Geology of the Himalaya, Karakoram and Hindukush in Pakistan

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INTRODUCTION

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 late 1960 s, when the Karakoram Highway patched them with the modern amenities.

Inspite 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 alongwith 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 achnowledges the poineering efforts of these stalwarts who for the sake of science faced all kinds of hardships while tamming 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 programme was initiated. Since 1964, after being transfered from the Geological Survey of Pakistan 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 their existed a vaccum 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 shortcommings greatly handicapped a regional geological correlation with Ladakh and northeastern Afghanistan with which the Karakoram and Hindu Kush repectively, are geographically linked.

To answere and arrest these problems, the best course to be adopted for their solution was to conduct a geological mapping programme, 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 uptodate 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 shetches 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 though with meager published literature available to the author from across the border.

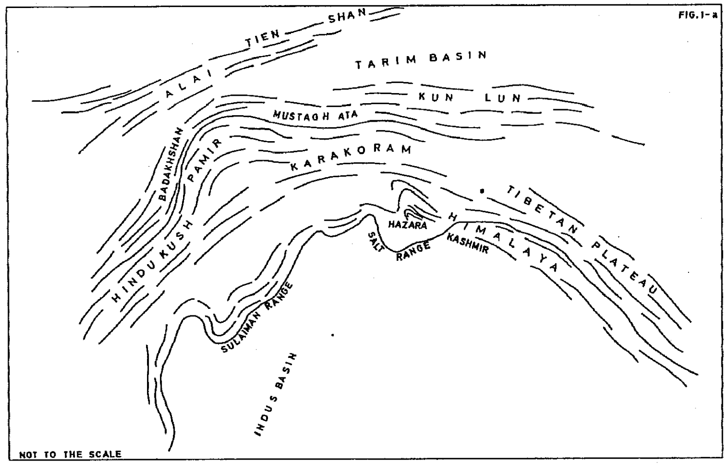
This is first attempt to present a regional geological mosaic of approximately 165000sq. km area in the northern Pakistan which was cradled by the tectonics emerging from the Indo-Pakistan-Eurasian collision and culminated during the attainment of structural configurations by the Pamir knot, Nanga Parbat-Haramosh 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 inacessibility 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.

GEOGRAPHIC DOMAINS OF HIMALAYA, KARAKORAM AND HINDU KUSH

The northern segment of Pakistan, north of Lat: $34^{0}50'$, constitutes a dominantly moutainous terrain. Here the three important mountain ranges of the Centra Asia namely, the north-western Himalaya, the Karakoram and the Hindu Kush rendezvous with each other. Out of these three, major part of the Karakoram Range lies within Pakistan and forms a link between the NW Himalaya in the east and the Hindu Kush and Pamir in the west and northwest respectively.

The Pamir knot occupies a spectacular position with respect to the Central Asian mountain system. In the regional geographical setup, the Karakoram, Hindu Kush and the NW Himalaya emanate from the Pamir mass lying on the north, from where the majority of the mountain ranges of the Central Asia branch off to the east and west. Among the others, the important ones are the Kun Lun, Alai and Tien Shan which bifurcate into numerous subranges in the southern and the central parts of China in the east and northern and central parts of Afghanistan and Iran in the west.



GEOGRAPHICAL DOMAIN OF THE CENTRAL ASHIAN MOUNTAIN SYSTEM

The NW Himalaya like the Tibetan Plateau has no direct link with the Pamir but the Mustagh Ata, Kun Lun and the Karakoram, after emanating from the Pamir mass, follow a southeastern orographic trend and merge with the Himalaya and the Tibetan Plateau in the east.

In Pakistan, the northern boundary of the Himalaya is demarcated tectonically by the Main Mantle Thrust and geographically by the Kohistan mass - which has been recognised to form an independent geographical and geological entity in the northern Pakistan. This part of the Himalaya constitutes the hill ranges of Kashmir, Hazara and across the Indus River includes those hills occurring on the eastern stretches of the Swat and Peshawar valleys.

The Outer Himalayan domain lies south of this belt and in Pakistan its major part is underlain by the Potwar Plateau and the Murree Hill tract. On the west and south, it is delimited by the Sulaiman Range and the Salt Range respectively - whereas in the north it is tectonically delineated by the Main Boundary Thrust and geographically by the Darra Adam Khel, Kala Chitta and Marghala hills.

The Nanga Parbat - Haramosh loop, verging towards south and terminated by the great Indus bend on the west, upstream of Chilas, constitutes the nothwestern extension of the Great Himalaya in Pakistan. Its southern contact is with the Lesser Himalaya of Kashmir and Hazara, and on the north and northwest it is bounded by the Ladakh Range, a sub - range of the Karakoram forming a buffer between the Great Himalaya and the Main Karakoram. The third highest peak of the world, Nanga Parbat with an elevation of 8190 m increases the eminance of this part of the Great Himalaya.

Recent researches have brought the Karakoram more closer to the Hindu Kush and Pamir than the Himalaya. In this context the diagrammatic sections drawn across the Himalayan and Karakoram-Hindu Kush domains in Fig.2 may be referred.

The eastern boundary of the Karakoram lies in the eastern Ladakh at the "Great Divide" where the Indus-Tsang Po line bifurcates into two sutures, the northern one previously known as the Upper Shyok Line and now called the Main Karakoram Thrust and the southern one earlier called the Indus Fault is now named as the Main Mantle Thrust. This tectonic division is supported by magmatism which marks the termination of the Ladakh Intrusives in the east. The orographic trends of the Karakoram and the Himalayan ranges do not indicate any change in support of this division.

During the last thirty years, the western boundary of the Karakoram with Hindu Kush has changed thrice. The great Indus bend on the west of the Nanga Parbat - Haramosh loop for many years remained the western boundary of the Karakoram. Later, the Italian geologists supported by Desio and others, shifted it to further west in the Yasin Valley and now during the recent years, it has again galloped further west in the vicinity of Mastuj.

Gansser (1964) considered the south-eastern Karakoram to be traced into the Kailash Range of the Transhimalayas while the NW Karakoram is extended to the south of the Pamir Plateau. The author, on the basis of his observations, considers the Sor Laspur - Mastuj - Broghil profile to roughly demarcate the western extent of the Karakoram. This line is not supported by the orographic trend of the Karakoram and Hindu Kush ranges, which merge with each other without any visible kinks. Here again this division gets support from the western extent of the Ladakh Intrusives and the Main Karakoram Batholith, two important magmatic emanations of the Karakoram of regional dimension, which terminate southwest of Sor Laspur and east of Mastuj respectively. The water-divide between the Ghizar river (Karakoram) and the Yarkun/Mastuj river (Hindu Kush) is another criteria in support of this division.

The Karakoram, besides K^2 the second highest peak in the world, also holds twelve out of thirty top peaks with elevations over 7500 meters. Among them Gasherbrum, Mashebrum, Boltoro and Rakaposhi groups of mountain ranges are well known.

The Karakoram being located on the same latitude as Gibralter in Europe, contains some of the largest glaciers outside the Polar region. These are: Biafo - 62 km long, Hispar - 61 km, Baltoro - 58 km, Gasherbrum - 38 km, Chogo Lungma - 38 km, Siachen - 72 km, and Batura - 58 km long. If one compares the proportion of ice covering some of these mountain ranges, then Karakoram is 23-25 percent under ice, Himalaya is 8-10 percent and the Alps is only 2.2 percent under ice.

The Hindu Kush mountain system emanates from the western flank of the Pamir syntaxis and extends southwestward through Chitral and Dir and across the border into Afghanistan. The mountain ranges occupying the western half of the Swat valley, those of Mohmand and Khyber are being considered to form a part of this system.

The Transalai range delimits the northern extension of the Hindu Kush and the hill ranges of Malakand, Swabi and the Attock - Cherat, all located west of the Indus river demarcate a tentative division between the Lesser Himalaya and the Hindu Kush. Tirich Mir located in Chitral with an elevation of 8736 meters is the highest peak in the Hindu Kush system.

