GEOLOGY OF KOHISTAN AND ADJOINING EURASIAN AND INDO - PAKISTAN CONTINENTS, PAKISTAN

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ABSTRACT

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 Kararkoram.

Bulk of Kohistan sequence consists of amphibolites, 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 Palaeozoic 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* (1976, 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.

INTRODUCTION

The first geological map of Pakistan was published by the Geological Survey of Pakistan in 1964. This map contains about 36000 km of geologically unmapped terrain located in the northwestern part of the country. Desio (1964), while differentiating the tectonic zones of Karakoram had distinguished this unexplored area as Kohistan zone.

Kohistan is located between long: 71°W, 76°E and Lat. 34° 30′S 36° 30′N, and is bounded by the geological provinces of Hazara, Diamir, Gilgit and Chitral, lying respectively to the south, east, north and west.

Kohistan, because of inaccessibility, remained eclipsed during the past for want of geological informations. During the recent years the construction of Karakoram Highway has paved way for access to several previously unknown geological sections, which so far had formed an information gap between the geological provinces of Hazara, Gilgit and Chitral to provide controls in deciphering stratigraphy, petrology and tectonics of the rock formations constituting this terrain.

In the begining, the Department of Geology and subsequently the Centre of Excellence in Geology, University of Peshawar, under a planned programme had started systematic probing of Kohistan from 1965, and by the end of 1977, had completed the geological observations on a substantial part of this area, which enabled production of the first geological map by Tahirkheli and Jan (1978) on 1 cm to 10 km scale. Further Jan, one of the research associates was admitted in King's College, London, for higher studies on his work in Kohistan and has recently returned after earning a doctorate. His results have contributed a lot to provide a firm base in understanding some of the geological riddles so far shrouding this zone.

This paper is primarily intended to introduce the geology of hitherto virgin terrain of Kohistan alongwith adjoining Indo-Pakistan and Eurasian plate margins which will supplement the already available data in enhancing the knowledge on the regional geology of the western part of the Himalayas and secondly to limelight the recent observations made on thc tectonics of Kohistan during a joint field work alongwith Mattauer, Proust and Tapponnier from the University of Montpellier, France. Some of the results of this investigation have already been published in two papers, one read in the Colloquium on the Geology of Himalaya at Paris (1976) and the second paper was published in R. Ann. Sc. Terre Reunes, France (1977). The third paper by these authors is accepted for publication in the forthcoming memoirs on the Geodynamics of Pakistan, being published conjointly by the Geological Survey of Pakistan and the University of Cincinnati, U. S. A.

GEOMORPHOLOGY

Kohistan is characterised by rugged terrain and high relief. The mountains have a general east-west trend and vary in elevations from 2 00 metres in the south near its border with Hazara to over 5000 metres in the north in the vicinity of Diamir. The mountain peaks show typical ice skittled sharp features with steep slopes, occasionally covered by sparse alpine type vegetation. The Indus river is the major drainage artery, whereas Ushu, Gabral and Kandia tributaries capture the drainage of the western part of Kohistan.

The major valleys inhabit the larger part of the population of Kohistan. The climatic conditions of these valleys are extreme; cold winters and hot summers. The summer maximum temperature may be above 110 °F and winter minima is below freezing point. The annual rainfall is variable in the valleys and ranges from 30 to 65 cm. Much of the precipitation is in the form of snow during winter months.

Kohistan in sparsely vegetated. Common plants upto 2000 metres elevation are oak, walnut, bankhor and pinus species. Above this height, deodar, palundar, silver fir, chalghoza, blue pine and juniper are the common varieties.

GEOLOGY

The geological scenario of Kohistan does not produce a coherent overview, firstly because of its complex evolutionary history as an island arc on the northwestern margin of the Indo-Pakistan platform and secondly due to its subsequent involvement in the interplay with the two mighty continental blocks. The resultant effect is reminiscent in its heterogenous denominations of intermingled rocks with superimposed complex tectonics, which distinguishes it from the surrounding geological provinces. The marine sedimentation, both on the Indo-Pakistan and Eurasian plates margins, which had started during Paleozoic or earlier remained in progress in the Tethyan geosyncline till Eocene which is represented by thick piles of pelitic, psammitic and calcareous rocks.

The Tethyan basin had narrowed and started shrinking towards the commencement of the Cretaceous, as a result the sedimentation had shifted towards the plate margins, before the throes of the continental collision and subsequent suturing. The marine conditions based on palaeontological evidences had ended about the close of Early Cretaceous along the northerly belt of Kohistan on the Eurasian side and somewhere during post-Early Tertiary on the south.

During the last lapses of sedimentation outpouring of lavas on a great magnitude is evidenced by the presence of volcanic rocks forming two parallel arcs, one running on the northern margin of Kohistan (Machelu—Hashupa—Chalt—Yasin—Drosh) and another forming bold and continuous outcrop in the vicinity of Kalam and extending south-westward towards Bajaur in Dir.

STRATIGRAPHY

As mentioned earlier, the Kohistani part of the Karakoram Himalaya, as far as its geology is concerned, has recently come into limelight. Some patchwork as a result of isolated traverses in the accessible areas of Kohistan has been published earlier by various workers, which is not suffice to complete a stratigraphic mosaic of the whole terrain. However, for preparing a regional geological map of Kohistan, this work did prove useful for correlation purposes.

For describing stratigraphy, the discussion is split in three parts to cover separately, the Indian Mass, Asian Mass and the Kohistan Sequence. It will be beyond the scope of this paper to digest in detail the description of all the stratigraphic units. Thus the discussion will be restricted to that part of the Mass which has vast extensions and is involved in the tectonics of the northern megashear or recently deciphered southern megashear called Main Mantle Thrust, (MMT)*.

INDIAN MASS

Some of the major established stratigraphic sequences on the Indian platform in Pakistan, which are associated with the suture zone of the Main Mantle Thrust and are involved in the major tectonics, are dominantly pelitic rocks, variously named as Hazara Slates, Dogra Slates, Manki Slate, Lower

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*A more detailed discussion on MMT may be seen in the subsequent pages under heading "Geotectonic Evolution of Kohistan".

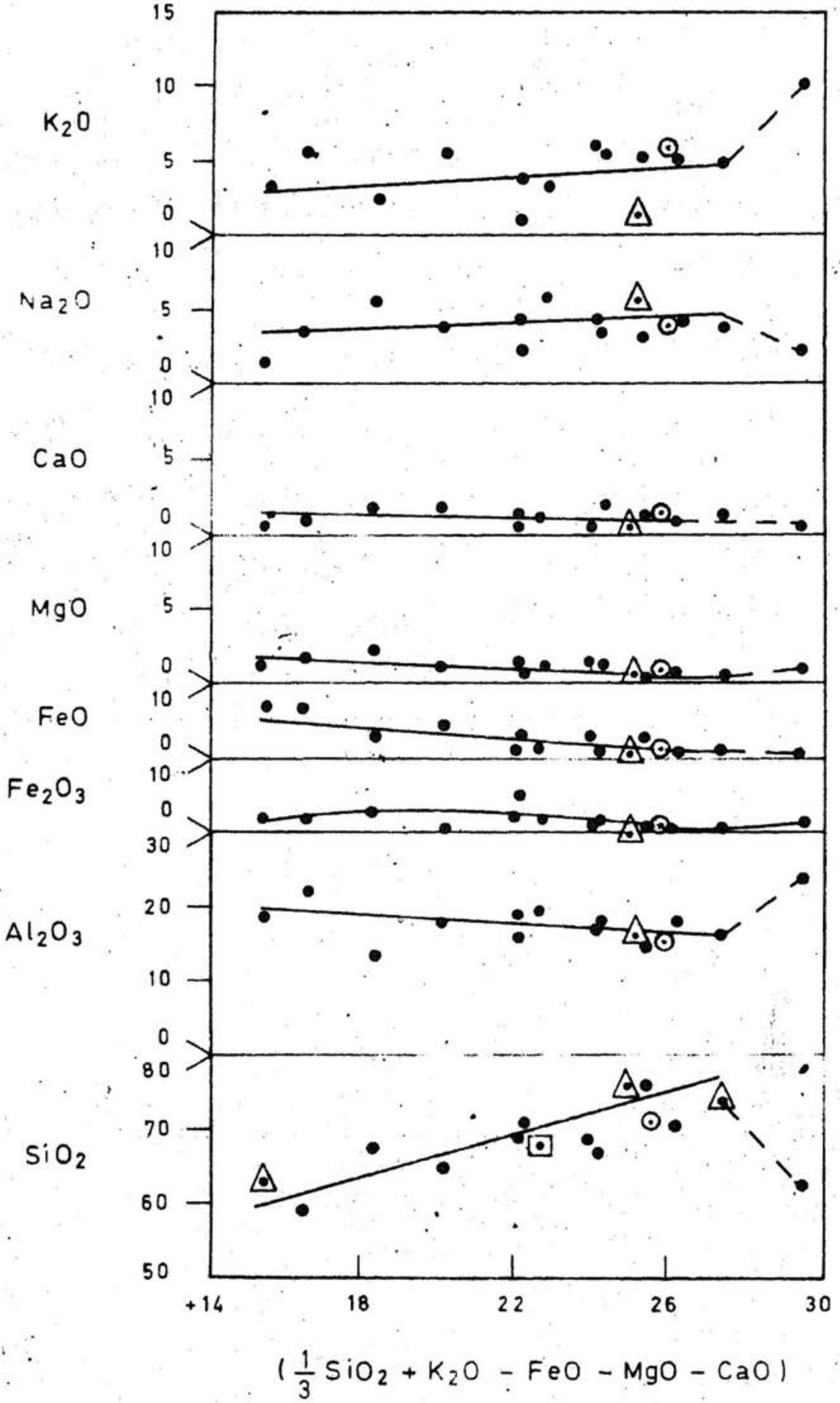

Fig. 2. Plot of Nanga Parbat granites in Larsen (1938) type variation diagram, alongwith data from Zennettin (1964) △ and Ahmad *et at.* (1976) □. ⊙ represents Nockold's (1954) average granite.

