rather frequent and their presence has been noted by several authors in Upper Paleozoic of Asia, America and Europe. It has to be remembered by the way, that the nearest geographic finding is given by the species Epimastopora alpine Herak, coming from the Darvasian of Davas (central Tajikistan – NW Pamir). This species, in opposition to the one I have examined, has been found in association with some other species of calcareous Algae.

Notwithstanding the fact that it has frequently been noted, genus Epimastopora is still not very well known as we are not in a possession of sure data to recognize it exactly.

From stratigraphical point of view it has a great importance, having a limited vertical distribution: its oldest forms appear in Upper Carboniferous and most recent ones are not going over Permian; each species occurs even shortest intervals. For what concerns ecology, Epimastopora testifies warm marine environment such as littoral sea.

Key words: Palaeontology, Permian alga, Hunza.

Z/60. Zarin, A., Ahmad, N. & Faridullah, 1978. Geology of the area between Saidu Sharif and Pir Baba. M.Sc. Thesis, University of Peshawar, 96p.

This area is occupied by metamorphosed sedimentary rocks (politic to calcareous schists) and granitic gneisses (The Ilum granite), with sheets of amphibolites.

Key words: Metasediments, granitoids, Swat, Buner.

Z/61. Zeb, A., 1983. Geochemistry of Tora Tiga complex, southern Dir District. M.Sc. Thesis, University of Peshawar, 108p.

The Tora Tigga complex sits in the hanging wall of the Indus suture in south-western Dir. It is a part of the Kohistan terrain. This ultramafic body comprises hornblendites, a range of pyroxenites, and peridotites, as given here under Banaras and Ghani (1982), and Jan et al. (1983). Zeb provided preliminary geochemistry of the rocks, which can be seen in Jan and Tahirkheli (1990).

Key words: Ultramafic, mafics, plagiogranite, geochemistry, Dir

Z/62. Zeb, M.A., Ajmal, M. & Asif, M., 1988. Petrology and economic significance of barite deposits of Hazara. M.Sc. Thesis, University of Peshawar, 52p.

Key words: Economic geology, barite, petrology, Hazara.

Z/63. Zeilinger, G., Arbaret, L., Burg, J.P., Chaudhry, M.N., Dawood, H. & Hussain, S.S., 1998. Structures in the lower units of Kohistan arc, Northwest Pakistan: Preliminary results. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 224-227.

For further details, consult the following account.

Key words: Structure, lineation, Kohistan.

Z/64. Zeilinger, G., Burg, J.P., Chaudhry, M.N., Dawood, H. & Hussain, S.S., 2000. Fault systems and palaeo-stress in the Indus Suture zone (NW Pakistan). Journal of Asian Earth Sciences 18, 547-559.

Analysis of fault-striations measured in the Kohistan part of the Indus Suture Zone (NW Himalayas, Pakistan) has been carried out to document dynamic evolution during the brittle stage of the collision of India and Asia. Processing of the data with a direct inversion method identified four stress fields, which were chronologically ordered from field evidence as SSE-NNW compression, E-W compression, radial extension and SSW-NNE compression. The last corresponds to the present-day stress field defined from seismic activity. The earlier stress fields are related to times during the Miocene, when convergence-related stresses were disturbed by the formation of the nearby Nanga Parbat and Indus syntaxis.

Key words: Structure, tectonics, stress fields, Indus Suture Zone.

Z/65. Zeilinger, G., Burg, J.P., Schaltegger, U. & Seward, D., 2001. New U/Pb and fission track ages and their implication for the tectonic history of the Lower Kohistan arc complex, Northern Pakistan. Journal of Asian Earth Sciences 19, 16th HKTI workshop special abstract issue, p.79.

The Kohistan arc complex separates the Indian and Asian plates in NW Pakistan. It was formed as an Island arc during Mesozoic times. Accretion to Asia and subsequent thrusting onto the northern margin of the Indian plate along the northward dipping Indus suture zone (ISZ) constitute the collisional history. The early tectonic evolution of the arc can be subdivided into 2 stages: (1) a juvenile stage (estimated at ca. 110±95 Ma): lithospheric growth through partial melting of a fertile mantle in an intraoceanic subduction environment and SW-thrusting expressed by anastomosing shear zones in the southern, i.e. lower part of the arc imposed by

subduction of the Tethys oceanic crust; and (2) an intra-arc rifting stage (around 80 Ma) with the emplacement of large bodies of gabbro and of felsic dykes. We will present two groups of new ages obtained in the lower Kohistan arc complex: (1) crystallization ages of gabbro to granodioritic intrusions reflecting the early arc related history and (2) zircon and apatite fission track (FT) cooling ages related to the younger continent/arc±continent collision and post-collisional uplift.

Key words: Geochronology, U-Pb dating, tectonic history, Kohistan arc.

Z/66. Zeilinger, G., Schaltegger, U., Burg, J.P., Chaudhry, M.N., Dawood, H. & Hussain, S.S., 2001. Precise U-Pb ages from the Kohistan complex (Northern Pakistan) illustrate rapid formation of arc-type crust. 11th EUG Meeting, Strasbourg, J. Conference Abstract 6, p.388.

The Kohistan Arc Complex in northern Pakistan was formed in the Tethys ocean in Mesozoic times and subsequently obducted onto the Indian plate along the Indus Suture in the Late Cretaceous - Paleocene times. The tectonic evolution of the arc can be subdivided into (1) a juvenile stage (estimated at ca.110-95 Ma) involving lithospheric growth through partial melting of a fertile mantle in an intra-oceanic subduction environment; (2) intra-arc rifting (around 85 Ma) marked by the emplacement of large volumes of volcanoclastic rocks in the intra-arc extensional basin and underplating of the arc crust by gabbroites; (3) a mature stage with Andean-type granitoid magmatism, which ceased with the India-Asia collision 60 to 40 Ma ago.

The structurally lowest levels of the Kohistan Arc Complex comprise the Jijal complex, which consists of ultramafic rocks overlain by granulite-facies gabbros. The complex is covered by a pile of metamorphic gabbro to tonalitic dykes and sills overlain by metabasalts and metasediments. This association was intruded by partial melts of mantle origin (gabbros, tonalites, granitoids) representing the first stages of crustal growth (stage 1) in an intraoceanic arc. Precise age determinations yielded for a sub-granulitic gabbro and a granitoid sheet-like intrusion significantly discrete ages of 99 and 97 Ma, respectively; a tonalite body was emplaced into the same environment at 92 Ma. The whole complex was again penetrated by mantle melts (gabbroites to granitoid dykes) during rifting (stage 2). A gabbroite from the so-called Chilas Complex and a granitoid kyanite-bearing dyke yielded ages of 85 Ma and 83 Ma, respectively.

The time period for the initial arc buildup with intrusion of gabbro to granitoid melts is constrained to a short time period between 99 and 92 Ma. Intra-arc rifting characterized by the intrusion of gabbroites and granitoid dykes is dated between 82 and 85 Ma. The ages represent the first protolith ages from the sub-arc mantle-crust transition. Initial arc magmatism may therefore be constrained to at least three magmatic pulses of <5 m.y. duration with each magmatic cycle most likely comprising gabbro to granitoid lithologies, pointing to rapid differentiation processes. The granitoid stocks, sheets and dykes were emplaced prior to obduction onto the Indian plate.

Key words: Geochronology, U-Pb dating, tectonics, Indus suture, Kohistan arc.

Z/67. Zeitler, P.K., 1980. The tectonic interpretation of Fission-Track ages from the Himalayan Ranges of Northern Pakistan. M.A. Thesis, Dartmouth College, 92p.

Fission track ages of sphene, zircon and apatite from rocks collected along the Swat valley and from Hunza (north Pakistan) date the recent uplift history of this region. A major E-W fault, the Main Mantle Thrust (MMT) or Patan Fault crosses the Swat valley and separates regions of markedly different uplift history. Ages ranging from 50 to 55my for apatite were obtained from the region north of this fault. To the south the ages range are 20 to 25my for sphene, 17 to 26my for zircon and 16 to 23my for apatite. This distribution of ages indicates either that differential uplift occurred across the MMT prior to about 15 my, or that this fault has brought together terrains of differing uplift history. Should the latter have been the case, the fission track data indicate that the faulting took place between 15 and 20my at depths of between 3.5 and 6 km. As the MMT may represent the traces of collision between India and an Island arc at 53 my, the offset along this fault at 15 my determined in this study may indicate that the process of complete.

Key words: Tectonics, fission-track ages, Himalaya.

Z/68. Zeitler, P.K., 1983. Uplift and Cooling History of the NW Himalaya, Northern Pakistan. Evidence from Fission-Track and ⁴⁰Ar/³⁹Ar Cooling Ages. Unpublished Ph.D dissertation, Dartmouth College Hanover, New Hampshire 03755, 266p.

This study reports 145 fission-track and 21 ⁴⁰Ar/³⁹Ar cooling ages from the Himalaya of northern Pakistan. Studies of the Himalaya are important because they provide geologists with an opportunity to test models of

orogenesis in an active tectonic setting. As the Himalaya become better known and models become more quantitative, information about thermal histories and rates of uplift and erosion will be needed. This provides the motivation for this dissertation.

The cooling ages suggest, and thermal modeling confirms, that throughout the Tertiary, the cooling history of northern Pakistan was controlled by the effects of accelerating uplift and erosion. On average, from 30 Ma to the present, uplift rates increased from less than 0.1 mm/yr to 0.4 mm/yr. This uplift and erosion, however, has been variable in space as well as time. For example, over the past 10 Ma, western and southern portions of northern Pakistan have been uplifted less than 3.5 km at rates as high as 1.0 mm/yr, and the Nanga Parbat-Haramosh Massif and Hunza regions have been uplifted on the order of 10 to 15 km at rates (over the past 0.7 Ma) nearly 5 mm/yr.

The association of the Nanga Parbat-Haramosh Massif and Hunza with very young cooling ages and with rapid uplift maintained for a period of several million years is the most striking discovery made by this study. The location of these two areas at the heart of the Pamir-Himalaya Arc suggest that their anomalous behavior is linked in some way to a locally vigorous collision of India and Eurasia, possibly due to a promontory of India crust. Several of the cooling ages reported here helps constrain the emplacement ages of intrusives located in northern Pakistan. In addition, cooling ages from the southern Swat-Hazara region can be interpreted to give the time of (final?) southward thrusting of the Kohistan Arc along the Main Mantle Thrust, at about 30 Ma.

Key words: Geochronology, Ar-Ar ages, Fission-track ages, uplift, cooling, NPHM, MMT.