PAST RESEARCHES

In the northern Pakistan, right from the pre-Independance days, the main interest remained focussed on the Salt Range, Hazara-Kashmir part of the Lesser Himalaya and Potwar-Kala Chitta, the areas which were easily accessible and were free of administrative turbulance. The Karakoram and Hindu Kush remained landlocked till very recent time and could not receive much attention, except the work performed by those geologists who had accompanied the scientific or mountaineering expeditions. A few solo efforts were made by some of the past workers during the earlier days, notably by Lydekkar (1881), McMahon (1900), Huddleston (1902), Hayden (1904), Bridges (1906), Reed (1922), and a few others whose poineer work provided a good base to introduce the geology of this terrain and their work is still cherished to be evergreen by their successors.

The Karakoram and Hindu Kush started getting consistant and continual attention from late 1950 s when score of geologists penetrated this area and published their work in numerous foreign journals. Most of this work was scattered to the isolated valleys which could only provide an access to this forbidden terrain. These valleys trend north - south and cut across the strike of the beds and provide an excellent overview of the complete cross section of the rock formations.

In this work one gets a good grasp on the geology of the individual valleys but the description remains so variable from valley to valley by different workers that it became difficult to produce a regional geological mosaic of this terrain.

The first attempt to knit together the geology of these valleys was made by Ivanac et.al. (1965) and Bakr (1965), who were engaged by the Geological Survey of Pakistan to investigate this region during 1949-50. This map introduces the following sequential order of the Karakoram.

Ladakh Granodiorite	
Karakoram Granodiorite	Tertiary
Darkut Pass Granodiorite	
Yasin Group	Cretaceous
Greenstone Complex	Triassic
Darkut Group	Permo-Carboniferous

Schneider (1975) had produced a five zone subdivision for the NW Karakoram and according to him this order can be applied to the whole of the range with some modifications, which from south to north is, 1. The Rakaposhi Range, 2. The Chalt Schists, 3. A zone of old schists and gneisses, 4. The axial zone with its predominantly plutonic rocks and 5. The Tethyan Karakoram.

Gattinger (1961) had subdivided the Karakoram range into seven units which incorporated various zones of Schnieder also, which from north to south are as follows– 1. The Tethyan Karakoram, 2. The Tethys Thrust zone, 3. An axial zone of young granitic intrusions of alpine age, 4. A central crystalline zone of north of the axial intrusions, 5. Schuppen zone corresponding to the Chalt schists of Schnieder, 6. A southern border of the crystallines and 7. Granitic zone.

Desio (1964) introduced another regional geological map of the Karakoram, in which he distinguished nineteen sedimentary formations, eighteen metamorphic formations and differentiated six igneous bodies.

Gansser (1964) had proposed a three-fold generalized sub-division for the Karakoram, which is as follows:-

1. A northern sedimentary zone (Tethys Karakoram),
2. A Central metamorphic zone with a plutonic core, and,
3. A southern volcanic schist zone.

In his latest published work Gansser (1978,1979) has updated his old data and produced a comprehensive picture on the stratigraphy, tectonics and magmatism of the Karakoram and Hindu Kush. In this work, he discussed the geology under the context of plate tectonics.

Calkins et al.(1969)had mapped the southern and the eastern parts of Chitral which fall in the Hindu Kush domain. He established the following stratigraphic sequence.

1. Reshun Formation (Early Cretaceous),
2. Volcanic Greenstone (Triassic),
3. Limestone and Phyllite(Cretaceous-Early Tertiary),
4. Greenschists.

Stauffer (1975) has also conducted geological investigation in the eastern Chitral, covering some parts, earlier mapped by Calkins. He differentiated: 1. Reshun Formation (Cretceous- Tertiary),2. Limestones (Permian and Carboniferous),3. Sirikol Shale (Carboniferous to Devonian), 4. Chitral Slate (Palaeozoic). The oldest rocks in the sequence below the Chitral Slates are Calcareous Phyllite and Greenstone Volcanics.

Desio (1975) produced a comprehensive geological picture on the rocks of Chitral. He had started his observations from the Lawarai Top in Dir and extended the work along the road beyond Mastuj. He described the following rock formations:

1. Chitral Slates,
2. Ashret and Kaghozai Schists,
3. Kesu Gneisses,
4. Fusulina Limestone,
5. Shogram Formation,
6. Gahiret Crystalline Limestone,
7. Lun Shale,
8. Dundai Gol Volcanic Agglomerate,
9. Orbitolina Limestone,
10. Mirkani Quartz Porphyrite,
11. Gabbrodiorite-norite and amphibolite,
12. Reshun Conglomerate and
13. Leucogranites.

Lately, Talent et al (1979) has come up with an illuminating paper on the fossiliferous sedimentary sequences of Chitral. His work was based on the selected sections and the main thrust was on the biostratigraphic correlation. Beside updating the results of the past workers, he brought many fossils on record which include graptolites, a first recorded appearance in Pakistan. His work established the occurrence of an Ordovician sequence near Broghil, which is the first record in the stratigraphy of Pakistan.

The joint Punjab University-Kyoto University (Japan) scientific expedition to the Karakoram and Hindu Kush (Matsushita and Hunzita, 1965) has added much to the knowledge of this region. It brought many new areas within the fold of investigation which helped in correlating the rock sequences, earlier mapped in the isolated major valleys. The author was also a member of this expedition during 1957 which provided first opportunity to be introduced with the geology of this region.

As mentioned earlier, the Pakistani part of the Himalaya has received visits from many renown geologists from 1870 and voluminous publications are available on various aspects of geology. Among them Varchere (1866), Devernevil (1866), Waagen (1872), Wynne (1874), Middlemiss (1896), Pilgrim (1913) and Pasco (1920) are the ones who poineered to lay a geological base in the northwestern Himalaya. They were followed by Wadia (1924-43) who produced a classical work on the northwestern Himalaya. In the Higher Himalaya sections the commedable work of Peter Misch (1934-49) in the vicinity of Nange Parbat and Astor is of great help in understanding the geology of the Nanga Parbat-Haramosh massif.

After independence, Latif (1970-76), Shams (1961-67) alongwith other geologists from the Punjab University and Calkins, Offield, Tayyab and others (1968-69) from the Geological Survey of Pakistan remained busy in the Hazara Himalaya and produced geological maps and several publications which helped in understanding the problems of the Lesser Himalaya in Pakistan.

This is a brief introduction to the researches carried out during the past on the Karakoram, Hindu Kush and Himalaya. But this may not be considered the last words because still many workers are left whose contributions are quite substantial and very illustrative in getting solutions to various problems. The scope of this publication has limitations which does not permit to further enhance this chapter. However, their names will be incorporated in the reference.

REGIONAL GEOLOGICAL SETUP

The stratigraphy of the northern part of Pakistan remained marred with confusion because of lack of a regional correlation mosaic. The main problem was in understanding the regional tectonic setup, which due to trapping of the Kohistan Island arc in between the two mighty continents had created a situation different than the rest of the Himalayan domain in India and Nepal, where most of the earlier workers had concentrated.

As far as the stratigraphy of the Lesser Himalayan domain is concerned, there appears to be no problem except that in the Indian-Nepal Himalayas, the Main Central Thrust demarcates the northern boundary of the Lesser Hamalaya, whereas in Pakistan, it is the Main Mantle Thrust, the southern suture which delimits its northern extent. In many old and new publications on the Lesser Himalaya, emanating from the pre-Independence days in the Indo-Pakistan subcontinent and abroad, the geologists working in this region attempted correlations of the rock formations, some of which still hold good. Among them the Salkhala = Jatog = Chail Series, Hazara = Dogra = Simla Slates, Deoban = Shali = Sirbon Formations and a few others are noteworthy. Recently, Valdiya (1981) has come up with a very illuminating discussion on the regional correlation of the Lesser Himalayan rock formations and have included the Pakistani part of this belt, which introduced a very matching picture.