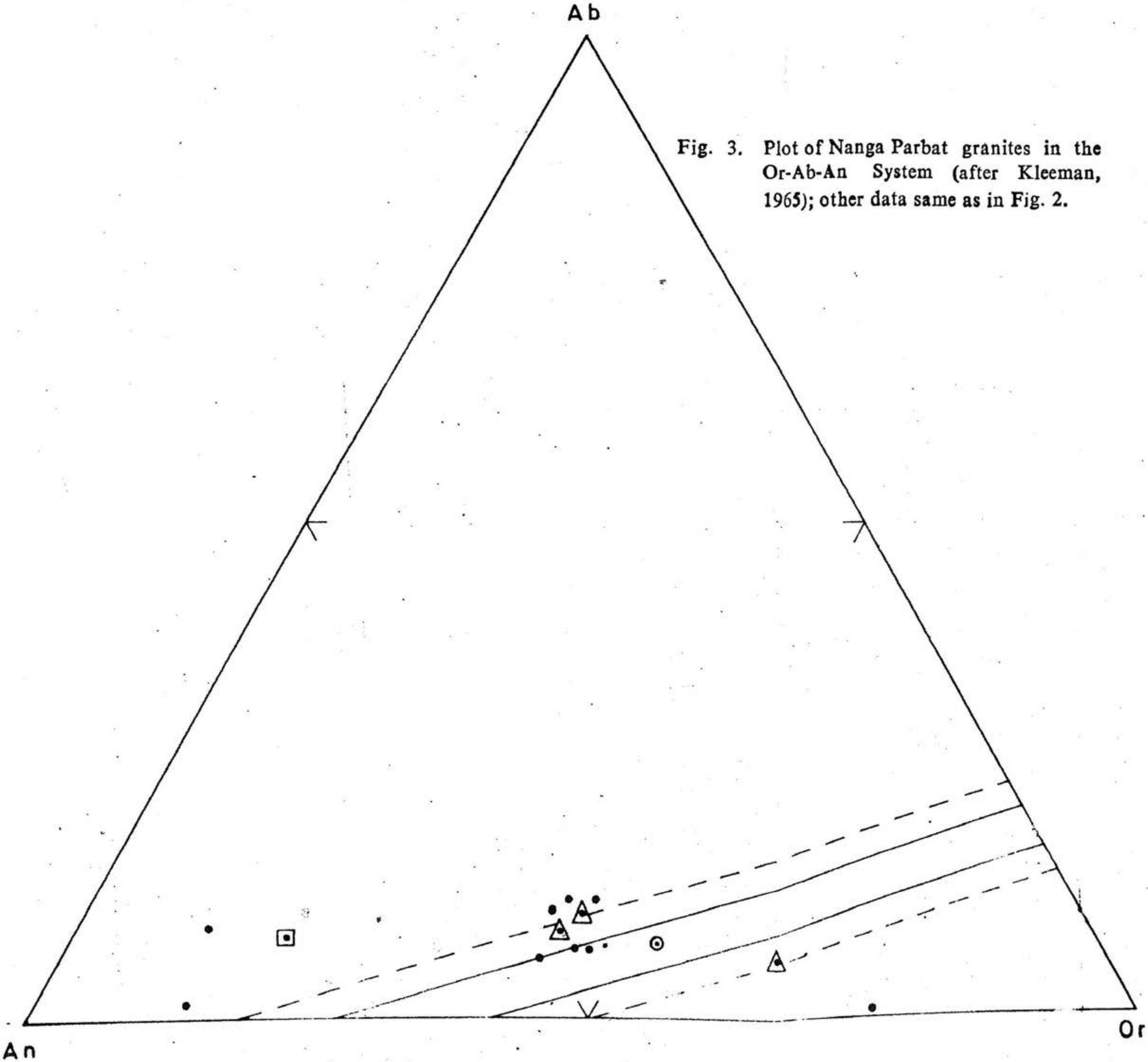

Fig. 3. Plot of Nanga Parbat granites in the Or-Ab-An System (after Kleeman, 1965); other data same as in Fig. 2.

Swat-Buner Schistose Group and recently established Besham Group, which constitute nearly seventy percent of the outcrops. Next in order of abundance are the carbonate rocks of Palaeozoic age or older, namely Abbottabad Formation, Great Limestone, Shakhai Limestone, Pirthan Limestone, Ali Masjid Limestone and their equivalents distributed in Malakand, Dir and Mohmand areas. The Tanawal Quartzites of Hazara and their equivalents located on the west of the Indus, namely Gadun Quartzite, Chamla Quartzite, Swabi Quartzite and Misri Banda Quartzite overlie the slate series already discussed and have equal importance of being one of the major stratigraphic sequences holding pivotal position in being involved in the regional tectonics.

Salkhala Series have been placed as the oldest unit of the lesser Himalaya and underlie the Dogra Slates. The series is comprised of dominantly pelitic rocks containing widespread associations of graphitic schists. The Salkhalas have type section in Kashmir and small outcrops of these rocks are reported south of Deosai in Kashmir, in Babu Sar Pass south of MMT in Hazara and in the Black Mountains south of Thakot. Many such outcrops, which on lithological basis may be correlated with the Salkhalas have been located west of the Indus river in Swat, Dir, Malakand and Mohmand, which are yet to be stratigraphically formalized.

Salkhala Series has not been found in direct association with the Main Mantle Thrust, nevertheless, several thick graphitic bands occur in the close vicinity of the thrust, all along its course between Kashmir in the east to Bajaur in the west.

All of the pelitic sequences named earlier are located south of Kohistan on the Indian continental margin in Pakistan. These rocks have got uninterrupted extension to the north towards Kohistan border with a well marked change in lithology. To differentiate a pelitic sequence represented in Kohistan, which is involved in the Main Mantle Thrust and is subducted under the island arc, the author has distinguished Besham Group, which constitutes two lithologies. The lower one is Chail Formation which is dominantly pelitic and the upper one is Banna Formation, which is dominantly calcareous. The type section of the group is located in the vicinity of Besham on the main Karakoram Highway, whereas the type sections of the two formations, Chail and Banna, are located east of the Indus in the Allai area of Kohistan.

As far as the depositional history of the rocks of the Besham Group and their equivalents, located further south, is concerned, it may be considered coeval; sharing a common basin of Tethyan geosyncline. Subsequent deformations, occuring during and after Eurasia—Indo-Pakistan continental collisional period, have left variable metamorphic scars on these rocks, being more pronounced in the vicinity of the Main Mantle Thrust. The intensity of this deformation shows gradual decrease towards south.

The Chail Formation is dominantly pelitic and constitutes slates, phyllite, various types of schists and gneisses, alongwith interbedded subordinate bands of calcareous and psammitic rocks. Among the schistose rocks, mica schist, quartz-mica schist, talc schist, calc schist, graphitic schist, kyanite schist, staurolite schist and para-amphibolite comprise a signifacant assemblage of this suite. In the kata-zone, in the close vicinity of MMT, the frequency of amphibolites, gneisses and marble shows a marked increase.

In another sequence, between Besar village and Babu Sar Utla, in the upper reaches of Kaghan Valley the dominant lithological element constituting the Chail Formation of Besham Group from south to north are: garnet-mica-schist, graphitic schists, kyanite schist, biotite gneisses, sillimanite gneisses and amphibolites. The greenschists alongwith some sporadic glaucophane-bearing blueschists are exposed on the southern slope of Babu Sar Pass and occur along the subduction zone with the Main Mantle Thrust.

The amphibolite bed is repeated several times in this section and in the vicinity of Lulu Sar lake, its folded limbs show crenulated banding of epidote-rich lamina. Marble beds with flow-folding and biotite gneisses also incorporate the more tectonized part of the section.

The Kaghan section comprises the northwestern limb of the Hazara syntaxis which has been subjected to two major regional stresses. The earlier one is directed north-south as a result of overthrusting along the MMT and the latter is related to the building of syntaxis during wedging of India into Asia. West of the Indus near Afghanistan border in another section between Dargai and Khar, across Malakand, Mohmand and Dir, the Indo-Pakistan Mass listed from south to north constitutes :

1. Dargai ultramafics comprising dunite, peridotite, pyroxenite and serpentinite.

2. A thick metasedimentary sequence involving pelitic and calcareous rocks; among the former hornfelses, quartz schists, mica schists, garnet schists, graphitic schists and staurolite schists are noteworthy. The carbonate sequence comprises of semi- to medium crystalline dolomitic limestone with interbedded phyllitic slates. Among the igneous intrusions dolerite, granite, pegmatite and quartz veins are common.

   The metasedimentary sequence has been thrust over the Dargai ultramafics.

3. Ghalanai anticline with east-west trending axial-plane forms one of the major structural features of Mohmand. This fold involves four lithological elements, which from bottom to top are :

   (i) Schistose rocks with crystalline limestone bands showing frequent intrusions of acid and basic rocks,

   (ii) Thin bedded dolomite,

   (iii) Thin bedded, fine to medium and friable calcareous quartzite and

   (iv) Phyllitic schists.

   The schistose rocks occupy the core of the structure and is comprised of mica schists, talc schists, graphitic schists, garnet schists, quartz schists and para-amphibolite. These metasedimentary rocks are intruded by dolerite, diorite, gabbro, pegmatite and vein quartz; the last two mentioned being more frequent.

4. Nawagai Limestone, a thick calcareous sequence in the north, is thin to thick bedded, fine to medium grained and medium crystalline. Scattered volcanic, mafic and ultramafic bodies strew the northern fringe of the outcrop, which is associated with the subduction zone of the Main Mantle Thrust.

In the pelitic part of the sequence in Jandul Valley, which is in direct contact with the MMT, the amphibolite facies rocks consisting of hornblende-garnet-plagioclase schists, epidote-hornblende-plagioclase schists and greenschists are in common occurrence.

Glaucophane schist is associated with the subduction zone of the Main Mantle Thrust. A thick section where this rock is well developed is located in the vicinity of Shangla Pass in Swat Kohistan. Here approximately 400 metres thick section between the valley and the pass on the south, exposing greenschists, mica schists and quartz schists contains bands of glaucophane schists. Its occurrence becomes thicker towards the hill-top.

Some indications of blueschists occurrences have been recorded in the vicinity of Babu Sar Pass in the upper reaches of Kaghan valley in Hazara, which have sporadic extension along the MMT towards west. Some isolated sections in Swat and Dir have also yielded glaucophane which are under investigation.