Z/69. Zeitler, P.K., 1985. Cooling history of the NW Himalaya Pakistan. *Tectonics* 4, 127-135.

Fission-track and $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages indicate that the late-Tertiary cooling history of the Himalayan ranges of northern Pakistan is largely a function of uplift and erosion. Interpretation of cooling ages which range from under 0.5 Ma to over 80 Ma suggests that during the late Tertiary, long-term uplift rates at least doubled, from under 0.2 mm/yr to in some cases well over 0.5 mm/yr. Uplift rates show strong and systematic regional variations as well which reflect the greater uplift of eastern and northern regions. The association of very rapid uplift and erosion with the Nanga Parbat-Haramosh Massif can be explained by a locally vigorous collision of India with Eurasia near a promontory of Indian crust. The resultant rapid uplift of the Nanga Parbat-Haramosh Massif reactivated the Main Mantle Thrust melange zone with a reversed sense of motion. Discontinuities in the cooling age distribution along the Main Mantle Thrust in the southern Swat-Hazara region may be the result of the thermal effects of overthrusting.

Key words: Geochronology, Ar-Ar ages, Fission-track ages, Cooling ages, NPHM, Himalaya.

Z/70. Zeitler, P.K. 1988. Ion microprobe dating of zircon from the Malakand granite, NW Himalaya, Pakistan. A constraint on the timing of Tertiary metamorphism in the region. Abstract with Program, Geological Society of America 20, 323.

The Malakand granite and Ambela syenite yield carboniferous ages. The margins of the zircons in Malakand granites are about 45 Ma, suggesting development metamorphism.

Key words: Geochronology, U-Pb dating, Malakand granites, Ambela syenite, Himalaya.

Z/71. Zeitler, P.K., 1994. Active tectonic processes in the NW Himalaya. *EOS* 75, p.184.

Key words: Tectonics, Himalaya.

Z/72. Zeitler, P.K. & Chamberlain, C.P., 1990. U-Pb dating of very young leucogranites (NW Himalayas) using an ion microprobe. Abstracts, International Conference on Geochronology, Cosmochronology, and Isotope Geochemistry, 25 September 1990, Canberra.

Very young leucogranites, some only a few million years, occur in NW Himalaya in the Nanga Parbat area. The tectonic significance of these is discussed. For additional information, consult the following account.

Key words: Petrogenesis, tectonics, leucogranites, ion microprobe, NW Himalaya.

Z/73. Zeitler, P.K. & Chamberlain, C.P., 1991. Petrogenetic and tectonic significance of young leucogranites from the northwestern Himalaya, Pakistan. *Tectonics* 10(4), 729-741.

In the Himalaya of northwestern Pakistan, small discordant bodies of leucogranite intrude metamorphosed basement of the Indian crust. As the first step in assessing the tectonic significance of these granites, we have used the SHRIMP ion microprobe to obtain U-Pb dates on zircon. Zircons of igneous appearance are scarce in the leucogranites, and with one exception are associated with xenocrystic components, which occur as discrete grains and as cores rimmed by young zircon. Zircons of igneous appearance are high in U [5000 to 40,000 ppm], low in Th/U [0.01 to 0.05], and frequently colored a distinct blue. Xenocrystic components give a range of Proterozoic ages consistent with ages previously reported for Indian crust. In sharp contrast, zircons of igneous appearance yield clusters of concordant Tertiary ages. Two leucogranite dikes from southern localities yield rather old emplacement ages of about 35 Ma (Swat) and about 50 Ma (Naran). Together with previously determined $^{40}\text{Ar}/^{39}\text{Ar}$ and fission track cooling ages, these ages document immediate and rapid metamorphism and denudation following Eocene collision. Three leucogranite dikes from northern localities within the Nanga Parbat-Haramosh Massif are very young, having emplacement ages of about 2.3 Ma, 5 Ma, and 7 Ma. The formation and emplacement of these leucogranites during the rapid late Tertiary denudation of the Nanga Parbat region suggests to us that decompression melting may be a viable mechanism for leucogranite genesis.

Key words: Petrogenesis, tectonics, leucogranites, Himalaya.

Z/74. Zeitler, P.K. & Chamberlain, C.P., 1991. Quaternary anatexis at Nanga Parbat, Pakistan. Geological Society of America, Abstracts with Programs 23, A-135.

Key words: Quaternary, metamorphism, Nanga Parbat, NW Himalaya.

Z/75. Zeitler, P.K., Chamberlain, C.P. & Smith, H., 1990. Very young U-Pb ages from zircon and monazites of the Nanga Parbat Massif, Pakistan: Implications for metamorphic processes. Geological Society of America, Abstracts with Programs 22, p.97.

Key words: Metamorphism, NPHM, Himalaya.

Z/76. Zeitler, P.K., Chamberlain, C.P. & Smith, H., 1992. Quaternary anatexis and Neogene metamorphism at Nanga Parbat, Pakistan. Abstract Volume, 7th Himalaya-Karakoram Workshop, Department of Earth Sciences, Oxford University, England, 102.

Our recent geochronological work has shown that the Nanga Parbat massif (NW Himalaya, Pakistan) has experienced extensive metamorphic and igneous activity within the past 10 Ma. We summarize here our geochronological and petrological observations, which include U/Pb analyses on zircons and monazites from a variety of igneous and metamorphic units.

Tourmaline-bearing pegmatite dikes, which occur along the western and northern flank of the Nanga Parbat massif yield ages of between 2.2 and 8 Ma, based on monazite and zircon analyses. Monazite from samples of metamorphic basement yield ages ranging from 4 to 11 Ma. Finally, use of the SHRIMP ion microprobe in drilling mode reveals that zircons from two samples of schists are overgrown by thin, high-U rims which are less than 5 Ma in age, a result similar to that obtained from drilling analysis of zircons sampled along the Indus River section some 80 km to the north.

In the core of the Nanga Parbat massif, between Tato village and the northern face of Nanga Parbat, extensive migmatites are present in which pelitic units commonly show the assemblage alkali feldspar-cordierite-sillimanite-garnet. A variety of granites intrude these migmatites and associated biotite gneisses and calc-silicates, including a 1-km stock of fine-grained, equigranular two-mica granite, dikes similar in composition to this granite, coarse tourmaline-bearing pegmatites, and several-meter-thick granite sheets containing clots of biotite. Ion-probe analyses of zircon from all these units yield well-defined ages of ~1 Ma. Zircons extracted from a sample of migmatite yield scattered ages which average about 3.5 Ma, two monazite fractions from the same sample yield concordant ages of 3.3 Ma, and $^{40}\text{Ar}/^{39}\text{Ar}$ ages of hornblende are between 1 and 2 Ma.

Migmatization within the core of the Nanga Parbat massif occurred at about 650°C and 4.5 kbar. Together with the age of 3.3 Ma determined on migmatites, the petrological data confirm previous cooling-age estimates for the rapid Quaternary denudation of the Nanga Parbat massif. Our new data suggest a mean denudation rate of .5 mm/yr for the past 3 my, indicating that unroofing of Nanga Parbat has been both extensive and rapid.

Key words: Quaternary anatexis, Neogene metamorphism, Nanga Parbat, NW Himalaya.

Z/77. Zeitler, P.K., Chamberlain, C.P. & Smith, H.A., 1993. Synchronous anatexis metamorphism and rapid denudation at Nanga Parbat (Pakistan Himalaya). *Geology* 21, 347-350.

The Nanga Parbat-Haramosh massif of the western Himalaya is a north-trending half-window of Indian crust that provides spectacular exposures of Precambrian basement gneisses that have been overprinted by Himalayan metamorphism. We report here petrologic data and U/Pb dates on zircon and monazite which document that Nanga Parbat gneisses underwent a Pliocene-Pleistocene episode of high-grade metamorphism and anatexis during an interval in which the Nanga Parbat massif was undergoing rapid denudation at mean rates of ~ 5 mm/yr. We speculate that by initiating decompression melting, this denudation may be at least partly responsible for the anatexis and high-grade metamorphism.

Key words: Denudation, anatexis, metamorphism, Nanga Parbat, NW Himalaya.

Z/78. Zeitler, P.K., Johnson, N.M., Naeser, C.W. & Tahirkheli, R.A.K., 1982. Fission-track evidence for the Quaternary uplift of the Nanga Parbat region, Pakistan. *Nature* 298, 255-257.

The north-striking Nanga Parbat-Haramosh Massif protrudes into the northwestern Himalaya along the axis of a great syntaxis^{1,2} (Fig. 1), where the Hindu Kush, Karakorum, and Himalayan ranges converge. As the Indus Suture Zone³ enters this region from the east it bifurcates into two branches, encircling what may be a docked island-arc terrane⁴. The southern branch (the Main Mantle Thrust) crops out on both flanks of the Nanga Parbat massif, forming a tight structural loop⁵. This massif and the adjacent terrane contain some of the highest peaks in the Himalaya; Nanga Parbat and the Indus River (located just 20km away) define the world's greatest continental relief (6,930 m). We report here the discovery of unexpectedly young sphene, zircon and apatite fission-track dates from the Nanga Parbat-Haramosh Massif. These dates (as low as 1.3 Myr for zircon and 0.4 Myr for apatite) imply that during the Pleistocene the Nanga Parbat region was uplifted and eroded at nearly 1 cm yr⁻¹.

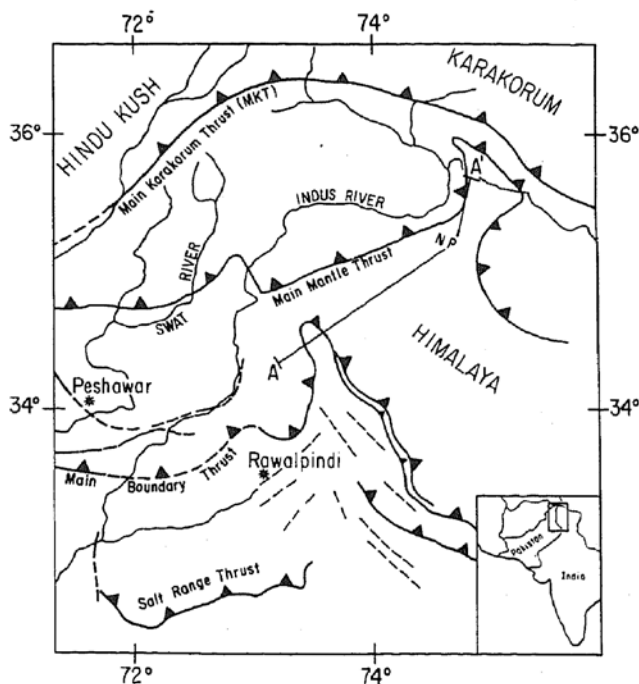


Fig. 1 Structural trends of northern Pakistan. Heavy barbed lines show suture zones and major thrust faults. Dashed lines show trends of folds in molasse sediments. NP, Nanga Parbat (8,126 m), located on Nanga Parbat-Haramosh Massif. A-A' is line of profile

Key words: Fission-track ages, Quaternary, Nanga Parbat, NW Himalaya.