With an intention to introduce the work of the past researchers, indicating a progressive growth in understanding of the Lesser Himalayan sequences in Pakistan, the following table is being produced for a quick grasp. This table contains the versions on the stratigraphy of the Hazara Himalaya by various geologists right from the 1870 till date.

Table - 1 Stratigraphic sequences established by various workers in the Hazara Zone of the Lesser Himalaya in Hazara

	Verchere (1866-67)	Waagen & Wynne (1872-79)	Middlemiss (1896)	Mark and Mohd Ali (1961-62)	Gardezi and Ghazanfar (1965)	Latif,(1969)	Calkins et al (1975)	Tahirkheli (1979-81)
CAMBRIAN	Volcanics	3rd Division	Volcanic etc	Lower Fm.	Hazira Fm. Haematite Fm.	Hazira Fm. Galdanian Fm.	Panjal and Kingriali Fms. and Agglomeratic slate.	Hazira Fm. Galdanian Fm.
			Infra-Triassic Series	Abbottabad Fm.	Abbottabad Fm.	Sirbon Fm.	Tanawal Fm.	Abbottabad Fm.
PRECAMBRIAN		Upp. Division	Upp. Lst	Upp. Fm.		Kakul Fm.		
		Lower Division		Lower Fm.		Mirpur Mbr. Mohmda Gali Mbr Sangar Gali Mbr Tanakki Mbr	Hazara Fm.	
		Tanol Series	Lower Sst and Shale	Tanol Fm.		Tanol Fm.		Tannakki Conglomerate
						Hazara Group Upp. Fm.		Tannawal Fm.
		Attock Slates	Slate Series	Hazara Slate		Langrial Fm Middle Fm.		Langrial Limestone.
			Abbreviations:	Fm. Formation Mbr. - Member Lst. - Limestone Sst. - Sandstone		Miranjani Lst. Lower Fm.	Salkhala Fm.	Hazara Slates Salkhala Series

The problemmatic area, where a regional stratigraphic mosaic remained incomplete, lies in the Karakoram-Hindu Kush domain. The past researches carried out in this region bespeak of a Devonian stratigraphic base in the Hindu Kush (Desio, 1964) and the Permo-Carboniferous rocks forming the oldest sequence in the Karakoram. The author feels that after the discovery of the Middle Ordovician bed (Talent et al. 1959) there is a need of a revised stratigraphic scheme for this region (Fig. 20). Besides, the addition of some new formations which previously remained confined to some of the major valleys, the demarcation of the Main Karakoram Thrust, a northwestern counterpart of the Indus Tsang Po Line and incorporation of a new sequence of the Kohistan arc, the whole stratigraphic picture of this region has changed and comprehends to devise a new scheme which could find accommodation for this new setup.

The author based on this idea has attempted to prepare a geological map of the Karakoram and southern Hindu Kush (Fig. 3), which besides his work conducted in this region since 1957, has also accommodated the result of the researches carried out by the other workers during the recent years. This need was felt while establishing a stratigraphic order in the Hindu Kush, where though the biostratigraphers had created a very good base, yet the lithological characteristics of the sequences were so variable and intermingled that in some cases it became difficult to assign the formational names.

The Darkut Group in the Karakoram has been assigned a Permo-Carboniferous age. This group constitutes a thick metasedimentary sequence, occupying the southern margin of the Eurasian plate and has a quite vast extension. Its western extent has been covered upto Sandur Top and the earlier literature on its geological behaviour beyond this point is calm. As a result, the Chitral Slates which have similar lithology in the Hindu Kush, have always been reflected as a separate formation. In the Korakoram,during recent investigations the author had concentrated on this problem. In the Sor Laspur Valley,a meeting place of the two metasedimentary sequences, the observations revealed that the Darkut Group with east-west strike merges with the Chitral Slates and with this strike together continue towards the Afghanistan border. This evidence beyond any doubt places the Darkut Group of the Karakoram as a stratigraphic equivalent of the Chitral Slates and is held to occupy the same stratigraphic level.

In the Karakoram, the metasedimentary part of the Darkut Group occurs on the southern flank of the Main Karakoram Batholith, which separates it from the fossiliferous folded Tethyan Belt lying on the north. In the Hindu Kush,the Main Karakoram Batholith has no extension and the Chitral Slates come in direct contact with the Devonian-Cretaceous sequences.

Whether the whole or a part of the metasedimentary sequences in the Karakoram belong to the Darkut Group, is a point to be reviewed. The Darkut Group has extension into the Karakoram from the west and constitutes a Hindu Kush lithofacies. This statement is to be varified on the basis of three factors. Firstly, the lithology encountered in the Darkut Group at its type section contains over 70 percent carbonate rocks, whereas in the metasedimentary sequence the pelites predominate. And secondly the fossiliferous horizon is only located in the Yasin Valley and nowhere else in the Karakoram, Permo-Carboniferous fossils have been reported so far. Thirdly, the grade of metamorphism of the metasedimentary rocks included in the Darkut Group of the Karakoram is generally much higher than the rocks of the Darkut at its type section.

These points favour the Darkut Group to have a separate entity than the other metasedimentary rocks of the Karakoram. This view was earlier given by Desio (1963) and Stauffer (1968), who designated the metasedimentary sequences in the Shigar and the Hunza valleys as Dumurdu Formation and Baltit Group respectively, for differentiating them from the Darkut Group.

In the Yasin Valley, the Darkut Group is located on the north of the Main Karakoram Batholith, which cuts it between the Yasin and Ishkuman valleys, as a result, at the latter section it lies on the south of the batholith . The last outcrop of the Darkut is seen behind the Ishkuman village in the Ishkuman valley, which may have extension across the valley for a few kilometers more.

Desio (1963) suggested to incorporate the Passu Slate, Gircha Formation, Kilik Formation and Misgar Slate of the Upper Hunza Valley into this group. The author favours this stratigraphic scheme for differentiating the Permo-Carboniferous of the Karakoram from the older rocks. It is suggested that the Permo-Carboniferous sequences of the Hindu Kush may also be grouped under the Darkut Group, because this section occupies a central position and the name is also deeply coined in the geological literature.

On the basis of these evidences, the author retains the name Baltit Group of Stauffer for the metasedimentary rocks of the Krarakoram. A point which favours assigning this name is the central location of Baltit in the Karakoram and an easy access to the section along the Karakoram highway, which passes through the Hunza Valley.

The stratigraphic equivalent of the Baltit group in Hindu Kush as mentioned earlier is the Chitral Slates. Tipper (Fermor, 1922) had reported to have found Spirifer, a small Dialasma plus two unidentified corals on the basis of which he had assigned a Permian age to this sequence. Many geologists including Desio and the author subsequently had paid visits to this section but none was successful in locating this horizon. Calkins et al. (1969) on the basis of a contact relationship of the slates with the Cretaceous rocks, on the other hand, had favoured a Cretaceous age for the Chitral Slates.

Both of the abovementioned statements on the age of the Chitral Slates do not fit squarely in the stratigraphic scheme of the Hindu Kush-Karakoram domain. The author has examined at least two sections in the Mastuj Valley, e.g. across Sanoghar village downstream of Mastuj and another between Nol and Brehnis, where the Chitral Slates are found underlain by the Devonian rocks. Thus the Chitral Slates on the basis of this evidence may conveniently be assigned a Pre-Devonian age. Across the border in Afghanistan, the Chitral Slates are placed in the Precambrian, whereas inthe east in Ladakh, the metasedimentary sequence associated with the Tegar Granite (Shàrma et al. 1978) could be the extension of the Baltit Group and as considered to be of Palaeozoic age is still to be ascertained.

A greenschist horizon is conspicuously developed on the northern fringe of the Chitral Slates and is well marked in the road section between Nol and Brehnis in the Mastuj Valley. This horizon has specially been mentioned by Calkins et al.(1969), Stauffer (1971) and Desio et al.(1977), who had assigned it a separate entity and considered it to form the oldest sequence in Chitral. This section was visited by the author who considers it a part of the Chitral Slates and is placed between the lower and middle horizons of this sequence.