KOHISTAN ISLAND ARC SEQUENCE

KALAM GROUP

The name Kalam Group was assigned by Matshushita *et al* (1965) to a sequence of metasedimentary rocks exposed in the vicinity of Kalam in upper Swat. These rocks extend westward as far as Baraul Banda in Dir and in the east its isolated outcrops have been mapped in Kandia stream by Jan *et al* (1970) and another near Sazin in Kohistan by Desio (1977).

Recent investigations by the author in the far east in Baltistan, has revealed an outcrop of similar lithology south of Skardu, skirting the northern fringe of Deosai plateau.

At Kalam the thickness of the group is in the vicinity of 800 metres and is comprised of three main lithological elements, which occur as mapable units. These are :

i.	Shou Quartzites	600 m.
ii.	Deshan Banda Limestone	35 m.
iii.	Karandoki Slates	120 m.

Shou Quartzites comprise the thickest unit which cover nearly three-fourth of the lot, then come slates and the thinnest among them being limestone. On the south, the Kalam Group is intruded by the diorites belonging to Kohistan Basic Complex of Jan *et al* (1971), and on the north it shows a faulted contact with the slaty shales of Dir Group.

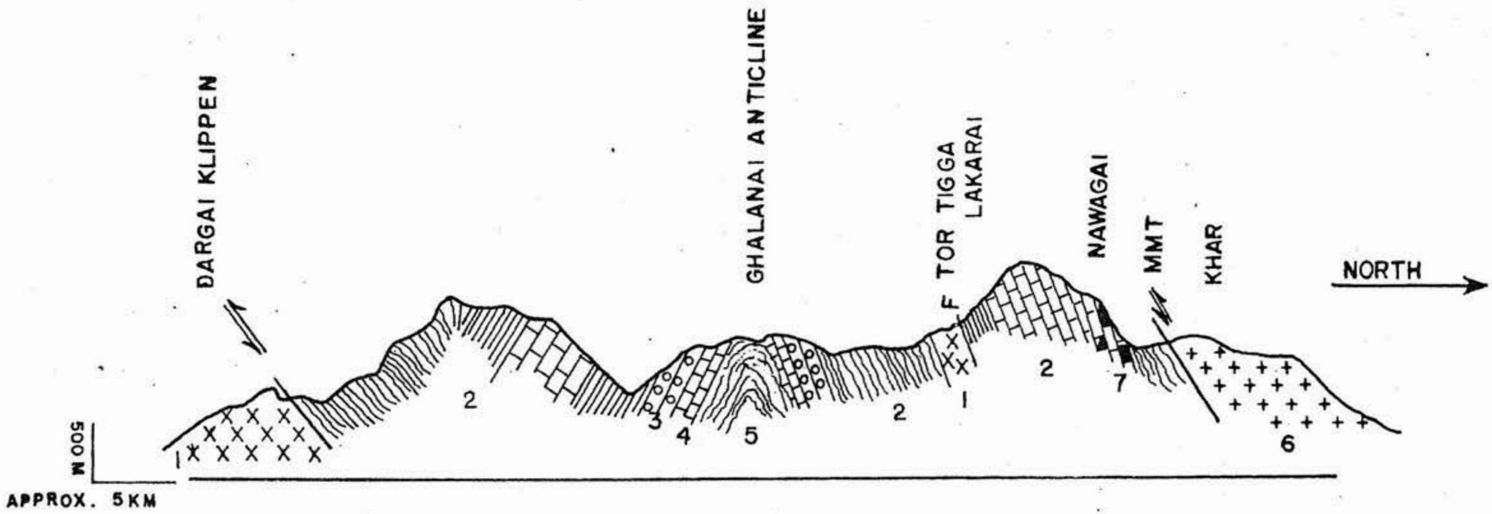

FIG:-1 A DIAGRAMMATIC GEOLOGICAL SECTION ACROSS MOHMAND, MALAKAND AND DIR, SHOWING THE POSITION OF MMT WITH RESPECT TO THE INDIAN MASS.

1 DARGAI ULTRAMAFICS, 2. METASEDIMENTS, 3. QUARTZITES, 4. DOLOMITE
5. METASEDIMENTS OLDER TO 2, METAMORPHOSED TO KATA-GRADE,
6. AMPHIBOLITE, 7. VOLCANICS AND MAFICS-ULTRAMAFICS.

FAZAL AHMAD

The type section of quartzites is Shou stream across Ushu river near Kalam, where they are developed in a broad antiform structure with limbs dipping at 30°—35° towards north and south. The core of the anticline is filled with detritus which eclipse its lower contact with the older limestone and slates. Shou Quartzites show extension towards west and have been traced through Shringal Valley to Baraul Banda in Dir.

Shou Quartzites are light to dark grey on fresh faces and brownish grey on weathered surfaces. They are thin- to thick- bedded and very fine to fine-textured. The grains are angular and the binding material is usually siliceous, specifically chert forms intimate association. Two sets of fractures, vertical and horizontal are common. Some of these fractures are filled with quartz and pegmatite intrusions. Banding and gradational beds are conspicuously noted in these quartzites,

The limestone is thin-bedded, light grey, fine-textured, medium crystalline and sparingly fossiliferous. At Deshan Banda, it is about 35 meters thick, but its occurrence elsewhere is not persistant, and it may be seen in other sections as thin crenulated bands in squeezed horizons. Due to crystallization the fossils have become deshaped, as a result their identification has so far remained controversial. Jan *et al* (1971), on the basis of studies conducted on these fossils by Attaullah Khan (personal communication), have assigned a Permo-Carboniferous age to Deshan Banda Limestone.

Karandoki Slates form the oldest horizon in the Kalam Group. The type section where they are well exposed and form thick sequence in Karandoki stream about two km south of Kalam. In the slate sequence, the lower most beds are of mica schists which grade upward to phyllitic-slates and slates.

The slates are thin-bedded, grey, green and maroon coloured. They are varyingly siliceous and fine to very fine-textured. They are in direct contact with a thick diorite body on the south, as a result chilled portions with hornfelsic texture are quite conspicuous. In Dir and elsewhere, para-amphibolite bands are also associated with this horizon which may be the result of high grade metamorphisn of calc-rich bands in Karandoki Slates.

The Kalam Group, as mentioned earlier, has been placed in the Permo-carboniferous by the earlier workers. The present author on the basis of their lithology and stratigraphic association considers this group to be of Cretaceous aga.

DIR GROUP

Dir Group is a new stratigraphic nomenclature introduced by the author to denote a sequence of dominantly pelitic rocks and the associated volcanics of Upper Swat and Dir. These rocks have east-west extension, the eastern limit being Ushu Valley and in the west they traverse the northwestern part of Dir district and cross the Afghanistan border in Bajaur. Their maximum thickness estimated to be 1000-1200 meters has been noted in two sections, one north of Kalam across Gabral river and another south of Dir. Dir Group has been divided into the following two parts, both of them occur as mapable units.

ii. Utror Volcanics

i. Baraul Banda Slates

Baraul Banda Slates

Baraul Banda in Dir is the type section of the pelitic sequence of Dir Group. Other accessible sections where Baraul Banda Slates are extensively exposed are north of Kalam on the western bank of Gabral river in upper Swat and another upstream of Shringal-Panjkora confluence along Dir road. These two sections run across the strike of the slates. Shringal and Baraul Banda streams running in east-west direction expose the lower contact of the slates with the Shou Quartzites.

Baraul Banda Slates are light grey to greenish grey, thin- bedded, fine-textured and occasionally silty. Light grey, thin- bedded limestone occurs as thin bands in the slates, which are sparingly fossiliferous. The level of metamorphism in the slates ranges to chlorite and sericite grade.

The slates strike in east-west direction and have northerly dip. They are isoclinally folded and have faulted contact with the underlying Shou Quartzites. This fault is a strike-slip with a downthrow of 50-80 meters. It was first observed in the ridge northwest of Kalam where brecciated slates were noticed along the fault plane. The westward extension of this fault is located along the Shringal and Baraul Banda streams in Dir.

Baraul Banda Slates have yielded fossils in the vicinity of Shahi in Dir. The fossils identified are Actinocyclina, Discocyclina and Nummulites atacicous, which suggest an age of Lower Eocene for the slates. A widespread outpouring of volcanics are associated with these slates.

Utror Volcanics

Utror volcanics in Kohistan form a linear belt trending northeast-south west, between Kalam in Upper Swat in the east, and in Suraighat mountains and Jabazai near Shahi in the west in the western part of Dir, near Afghanistan border. Their southern contact is with the Baraul Banda Slates whereas extensive bodies of diorites, both younger and older to the volcanics, make a sharp contact along the northern fringe of the volcanics. The maximum width of the volcanic body is in the vicinity of Utror, the type section, where they span 4—5 km wide belt whereas in the west near Shahi they occur interbedded with the Baraul Banda Slates and have a thickness of about 3000 meters.

The Utror volcanics are comprised of andesite, dacite, rhyolite, tuffs and agglomerate of grey, green, brown and pink hues, which are thin- bedded to massive, except volcano-clastics, which are angular to subrounded and usually form a confused mixture with the flows. The ignimbritic character in the tuffs is quite prevalent. Due to fine texture and intense alteration, it becomes difficult to decipher various cycles of volcanism with authentisity. However the cumulative evidence based on studies of several isolated sections in the field point out to five major cycles.

First phase mostly constitutes pink and brown volcanic rocks, which are quite widespread and dominate in some sections. They contain tiny phenocryst in a fine-grained groundmass and form xenoliths in the older rocks. The second phase contains light to dark green rocks which are very fine grained with no phenocrysts, but vesicles are quite common. The third phase is grey to brownish-grey rocks with well developed phenocryst in fine to medium grained ground mass. The fourth cycle is represented by agglomerate and tuffs. Volcano-clastics appear to belong to the last phase which are usually banded and composed of large fragments mixed in tuffaceous lava matrix.

The general texture of the volcanic rocks is fine to medium grained, holocrystalline, porphyritic with euhedral crystals. Plagioclase (andesine), quartz and hornblende occur as major constituent minerals with sphene, ores, clinopyroxene usually forming the accessories; the latter being not very common. Small laths and crystals of biotite, muscovite, epidote, chlorite, sericite and caleite usually occur as products of weathering, alteration or low grade metamorphism.