Z/79. Zeitler, P.K. & Koons, P.O., 1998. Nanga Parbat as tectonic aneurysm: a metamorphic signature of indenter-corner dynamics. *Eos Transactions, Geophysical Union* 79 Supplements F910.

Key words: Tectonics, metamorphism, Nanga Parbat, Himalaya.

Z/80. Zeitler, P.K., Koons, P.O., Bishop, M.P., Chamberlain, C.P., Copland, L., Craw, D., Edwards, M.A., Hamidullah, S., Jan, M.Q., Khan, M.A., Khattak, M.U.K., Kidd, W.S.F., Le Fort, P., Mackie, R.L., Meltzer, A.S., Park, S.K., Pecher, A., Phillips, W.M., Poage, M.A., Sarker, G., Schneider, D.A., Seeber, L. & Shroder, J.F., 1999. Geodynamics of the Nanga Parbat Massif, Pakistan Himalaya. *Terra Nostra* 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 189-190.

Within the great syntaxial bends of the India-Asia collision, the Himalaya terminate abruptly in a pair of active metamorphic massifs. Nanga Parbat in the west and Namche Barwa in the east are antiformal domes, which expose Quaternary metamorphic rocks and granites, and are loci of ferocious denudation where they are transected by major Himalayan rivers (Indus and Tsangpo). Comprehensive geophysical and geological data we have collected at Nanga Parbat support a model in which these metamorphic massifs owe their origin to erosionally induced deformation of the crust near deep gorges cut by the Indus and Tsangpo as these rivers turn sharply towards the foreland and exit their syntaxes. Primarily, the intense metamorphic and structural reworking of crustal lithosphere seen at the terminations of the Himalayan arc owes its origin to mesoscale feedbacks between erosion and tectonics.

Widely taken as the type example of a collisional mountain belt, the Himalaya have seen increasing use as a natural laboratory in which to examine a variety of collisional processes. Over the past four years, an approximately 5,000-km² area of the central Nanga Parbat massif of the northwestern Himalaya has been the focus of our Nanga Parbat Continental Dynamics Project, a multidisciplinary study aimed at understanding how the continental lithosphere comes to be pervasively reworked during continental collision. Nanga Parbat exposes extremely young metamorphic and igneous rocks and is an ideal place to examine the specific processes involved in crustal reworking, particularly erosion, which has come to be recognized of late as a critical control on the mechanical and petrological evolution of mountain belts. The Nanga Parbat project involved the coordinated effort of numerous investigators, working in a broad range of disciplines, including the areas of geochronology, structural geology, geomorphology, seismology, remote sensing geomorphology, dynamical modeling, geochemistry, magnetotellurics and neotectonics. Together with petrologic and geomorphic studies carried out by other groups, we now have an excellent understanding of the evolution and state of the crustal lithosphere at Nanga Parbat.

The Nanga Parbat-Haramosh Massif exposes polymetamorphic Indian-plate gneisses which have been undergoing an episode of pronounced crustal reworking; this has involved pervasive deformation, young metamorphism and melting, widespread fluid flow, rapid and pronounced exhumation, and sculpting of the crust into spectacular, steep topography. Within the core of the Nanga Parbat massif, there is a bull's-eye coincidence between the massifs most extreme topography and high-temperature granulite-grade migmatites, a young and active anti formal pop-up structure, young 1-2 Ma granitoids, abundant seismicity with sharp bottom and lateral cut-offs, pronounced hydrothermal activity, steep new-surface thermal gradients, and rapid denudation documented across a wide range of timescales. These coincident features beg a simple, shared explanation.

Erosionally concentrated strain attributable to large magnitude incision by the Indus River focuses Indian Plate material from the south into the developing Nanga Parbat massif. Advection elevates isotherms beneath the massif, creating a relatively high-temperature/low-pressure region where sillimanite and dry melt are stable that coincides with a zone of anomalously low electrical conductivity. At approximately 12 km depth these relatively dry rocks interact with highly-exchanged meteoric or metamorphic water and generate vapor-present, cordierite-bearing granitic veins. The hot rock packet then passes toward the northwest, advecting isotherms, elevating the position of the brittle-ductile transition, and generating a vigorous hydrothermal system. The base of the predicted rheological transition coincides with a cutoff in observed microseismicity.

Work by J. Burg and colleagues and mapping by Chinese geologists suggests that the Namche Barwa massif in the eastern Himalayan syntaxis shares a very similar geological and tectonic setting with Nanga Parbat. We suggest that such hyperactive metamorphic massifs may be signature features of syntaxial regions, where large orogen-scale rivers such as the Indus and Tsangpo are diverted towards the foreland, rapidly cutting deep gorges as they make their steep exit from the hinterland.

Local, sub-orogen scale erosional exhumation at Nanga Parbat (and, we suspect, at Namche Barwa), far from being overrated, is in fact of first-order importance in controlling the metamorphic, topographic, and structural

evolution of the cores of the Himalayan syntaxes. Such pervasive structural and metamorphic overprinting of old basement rocks is a fundamental geodynamic process in its own right. Ultimately, the dynamics of syntaxial metamorphic massifs may be reconciled with broader orogen-scale collision processes through the feedbacks between deformation, topographic evolution, and erosion that lead to the channeling of major river systems through the syntaxes. Our results contribute to the growing appreciation of the importance those surficial processes and crustal rheological variations have on controlling the shape, dynamics, and evolution of mountain belts, at many scales.

Key words: Geodynamic, geochronology, tectonics, NPHM, NW Himalaya.

Z/81. Zeitler, P.K., Koons, P.O., Bishop, M. L., Chamberlain, C.P., Craw, D., Edwards, M.A., Hamidullah, S., Jan, M.Q., Khan, M.A., Khattak, M.U.K., Kidd, W.S.F., Mackie, R.L., Meltzer, A.S., Park, S.K., Pecher, A., Poage, M.A., Sarker, G., Schneider, D.A., Seeber, L., and Shroder, J., 2001. Crustal Reworking at Nanga Parbat, Pakistan: Evidence for erosional focusing of crustal strain. *Tectonics*, 20, 712-728.

Within the syntaxial bends of the India-Asia collision the Himalaya terminate abruptly in a pair of metamorphic massifs. Nanga Parbat in the west and Namche Banwa in the east are actively deforming antiformal domes which expose Quaternary metamorphic rocks and granites. The massifs are transected by major Himalayan rivers (Indus and Tsangpo) and are loci of deep and rapid exhumation. On the basis of velocity and attenuation tomography and micro-seismic, magnetotelluric, geochronological, petrological, structural, and geomorphic data we have collected at Nanga Parbat we propose a model in which this intense metamorphic and structural reworking of crustal lithosphere is a consequence of strain focusing caused by significant erosion within deep gorges cut by the Indus and Tsangpo as these rivers turn sharply toward the foreland and exit their host syntaxes. The localization of this phenomenon at the terminations of the Himalayan arc owes its origin to both regional and local feedbacks between erosion and tectonics.

Key words: Orogeny, tectonics, Nanga Parbat.

Z/82. Zeitler, P.K. & the Nanga Parbat Working Group, 1998. Crustal reworking at Nanga Parbat: The Nanga Parbat continental dynamics project. *Geological Bulletin, University of Peshawar* 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 227-228.

A considerable amount is now known about the Nanga Parbat massif, which has been the focus of intense study over the past several years by several teams. Our ongoing Nanga Parbat Continental Dynamics Project has been using Nanga Parbat as a natural laboratory to examine processes of pervasive synorogenic crustal reworking, on the basis that the Precambrian rocks of the massif have been deeply overprinted by a recent and intense metamorphic, magmatic, and deformational episode that remains active today. We are currently synthesizing results from investigations in the areas of magnetotellurics, seismology, structural geology, tectonics and neotectonics, geochronology, geomorphology, petrology, geochemistry, and dynamical modelling in order to test hypotheses about mesoscale linking between petrologic, tectonic, and surficial processes.

The Precambrian rocks of the Nanga Parbat massif occur within a northward projection of Indian-plate basement flanked to the west and east by rocks of the Mesozoic Kohistan-Ladakh arc terrane and to the north by rocks of the Asian plate. Originally overthrust from the north (in the early Tertiary) by mafic and intermediate volcanic and plutonic rocks of the Kohistan terrane, Nanga Parbat basement has recently been exhumed by NW-directed thrusting and development of a large north-south oriented antiform. Ferocious exhumation has occurred by mass wasting and glacial erosion, with the nearby Indus River providing efficient removal of debris from the region: fluvial incision rates along the Indus are among the highest in the world, reaching 12 mm/yr (Burbank et al. 1996). The summit massif in the central portion of the antiform is ringed by concentric isograds, which culminate in cordierite-K-feldspar grade, and in this region a moderate number of undeformed granitoid dikes and pegmatites as well as a few small bodies of undeformed granite occur. To the south of Nanga Parbat, towards Babusar Pass and the relatively low-grade rocks which occur there, there is a major telescoping of isograds across what is most likely a thrust system of some sort.

Much of the exposed geology at Nanga Parbat is young or the result of ongoing rapid processes. The 7000 meters of relief defined by Nanga Parbat and the Indus River reflect unroofing rates as high as 5 mm per year, as documented at several time scales by geomorphic, petrologic, and fluid-inclusion studies. These rapid unroofing rates are also reflected in the very young cooling ages seen within the Nanga Parbat massif, with mica Ar-Ar ages of as young as 1 Ma and metamorphic monazite ages on migmatites of known P-T conditions of as young as 3 Ma; these data suggest cooling rates for exposed surface rocks of well over 200 C/m.y., and unroofing in

the past 3 Ma of some 15-20 km. Granite ages from 1 to 8 Ma indicate that emplacement in at least some places took place during exhumation, leading to the suggestion that some of the Nanga Parbat granites owe their origin to decompression melting. There is abundant evidence for fluid flow within the Nanga Parbat massif involving circulation of metamorphic and magmatic waters as well as penetration of meteoric water to depths having temperatures of some 600°C. This fluid flow and the high thermal gradients under the massif are attested to by the presence of numerous hot springs, and fluid-inclusion studies suggesting gradients over the top 3 km being some 100 C/km. Active faulting is common within the Nanga Parbat massif, and includes the substantial NW-directed Raikot/Liachar thrust, which places basement over gravels, as well as faults further outboard to the west of Nanga Parbat which have displaced rocks of the Kohistan terrane. The massif is quite active microseismically, but only to depths of some 7 km, presumably reflecting the high thermal gradients and a shallow brittle-to-ductile transition. To date we have found no evidence for significant extensional exhumation and it appears that the extreme exhumation at Nanga Parbat stems from erosion of rocks exposed by reverse faulting.