A marble bed named as Gahiret Marble by the earlier workers has association with the Chitral Slates on its southern fringe. Its maximum thickness is recorded in the Chitral Valley. It gradually thins out in the east beyond Awi in the Mastij Valley and extends as isolated pockets within the slates.One such marble bed was observed in the Hunza Valley,is located on the northern slope of the Rakaposhi, just outside the Main Karakoram Thrust zone south of Minapin. Such marble beds have also been recorded in the Baltit Group in the Shigar and Hushe valleys in Baltistan in the eastern Karakoram.

These marble beds in the eastern,central and western karakoram have also been mentioned by Schneider (1975, 60). Gansser (1964) reports a very similar marble occurrence in the Hindu Kush of Afghinistan. A part of the marble discussed by Schneider includes the Ganesh Marble of the author which forms the top sequence of the Baltit Group.

The Rakaposhi Volcanic Complex is another formation which has uninterrupted extension between the eastern and the western stretches of the Karakoram and Hindu Kush respectively. It attains maximum thickness in the Hunza, Yasin and Ishkuman valleys and gradually thins out in Baltistan and in the southern Hindu Kush. Its northern contact is with the Yasin Group, which is unconformable and faulted. On the south, it has a sharp contact with the Ladakh Intrusives in the Karakoram and with the Lawarai Granites and Deshai Diorites in the Hindu Kush. The lithology of the Rakaposhi Volcanic Complex bespeaks of its oceanic origin during the convergence of the Indo-Pakistan and the Eurasian plates.

The Yasin Group in the Karakoram was earlier mapped as an isolated oval-shaped body (Ivanac et al. 1965) on both the banks of the Yasin river at Yasin. Later, Desio et al. (1971) mentioned a rock sequence equivalent to the Yasin Group in the Chumarkhan area on the western edge of the Karakoram. The Orbitoline Limestone of Hayden (1916), the Reshun shales and conglomerate, and limestone of Krinj are some of the other Cretaceous beds which were mentioned in the earlier literature in the Hindu Kush.

The author found the Yasin Group to have east-west uninterrepted extension in the Karakoram and the southern Hindu Kush alongwith the Rakaposhi Volcanic Complex. The Chumarkhan outcrop and the Orbitolina limestone of Drosh are the continuation of the Yasin Group in the west. The other sections where the occurrences of the Yasin Group have been confirmed are located: i. south of Chotarkhan in the Ishkuman Valley, ii. south of Chalt in the Hunza Valley,and iii.at Machelu in Hushe stream a tributary of the Shyok river.From here it extends eastward in the outcrops exposed on the northern bank of the Shyok river. In the western Karakoram and Hindu Kush it is exposed .i. north of Teru, ii. in the vicinity of Rehman village in the Sor Laspur Valley and then the Yasin outcrop emerges in the Sisi Kuh, enveloping the Drosh town from where it extends southwest towards the Afghanistan border.

The Yasin outcrop forms a linear belt, having maximum thickness at its type section at Yasin. The fossiliferous horizons in the Yasin Group are located at Yasin, Teru, Chumarkhan and Drosh. Elsewhere, the fossils become rare where no paleontological studies have so far been made.Its lithology is variable.The basal conglomerate bed is quite persistent in the western sections, but in the east it has not been recorded in some sections. Conglomerates in the Yasin Group occupy more than one horizons. Microconglomerate bed has also been recorded in the Yasin Group in the Hispar Valley.

Desio (1963) based on his observations in the Yasin Valley has produced a three-fold subdivision for the Yasin Group, which the author has adopted in his stratigraphic scheme. This classification may hold good in the type section at Yasin but variation in lithology coupled with paucity of fossils may create problem in enforcing this stratigraphic scheme elsewhere.

The Yasin Group is bounded by two faults. On the north, the Main Karakoram Thrust disrupts its contact with the ophiolitic melange and on the south it has a faulted contact with the Rakaposhi Volcanic Complex. The emplacement of the Yasin Group suggests that it forms a back-arc apron over the Kohistan sequence and was deposited during the last phases of convergence when the entrapped Tethys was close to annihilation.

The Indus Tsang Po Line in Ladakh in the eastern Karakoram, bifurcates into two suture zones. The northern one, previously known as the Upper Shyok Line, has now been extended to the west (Tahirkheli and Jan 1978) as the Main Karakoram Thrust. This suture incorporates the earlier known dislocations named as Hini-Chalt Fault and the Drosh Fault. This suture and the associated ophiolitic melange provide a tectonic link to the Karakoram-Hindu Kush domain with the Himalaya.The ophiolitic melange is tectonized and is comprised of dislocated and localized pockets of serpentinite, ophicalcite, basalt, andesite, radiolarite and rarely peridotites in association with the flychoid rocks. Serpentinites and andesite being the more common associations among the magmatic rocks.

The Devono-Permo-Carboniferous sequences of the Hindu Kush have extension into the Karakoram, is now an accepted fact. From the Chitral side the extreme end in the north-east to which the past workers could get an access was upto Shewa Shur , located at about 15-20 km east of Broghil. Beyond this point the terrain is covered by the glacier and the exposed rock outcrops are steep having high elevations, thus forbiding an easy access.

Apart from Shewa Shur, another valley which can provide access to a part of this terrain from the east is through the upper reaches of the Hunza Valley. This area has been investigated by Desio & Martina (1972), Buri (1965), Siloa (1965), Sestisic (1965), Desio (1964) and Hayden (1915) who provided informations on the rock sequence and the fossils.

These investigations have also confirmed the existence of the fossiliferous Tehyan rocks of the Hindu Kush affinity in the Upper Hunza Valley, which form part of the Central Karakoram. Between the Upper Hunza Valley and Shewa Shur, a distance of 80-100 km is still lying unexplored but from the regional strike of the beds one can postulate a link between the two Tethyan domains, extending east-west along the northern margin of the Main Karakoram Batholith.

As has earlier been mentioned, the Karakoram holds two gigantic magmatic bodies, namely the Main Karakoram Batholith and the Ladakh Intrusives, which have their east-west extension confined to this range. These batholiths because of their sympathetic relationship with the Karakoram, have been used to demarcate its eastern and the western extents. Besides, the Rakaposhi Volcanic Complex is another formation, which has a thick association of the volcanic flows.

In the Hindu Kush, except the Rakaposhi Volcanic Complex, there is no extension of the other magmatic bodies. The Main Karakoram Batholith terminates just short of the Mastuj Valley, east of the Mastuj town. The Ladakh Intrusives end in the water-divide of the Sor Laspur river, south of the Sor Laspur village.

Beyond these points towards the west, there exists isolated granitic bodies in association with the metasedimentary and sedimentary sequences in Chitral but none attains a batholithic domension. The main granitic bodies are located in the upper part of the Golan stream, south of Kaghozai, Sissi Kuh valley, Lawari, Tirich Mir and in the upper reaches of the Lutkho river. Some minor granitic bodies are seen in the Dammar Nisar area southwest of Drosh, in the three valleys of Kafiristan, southwest of Chitral and in the vicinity of Garam Chashma. These granite bodies form isolated patches and only a few of them may form mappable units.

From the texture and composition of the granites it appears that they belong to two or three magmatic episodes, the youngest may belong to Miocene-Pliocene age and the earliest may be of late Cretaceous. One of these magmatic episodes may be synchronous to the younger generations of the granitic magmatism of the Karakoram. For differentiating the granites of the Hindu Kush in Chitral, for incoroporation in the stratigraphic scheme, the author has distinguished two types, one called the Tirich Mir Granites and another the Lawarai Granites. The former represents the granitic bodies occuring on the Eurasian plate and the second belong to the Kohistan arc, which geologically has a separate entity but geographically forms a part of the Hindu Kush.