Utror Volcanics interbed the Baraul Banda Slates which on the basis of fossils are placed in the lower Eocene. Thus the age of the utror volcanism is considered to range from Middle to Upper Eocene.

KOHISTAN COMPLEX

Kohistan Complex includes the mafic and calc-alkaline rocks of Kohistan island arc which incorporate five main mafic and ultramafic rock types, namely, Pattan garnet-granulites, Jijal ultramafics, Kamila amphibolites, Bahrain pyroxene-granulites and Deshai diorites. A cursory discussion on Kohistan Complex will be attempted here because separate papers on these bodies have been contributed by Jan, Majid, and Khalil and Afridi in the subsequent pages.

The Jijal complex, a northwest trending ultramafic body is exposed for about 6 km on the western bank of the Indus between Jijal and Dubair Qilla and extends into Allai, east of the Indus in the vicinity of Barai, Pashtokaley and Dumdarra. The other noteworthy outcrops of Jijal Complex are located between Alpuri and Shangla pass, Dargai Klippe in Malakand which has extension into Mohmand area and isolated peridotite bodies mentioned in Thak nala (Shams, 1975) in Chilas area and near Babu Sar in the upper reaches of Kaghan in Hazara. Besides, many small bodies of ultramafic rocks have been noticed strewing the metasediments and amphibolites in the MMT zone in Dir, Swat and Kohistan.

The thickness of Jijal complex varies from 4500 meters between Jijal and Pattan to less than 200 meters east of the Indus in the Allai area. The main rock types constituting the ultramafics are pyroxenites, peridotites and serpentinites. The Jijal complex, on the south has thrust-over the Besham Group, comprised of metasedimentary rocks.

Garnet granulites with the paragenesis of high pressure granulite facies is in order of garnet + diopsidic pyroxene + plagioclase + hornblende $\pm$ quartz $\pm$ rutile $\pm$ clinozoisite. The garnets are pyrope-almandine-grossular mixtures. According to analysis conducted by Jan, pyroxenes are aluminous and contain uPto 10 percent of $Al_2 O_3$. The pyroxenites and peridotites with densities 3.3 to 3.4 and garnet-granulites with densities 3.2 to 3 5 are distinctly higher than the surrounding rocks and represent the tectonically transported slices of the upper mantle.

Martin *et al* (1962) first described a suite of rocks with predominance of hornblende near Charbagh in Swat and named it as the Upper Swat Hornblendic-Group. The main rock types distinguished in this suite are diorites, metadiorites, hypersthene gabbros and garnet-amphibole gneisses. These northeast-southwest trending rocks occupy a larger part of the northern Kohistan and extend westward into Dir where the outcrops are flanked by younger diorites, and the rocks of "hornblendic group" are gradually assimilated near the contact.

Jan (1977) has divided the hornblendic group of Martin *et al* into Kamila Amphibolites and Bahrain Pyroxene Granulites. In the field, amphibolites could be distinguished as light coloured homogeneous and massive variety, and dark banded or gneissose variety. Amphibolites are medium to coarse grained, and have intrudded the banded and fragmentary tuffs already contaminated with sedimentary rocks by assimilation. Metamorphism post-dates the assimilation process, thus varyingly affecting the whole mass. Foliation, compositional banding and microfolding in the more schistose rocks are quite common. A cumulative analysis, based on petrological examination of several thin sections revealed: hornblende (45 %), andesine-labradorite (25 %), clinoziosite (10 %), quartz (10 %) and almandine garnet (6 %).

The pyroxene granulites are basic to intermediate in composition and were probably intrudded in their present environment as remobilized crystalline material capable of plastic flow. Jan (1977) considers their passage to final abode in rather cooler temperature as a result they could not produce metamorphism higher than the amphibolite grade.

Deshai diorites occur as northeast trending body on the southern and central part of Kohistan island are bordering Chitral and Diamir. Three types of diorites have been distinguished by Khalil *et al* (1973) and Jan and Mian (1971). These are gneissose diorites, smoky diorites and orbicular diorites. Recently, Jan has added another variety called Laikot diorites which are generally homogenous and massive.

The diorites are grey te dark grey and greenish grey, medium- to coarse-grained and contain well- developed closely spaced vertical and oblique joints. Gneissose diorites are quartz rich and are most widespread. Orbicular diorites occur in the upper reaches of Ushu on the eastern side of Ushu Gol and exhibit typical development of orbicular structure.

The individual orbicules are rounded to ellipsoidal with diameters ranging from 3 cm. to 20 cm. Smoky diorites are usually medium-grained and are of darker hue and occur in Gabral and Ushu areas.

Majid (1978) has produced a petrological classification of Deshai diorites based on coloured constituents, viz. (a) hornblende-biotite diorites and (b) pyroxene-biotite diorites, the former compares with the smoky diorites of Khalil *et al*.

On the basis of these classifications one may consider Deshai diorites belonging to more than one phases of evolutionary history. The metamorphosed gneissose quartz diorites may be the earliest. As indicated by Majid, the source of Deshai was not of sialic character because the values on their mineralogy are distinctly different from the normal average of the crustal rocks. He considers the evolution of diorites from a parental magma which by some process of gradational differentiation produced calc-alkaline series in Kohistan. Jan (1977), while analysing Deshai diorites and pyroxene-granulites of Kohistan has identified different alkali and some trace elements pattern in the former and does not consider them co-magmatic with the latter.

GREENSTONE COMPLEX

The earlier workers, who mapped Gilgit region have differentiated a sequence containing heterogenous and multi-lithological assemblage of rocks with predominant greenish hue and called it Greenstone Complex, (Ivanac *et al*, 1954) or Greenstone Volcanics in Chitral, (Calkins *et al*, 1969). These rocks are developed on both the flanks of the Kailash Range with east-west extension, through Ghizar and Gilgit valleys to as far as Shigar and Shyok valleys in Bultistan in the east.

Its western extension in Chitral beyond Laspur has remained eclipsed for want of detailed geological informations. In this area, though its morphological characteristics were discussed by the earlier workers, yet they never endeavoured to give it an independent stratigraphical entity.

The present author on the basis of his studies believes that most of the material for the greenstone complex has been derived from the Dras and Panjal volcanics, located to the east and the basin of deposition has extended to as far west in Pakistan as Chitral and even across the border in Afghanistan. Its extension is interrupted and sliced by the younger granite intrusions. The

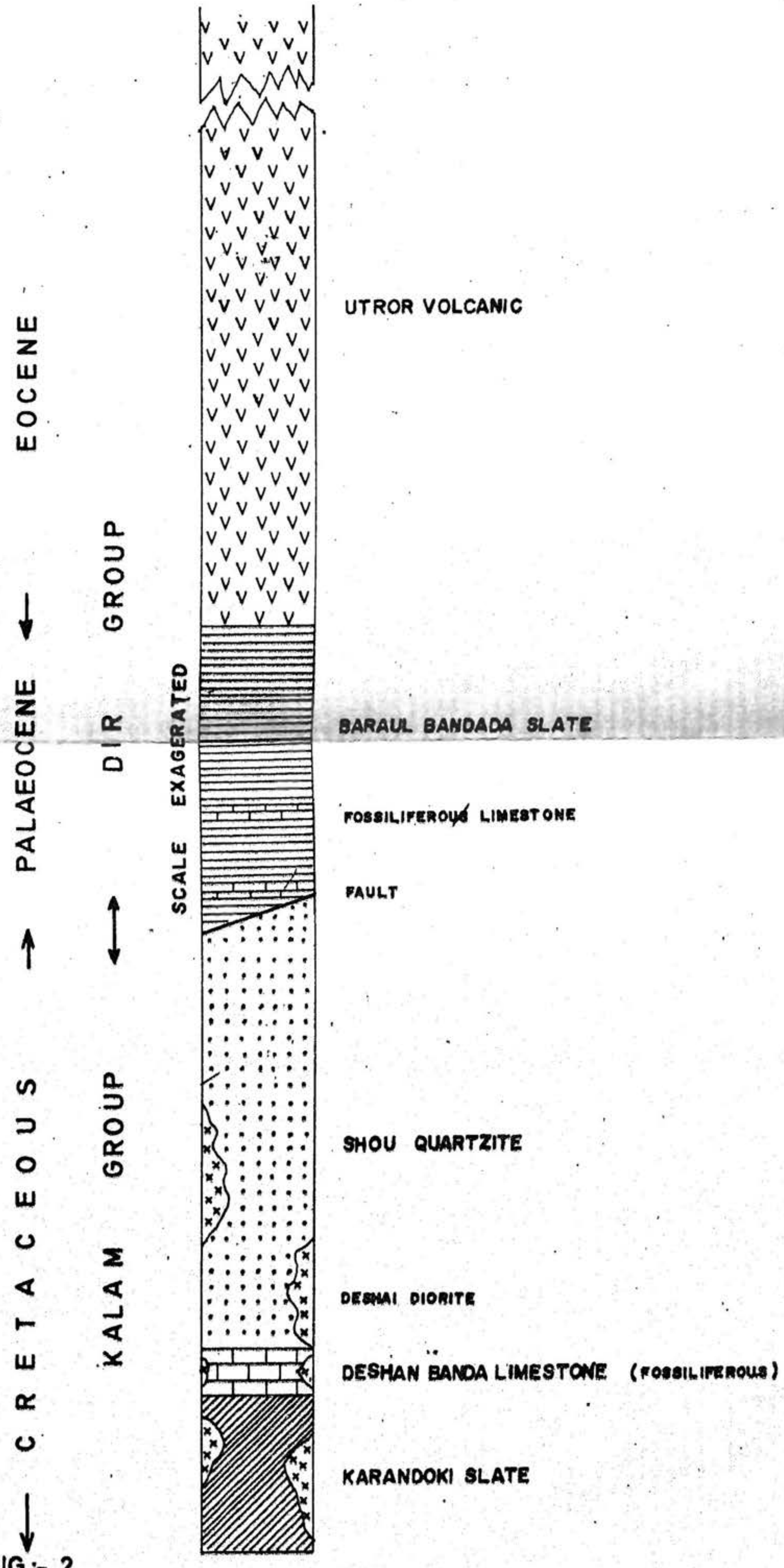

FIG:- 2
COLUMNAR SECTION OF CRETACEOUS-LOWER TERTIARY SEQUENCE AT KALAM

greenstone complex, throughout its course from east to west, gives a typical green and yellowish-green hues except that lithological variations have been observed in various sections.