The relationship between the spatially rather limited metamorphic anomaly at Nanga Parbat and its broad geodynamic setting is an important question to which we are ultimately directing our efforts. Recent reports by J.-P. Burg and coworkers suggest that the geology and active tectonics of Namche Barwa, located at the far eastern end of the Himalayan chain, is remarkably similar to that seen at Nanga Parbat. The location of the Himalayas' two hyperactive metamorphic massifs precisely within the orogen's two great syntaxes is surely no coincidence, and raises interesting questions about the nature and evolution of indentor corners.

Key words: Geochronology, Orogeny, Tectonics, NPHM, Himalaya.

Z/83. Zeitler, P.K., Sutter, J., Williams, I.S., Zartman, R.E. & Tahirkheli, R.A.K., 1986. The Nanga Parbat-Haramosh Massif, Pakistan: Geochronology and cooling history. Geological Society of America, Abstracts with Programs 18, p.800.

Consult the following for further information

Key words: Geochronology, tectonics, NPHM, Himalaya.

Z/84. Zeitler, P., Sutter, J., Williams, I.S., Zartman, R.E. & Tahirkheli, R.A.K., 1989. Geochronology and temperature history of NPHM, Pakistan. In: Malinconico, Lillie, R.J. (eds.), Tectonics of the Western Himalayas. Geological Society of America, Special Paper 232, 1-22.

The gneisses of the Nanga Parbat Haramosh Massif (NPHM), Pakistan, experienced peak metamorphic temperature in the interval from 25 to 30 Ma, as revealed by $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages of hornblende and the ages of the youngest intrusions of the Kohistan batholith located immediately adjacent to the NPHM. $^{40}\text{Ar}/^{39}\text{Ar}$ and fission-track mineral ages indicate that the postmetamorphic cooling history of the NPHM has been controlled over the past 5 – 10 M.Y. by active tectonism associated with the Raikhot Fault, although passive uplift and erosion in response to over thrusting of the NPHM by the Kohistan Arc has been underway as well. Net cooling rate for the NPHM gneisses exposed today along the Indus River at low elevations have accelerated from 200C / m.y. at ~20Ma to 3000C /m.y. at 0 to 0.4 Ma. following emplacement of aplite dikes at about 30 to 35 Ma, portions of the Kohistan batholith adjacent to the NPHM experienced cooling rates similar to the NPHM of about 20 C/m.y. over the period of 25 to 10 Ma, but the net cooling rates for the batholith of ~30C/m.y. over the past 10 m.y. have been much lower than those experienced within the NPHM. Ion microprobe and conventional U/Pb analyses of Zircon show that the protoliths for the Iskere gneiss and the structurally lower Shensgus gneiss of the NPHM are, respectively, ~1850 Ma and 400 to 500 m.y. in age.

Key words: Geochronology, tectonics, NPHM, Himalaya.

Z/85. Zeitler, P.K., Tahirkheli, R.A.K., Naeser, C.W. & Johnson, N.M., 1982. Unroofing history of a suture zone in the Himalaya of Pakistan by means of Fission-Track annealing age. Earth and Planetary Science Letter 57, 227-240.

The uplift history of the Swat Valley and Hazara region of northwestern Pakistan has been established using 22 fission-track dates on apatite, zircon and sphene. A major fault, the Main Mantle Thrust (MMT) strikes east-west across the Swat Valley, separates regions of markedly differing fission-track age regimes, and may be a suture zone separating an extinct island arc terrane on the north from the Indian plate to the south. Fission-track ages ranging from about 55 to 58 m.y. for sphene, 18 to 53 m.y. for zircon, and 9 to 17 m.y. for apatite were

obtained from the region north of the MMT. To the south the fission-track age ranges are 20 to 25 m.y. for sphene, 17 to 26 m.y. for zircon, and 16 to 23 m.y. for apatite. Disparate zircon and sphene ages on each side of the MMT imply different cooling histories for each side of the fault prior to 15 m.y. Similar apatite ages on both sides of the fault imply similar cooling histories during the past 15 m.y. This may indicate that faulting ceased by 15 m.y. Mean uplift rates have been derived from the fission-track data using mainly the mineral-pair method. Uplift rates in the region north of the MMT increased from 0.07 to 0.20 mm/yr during the period 55 to 15 m.y. south of the fault, uplift rates averaged in excess of 0.70 mm/yr for the period 25 to 15 m.y. During the past 15 m.y. uplift across the MMT in the Swat Valley shows no discontinuities, ranging from 0.16 mm/yr in the south to 0.39 mm/yr in the north. A plausible interpretation for the fission-track uplift data has the MMT verging to the south with overthrusting taking place at a depth between 3.5 and 6.0 km, juxtaposing two terranes that were originally separated by a substantial, but unknown distance. In this model, regional uplift followed cessation of faulting just prior to 15 m.y.

Key words: Fission track dating, Himalaya.

Z/86. Zeitler, P.K., Tahirkheli, R.A.K., Naeser, C., Johnson, N. & Lyons, J., 1980. Preliminary fission track ages from the Swat valley, Northern Pakistan. *Geological Bulletin, University of Peshawar* 13, 63-65.

A number of the lithologies found in the Swat Valley have been dated by the fission track method to assess and to describe the area's uplift history. Pb/U determinations made on three zircon splits obtained from the pyroxene granulite located to the north of the MMT fall nearly on Concordia at about 84 m.y. Zircon obtained from a metasediment located south of the fault give a fission track age of about 22 m.y., the same as zircons obtained from associated granites and gneisses. Thus it can be shown that the fission track ages of rocks located north of the MMT are not intrusive ages, and similarly that ages of rocks located south of the MMT must be yielding uplift ages.

Key words: Geochronology, Fission track dating, U-Pb dating, Swat.

Z/87. Zeitler, P.K., et al., 1981. Rapid uplift/erosion rates in the Nanga Parbat-Haramosh area as determined from fission-track data. *Geological Society of America, Abstracts with Programs* 13, p.587.

Consult Zeitler et al., 2001 for further information.

Key words: Uplift, erosion, tectonics, NPHM, Himalaya.

Z/88. Zeitler, P.K., et al., 1982. Tectonic terrains in northern Pakistan have different cooling histories. *EOS* 63, p.1125.

Consult Zeitler et al., 1980 for further information.

Key words: Tectonics, Northern Pakistan.

Z/89. Zeitler, P.K., et al., 1994. Crustal reworking during orogeny: An active-system Himalayan perspective. In: *Program, ILIAD Workshop, Taos, New Mexico, 5-9 November, 1994*.

Key words: Orogeny, cooling histories, tectonics, Himalaya.

Z/90. Zhang, Jinhua, & Bai Zhongyan, 1980. The surface ablation and its variation on the Batura Glacier. In: Shi, Y. (ed.), *Professional Papers on the Batura Glacier, in Karakoram Mountains*. Science Press, Beijing, 83-98.

Key words: Glaciers, ablation, Batura.

Z/91. Zhang, Xiangsong, 1984. Recent variations of some glaciers in the Karakoram Mountains. In: Miller, K.J. (ed.), *The International Karakoram Project, 1, 39-50*. Cambridge University Press.

In 1974-1975 and in 1978, the author was a member of the Batura Glacier Investigation Group of the Karakoram Highway Engineering Headquarters of the People's Republic of China. Studies of contemporary glaciation along the Karakoram Highway have been actively carried out and some valuable data on glacial variation gathered. During our investigations we were warmly supported by our Pakistan friends. This article is based on the geomorphological investigation together with documentary records with especial comparison to the landsat images in the 1970's and topographic maps in various years, and aims at explaining recent variations.

Key words: Landsat imaging, geomorphology, glaciers, Batura, Karakoram.

Z/92. Zhong, Xiangsong, et al., 1980. General features of the Batura Glacier. In: Shi Y. (ed.), Professional Papers on the Batura Glacier, in Karakoram Mountains. Science Press, Beijing, 8-27.

Key words: Glaciers, Batura, Karakoram.

Z/93. Zhang, Y, Xie Yingiran, Xu, Ronghua, Widal, P., & Arnaud, P. 1996. Geochemistry of granitoid rocks. In: Pan, Y. (ed.), Geologic evolution of the Karakorum and Kunlun mountains. 94-136.

Granitic rocks occurring in Kunlun and northern Karakorum belts, and Taxkorgan alkaline complex are described. The Khunjerab granitic belt in northern Karakorum extends along the border of Pakistan and China. It is composed of tonalite, monzolithic granite, K-feldspar granite and two-mica alkali feldspar granite, with isotopic ages around 100 ma. they contain 59-75 % SiO₂ and classify as calc-alkaline. Trace elements and REE data are given for the rocks; they contain high REE and LREE/ HREE = 10.3. The analyses plot in the field of volcanic arc /post collision granites and in active plate margin fields.

Key words: Granite, Kunlun, Khunjerab, Northern Karakorum.

Z/94. Zhongguo Ke Xue Yuan., 1980. Professional paper on the Batura Glacier in the Karakoram Mountains. Science Printing House, Beijing.

Key words: Glaciers, Batura, Karakoram.

Z/95. Zimmermann, J.L., Debon, F. & Bertrand, J.M., 1986. The upper Miocene Baltoro granite (Karakorum axial batholith, northern Pakistan): K-Ar dates and cooling history. Terra Cognita 6, p.193.