In the preceding discussion on the regional geological net of the Karakoram-Hindu Kush,it becomes clear that this domain had shared a common basin of deposition.On the basis of fossils,the Middle Ordovician bed,named the Broghil Formation by the autor,is confirmed to form the base of this domain. But in case the Baltit Group = Chitral Slates are placed in the Precambrian-Lower Palaeozoic, as the author contends on the basis of their having a typical lithology, unfossiliferous nature and their status across the border in Afghnistan, then this basin should have an older core with deposition starting from the Precambrian. If so, then so far no Cambrian and Silurian sequences are established in this domain, thus we may expect depositional gaps during these periods, but again deposition continues uninterrupted from the Devonian to the time of Eurasia-Kohistan arc collision.

Thus the sequence of deposition in this domain contains a wide range of depositional facies ranging from deep marine during the earlier period to shelf type in the Devonian. Again becoming deeper during the latter Devonian-Triassic and shallowing in the Cretaceous.

During the Cretaceous period deposition occurred in two separate basins simultanously. One in the shrinking Tethys trapped between the Kohistan arc and the Eurasian plate, and the second formed a linear basin that had a link from the west and extended through the Hindu Kush eastwards to the northern Karakoram. In the former the rocks of the Yasin Group and its equivalents in the Hindu Kush, which incorporate the outcrops of Chumarkhan and Drosh Orbitolina Limestone were deposited. The latter basin contains the deposits of Krinj Limestone, Reshun shales and conglomerates, and its counterpart in the Gasherbrum mountain group in the Upper Boltoro Glacier, earlier also mentioned by Desio (1936) and Gattinger (1961).

These two basins were isolated by a barrier formed by the Chitral Slates and Devono-Permo-Carboniferous bed. The former basin had volcanic association whereas in the latter, besides the shelf carbonate rocks (Krinj Limestone) the maroon shales and conglomerates have an extensive distribution. In all the sections in the latter, the conglomerates contain exclusive carbonate clastics which in some sections show sign of deformations. Earlier Gattinger (1975) has also mentioned stretched pebbles in the Batura Conglomerate which forms the extension of the Reshun Conglomerate.

STRATIGRAPHY

The stratigraphy of the Lesser Himalaya has been spelt out by many workers right from 1970, . Thus a good base is laid to interpret various sections in Hazara, Kashmir and their equivalents elsewhere in northern Pakistan under the context of old and new researches. The major problem was faced in the Karakoram and Hindu Kush, where the old work was revised and as a result, new changes were brought in by adding new formations and new nomenclatures.

The Kohistan stratigraphy is quite a new addition in this region, which previously remained tagged either with Hazara-Swat on the south or with the Karakoram-Hindu Kush on the north. After the discovery of an ancient arc in this region, a new stratigraphic mosaic has emerged between the Indo-Pakistan and Eurasian plates, which has been incorporated separately under the "Kohistan Sequence".

LESSER HIMALAYA

A. Inner zone or Hazara zone (Tahirkheli, this publication Fig 2-c)

8. Mansehra Granites	Late Precambrian-Cambrian
7. Hazira Shales	Cambrian
6. Galdanian Formation	Cambrian
5. Abbottabad Formation	Late Precambrian
4. Tannakki Conglomerate	Precambrian
3. Tanol Formation	Precambrian
2. Hazara Slates	Precambrian
1. Salkhala Series	Precambrian

B Outer Zone Or Kala Chitta Zone (Tahirkheli this publication Fig 2-c)

7. Marghala Hill Limestone	Early Eocene
6. Patala Formation	Late Palaeocene
5. Lockhart Limestone	Palaeocene
4. Kawagarh Marl	Late Cretaceous
3. Samana Sukh Formation	Middle Jurassic
2. Chak Jabbi Limestone	Middle Triassic
1. Mianwali Formation	Lower Triassic

C. The Kala Chitta Zone in the Hazara Lesser Himalaya as differentiated by Latif (1970)

<u>Gallis Group</u>	
5. Kuldana Limestone	Lower to Middle Eocene
4. Lora Formation	Lower Eocene
3. Margala Hill Limestone	Early Lower Eocene
2. Kuza Gali Shale	Upper Palaeocene
1. Mari Limestone	Lower Palaeocene
<u>Hothla Group</u>	
3. Channali Limestone	Upper Cretaceous
2. Giumal Sandstone	Late Lower Creteceous
1. Spiti Shale	Lower Cretaceous
<u>Thandiani Group</u>	
2. Sikhar Limestone	Upper Jurassic
1. Maira Formation	Lower Jurassic

Table 2. REGIONAL STRATIGRAPHIC CORRELATION
LESSER HIMALAYA

ERA	HAZARA—KASHMIR	PUNJAB—KUMAUN	NEPAL—BHUTAN SIKKIM
CAMBRIAN	MANSEHARA GRANITES	MANDI GRANITES	SIMCHAR/NARAYAN TAN GRANITES
	HAZIRA SHALES	CHAIL FM/BASANTPUR FM/ MANDHALI FM	
	GALDANIAN FM		
	ABBOTTABAD FM	SHALI FM/DEOBAN FM	BOXA DOLOMITE
PRECAMBRIAN	TANNAKKI CONGLOMERATE	BLAINI FM/MANJIR CONGLOMERATE	DIURI BOULDER SLATE
	TANNAWAL FM	KHAIRA QTZ/RAUTGARA FM	SINCHULA QTZ./JAINTI QTZ
	HAZARA/DOGRA SLATES	SIMLA SLATES/CHAKRATA FM	DALING FM/BOXA FM
	SALKHALA SERIES	CHAIL/JATOG SERIES	THIMPU FM/SUMAR FM

KARAKORAM

9.	Main Karakoram Batholith			Eocene-Pleistocene
8.	Ladakh Intrusives			Eocene-Pliocene
7.	Ghizar Molasse			Late Miocene-Early Pleistocene.
6.	Chalt Ophiolitic Melange			Late Cretaceous-Early Tertiary
5.	Yasin Group	i.	Taus Shales	
		ii.	Manich Sandstone	Lower Cretaceous
		iii.	Gojalti Formation	
4.	Rakaposhi Volcanic Complex			Late Lower Cretaceous
3.	Darkut Group	i.	Misgar Slate	
		ii.	Kilik Formation	
		iii.	Gircha Formation	Devono ? Permo-Carboniferous
		iv.	Passu Slate	
2.		i.	Broghil Formation	Middle Ordovician
1.	Baltit Group	i.	Ganesh Marble	Precambrian-Lower Palaeozoic
		ii.	Minapin Formation	

HINDU KUSH

10.	Tirich Mir Granites	Triassic-Lower Tertiary
9.	Reshun Shales	Upper Cretaceous-Lower Tertiary
8.	Awi Conglomerate	Lower Cretaceous
7.	Krinj Limestone	Lower Cretaceous
6.	Zait Limestone	Permian-Triassic
5.	Parpish Limestone	Permo-Carboniferous
4.	Shogram Formation	Upper Devonian
3.	Lun Shales	Lower Devonian
2.	Broghil Formation	Middle Ordovician
1.	Chitral Slates	Precambrian-Lower Palaeozoic

Main Karakoram Thrust

7.	Chalt Ophiolitic Melange	Late Cretaceous-Early Tertiary
6.	Yasin Group	Lower Cretaceous
5.	Rakaposhi Volcanic Complex	Late Lower Cretaceous
4.	Lawarai Granites	Oligocene-Pliocene
3.	Deshai Diorites	Late Eocene-Miocene
2.	Utror Volcanics	Middle Jurassic-Cretaceous
1.	Baraul Banda Slates	Palaeocene-Eocene