The maximum thickness of greenstone complex is recorded in Gilgit area: between Gilgit and Chalt, Gilgit and Gopis, Gopis and Yasin and south of Gilgit, where it attains several hundred meters thickness.

Greenstone complex consists of an assemblage of volcanics and sedimentary rocks which have been metamorphosed to varying degrees as a result of its involvement in the regional tectonics and intertonguing with the granite and granodiorite. The metamorphosed rocks, as a result, have become rich in micas, hornblende, epidote, and serpentine minerals. The typical rock constituents of the complex are quartzites, mica schists, hornblende schists, hornblende gneisses, medium crystalline limestone and marble, epidiorite, dolerite, basalt, rhyolite, andesite, hornblendite and agglomerate. The fragments in agglomerate are of andesite, red and grey chert, tuffs, aphinitic basalt and fine to coarsely crystalline marble. The hornblende schists and epidiorite represent the metamorphosed dolerite.

Greenstone complex comprises an important stratigraphic sequence in the northern part of the Kohistan island arc. The pillowed serpentines associated with the complex point out to volcanic activities associated with the sediments under water during deposition. The complex has got a faulted contact on the north with the metamorphosed rocks equivalent to Dumordu Formation. The fault is a southward directed thrust which places the Dumordu Formation over the Greenstone complex.

The earlier workers, on the basis of Permo-Carboniferous fossils found in the older rocks (Dumordu Formation/Darkot Group) have placed the Greenstone complex in the Triassic. During a recent investigation, conducted in Baltistan alongwith Mattauer, Tapponnier and Andriux from Montpellier University, France, the former discovered fossiliferous slates in the lower part of greenstone complex near Tissar in the upper reaches of Shigar Valley. Fossil tentatively identified is Glubotruncana, which gives a Cretaceous age to the complex.

YASIN GROUP

Yasin Group constitutes the youngest Tethyan remnant, located on the northern edge of Kohistan island arc, which is involved in the tectonics of the northern megashear. In Yasin section, it is 800 to 1000 meters thick and occurs as a lensoid shaped body, exposed on both the sides of the valley. This name was first assigned by Ivanac *et al* and the author would like to retain this name to incorporate all the sedimentary and volcano-clastic rocks which are coeval and are distributed elsewhere in Chitral and Baltistan, occupying the similar stratigraphic horizon,

Yas;n Group in Gilgit overlies the greenstone complex with a well marked unconformity which is disrupted by overfolding or faulting.

It occurs as tectonic slices in isolated outcrops along the northern megashear in Gilgit, Chitral and Baltistan. On the basis of rock assemblage, Desio (1963) had differentiated three litho-units, giving them the status of formations. These are upper Taus Shales, middle Manich Sandstone and the lower Ghojalti Formation.

The author suggests a two-fold subdivision of the Reshun Group, the upper and lower, based on lithological, faunal and volcanic rocks associations.

i. Light to dark grey limestone semi- to medium- crystalline thin-bedded to massive, shaly and fossiliferous near the top. Grey, green and maroon shales and slates occur as intercalations on the top of the bed. Among the fossils Hippurites, Corals and Orbitolina of Lower Cretaceous age are recorded. Lenses of conglomerate are also associated near the top and base of the bed.

ii. Thin- bedded grey slates, flaggy sandstone and conglomerate with rhyolite, basalt, tuffs and agglomerate

In Baltistan, downstream of Skardu in the Indus Valley and in the Shigar Valley near its confluence with the Indus, metasediments are exposed which show higher grade of metamorphism than the surrounding rocks. These rocks extend westward over the northern edge of Nanga Parbat-Haramosh loop and appear in the vicinity of Sassi in the Indus Valley and south of Hini and Chalt in the Nagar and Hunza valleys. Another outcrop extends in east-west direction south of Gilgit.

These rocks are located south of the northern megashear in the Kohistan island arc. In Baltistan, they include biotite schists, biotite gneisses and amphibolites in the Shigar Velly whereas mica schists, garnet-mica schists and gneisses are encountered in the Indus Valley downstream of Skardu.

In Gilgit area these rocks are represented by slates, phyllites, mica schists, graphitic schists, staurolite schists, quartzites and crystalline limestone.

In Bàltistan, Desio (1963) called them Katzarah Formation, whereas in Gilgit area Wadia (1932) on the basis of graphitic association correlated part of the sequence with the Salkhala Formation. Ivanac *et al* included these rocks in the Darkot Group of Permo-Carboniferous age.

The author has grouped these rocks under Chalt Formation, a name assigned earlier by Gansser (1964) to an outcrop of similar lithological characteristics located south of Chalt in Hunza Valley.

Chalt Formation lies between the two major tectonic scars of this region: on the north it is bounded by the northern megashear and on the south it is involved in the Nanga Parbat-Haramosh transverse antiform fold. Consequently these rocks have been subjected to severe stresses and thus have attained higher grade of metamorphism than the other metasedimentary outcrops of the Island arc. Nevertheless, it is also possible that the Chalt Formation, being in close location to the northern megashear, some tectonic slivers of Dumordu Formation of the Asiatic Mass are added in the subducted zone of the Island arc. Chalt Formation is placed in the Cretaceous.

ASIAN MASS

Hindu Kush Sequence in Chitral

The oldest sequence in Chitral is represented by gneisses, slates and marble, which underlies the fossiliferous rocks of Devonian age. These rocks have been assigned the names of ***Kesu Gneisses*** (Desio, 1975), ***Chitral Slates*** and ***Gahiret Marble*** (Hayden, 1915). The slates extend from the Afghanistan border in the west to as far east as the border of Gilgit in the vicinity of Mastuj with a general east-west strike. Near Mastuj, the Chitral Slates merge with the Darkot Group of Ivanac *et al*, which on the basis of fossils is assigned a Permo-Carboniferous age.

Chitral Slates are comprised of slates and phyllitic slates with sericite, developed in the relatively more metamorphosed zones. Light to dark grey is common colour but green chlorite-rich and black carbonaceous bands are not uncommon. Intercalations of silty and calcareous bands are common. Well cleaved slate horizons have sporadic destribution and are localized in those sections where the slates are dominantly pelitic and structurally less disturbed. The slates contain sills, dykes and veins of dolerite, diorite, gabbro, pegmatite, aplite and quartz. The first and the last mentioned bodies in basic and acid suites are more frequent.

The author's past experiences on Hazara Slates, Dogra Slates, Manki Slates, Landikotal Slates, Sirikot Slates and their equivalents elsewhere on the Indian Platform in Pakistan, impel him to correlate them on lithological basis with the Chitral Slates. Gahiret Marble, forms a rim around the the Chitral Slates on the south. Its north-eastern outcrop is exposed on the western bank of Yarkun river near Mastuj and in the west it extends into Afghanistan. The marble in thin bedded to massive, white to pale yellow and medium- to fine-grained.

Gneisses are exposed between Drosh and Gahiret and have got a faulted contact with the overlying Gahiret Marble. Desio (1975) had named this bed as Kesu Gneisses. They are dark grey with quartzose-feldspathic composition.

Cherun Quartzite and overlying Shogram Formation on the basis of fossils are placed in the Devonian. Their thickness according to Desio (1966), varies from 600-800 meters in the vicinity of Shogram but in Cherun Gol and Reshun Gol it measures to 350-500 meters. The lower contact of Cherun Quartzite is faulted, whereas the upper one has shown a well marked unconformity with the overlying Shogram Formation.

Cherun Quartzite in the type section is white to light grey on fresh faces and yellowish-brown on weathered surfaces. It is thin bedded and medium textured, the cementing material being siliceous. It can be followed in a thirty km long belt between Parpish and in the vicinity of Buni in Mastuj Valley with more or less a constant thickness. In Cherun Gol, its type section, thickness is about 120 meters. On the basis of brachiopod fossils examined by Talent (1978), he considered them partly to be Late Silurian.

The overlying *Shogram Formation* is comprised of three main lithological elements: i. a lower massive dolomite, ii. a middle flaggy dolomite, and fossiliferous light to dark grey limestone with interbedded dark grey to black splintery shales, and, iii. an upper quartzite. Out of these three units, the lower unit is the thickest varying from 200 to 250 meters. The middle limestone bed yielded fossils of late Devonian age.

Recent studies by Talent *et al* (1978) have brought to light many other sections in Chitral where the rocks of Devonian age are developed. Some of these sections were reported by the earlier workers too. These sections occur at or near Shogram which is the type section, others are Kuragh, Barum Gol, Owir An, Turikho Valley, Baroghil and Shower Shur. In all these sections fossils ranging from Early to Late Devonian are recorded.

The Devonian rocks usually form steep ridges along the skyline and have an extensive distribution in Chitral. They spread over an area of approximately 140 km long and 50 to 80 km wide belt along Mastuj and Yarkun Valley, between Partsan in the southwest to Shower Shur located in the northeastern tip of Chitral.

Sarikol Slates were first differentiated by Hayden (1915), who named them as Sarikol Shale. These rocks are located in the northwestern corner of Chitral but bulk of them are exposed in little Pamir in Afghanistan, Sarikol Range in Turkestan and part of Mustagh Ata Range in China. The upper reaches of Mastuj Valley has well exposed sections of Sarikol Slates located near Shah Jinali Pass, on the ridge near Khost Gol, between the villages of Lon and Barumkagh and in Broghil Pass.

Sarikol Slates are comprised largely of thin bedded slates and splintery slaty-shales of light to dark grey colour alongwith subordinate coarse quartzitic sandstone, dark grey limestone and conglomerate which contain associations of epidotized volcanic rocks.

Hayden found Triassic fossils in the limestones associated with the top bed, on the basis of which he considered the age of Sarikol Slates to be partly Triassic and partly Palaeozoic. Tipper (1924) found several specimens of *orthoceras* and crinoid stem fragments and assigned them a Devonian age. The latest work of Talent *et al* on the fossils of Sarikol Slates from several sections in Chitral, places part of the formation in the Triassic.