The Baltoro granite, an intrusion more than 100 km long and ca. 4 to 20 km wide, probably represents the youngest acidic plutonic unit of the composite Karakorum axial batholith. Proposed for a long time from a comparative study of pleochroic haloes in biotite, its Upper Miocene age of emplacement has only quite recently been revealed by isotope dating methods, viz. three internal Rb-Sr isochrons (8.8 ± 0.3 Ma) and ten K-Ar dates (8.5 ± 0.8 Ma). The K-Ar dates have yielded the following results : (1) for three whole rocks : 8.85 / 9.35 / 9.25 Ma, average 9.2 Ma; (2) for three biotites and one muscovite: 7.45 / 8.0 / 8.85 / 8.85, average 8.3 Ma; (3) for three K-feldspars : 7.2 / 7.85 / 8.95, average 8.0 Ma. It is suggested that the three average ages (9.2, 8.3, 8.0 Ma) reflect the Cooling - crystallization timing of the Baltoro magma, from its emplacement (c a. 9.2 Ma) down to the K-feldspar isotope closure. Much detailed work is needed to be done to transform this rough speculative estimate into tested and accurate hypotheses. The Baltoro granite offers a rare possibility: a concrete and full-size approach of the cooling history of a plutonic body.

Key words: Granites, Miocene, Karakoram.

Z/96. Zuber, R., 1914. Beitrage zur Geologie des Punjab. Jahrbuch der Koniglich geologischen Reichsanstalt, 64, 327-356.

Key words: Geology, Punjab, India.

Add/1 Alizai, A.H.K., 2000. Geochemistry of Water and Soil from Dera Ismail Khan NWFP, Pakistan. M.Phil. Thesis, University of Peshawar.

The aim and motive to start 'work on the waters and soils of D.I. Khan division was to establish a brief chemical and environmental report on the quality of water, because various types of diseases have been reported from the area. For this purpose water of the area was divided into four categories i.e. deep water (tube-wells); shallow water (dug-well, settling ponds/nalas and hand-pumps), surface water (streams and rivers). A total of thirty-four water samples were selected for study of twenty-two parameters. In order to see any contribution made by soils and rocks to the water. Twenty-two soil samples adjacent to water samples and five rock samples were also analyzed for major and trace elements.

The results obtained for the water samples from different places of D.I. Khan division are compared with that US-EPA (1989) and WHO (1981) standards for safe drinking water. On the basis of these standards the water quality of many areas are found not suitable for drinking. For example water sample from Gomul Rivers suggest that it is not safe for drinking water, however, major portion of population of the D.I. Khan division use it for drinking. The chemical radicals exceeding the permissible limit of US-EPA (1989) and WHO (1981) are: Bicarbonate (225 mg/l), sulphate (400 mg/l). Iron (43.3 mg/l), Magnesium (47 mg/l). Manganese (0.21 mg/l). Na (102 mg/l) and copper (10 mg/l). In Porra the following constituents are out of permissible limit i.e. Sulphate (1600 mg/l); Bicarbonate (250 mg/l); Chloride (244 mg/l); Na (175 mg/l), Magnesium (73.7 mg/l). Apart from these two areas, the water quality of other areas, which is not safe for drinking purpose are Mullazai, Tank, Umer Ada. Potah. Chudhwan. Ramak. Kulachi and Gomul university. Sulphate is high in the middle and lower part of the D.I. Khan division. High sulphate concentration in water causes diarrhea and dehydration (Zunae, 1990). Nitrate is found high at shallow water (Dug well, hand pumps, settling ponds Nala). It is reported alarmingly high at Mullazai (17mg/l) and at Chudhwan spring (90 mg/l), as compared to the maximum limit (10 mg/L) of WHO (1984) for safe drinking water. High nitrate cause infection to gastrointestinal tract and large concentration of nitrate in water may result in the potential formation of carcinogenic nitro amines (Zunae, 1990). Chloride concentration is maximum i.e. 618 mg/l at Ramak area of D.I. Khan division, which considerably exceeds the permissible limit (200 mg/L) of WHO (1984). It crosses the permissible limit at eight other places of D.I. Khan division. Except two samples, iron is out of limit in all the water samples. Magnesium is also high at six places.

Manganese is crossing the limit at sixteen places. Potassium is high at five places. In trace elements copper is considerably out of range in the water of Gomul River. Pb is high (0.3 mg/L) in the water sample taken from Gomul University tube well where by the safe limit of lead in the drinking water is 0.05 mg/l. Fluoride is also high at six places. The generalized trend for many constituents increase from north to south. The results show the concentration of many elements are high towards south.

Collection of soil and rock samples was made from the same areas where water samples were collected. The objective of this detail geo-chemical results of the rock and soil samples were to see the influence of these rock and soil samples on the water samples of the same area. The results are discussed in the concerned chapter. For the treatment or removal of these constituents can be done by the method established by US-EPA. (1988). Filtration, ion exchange and lime softening can remove copper and iron. Nitrate can be removed by biological denitrification. sulphate by ion exchange and fluoride by reverse osmosis. All these methods are effective but practically non-economical.

Key words: Geochemistry, Water, soil, D.I. Khan, NWFP.

Add/2 Anczkiewicz, R., Burg, J.P., Villa, I.M., & Meier, M. 2000. Late Cretaceous blueschist metamorphism in the Indus Suture Zone, Shangla region, Pakistan Himalaya. *Tectonophysics* 324, 111–134

Rb–Sr and ³⁹Ar–⁴⁰Ar phengitic muscovite dating of the transitional blueschist–greenschist facies rocks from the Shangla region of Pakistan Himalaya resulted in a concordant ca. 80 Ma age interpreted as a time of metamorphic peak. ³⁹Ar–⁴⁰Ar age spectra of sodic amphiboles were unsuitable for precise age determination. Mass-balance calculations show that the K concentration in glaucophane/crossite is ca. 25 ppm, and the K–Ar budget is dominated by inclusions of phengitic muscovite.

E–W-oriented (parallel to Kohistan arc) stretching lineation defined by preferred orientation of amphiboles was accompanied by synkinematic growth of riebeckite rims on the edges of microboudins. Evolution of the pressure conditions based on the Al₂O₃ content in sodic amphibole shows that this deformational stage was accompanied by a decrease in pressure from ca. 700 to ca. 400 MPa. This, together with our dating results, strongly suggests μ 10 km late Cretaceous exhumation of the Shangla blueschists. The exhumation may have been associated with the increase

of arc parallel displacement rate due to changes of arc obliquity. This led to thinning caused by arc parallel extension and to exhumation of the Shangla blueschists. A lack of strong Eocene metamorphic overprint implies that after the peak metamorphism, blueschists were accreted to the Kohistan arc, which helped to prevent burial and metamorphism during continental collision. The final emplacement of the Shangla blueschists most likely occurred during the India-Kohistan arc collision and was accompanied by the weak, locally developed greenschist facies overprint.

Keywords: $^{39}\text{Ar}/^{40}\text{Ar}$ dating, Rb–Sr dating, blueschists, collision tectonics, exhumation, Himalaya, Indus Suture.

Add/3 Anczkiewicz, R., Oberli, F., Burg, J.P., Villa, I.M., Gunther, D. & Meier, M. 2001. Timing of normal faulting along the Indus Suture in Pakistan Himalaya and a case of major $^{231}\text{Pa}/^{235}\text{U}$ initial disequilibrium in zircon. *Earth and Planetary Science Letters*, 191, 101 – 114. We report age data by TIMS $\text{U}^\wedge\text{Pb}$, LA-ICP-MS and $^{39}\text{Ar}/^{40}\text{Ar}$ techniques for main magmatic events in the Lower Swat region of Pakistan, in order to constrain the tectonic evolution of the northwestern Himalaya. The pre-Himalayan history of the Indian continent is documented by single-zircon $\text{U}^\wedge\text{Pb}$ results from the peraluminous Choga granite gneiss, which yielded a 468 ± 5 Ma lower concordia intercept interpreted to approximate the time of magmatic emplacement. The presence of a well-defined 870 ± 7 Ma inherited component (upper intercept) suggests a plutonic or volcanic protolith residing at unexposed levels of the Indian crust. Zircon data for the Swat granite gneiss from the northern part of the Loe Sar dome give an emplacement age of $267 \pm 6/33$ Ma, which is at variance with earlier correlations favoring an early Paleozoic origin. Subsequent to metamorphic overprint by the Himalayan orogeny, the Swat granite was intruded by late kinematic alkali-granite dykes. Single zircons from one of these dykes show reproducible $^{206}\text{Pb}/^{238}\text{U}$ data giving a precise mean age of 29.26 ± 0.12 Ma, whereas the $^{207}\text{Pb}/^{235}\text{U}$ ages scatter between 34 and 81 Ma, pointing to huge and variable enrichment in ^{207}Pb . The unsupported ^{207}Pb can be explained by incorporation of ^{231}Pa , an intermediate long-lived daughter nuclide in the ^{235}U decay chain, in excess of the secular equilibrium ratio. LA-ICP-MS measurements confirm the presence of unsupported ^{207}Pb , but do not show any correlation between the latter and other selected trace element concentrations in these zircons. A concordant $\text{Ar}^\wedge\text{Ar}$ muscovite age of 28.4 ± 1.1 Ma obtained for the same dyke postdates regional mica 'cooling' ages and indicates a lack of younger regional events capable of resetting the $\text{K}^\wedge\text{Ar}$ system in muscovite. Because the dyke is pre- to synkinematic relative to normal faulting and related north-vergent folds, its emplacement age provides a maximum age for this event or reflects already ongoing local extension. A lower limit of 15 Ma has previously been established by apatite fission track analysis. The 29 ± 15 Ma age bracket for normal faulting is coeval with extension along the South Tibetan Detachment System (STDS) on the north side of the High Himalaya. This suggests that the Indus Suture in Pakistan has acted as a western continuation of the STDS and that related faulting was roughly contemporaneous over most of the Himalaya. **Keywords:** Himalayas; Indus-Yarlung Zangbo suture zone; extension; geochronology; uranium disequilibrium; $\text{U}^\wedge\text{Pb}$; $\text{Ar}-^{39}\text{Ar}/^{40}\text{Ar}$; Pakistan.

Key words: Structure, dating, Himalaya, Indus Suture.