Table 3. REGIONAL STRATIGRAPHIC CORRELATION
KARAKORAM—HINDU KUSH

PERIOD	AFGHANISTAN	CHITRAL	GILGIT	LADAKH
TERTIARY			MAIN KARAKORAM BATHOLITH	TEGAR GRANITE
PERMO—TRIASSIC	ZEWAN FM	TIRICH MIR GRANITES		
PERMIAN	ABE KAKAN FM	ZAIT LIMESTONE	DARKUT GR: MISGAR SLATE	
CARBONIFEROUS	HELMAND FM/SALKALAJ FM	SIRIKOL SHALES	KILIK FM	
			GIRCHA FM	
DEVONIAN	HAJIGAKH FM/KALANDEZ FM	SHOGRAM FM	PASSU SLATE	
	KUNDALAJ FM	LUN SHALES		
ORDOVICIAN	LOGAR FM/NAWDES FM	BROGHIL FM	BROGHIL FM	
CAMBRIAN	ZARGARAN FM			
PRE—CAMBRIAN	KABUL FM	CHITRAL SLATES	BALTIT GR	METAMORPHIC HOST ROCKS ASSOCIATED WITH TEGAR GRANITE

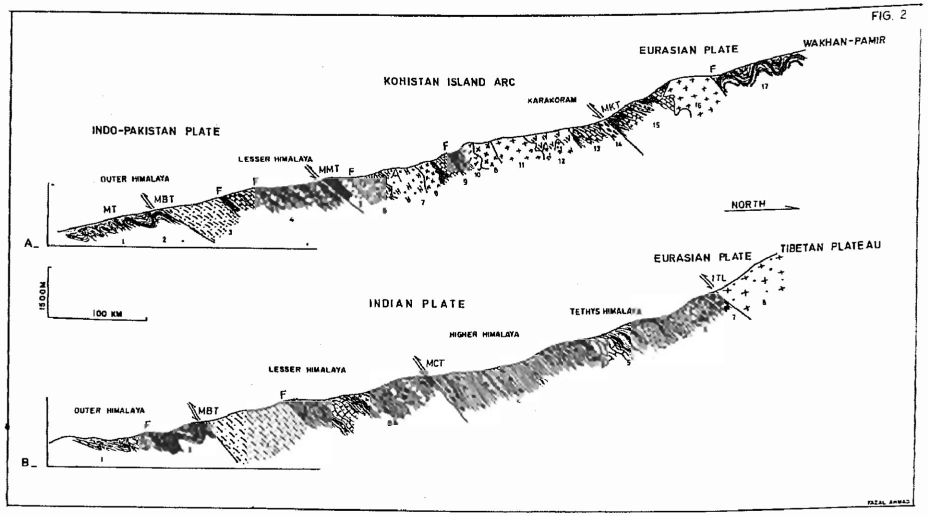
Table—4. REGIONAL STRATIGRAPHIC CORRELATION
KOHISTAN — LADAKH ISLAND ARC SEQUENCE

PERIOD	HINDU KUSH— KARAKORAM	LADAKH
LATE CRETACEOUS EARLY TERTIARY	CHALT OPHIOLITIC MELANGE	OPHIOLITIC MELANGE AND DEEP SEDIMENTS
LOWER CRETACEOUS	YASIN GROUP	INDUS FLYSCH AND VOLCANICS
LATE LOWER CRETACEOUS	RAKAPOSHI VOLCANIC COMPLEX	SHYOK VOLCANICS AND VOLCANO—SEDIMENTARIES
LATE CRETACEOUS EARLY TERTIARY	JIJAL ULTRAMAFICS CORRELATABLE WITH THE ULTRAMAPHICS ASSOCIATED WITH THE DRAS VOLCANICS	INDUS VOLCANICS/DRAS VOLCANICS/SAMDO FM
LATE MIOCENE EARLY PLEISTOCENE	CHIZAR MOLLASSE(?)	INDUS MOLLASSE
EOCENE—MIOCENE	LADAKH INTRUSIVES	LADAKH GRANITE AND GABBROIC INTRUSIONS

A. The Baltit Group in the Karakoram and the Chitral Slates in the Hindu Kush lateral equivalent to each other, occupying the southern margin of the Eurasian plate.

		——Main Karakoram Thrust——		(northern suture)
B.	12.	Chalt Ophiolitic – Malange.		Late Cretaceous-Early Tertiary.
	11.	Yasin Group		Lower Cretaceous
	10.	Rakaposhi Volcanic Complex.		Late Lower Cretaceous
	9.	Ghizar Molasse		Late Miocene-Early Pleistocene
	8.	Ladakh Intrusives		Eocene-Pliocene
	7.	Dir Group	i. Utror Volcanics and their counterparts in Deosai, south of Skardu forming part of the main central arc	Middle Jurassic-Cretaceous
			ii. Baraul Banda Slates	Palaeocene - Eocene
	6.	Kalam Group	i. Shou Quartzites ii. Deshan Banda Limestone iii. Karandokai Slates	Jurassic-Cretaceous
	5.	Deshai Diorites	i. Smoky Diorites ii. Orbicular Diorites iii. Quartz Diorites	Late Eocene-Miocene
	4.	Bahrain Pyroxene Granulites	Early Lower - Cretaceous	
	3.	Kamila Amphibolites	i. Massive & homogenous ii. Banded & Sheared iii. Bedded	Early Jurassic
	2.	Garnet Granulites		Middle Eocene-Early Oligocene
	1.	Jijal Ultramafics		
		Main Mantle Thrust		(southern suture)

Unfossiliferous Lesser Himalayan sequence belonging to the Hazara zone and occupping the northern margin of the Indo-Pakistan plate.



GEOLOGICAL SECTIONS ACROSS KARAKORAM (A) IN PAKISTAN & HIMALAYA (B) IN INDIA

FIG—2:

A. 1. Siwalik Formation,2.Murree Formation,3. Outer Lesser Himalayan Zone called the Kala Chitta Zone with the rocks ranging from lower Triassic to Eocene,4. Inner Lesser Himalayan Zone comprised of the rock sequence from Precambrian to Lower Cambrian,5. Jijal Ultramafics and Garnet Granulites,6. Kamila Amphibolites,7. Bahrain Pyroxene Granulites,8. Deshai Diorites,9. Kalam Group, 10. Dir Group, 11. Ladakh Intrusives, 12. Rakaposhi Volcanic Complex, 13. Yasin Group, 14. Chalt Ophiolitic Melange, 15. Baltit Group,16. Main Karakoram Batholith, 17. Tethyan Folded Belt with rocks ranging from Ordovician to Cretaceous.

B. 1. Siwalik Formation,2. Murree Formation,3.Outer Lesser Himalayan Zone, 3 a. Inner Lesser Himalayan Zone, 4. The Central Himalayan Crystallines, 5. Fossiliferous Tethyan Belt ranging in age from Cambrian to Cretaceous, 6.Indus Flysch-Kargil/Kailash Molasse-Hornblend granite, 7. Indus Tectonic Line, 8. Transhimalayan Batholith.

During the last several decades, the Indian part of the Himalaya remained the main foci of attraction for the geologists during which store of informations pertaining to various aspects of geology were gathered. These results by many workers, as is usually done by the alpine geologists, were transmitted to the NW part of the Himalaya including the Karakoram and were applied to solve many stratigraphic and tectonic problems. This resulted in creation of a hazy picture of many geological problems which are still in find of an authentic base to be properly spelt out for creating a model which is commensurate with the actual facts and findings.

In Fig.2, two diagrammatic sections are drawn, one is across the Karakoram domain in Pakistan (A) and another traverses the Himalayan domain in India (B) which depict the regional stratigraphic and tectonic build-up of these ranges. These cross-sections will enable a comparative study to demonstrate the similar and dissimilar features, some of them will be discussed in the ensuing paras.

The Indus Tectonic Line came to be known when the Kiogar exotic blocks were first reported by Diener (1895), till it was firmly established by the work of many geologists during last 60-70 years. Even now this problem is being potrayed in different context, based on individual observations in different parts of the Indian Himalaya.