The name *Parpish Limestone* has been assigned to fusilinid limestone bed located about 3-4 km northeast of Parpish village. Many other sections in Chitral having mapable exposures of this limestone are reported by the earlier workers too. Some of them are: Phasti Gol, Reri, Kuragh, Kosht Gol, Turigram, Tirich Gol and Khot Pass. This limestone forms the prominent scarp and is strongly folded. It is thin bedded to massive, light to dark grey and medium to fine grained. On the basis of fusulinids and other fossils, the Parpish Limestone has been assigned a Permo-Carboniferous age.

In Chitral, the youngest Tethyan sediments are generally known as *Reshun Formation*. Tnis name is first noticed in the geological literature in a paper by McMohan and Huddleton (1902), where it is referred to a bed of conglomerate in the vicinity of Reshun village. Hayden (1915), who subsequently visited this section, used the name "Reshun Conglomerate". Calkin (1969), Stauffer (1975) and Talent (1978) further elaborated the usage of this terminology by including red argillaceous bed alongwith conglomerate. In Chitral the Cretaceous-Lower Tertiary sedimentary rocks constitute the following three major litho-stratigraphic units.

Cherun Quartzite
Shogram Formation

..............unc..............

iii) Rudistal Limestone

ii) Red and maroon argillaceous bed

i) Conglomerate.

The Cretaceous limestone forming a tectonic slice was first reported by Hayden near Drosh which was fossiliferous and contained Orbitolina. Another thick outcrop of this limestone is found east of Shoghor in Lutkho Valley. The limestone is grey to black, thick bedded to massive and medium crystalline Its contact with the Chitral Slates is faulted. In the northwest, this limestone extends across Afghanistan border-whereas in the northeast it is exposed as far as Partsan. Here its apparent thickness is about 2000 meters which appears to be due to repetition as a result of faulting. Beyond this point, towards its north-eastward extension, the limestone laterally changes to red slaty-shales and then to conglomerate between Pasti and Reshun.

Tipper (1924) had also reported Cretaceous limestone with Orbitolina and Rudists of Eocretaceous age in the Krinj stibnite mine which extends northeast in the direction of Partsan and Reshun. The Cretaceous limestone has thick developmet outside Reshun section but during its extension towards Reshun it gradually changes facies and intermingle with the red argillaceous bed and conglomerate.

The author considers the limestone as a part of Reshun Formation and proposes elevation of this sequence to a group status, which should incorporate three litho-units: Conglomerate; Red argillaceous bed and; Limestone.

Reshun Group in Chitral is divisible in two belts, one of them is associated with the volcanic rocks of the island arc and extends from Chalt-Yasin in Gilgit through Chumerkhan and Laspur, thence following the course of Sassi Gol and appearing in the vicinity of Drosh. Another extends through Shoghor, Reshun, north of Awi over Khot Pass along the Yarkun river and terminates somewhere in the vicinity of Broghil. The presence of Shanoz Conglomerate considered equivalent to Reshun Conglomerate, between Passu and Khaiber in the Karakorm justifies its extension further northeast of Broghil. This belt unlike the previously mentioned, does not show any volcanic rock association. However it does poin out to the presence of another tongue of Tethys during Cretaceous - Lower Tertiary time, traversing the mainland across the Asian continental margin towards Little Pamirs.

In Baltistan, the already reported Cretaceous-Lower Tertiary sedimentary rocks included Burji Formation, Wakka Formation (Desio, 1964), Burzil Pass outcrop (Wadia, 1937) and reworked volcano-clastics of Shyok valley. As indicated earlier, recently some fossiliferous slate samples showing Cretaceous fauna have been collected in a nala south of Tissar in the upper reaches of Shigar Valley. This section is the extension of the northern megashear in Baltistan with which the outcrops of greenstone complex are associated. It is expected that thin slivers of sedimentary outcrops equivalent to Yasin and Reshun Groups disrupted by shearing, may occur along this tectonic line.

Karakoram Sequence in Gilgit and Baltistan

In Karakoram area, Gansser (1964) has differentiated three thrust zones. i. Northern Karakorm Tethyan sedimentary zone, ii. Central metamorphic zone with plutonic rocks and iii. Southern volcanic schists zone. Among these three zones, the first two zones fall in Karakorm and are underlain by a thick mass of sedimentary and metamorphic rocks, filling the southern margin of the Asian Platform. The third and the last mentioned zone with widespread volcanics and volcano-clastics is incorporated in the Kohistan Island arc, which is seperated from the former two zones by the northern megashear.

In the Central metamorphic zone, two rock units are differentiated. These are named Baltit Group, Stauffer (1975) or Dumordu Formation, Dèsio (1977) and Karakoram granodiorite batholith. Dumordu Formation is over 2000 m. thick and consists of marble, various type of schists and gneisses.

Marble is thick- bedded to massive, white to light grey, sacchroidal to coarse-grained and is intrudded by pegmatite, aplite and quartz veins. These intrusions are more frequent in the lower part of the section where contact minerals become more common in occurrence. Among the schistose rocks, mica schists, quartz schists, calc schists, garnet-mica schist and kyanite schist are noteworthy. Para-amphibolite bands in the gneissose part of the section are occasionally noticed.

Dumordo Formation has got tectonic contact with the Greenstons complex, Chalt Formation and Yasin Group with which it is associated on the south. This tectonic line constitutes one of the main suture zones in the northern part and differentiated as northern megashear along which the Dumordo Formation has obducted the latter. The Karakoram granodiorite batholith delimits its northern extension. The lips and tongues of acid igneous bodies intrude the Dumordo Formation along this contact. Dumordo Formation is tentatively placed in the Palaeozoic. ***Karakoram Granodiorite*** forms a linear belt which has been traced from Shyok Valley in Baltistan in the east and terminates south of Mastuj in Chitral in the west. It forms the main Karakoram Range and, in the Hunza Valley, its maximum width is over 2000 m.

Granodiorite is pale grey, medium-grained, sub-porphyritic and generally massive, except in those sections where it is involved in cataclastic metamorphism and gneissose texture is well developed. Accordion type vertical jointing, usually parallel to gneissosity is well displayed in the batholithic

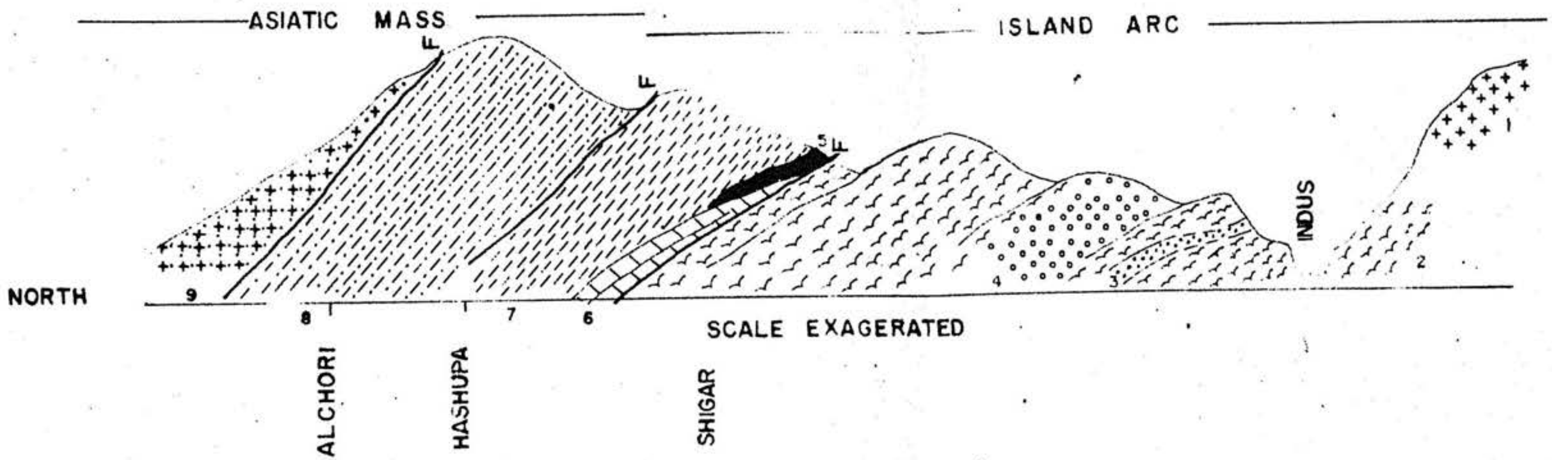

FIG:-3 A DIAGRAMMATIC GEOLOGICAL SECTION ALONG SHIGAR VALLEY, BALTISTAN.

1. LADAKH GRANODIORITE, 2. BIOTITE SCHIST AND GNEISSES, 3. META-GABBRO DYKE, 4. AMPHIBOLITE, 5. VOLCANIC: BASALT, ANDESITE, 6. MARBLE BAND 7. GREENSTONE COMPLEX, 8. DARKOT GROUP / DUMORDU FORMATION 9. KARAKORAM / DASSU GNEISSES

FAZAL AHMAD

mass along the skyline of Karakoram Range. Pegmatite, aplite and quartz alongwith subordinate mafic veins, sills and dykes are the common intrusions in granodiorite.

The essential minerals according to decreasing order of abundance are quartz, andesine and biotite, whereas hornblende, chlorite, apatite, clinoziosite, epidote and ores usually constitute the accessories.

Rb/Sr dating on two samples by Desio *et al* (1964) gave Karakoram Granodiorite an age of 8.6 m. y., thus placing it in Pliocene.

In the northern Tethyan Sedimentary Zone, six litho-units have been differentiated by Desio, Schnieder, Stauffer and others. These are Misgar Slate, Kilik Formation, Khaiber Series/Gircha Formation, Gujal Dolomite, Passu Slates and Shanoz Conglomerate. These rock formations are located on the northern side of Karakoram Granodiorite batholith and some of them have extensions in the north and transgress across the border. They occur on the same tectono-stratigraphic trend on which the rock sequences of Hindu kush in Chitral and extend eastward towards Karakoram, forming a concentric bend. Their correlation is based on similar lithological characteristics and common affinity in faunal assemblage.