Add/4 Butler, R.W.H., Casey, M., Loyd, G.E., Bond, C.E., McDade, P., Shipton, Z. & Jones, R., 2002. Vertical stretching and crustal thickening at Nanga Parbat, Pakistan Himalaya. a model for distributed continental deformation during mountain building. *Tectonics*, 21(4), 9-17. The localization of strain in the continental crust during compressional tectonics is examined using the active structures at the Nanga Parbat massif, an exhumed tract of Indian continental crust in the Pakistan Himalaya. This large-scale (~40 km wavelength) structure is considered to involve the whole crust. Thrusting at the modern surface places gneisses of the Indian continental crust onto Holocene deposits. At the Raikhot transect, the thrust zone carries a relatively narrow (2 km wide) shear zone within which minor structures are asymmetric and the deformation apparently noncoaxial. However, modeling of foliation and augen preferred orientation/ellipticity suggests that the bulk deformation is a combination of relatively small simple shear strains ($\gamma = 1$) with larger stretching strains. Heterogeneous stretching within the shear zone was accommodated by localized shearing on metabasic layers so that strain is partitioned. Outside this shear zone on the transect there is penetrative deformation throughout the Nanga Parbat massif. This broadly distributed deformation shows no asymmetry or evidence of rotation. Rather this deformation is better described as near pure-shear subvertical stretching. Augen ellipticities suggest subvertical stretches of greater than 200%. Consideration of plausible changes in crustal thickness during the amplification of the Nanga Parbat structure suggests the magnitude of vertical stretch decays with depth. Presumably these strains in the deep crust are more distributed but weaker than in the exposed middle crustal sections, assuming conservation of horizontal shortening displacement with depth. These studies suggest that penetrative vertical stretching through dominantly pure shear deformation is an effective mechanism for thickening the continental crust and that models which assume that simple shear zones penetrate the whole crust need not be of ubiquitous applicability.

Key words: Crustal thickening, deformation, Nanga Parbat.

Add/5 Clift, P.D., Hannigan, R., Blusztajn, J. & Draut, A.E. 2002. Geochemical evolution of the Dras–Kohistan Arc during collision with Eurasia: Evidence from the Ladakh Himalaya, India. *The Island Arc*, 11, 255–273

The Dras Volcanic Formation of the Ladakh Himalaya, India, represents the eastern, upper crustal equivalent of the lower crustal gabbros and mantle peridotites of the Kohistan Arc exposed in Pakistan. Together these form a Cretaceous intraoceanic arc now located within the Indus Suture zone between India and Eurasia. During the Late Cretaceous, the Dras–Kohistan Arc, which was located above a north-dipping subduction zone, collided with the south-facing active margin of Eurasia, resulting in a switch from oceanic to continental arc volcanism. In the present study we analyzed samples from the pre-collisional Dras 1 Volcanic Formation and the postcollisional Kardung Volcanic Formation for a suite of trace elements and Nd isotopes. The Kardung Volcanic Formation shows more pronounced light rare earth element enrichment, higher Th/La and lower end values compared with the Dras Volcanic Formation. These differences are consistent with an increase in the reworking of the continental crust by sediment subduction through the arc after collision. As little as 20% of the Nd in the Dras 1 Volcanic Formation might be provided by sources such as the Karakoram, while approximately 45% of the Nd in the Kardung Volcanic Formation is from this source. However, even before collision, the Dras–Kohistan Arc shows geochemical evidence for more continental sediment contamination than is seen in modern western Pacific arcs, implying its relative proximity to the Eurasian landmass. Comparison of the lava chemistry in the Dras–Kohistan Arc with that in the forearc turbidites suggests that these sediments are partially postcollisional, Jurutze Formation and not all pre-collisional Nindam Formation. Thus, the Dras–Eurasia collision can be dated as Turonian–Santonian (83.5–93.5 Ma), older than it was previously considered to be, but consistent with radiometric ages from Kohistan.

Key words: collision, Himalaya, isotopes, Kohistan.

Add/6 Fraser, J.E., Searle, M.P., Parrish, R.R. & Noble, S.R., 2001. Chronology of deformation, metamorphism and magmatism in southern Karakoram Mountains. *Geological Society of America Bulletin*, 113, 1443–1455.

U–Pb dating of metamorphic and igneous rocks from the Hunza Valley and Baltoro regions of the Karakoram Mountains in northern Pakistan addresses the thermal and magmatic evolution of the thickened Asian plate crust before, during, and after the collision of the Kohistan arc and the Indian plate. Crustal thickening and high-temperature, sillimanite-grade metamorphism in the southern Karakoram Mountains followed the collision and accretion of the Kohistan arc during the Late Cretaceous. U–Pb ages of metamorphic monazites from sillimanite gneisses in the Hunza Valley are 63.3 ± 0.4 Ma, ca. 50–52 Ma, and 44.0 ± 2.0 Ma, and monazites from a kyanite-grade schist from the Baltoro region are 28.0 ± 0.5 Ma. Metamorphic monazites from a highly graphitic garnet + staurolite schist from the Hunza Valley yield a crystallization age of 16.0 ± 1.0 Ma. Sillimanite gneisses from the Dassu dome have magmatic zircons of 1855 ± 11 Ma, reflecting a Proterozoic continental crustal source, and metamorphic monazites of 5.4 ± 0.2 Ma. Magmatism was also sporadic; early granodiorite, monzogranite, and leucogranite dikes yield zircon, monazite, and uraninite ages of 50–52 Ma and 35.0 ± 1.0 Ma. Widespread lower crustal melting during the latest Oligocene–early Miocene culminated with emplacement of the Baltoro Plutonic Unit in the Karakoram batholith that cuts deformation fabrics in the high-grade gneisses to the south. The youngest magmatic phase dated is the 9.3 ± 0.2 Ma Sumayar leucogranite pluton. On the basis of detailed structural field studies combined with U–Pb geochronology, sillimanite-grade metamorphism was either a protracted event lasting as long as 20 m.y. (64–44 Ma) or peaked at different times within the lower crust following collision of first, the Kohistan arc, and later, the Indian plate. We also present evidence for southward propagation of peak metamorphism and postmetamorphic thrusting and folding of isograds within the past 5 m.y. Detailed geochronology shows that deformation, metamorphism, and magmatism in the middle and lower crust of the south Asian margin has been occurring within the Karakoram metamorphic complex for more than 60 m.y. Similar processes may also have affected the unplumbed depths of the south Tibetan crust.

Key words: Chronology, Metamorphism, Magmatism, Karakoram.

Add/7 Heuberger, S., Burg, J.P., Dawood, H. & Hussain, S. 2001. Mapping on the North-Kohistan Suture Upper Shishi Valley, Chitral, NW Pakistan. 16th HKT in Austria. *J. Asian Earth Sciences*, 19 (3A).

The North-Kohistan Suture separates the Kohistan Paleo-Island Arc Complex from the Karakoram Plate. We report results from field work carried out in 1999 and 2000 in Chitral (Northwest Pakistan), more precisely in the Shishi Valley and in the region around Drosh. Several sections across the suture in the uppermost Shishi Valley show that the so-called *mélange* is an imbricate zone in which slices with well-defined lithologies can be recognised.

The Karakoram Plate consists of gabbros and diorites (Karakoram or Transhimalaya Batholith), of shelf type sediments like fossiliferous limestones (Aptian-Cenomanian age), shales, volcano-lithic conglomerates and metavolcanics, and of serpentinites and talcschists derived mostly from harzburgites.

The Kohistan Paleo-Island Arc Complex consists of sheared gabbros and diorites (Kohistan Pluton), of volcanosedimentary greenstones, calc-alkaline andesites succeeding to andesite lavas, tuffs and agglomerates, and of red shales and sandstones (deep water turbidites). The imbricate lithologies of the so-called *mélange* mostly belong to the Karakoram Plate. The present-day imbrication is due to a series of brittle sinistral faults that have faulted away the original, thrust-dominated imbrication of the suture zone.

Key words: Mapping, structure, Kohistan arc, Chitral

Add/8 Hildebrand, P.R., Noble, S.R., Searle, M.P., Waters, D.J. & Parrish, R.R. 2001. Old origin for an active mountain range: Geology and geochronology of the eastern Hindu Kush, Pakistan. *GSA Bulletin*, 113(5), 625–639, 10 figures; 1 table.

Prior to accretion of the Kohistan island arc during the Late Cretaceous and final suturing of India with Asia at ca. 50 Ma, the Hindu Kush mountains along the border of Afghanistan and northwest Pakistan were situated on the active southern margin of Asia. Geology and geochronology of the eastern Hindu Kush range in Pakistan demonstrate that localized crustal melting and leucogranite intrusion took place in the Gharam Chasma area at ca. 24 Ma. More regionally developed and widespread deformation, metamorphism, and magmatism took place before collision between both India and the Kohistan island arc with Asia. Ca. 195 Ma U-Pb monazite ages on a deformed leucogranite dike from the upper Lutkho valley indicate an Early Jurassic phase of crustal melting. U-Pb monazite ages of 135–126 Ma on a staurolite schist from near Gharam Chasma are interpreted as a minimum age for staurolite-grade metamorphism. Within the Tirich Mir fault zone, pegmatite dikes crosscut the staurolite schists. U-Pb dating of uraninites from one of these pegmatite dikes reveals an age of 114 ± 62 Ma. Monazites from the same rock give ages of 125–121 Ma, possibly due to inheritance of older cores. These Jurassic– Early Cretaceous constraints on metamorphism and magmatism relate to subduction and accretion processes, perhaps including the suturing of the Karakoram and Hindu Kush terranes along the Tirich Mir fault. In general, high-temperature, low-pressure metamorphism and subduction- related granitoid magmatism in the eastern Hindu Kush suggest a high thermal gradient in an active-margin setting from Early Jurassic to Cretaceous time. Keywords: active margin, collision, geochronology, Hindu Kush, metamorphism, monazite.

Key words: Geology, geochronology, Hindu Kush

Add/9 Houston, C.S., 1939. The American Karakoram Expedition To K2, 1938. *The alpine Journal*, 51, 54-68.

The author describes his visit to the Karakoram during an American expedition to the area. This travelogue does not have an abstract. The first few pages are reproduced here for ready reference.

For a hundred miles parallel to the great Himalayan backbone along its north-western end runs a minor range, the Karakoram. This small satellite of the main watershed boasts some of the world's most beautiful and least known peaks. Mt. Godwin Austen, called K2, 28,250 ft. high, is the highest of these and is now established as second only to Everest in altitude.

All about it cluster great peaks such as Broad Peak, Gasherbrum, Masherbrum, Bride Peak, Mustagh Tower. Truly the little travelled Karakoram is a climbers' paradise. In the 1860's Colonel Godwin Austen of the Survey of India entered the Karakoram and explored the Baltoro Glacier among others, and was probably the first to see K2 from nearby. In his honour the peak now bears his name. Sir Francis Younghusband, at the end of his great trek across Asia, crossed into India not thirty miles from K2 • Martin Conway and Dr. and Mrs. Bullock Workman also made extensive studies of the glaciers of the Karakoram and its peaks. In 1902 Wessely, Guillaumod, Eckenstein and Pfannl made an abortive attempt to climb K2 via the N.E. ridge, the first attempt ever made on the mountain, but their gallant effort was cut short by illness. In 1909 the Duke of the Abruzzi, one of the great expedition leaders of all time, led a huge party up the Baltoro Glacier to camp beneath K2. In the course of a forty-day campaign he reached 22,800 ft. on Savoia Pass where begins the steep and rocky W. ridge. He then went 20 miles eastward to Windy Gap from which he examined the E. and N.E. aspects of the mountain.