In the northwest, this problem could not get farther west of the central part of Ladakh, beyond which except cursory remarks made by some of the old workers including Desio et al.(1977) and Gansser (1979), the extension of the Indus Tectonic line in the Karakoram and Hindu Kush, for several years remained unspecified. During a reconnaissance trip in the Karakoram and Hindu Kush Gansser(1979) had recorded in his diagrammatic cross-sections some tectonic features which he considered to mark the extension of the Indus Tectonic Line. He also mentioned doubling of the Indus Tsang Po Line in the western part of Ladakh.

The first indication of the two suture zones in Pakistan was confirmed with the discovery of the Kohistan Island arc (Tahirkheli et al.1979). A tectonic-cum-geological map, based on this find, demarcating the extension of the Indus Tsang Po line, called the Northern Megashear in the Karakoram and Hindu Kush, was first prepared by Tahirkheli and Jan (1978). This map is sixty percent based on compilation from the previous published work and the rest of it was completed by the geologists from the Peshawar University. As far as the mapping of the two suture zones was concerned, it was done by Tahirkheli(1979).

One of the main tectonic differences between the Karakoram - Hindu Kush and the Himalayan domains is on the suture zone. The Indus Tsang Po Line, from the Assam Himalaya in the east to the Kashmir Himalaya in the west, constitutes a single tectonic feature which tectonically demarcates the Indian plate from Eurasia. In Central Ladakh it bifurcates into two faults, the northern one was known as the Upper Shyok Line and the southern one as the Indus Fault.

The Upper Shyok Line which is the northern dislocation, extends into the Karakoram and the Hindu Kush, incorporating the Hini-Chalt Fault in the Central Karakoram and the Drosh Fault in the southwestern Hindu Kush and crosses into the Afghanistan border west of the Lawarai Top.

The Indus Fault extends along the southern periphery of the Deosai plateau and passes through east of Astor . Beyond this, the fault is involved in the Nanga Parbat-Haramosh anticline and disrupts the Nanga Parbat mass (Precambrian) of the Indo-Pakistan plate from the Kohistan sequence (Cretaceous). In Pakistan, it has an extension of about 400 km through Baltistan, Diamir, Hazara, Swat and Dir, and crosses the border into Afghanistan, west of Khar in Bajaur.

Both of these faults have been recognised as the suture zones in Pakistan , the northern one is called the Main Karakoram Thrust and is the extension of the Indus Tsang Po Line into the Karakoram and Hindu Kush and tectonically delineates the Kohistan Island arc from the Eurasian plate. The Indus Fault beyond Dras encircles the southern peripherv of the Deosai plateau, running along the nothern fringe of the Lesser Himalaya in Kashmir and Hazara and is the southern suture named the Main Mantle Thrust along which the Kohistan arc is obducted onto the Indo-Pakistan plate.

This tectonic model in the nothern Pakistan is the result of the Kohistan Island arc which intervenes the Indo-Pakistan and the Eurasian plates. Nowhere, the Karakoram and the Hindu Kush are in direct contact with the Indo-Pakistan plate, as is the case along the Indus Tsang Po Line in the Himalayan domain, where the Indian plate is juxtaposed with the Eurasia along this tectonic line.

The Main Boundary Thrust; a southern lineament in the frontal part of the Himalaya has extension into Pakistan where the Murree Formation involved in this fault tectonic has got its type section. In Pakistan, this lineament was named the Murree Fault by Wadia (1931) which remained in common usage till the publication of the gelogical map of the northern Pakistan by Tahirkheli and Jan (1978), in which this fault was first correlated with its counterpart in the Himalayan domain in India and was named the Main Boundary Thrust.

The Lesser Himalaya in India is tectonically delineated by the MBT in the south and the Main Central Thrust in the north. In Pakistan, the southern tectonic boundary of the Lesser Himalaya, as usual, is the MBT but in the north it is bounded by the Main Mantle Thrust, a southern suture, which towards east in Ladakh coincides with the Indus Fault.

The Main Central Thrust, a very important lineament of the Himalayan domain after the Indus Tsang Po Line, has so far not been differentiated in Pakistan. Some Indian geologists have held the Panjal Fault in Kashmir to be an extension of the MCT. If this view is accepted, then the extension of the MCT in Pakistan may be traced along the eastern flank of the Hazara syntaxis. But keeping in view the tectonic position of the MCT in the Central Himalaya and the rock types it disrupts, it is very unlikely for the Panjal Fault in Pakistan to be the replacement of the MCT. Even the validity of the Panjal Fault to have extension into the western syntaxis is questionable, because except the Dogra Slates and a tuffaceous bed, 30-50 m thick, no other rocks encountered in its type section occur in this area.

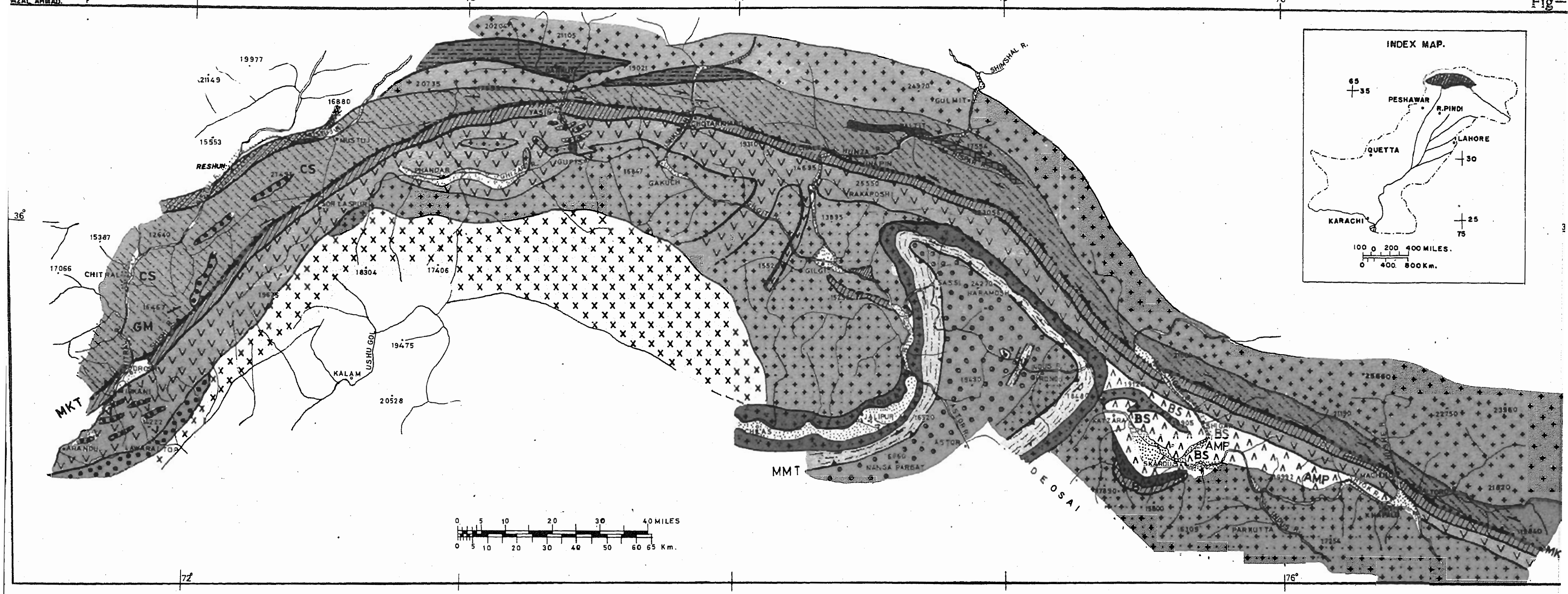
The Central Crystallines(Thakur, 1980), an important metamorphic belt of the Higher Himalaya, extending from the Central Himalaya as far west as Kashmir has still to be delineated in Pakistan. According to its stratigraphic position in the Himalayan domain, this belt in the Karakoram should have occupied the place of Kohistan. According to Wadia(1965)and Sexena(1971) this belt was considered to have formed a"geanticline" that acted as a barrier separating the fossiliferous Tethyan sediments from the unfossiliferous Lesser Himalayan sequence.