Ivanac *et al* have grouped all the metasedimentary litho-units occuring on the north and south of Karakoram Granodiorite batholith under Darkot Group, which has been extended in the east as far as Shigar valley and in the west to the vicinity of Mastuj in Chitral. The author, following the tectonic classification of Gansser, (1964) considers the Dumordo Formation in Gilgit and Chitral Slates, Kesu Gneisses and Gahiret Marble in Chitral to constitute the oldest stratigraphic units on the Asian Platform.

A brief lithological description alongwith their fauna, of the six litho-units differentiated in the northern Tethyan Sedimentary Zone in the Upper Hunza valley is given below.

Misgar Slate consitutes nearly 3500 meters thick monotonous sequence of light to dark grey slate and phyllitic-slate exposed in Barab, Kilik. Gonduri, Giraf and Khunjerab valleys in upper Hunza. The slate contains silty bands which at places form thick intercalations of white to light grey, thin- bedded, fine- textured quartzite. Thin intercalations of carbonaceous bands are also associated with the Misgar Slate which impart black tinge to the rocks involved. Among the igneous intrusions, dolerite sills and gabbroid bodies are the earliest, whereas, pegmatite, aplite and quartz-syenite porphyry are the latest and have extensive distribution. No fossil has been reported from the slate horizon though Misgar Slate, on the basis of stratigraphic horizon it occupies is placed in the Palaeozoic.

The name *Kilik Formation* was first assigned by Desio ***et al*** (1963) to a sequence of dominantly calcareous rocks forming a linear belt between Misgar Slates lying on the northeast and Gircha Formation to the southwest. It is about 2000 metres thick and consists of medium crystalline limestone and dolomite with thin partings of light grey, thin- bedded arenaceous slate and red quartzites. Desio (1966) on the basis of crinoidal stems has assigned an age of Devonian-Lower Carboniferous to Kilik Formation and correlates it with the Shogram Limestone of Chitral.

Gircha Formation was also differentiated by Desio *et al* (1963) as a mapable unit. It is comprised of a complex sequence of argillaceous-arenaceous-calcareous beds and have extensive distribution in Lupghar, Chapursan and Abgorch valleys. This formation had also been named as Khaiber Series by Clark, as reported by Ivanac ***et al*** (1956).

It is about 4000 meters thick and the upper part dominates in dark argillites with thin limestone/dolomite intercalations. The lower part contains light coloured sandstones in abundance which are thick bedded to massive with thin intercalations of calcareous-arenaceous shales. Veinlets of quartz are common. In the calcareous part of the sequence, brachiopods, corals, bryozoans and foramanifera were collected, which were referred to the Lower Permian age.

The name ***Passu Slate*** was first assigned by Schnieder (1957) to a thick sequence of dominantly argillaceous rocks. Its thick outcrops are observed in the vicinity of Passu village and in Ghulkin and Batura valleys, with a maximum thickness of over 1500 metres. The rocks constituting Passu Slates are, dominantly arenaceous slates and phyllitic-slates with dark grey limestone and subordinate grey and yellowish grey quartzite intercalations.

The stratigraphic position of Passu Slates is uncertain. In some sections it lies between the Karakoram Granodiorite and Gujal Dolomite but both the contacts are tectonic. Desio (1972) correlates the Fusulina Limestone of Gircha Formation with the Pseudofusulina of Passu Slates and places them in the Upper Palaeozoic.

The name Gujhal Dolomite was assigned by Desio *et al* to a dominantly calcareous formation, earlier called Gujhal Limestone by McMohan. The rock type in increasing order of abundance are, dolomite, dolomitic-limestone, limestone, conglomerate and arenaceous slates. The calcareous rocks are thick-bedded to massive, white to light grey, medium-to fine-grained and semi - to medium crystalline. The dark grey, thin-bedded siliceous slates form thin intercalations. Conglomerate occurs in two horizons and are lithologically different. The lower one gives a greyish tinge, having the characteristics of a transgressive conglomerate. The upper one which lies in the middle part of Gujhal Formation is multi-coloured and the cementing material is dominantly iron oxide. Calcareous breccia forms the base of the Gujhal Formation.

A maximum thickness of *Gujhal Formation* as reported by Desio is over 500 meters. The main localities where Gujhal outcrops have enormous distribution are in the range located to the north of Batura Glacier and in the neighbourhood of Passu. The base of the formation contains shells of Lamellibranchs, doubtfully interpreted by Hayden (1915) to be Hippurites, whereas Desio considers them to be poorly preserved shells of Megalodon. The latter author assigns a Permo-Triassic age to the Gujhal Formation.

A thick bed of conglomerate with epigrade metamorphism is located on the southeastern flank of Mt. Shanoz, near the road connecting Passu with Khaiber, on the right bank of Hunza river. The cobbles and pebbles in the conglomerate bed are dominantly calcareous which are embedded in a fine-grained, yellowish coloured siliceous matrix. Similar type of conglomerate bed has earlier been reported by Desio amid the glacial deposit of Choga Lungma, which according to him has been derived from the eastern spur of Haramosh where it occurs in association with the Cretaceous formation.

Earlier, Hayden correlated *Shanoz conglomerate* with the Reshun Conglomerate of Chitral which overlies the Rudist and orbitolina limestone of Lower Cretaceous age. Desio also considers the Shanoz Conglomerate to be equivalent to Reshun Conglomerate.

GRANITES

A general discussion on the granites of Kohistan and those occuring on the Indo-Pakistan and Asian Platforms is intended here to decipher and delineate the entities of various episodes of granitization associated with the long period of Himalayan orogeny. The author, while attempting this problem is well aware of constraints in having available adequate data on geochronology and geochemistry of the granites of this region. As a result regional structure, texture and structure of the rocks and petrological classifiation will form the base to attempt an approach to realize the desired results.

The word granites here will incorporate the acid igneous bodies, consisting of various types of granites, granodiorites, ortho-gneisses and associated younger intrusives like pegmatites, aplites, quartz and mafic rocks.

The name Ladakh Granodiorite was first used by Ivanac *et al* in which they incorporated the acid igneous bodies encountered in Kohi-Ghizar and Gilgit areas, east of the Chitral border. The Ladakh Range is located in Baltistan and constitutes high ranges of Deosai plateau and Shyok Valley, south of Skardu. The eastern flank of the Nanga Parbat-Haramosh loop delimits the western boundary of the Ladakh Range. Thus the name Ladakh should be confined to that part of the acid igneous mass which lies east of Nanga Parbat-Haramosh anticline.

In the attached Geological Map of Kohistan, the name Ladakh has been retained to designate all the acid igneous bodies occuring on the island arc in Baltistan and Gilgit area. But the author would like to suggest in the text a geographical differentiation for both the masses, which are separated by the Nanga Parbat antiform fold by a stretch of nearly one hundered kilometers.

The name Ladakh Granodiorite may be retained for the acid igneous mass associated with the Ladakh Range in Baltistan, east of the eastern limb of Nanga Parbat-Haramosh loop. Another name Kohistan Granodiorite may be added for that part of the acid igneous mass, located in the island arc in Gilgit area west of the western limb of Nanga Parbat-Haramosh loop. In the west, it extends as far as Laspur area in the vicinity of Gilgit-Chitral border and in the north its extension is delimited by the northetn megashear.

The granites of this region may be divided into following three groups: i. Those granites bodies occuring on the Island arc such as Ladakh Granodiorite and recently differentiated Kohistan Granite alongwith several other isolated bodies located in Dir and Swat, ii. Granites associated with the Asian platform such as Karakoram Granodiorite, Darkot Pass Granodiorite, Tirich Mir Granite and others found scattered in Baltistan and Chitral and iii. Hazara-Swat Granites which include Mansehra Granite, Nanga Parbat ortho-gneisses, Utla granite, Buner granite and gneisses and other small granitic bodies located in Khyber, Malakand, Mohmand and Kurram.

Three types of granites are differentiated which form major acid igneous bodies in this region.

i. A coarse to very coarse granite-gneiss, dull grey to yellowish white, sub-equigranular with abundant micas, some containing vermaculite too. Augen structure frequents in such type and xenoliths are quite conspicuous. These bodies are usually concordant to the regional structure and their contact with the country rocks is not sharp. Examples of this type are Buner gneisses, Besham-Karora granite-gneisses, and gneissose bodies around Thakot, Oghi and Batagram in Hazara,

ii. Fine to medium grained foliated gneisses which are dull white to light grey in colour. Micas are relatively less developed. They are rich in quartz and feldspar with subordinate sericite and some chlorite. They display subequigranular to equigranular texture. Their contact with the country rocks is not sharp. Most of such bodies belong to the later orogenic episodes than the ones discussed earlier. These may include Chakdarra gneiss, Ambela granite and Warsak granite.

iii. Normal or homogenous granites, which are white to light grey, medium to coarse and sub-equigranular to porphyritic. They are rich in feldspars and quartz whereas black tourmaline and other accessories including ores are quite common. They are post-tectonic and form discordant bodies, having sharp contact with the country rocks, e. g. Diwangar granite, Karakoram granodiorite and parts of Laddakh and Kohistan batholiths.

All the above mentioned three categories of granites are intrudded in varying proportions by younger generations of acid and basic igneous bodies forming veins, sills and dykes.

The earliest granite plutonism was associated with the marginal continental masses constituting thick metasedimentary sequences of Besham Group and Lower-Swat Schistose-Group on the Indian platform and their equivalents on the Asian Platform. The first category of granite-gneisses with well-developed augen structure thus belongs to pre-continental collision and may be older than 55 million years. The second category of granite is associated with the Himalayan orogeny which remained in force after the collision during Oligocene-Miocene/Pliocene periods. The last category of granites which are homogenous and are not as tectonized as the earlier ones, belong to the last phases of Himalayan orogeny during late Pliocene-Pleistocene period when the pressure on account of horizontal and vertical movements had considerably decreased.