Finally he made a brief but determined attempt on the S. ridge which is now called Abruzzi Ridge. On this he reached about 21,000 ft., where he was forced to turn back owing to limited time and continuous difficulties. In his opinion the W. ridge seemed to be the route of choice. The map of the Baltoro Glacier, and the famous photographs taken by Vittorio Sella and not yet surpassed, form a great contribution to the records of exploration.

Twenty years later the Duke of Spoleto with another large expedition continued the geographical and geological survey of the district, but did not touch K2. Half a dozen other parties have seen the mountain from various angles but there have been no other assaults on its summit. It has come to be recognized as an outstanding problem for the mountaineer and a challenge to the explorer. After two years of effort the American Alpine Club obtained permission from the Government of Kashmir to enter Baltistan and accept this challenge. In October 1937 plans for the first American Alpine Club expedition were begun. Owing to the formidable nature of the mountain, to the obstacles encountered by our illustrious predecessors, and to our own convictions it was definitely planned that the first expedition should be one of reconnaissance primarily. We were to make careful study of the three great routes on the mountain and decide which of these was the most favourable for an attack. Once this survey was completed we were to try to go as high as possible on the route chosen. Only in our secret thoughts did we expect to do much more than a thorough preliminary study. The nucleus of the party was soon formed and about it gathered other climbers. From many candidates a small team at last emerged: Robert H. Bates of Philadelphia, veteran of many Alaskan climbs; Richard L. Burdsall of Port Chester, New York, who was one of the conquerors of Minya Konka; William P. House of Concord, New Hampshire, one of the two who reached the summit of Mt. Waddington; Paul K. Petzoldt of Jackson Hole, Wyoming, with many fine climbs in the Tetons to his credit; and myself. To our great good fortune the Government of India gave permission for Captain N. R. Streatfeild, M.C., of the Bengal Mountain Artillery, to accompany us as liaison officer.

Even after consulting all available literature and many authorities we could find no unanimous opinion about weather in the Karakoram. Some said that the monsoon began in June, others said July, while still others said that the monsoon did not reach K2 May and June, June and July, September and October, all were advocated as the best two months for climbing in the Karakoram. In despair we decided to take the two months most convenient for us: June and July.

Key words: K-2, expedition, Karakoram.

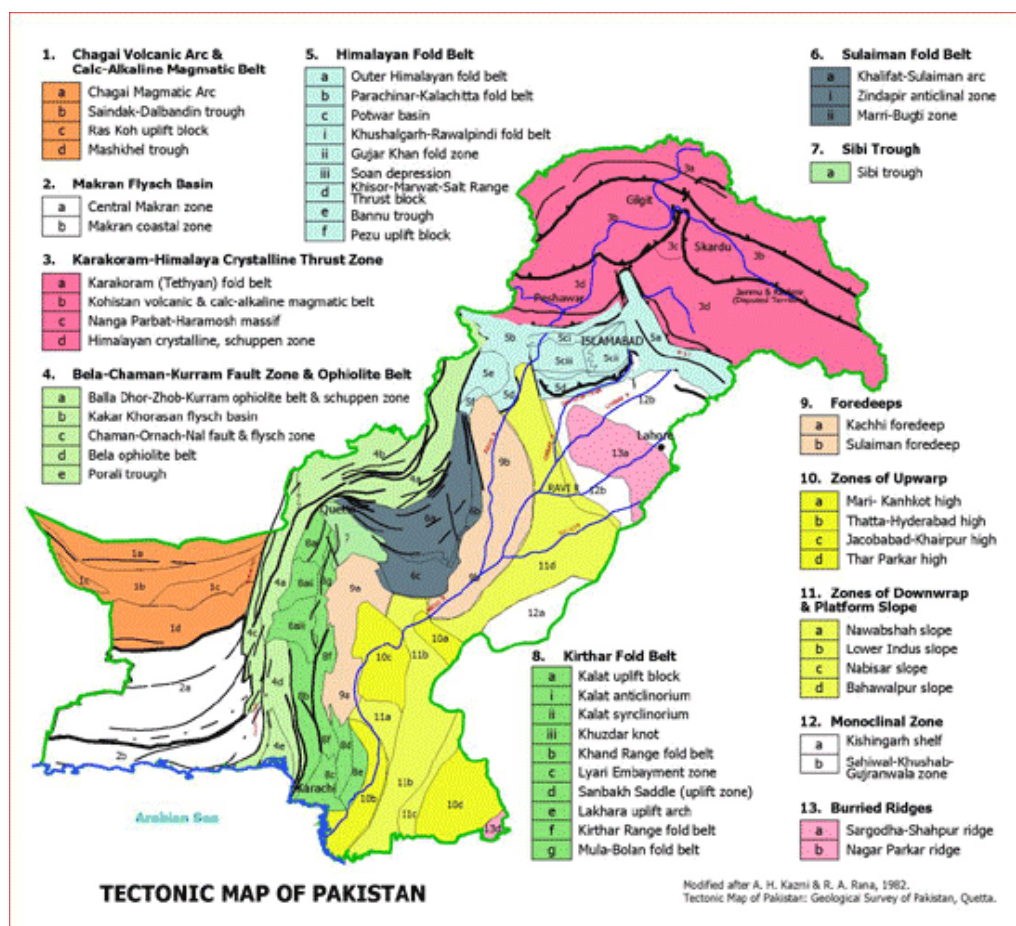
Add/10 Karim, A. & Veizer, J., 1999. Weathering processes in the Indus River Basin: implications from riverine carbon, sulfur, oxygen, and strontium isotopes. *Chemical Geology*, 170(1–4), 153–177.

This study deals with the major ions and isotope systematics for C, O, S, and Sr in the Indus River Basin (IRB). Major ion chemistry of the Indus, and most of its headwater tributaries, follow the order $\text{Ca}^{2+} > \text{Mg}^{2+} > (\text{Na}^+ + \text{K}^+)$ and $\text{HCO}_3^- > (\text{SO}_4^{2-} + \text{Cl}^-) > \text{Si}$. In the lowland tributaries and in some of the Punjab rivers, however, $(\text{Na}^+ + \text{K}^+)$ and $(\text{SO}_4^{2-} + \text{Cl}^-)$ predominate. Cyclic salts, important locally for Na^+ in dilute headwater tributaries, constitute about 5% of the annual solutes transported by the Indus. Weathering of two lithologies, sedimentary carbonates and crystalline rocks, controls the dissolved inorganic carbon (DIC) concentrations and its carbon isotope systematics throughout the Indus, but turbulent flow and lower temperatures in the headwaters, and storage in reservoirs in the middle and lower Indus promote some equilibration with atmospheric carbon dioxide. Combined evidence from sulfur and oxygen isotopic composition of sulfates refutes the proposition that dissolution of these minerals plays a significant role in the IRB hydrochemistry and suggests that any dissolved sulfates were derived by oxidation of sulfide minerals.

In the upper Indus, silicate weathering contributes as much as 75% (or even higher in some tributaries) of the total Na^+ and K^+ , declining to less than 40% as the Indus exits the orogen. In contrast, about two-thirds of Ca^{2+} and Mg^{2+} in the upper Indus (over 70% in some tributaries) and three-fourth in the lower Indus, are derived from sedimentary carbonates. The $^{87}\text{Sr}/^{86}\text{Sr}$ ratios tend to rise with increasing proportions of silicate derived cations in the headwater tributaries and in the upper and middle Indus, but are out of phase or reversed in the lower Indus. Finally, close to the river mouth, the discharge weighted average contribution of silicate derived $\text{Ca}^{2+} + \text{Mg}^{2+}$ and silicate derived $\text{Na}^+ + \text{K}^+$ are, respectively, about one-fourth and two-thirds of their total concentrations.

Key words: Himalayan weathering; Strontium; Stable isotopes,

Add/11 Kazmi & Rana 1982, GSP, QUETTA



Add/12 Lemmenicier, Y., Le Fort, P., Lombardo, B., Pecher, A. & Rolfo, F., 1996. Tectonometamorphic evolution of the central Karakorum (Baltistan-northern Pakistan). *Tectonophysics*, 260, 119-143.

Key words: Tectonics, Karakoram.

Add/13 Roland, Y., Maheo, G., Guillot, S. & Pecher, A., 2001. Tectono-metamorphic evolution of the Karakorum Metamorphic Complex (Dassu-Askole area, NE Pakistan): Exhumation of mid-crustal HT-MP gneisses in a convergent context. *Journal of Metamorphic Geology*, 19, 717-737.

Key words: Metamorphism, tectonics, Karakoram.

Add/14 Rolland, Y., Picard, C., Pecher, A., Carrio, E., Shepard, S.M.F., Oddone, M. & Villa, I.M., 2002. Presence and geodynamic significance of Cambro-Ordovician series of SE Karakoram, (N Pakistan). *Geodinamica Acta*, 15, 1-21.

Key words: Geodynamics, Cambro-Ordovician, Karakoram.

Add/15 Scarer, U., Copeland, P., Harrison, M.T. & Searle, M.P., 1990. Age, cooling history and origin of post-collisional leuco-granites in the Karakoram batholith, a multi-system isotope study. *Journal of Geology* 98, 233-251.

Key words: Cooling history, leucogranites, Karakoram batholith.

Add/16 Schaltegger, U., Zellinger, G., Frank, M. & Burg, J.P., 2002. Multiple mantle sources during island arc magmatism: U-Pb and Hf isotopic evidence from the Kohistan arc complex. *Terra Nova*, 14, 461-468.

Key words: Magmatism, U-Pb, Kohistan island arc.

Add/17 Schneider, D., Zeitler, P., Kidd, W., Edwards, M., 2001. Geochronologic constraints on the tectonic evolution and exhumation of Nanga Parbat, western Himalaya syntaxis, revisited. *The Journal of Geology* 109, 563-583.

Key words: geochronology, Tectonics, Nanga Parbat.

Add/18 Searle, M., Khan, M.A., 2001. Geological Map of North Pakistan: And Adjacent Areas of Northern Ladakh and Western Tibet: (Western Himalaya, Salt Ranges, Kohistan, Karakoram, Hindu Kush). British Geological Service (BGS).

Key words: Geological map, Ladakh, Tibet, Kohistan, Karakoram.

Add/19 Zeitler, P.K., Meltzer, A.S., Koons, P.O., Craw, D., Hallet, B., Chamberlain, C.P., Kidd, W.S.F., Park, S.K., Seeber, L., Bishop, M. & Shroder, J., 2001. Erosion, Himalayan Geodynamics, and the Geomorphology of Metamorphism. *GSA Today*, 11(1), 4-9.

Is erosion important to the structural and petrological evolution of mountain belts? The nature of active metamorphic massifs co-located with deep gorges in the syntaxes at each end of the Himalayan range, together with the magnitude of erosional fluxes that occur in these regions, leads us to concur with suggestions that erosion plays an integral role in collisional dynamics. At multiple scales, erosion exerts an influence on a par with such fundamental phenomena as crustal thickening and extensional collapse. Erosion can mediate the development and distribution of both deformation and metamorphic facies, accommodate crustal convergence, and locally instigate high-grade metamorphism and melting.

Key words: Erosion, geodynamics, geomorphology, metamorphism, Himalaya.

Add/20 Zielinger, G, Arbaret, L., Burg, J.P., Chaudhry, N. Dawood, H. & Hussain, S., 1998. Structures in the lower units of the Kohistan arc (NW Pakistan): preliminary results. Geological Bulletin, University of Peshawar 31, Abstract Volume, 13th Himalayan-Karakoram-Tibet International Workshop, 224-227.

In NW Pakistan, the Kohistan paleo-arc, which was developed as plate an island arc above the northward subduction zone of the Tethyan Ocean during the Mesozoic, separates the Indian from the Asian plates. The southern boundary of the Kohistan arc is the so called Main Mantle Thrust (MMT), a crustal scale, northward dipping thrust on which the southern parts of the Kohistan are have been thrust over India.

Preliminary results of detailed mapping carried out in the uppermost Indian Plate (at Duber Bazar,) and the low levels of the Kohistan paleo-arc (from Jijal to Kiru) has covered the following lithologies:

Indian units: Granodiorite and strongly foliated gneisses. SW of MMT the gneisses are folded parallel to the SW trending stretching lineation. Kinematic determination shows a dominant southwestward sense of shear.

Kohistan units: The lowest levels of the Kohistan paleo-arc are dominated by dunites, pyroxenites and peridotites. Dikes of greenish chromite-clinopyroxenites cut this ultramafic sequence. Upwards, meta-gabbros (age 101 ± 5 Ma., R. Anczkiewicz, oral com.) with high magmatic garnet content complement the so called Jijal Complex. Ca. 700 m SW of Patan, anastomosing shear zones appear in these garnet rich rocks. The density of the anastomosing shear deformation increases northward in this ca. 3 km wide zone, up to 2 km NE of Patan. This shear zone is described in more details in a companion poster. To the NE of this anastomosing shear zones, rocks are variable in composition, but mainly comprise of gabbros, hornblendite gabbros, diorites, norites, amphibolites and smaller bodies of nearly pure hornblendite (Kamila Belt). Pegmatites intruded this sequence during and after ductile deformation and correspond to a late magmatic event.

In this poster we present structural data on the anastomosed shear zone. The anastomosed shear zone, developed during finite magmatic stage, shows all deformation facies from undeformed protolith to ultra-mylonite (for details: The sense of shear on the dispersed, but in average flat to NE dipping shear zones shows dominantly SW directed relative movement of the hanging wall and minor NE directed shear. To the NE of these zone of anastomosing pattern, other shear zones form parallel W-E striking units of amphibolite facies (age 83 ± 1 Ma.). These regular shear zones, containing porphyroclastic garnet, reach a thickness of up to 20m. Lineations strike NE-SW. The foliation of the shear zones dips more regularly to the NNE and the relation between normal and reverse shearing is balanced. The difference in the features and age (ca. 18 Ma.) between the anastomosed shear zone and the amphibolitic shear zone let us to separate the Kamila shear zone s.s., to the NE, from the Patan ductile shear zone, which is the anastomosed system described here and in the companion poster.

The region underwent late, pervasive faulting. Striations record essentially strike-slip and normal faulting. Results of principal stress calculation show three different stress fields: a poorly recorded one has a SW-NE maximum compressive principal stress (σ_1), a second one has a NW-SE σ_1 , dominantly identified by strike-slip movements. Preliminary analysis of superimposed striations indicates the SW-NE (σ_1) as the older one. The youngest, best represented stress field shows a SW-NE minimum principal stress and steep cycle, responsible for normal faulting. The NE dipping Patan-fault is a prominent fault-structure which cuts the anastomosed shear zones. Minor offsets in lithology, recent seismic activity, rotated blocks (indicated by the change of foliation attitude from mainly W-E to NNE-SSW, south of Patan-fault) and the smooth topography in the widened Indus valley at Patan indicate a still active Patan-fault, but it seems to be a recent and regionally minor fault-contact. The Patan ductile shear zone must be separated from the Kamila shear zones. Further work on these structures will give more details about the evolution of the "Patan shear zone" and the relationship with the Kamila shear zone.

Key words: Collision, Subduction, Structure, Southern Kohistan arc.

Add/21 Zielinger, G., Arbaret, L., Burg, J.P., Chaudhry, N., Dawood, H. & Hussain, S., 1999. How is the petrography affected by shear zones in the Kohistan complex, N Pakistan? Terra Nostra 99, Abstract Volume, 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal, Germany, 187-188.

In NW Pakistan the Kohistan complex separates the Indian and Asian plates. It was formed as an Island Arc during Mesozoic times (Bard, 1983; Coward et al., 1986). Accretion to Asia and subsequent thrusting over the northern margin of the Indian plate along the northward dipping Indus Suture (also called Main Mantle Thrust = MMT) (Tahirkheli et al., 1979) constitute the collisional history (Coward et al., 1987). Earlier history involves arc related deformation like splitting the arc in a volcanic and remnant arc (Burg et al., 1998) and SW-thrusting expressed by

anastomosing shear zones in the southern, i.e. lower part of the arc probably imposed by subduction of the Tethys oceanic crust.

Our area of interest is comprised of two lithologies: The granulitic gabbro forms the upper part of the Jijal complex and is described as a calc-alkaline magma emplaced during the arc activity (Jan and Howie, 1981). The granulitic gabbro is intrusive in, and intruded by Hornblendites. P-T conditions point to granulite facies metamorphism ($T > 750^{\circ}\text{C}$ and $P > 1.8$ GPa, Ringuelet et al., 1998) and Sm-Nd cooling ages are 91 Ma and 96 Ma (Yamamoto and Nakamura, 1996; Anczkiewicz and Vance, 1997).

The Sarangar gabbro (NE of Patan) crystallised at 800°C and 0.8-1.1 GPa as deduced from preserved plagioclase-clinopyroxene assemblages (Yoshino et al., 1998). Ages are not available but structural relationship indicates that the Sarangar gabbro is younger and intrusive into the granulitic gabbro (see companion abstract Arbaret et al., this conference). Regional amphibolite facies metamorphism affected these rocks and ended probably 83 Ma ago (Ar-Ar age of amphibole, Treloar et al., 1990). All these sites show remarkable strain localisation and provide sections from undeformed, weakly deformed with well preserved magmatic fabric, to mylonitic high shear strain zones within tens of centimetres. Bard (1983) and Treloar et al. (1990) estimate the metamorphic conditions for the shear zones in the Sarangar gabbro at $550\text{--}650^{\circ}\text{C}$ and 0.9-1.0 GPa.

Many petrographical and geochemical studies on these rocks have been published and are partly cited above. Unfortunately they do not describe in details the relationship between petrography and deformation. Our particular aim is to obtain a better understanding of the interaction of petrography and ductile deformation. Therefore petrographic analysis across anastomosing shear zones was carried out at these distinct sites, in both the granulitic and Sarangar gabbros.

The composition in the undeformed rock of the granulitic gabbro is plagioclase, pyroxene, garnet, amphibole, quartz and rutile. The mid to fine-grained heteroblastic rock shows a granoblastic texture. The pyroxene is hypidioblastic with lobate to symplectitic contacts to plagioclase. The intensity of the symplectitic feature is getting stronger closer to the shear zone. The garnets are poikiloblastic intergrown with plagioclase, quartz and amphibole. At the scale of hand-specimen a magmatic foliation is visible but there is no evidence, even under the microscope, for deformation structures. The magmatic foliation is bent close to the shear zone into the well-defined mylonitic foliation within the shear zone. Beside a strong decrease in grain size, the decrease in amount of pyroxene and the increase of amphibole and quartz are the most striking phenomenon. The garnet is porphyroclastic in the very fine-grained matrix ($\sim 0.3\text{ mm}$), partly rotated and fractured with new grown amphibole inside these fractures. Recrystallised quartz in the pressure shadows of garnets as well as the amphibole crystals oriented parallel to the foliation point to a higher shear strain. The change in the mineral assemblage points to a sharp increase of hydration from the undeformed to the mylonitic part of the garnet granulite.

Dominant composition in the Sarangar gabbro is amphibole (mainly hornblende), pyroxene, plagioclase, epidote and quartz. In a 13 cm long section from the undeformed gabbro to the centre of one reference shear zone the main changes are as follow:

The hypidioblastic magmatic pyroxene is successively replaced by metamorphic pyroxene, amphibole and quartz. Close to the shear zone the metamorphic pyroxene is idioblastic whereas further away it rims the magmatic pyroxene. This first rim shows symplectitic intergrowth with the second rim comprised of greenish amphibole. In the shear zone, no magmatic pyroxene was observed. The plagioclase shows also symplectitic structures within the vicinity of the shear zone. The amphiboles underline the fabric in the shear zone and are cut by small quartz veins. Poikiloblastic garnet occurs infrequently. The macroscopic porphyroclasts ($\sim 2\text{ mm}$) are plagioclase, quartz and pyroxene. Hydration towards the shear zone is remarkable.

Amphibolitic facies developed new minerals preferably in the shear zones and progressively (in the range of a few centimetres) into the undeformed gabbro. The hydration in the shear zone is strong and is propagating successively from the high shear strain zones to the nearly undeformed parts.

Our observation points to a high fluid flux in developing shear zones that were weak features (reduced grain size) with the hydration being concentrated in these thin zones. This process further reduced the hydrated rock strength in which in turn could be the site of increased fluid flow and subsequent amphibolitisation in the shear zone and their vicinity. The biggest amount of amphibolitised gabbro is therefore limited to the shear zones protecting the granulitic undeformed parts by channelling the fluid flux. The quantity of amphibolitised gabbro is small relatively to the undeformed gabbro.

Key words: Collision, shear zone, petrography, Kohistan arc.

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