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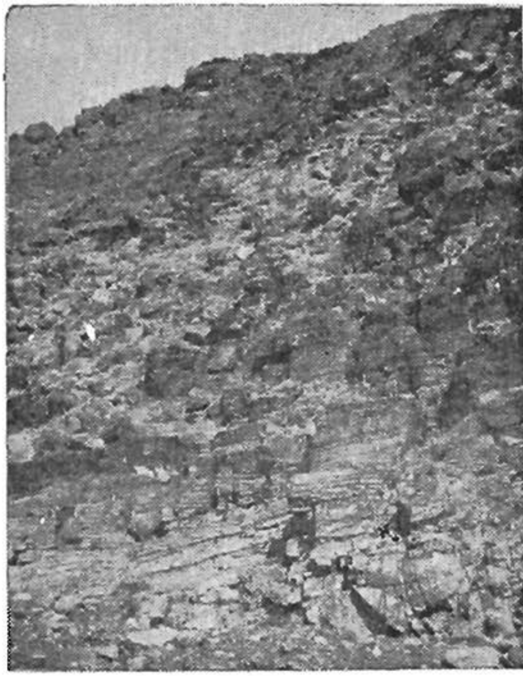
Plate 1

A



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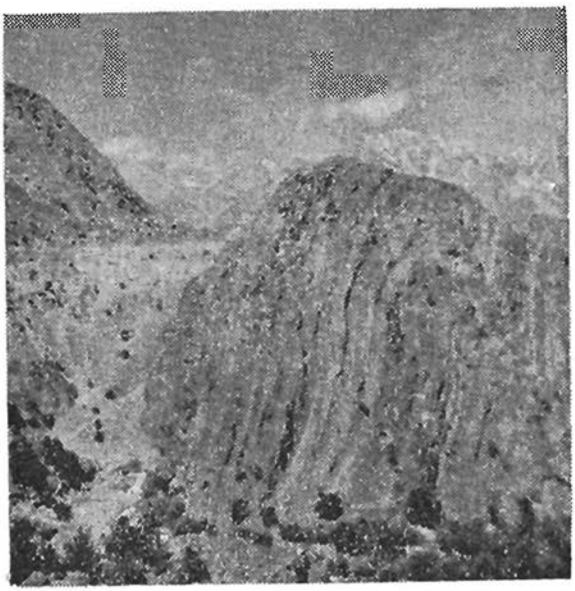

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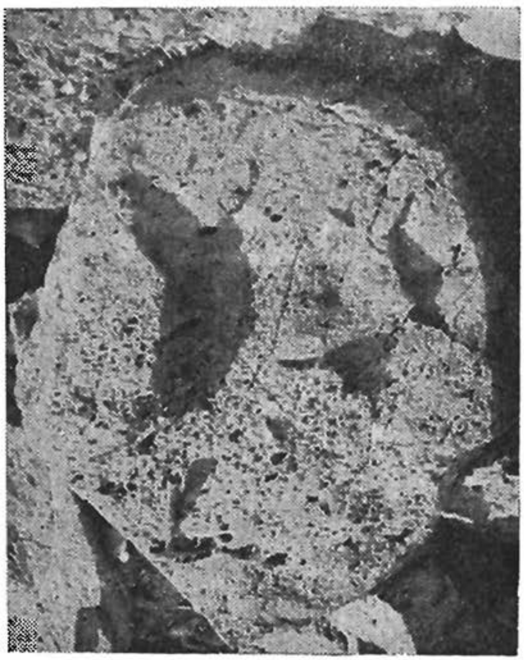

D

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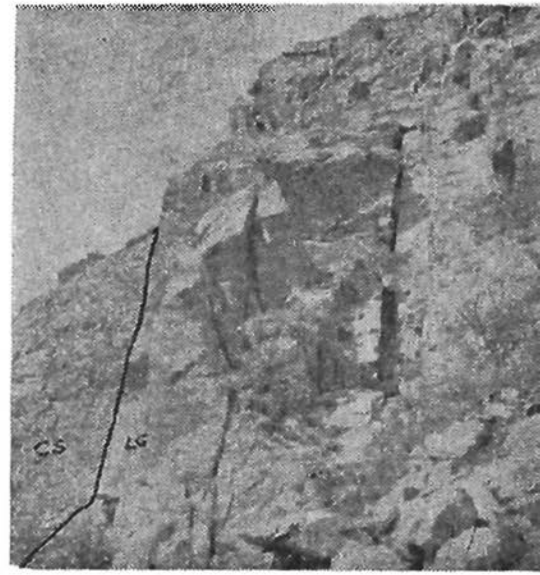

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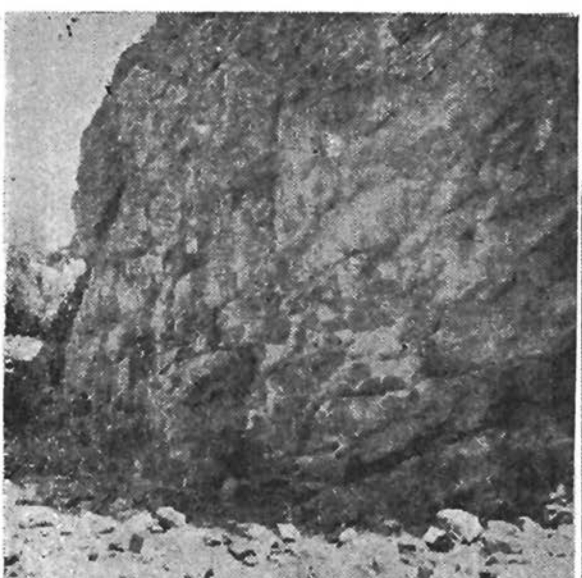

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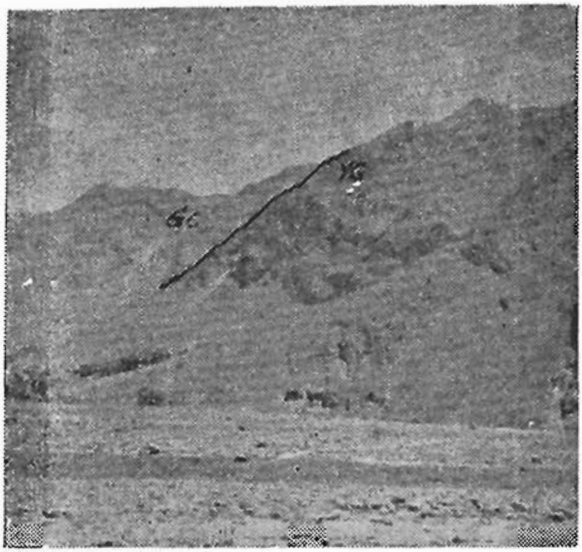

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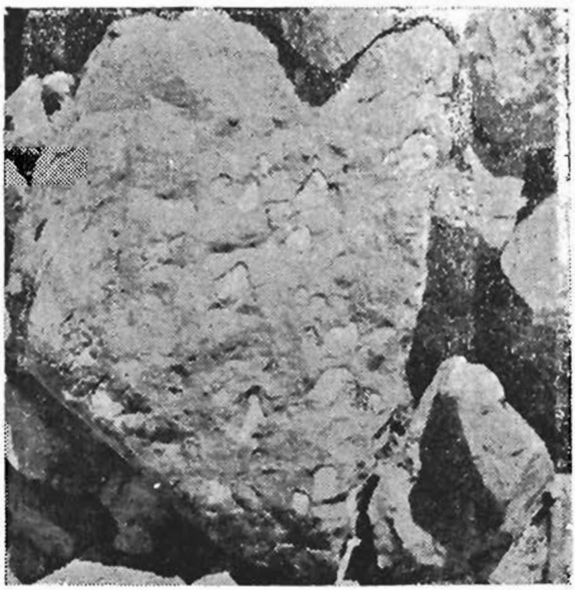

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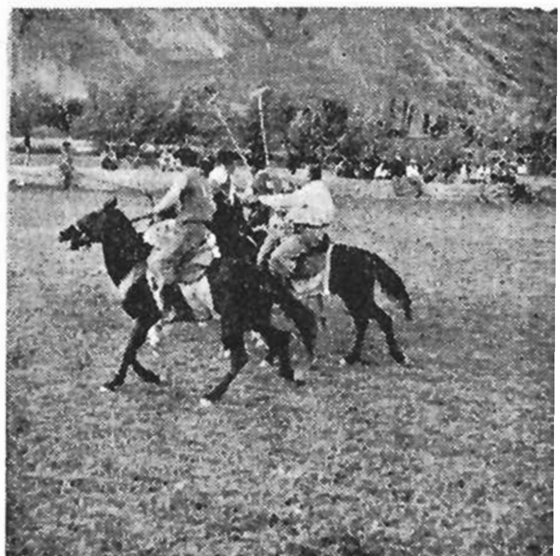

D

PLATE 1

A. Carbonate Sequence equivalent to Banna Formation on the margin Indo-Pakistan platform in Bajaur, Dir.

B. Banded Carbonate sequence; Banna Formation at its type section in Allai area, Indo-Pakistan plate margin.

C. Nanga Parbat ortho-gneisses exposed near thc axial plane of a transverse antiform, along the Indus valley road in Baltistan.

D. An andesite boulder with vesicles, derived from Utror volcanics, along Kalam—Gabrial road, Kohistan.

PLATE 2

A. A contact between Greenstone Complex and Kailash Granodiorite in Gilgit district, Kohistan.

B. Ladakh Granodiorite in contact with the Cretaceous metasediments in the Indus valley, south of Skardu, in Baltistan.

C. Volcanics associated at the base of Yasin Group, equivalent to Gojhalti Formation of Desio, in the vicinity of Yasin in Gilgit district, Kohistan.

D. Pillow structure in the volcanics, associated with the northern megashear in Chalt section in Gilgit district, Kohistan.

PLATE 3

A. A Ridge east of Yasin village—showing contact between Yasin Group and Greenstone Complex, Kohistan.

B. Acid igneous veining in Dumordu Formation near Baltit in Hunza valley, Karakoram, on the Eurasian plate margin.

C. Boulders of Shanoz Conglomerate near Passu in Karakoram, considered equivalent to Reshun conglomerate in Chitral, on Eurasian platform.

D. Polo, a popular sport of the people living in Hindu Kush and Karakoram is being played in Mastuj The outcrop on the other side of the valley exposes rocks equivalent to Passu slates, lying on the north of Karakoram Granodiorite botholith.