Thakur (1980) has differentiated the Outer Crystallines from the Central Crystallines and considered the Salkhala Series with a faulted contact to form its base in Kashmir. The Salkhalas form the basements of the Inner Zone of the Lesser Himalaya in Hazara and Kashmir which is assigned a Precambrian age. Thus, if Thakur extends the domain of the Central Crystallines to the Precambrian Lesser Himalayan sequence forming a part of this province, then in Pakistan probaby the Hazara Zone may be expected to have an affinity with the Outer Crystallines.

This outer crystalline domain in Hazara will counter Fuch's (1979) earlier contention of a sequence in northern Pakistan in Hazara which is transitional between that of the Lower Himalaya and the Tibetan Zone. I do not recollect an existence of any such section recorded in Hazara where a fossiliferous Tibetan zone is exposed. However, the Central Crystallines have no extension in the Karakoram- Hindu Kush domain.

The Tethyan Himalayan Belt in the Higher Himalaya has got an unconformable southern contact with the central crystallines, and on the north it has a gradational contact with the geosynclinal facies of the Indus Flysch. This belt lies on the south of the Indus Tectonic Line and falls in the Indian part of the Himalayan domain.

FAZAL AHMAD. Fig—



GEOLOGICAL ZONATION OF KARAKORAM AND SOUTHERN HINDUKUSH IN PAKISTAN

1. NANGAPARBAT GNEISSES PRECAMBRIAN
2. MINAPIN FM. PRECAMBRIAN-LOWER PALEOZOIC (BALTIT GROUP)
3. GANESH MARBLE PRECAMBRIAN-LOWER PALAEOZOIC (BALTIT GROUP)
4. DARKUT FM. PERMOCARBONIFEROUS
5. KAMILA AMPHIBOLITE JURASSIC-EARLY CRETACEOUS
6. BAHRAIN PYROXENE GRANULITE EARLY LOWER CRETACEOUS
7. KATZARA FM. EARLY LOWER CRETACEOUS
8. RAKAPOSHI VOLCANIC COMPLEX LATE LOWER CRETACEOUS
9. YASIN GROUP (UNDIFF.) LOWER CRETACEOUS
10. CHALT OPHIOLITIC MELANGE WITH FLYSCH LATE CRETACEOUS-EARLY TERTIARY
11. LADAKH INTRUSIVES LATE UPP. EOCENE-LOWER MIOCENE
12. MAIN KARAKORAM BATHOLITH MIOCENE-PLIOCENE
13. DEOSAI VOLCANICS LATE UPP. EOCENE
14. DESHAI DIORITES LATE EOCENE-MIOCENE
15. GRANITES LATE EOCENE-MIOCENE
16. GHIZAR MOLASSE AND EQUIVALENTS LATE MIOCENE-EARLY PLEISTOCENE
17. ALLUVIALS MIDDLE PLEISTOCENE-RECENT
18. RESHUN GROUP UPP. C

AMP AMPHIBOLITE
BS BIOTITE SCHISTS AND GNEISSES
CS CHITRAL SLATE
MKT MAIN KARAKORAM THRUST
MMT MAIN MANTLE THRUST
GM GAHIRAT MARBLE
T THALICHI BED
B BURJI LA FM.
THRUST FAULT
FAULT, PROBABLE

GEOLOGY BY:- R. A. KHAN TAHIRKHELI
NATIONAL CENTRE OF EXCELLENCE IN GEOLOGY
UNIVERSITY OF PESHAWAR, SPECIAL ISSUE, 1981
COMPLETED DURING ROYAL GEOGRAPHICAL SOCIETY KARAKORAM EXPEDITION, JUNE-SEPT., 1980.

In the Karakoram-Hindu Kush, the Tethyan Belt constitutes a part of the southern marginal mass of the Eurasian plate and lies north of the Main Karakoram Thrust, an extension of the Indus Tsang Po Line.

On the southern margin of the Eurasian plate in the Karakoram-Hindu Kush, the Baltit Group (Karakoram) and the Chitral Slates (Hindu Kush), which were earlier placed in the Premo-Carboniferous (Darkut Group: Ivanac et al. 1956), Permian (Tipper in Fermor, 1924) and Cretaceous (Calkins et al. 1969), have got their stratigraphic status revised because of this investigation.

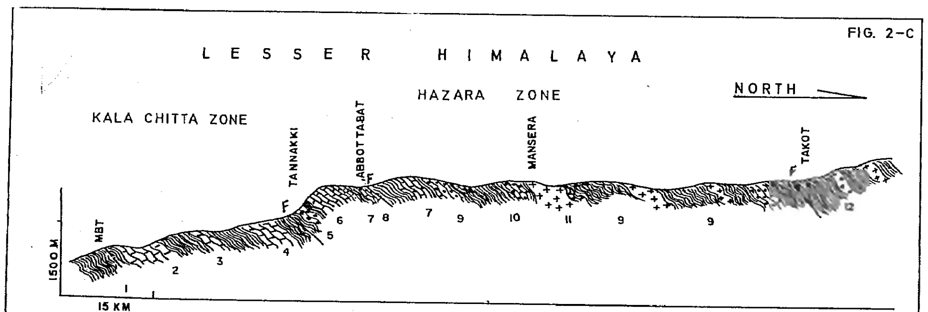
During recent geological mapping of these rocks by the author, the Darkut Group of the Permo-Carboniferous age in the Karakoram has been restricted to its type section in the upper reaches of the Yasin Valley and the rest of the metasedimentary rocks with different lithology have been assembled under the Baltit Group (Stauffer, 1969) and assigned a Precambrian-Lower Palaeozoic age. The Baltit Group of the Karakoram extends westwards with the east-west strike and laterally merges with the Chitral Slates along the Sor Laspur-Mastuj profile and thus both of them share a common stratigraphic level. Their lithology is also similar.

The Darkut Group is a Hindu Kush lithofacies and its lithology differs from the Baltit Group in having a dominant component of the carbonate rock in the sequence. No Permo-Carboniferous fossils of the Darkut affinities have been found in the other metasedimentary rocks except in its type section. Some fossiliferous localities reported by the earlier workers including the one reported in the Chitral Slates by Tipper could not be confirmed by the subsequent workers. Probably some of these fossil localities could be tectonic slivers of the younger rocks incorporated in the Baltit Group and the Chitral Slates.

Thus, the Baltit Group (the Chitral Slates are also included), occupying the southern margin of the Eurasian plate in the Karakoram-Hindu Kush domain are contemporaneous to the Inner Zone or Hazara Zone of the Lesser Himalayan sequence, occupying the northern margin of the Indo-Pakistan plate.

Earlier, Gansser (1979) while discussing the doubling of the sutures in Ladakh had remarked about the Himalayan and the Karakoram-Hindu Kush domains in the following words, "It is difficult to decide if this doubling is due to tectonic causes only or if two different belts existed originally with a different composition and possible in different age (Stocklin, 1979)".

This cursory overview of the regional stratigraphic and tectonic trends in the two domains, the Himalayan and the Karakoram-Hindu Kush, throw ample light on some of the disimilar features existing not only in the tectonics but in composition of the rocks and their stratigraphic order. This point out to their inheriting independent geological moorings right from their birth. The geological features which can bring them closer to each other were stamped latter and these are the tectonic scars produced by the neotectonics.



THE INNER AND THE OUTER DOMAINS OF THE LESSER HIMALAYA IN PAKISTAN

FIG:2-C

1. Murree Formation, 2-3-4. The Kala Chitta zone comprising of Lower Triassic-Eocene rocks, 5. Hazara Slates, 6. Tannakki Conglomerate overlain by red and maroon silty slates, 7. Sirbon Formation, 8. Hazira Formation overlain unconformably by Daulatmar Limestone of Middle Jurassic age, 9. Tannawal Formation. 10. Hazara Slates, 11. Mansehra Granites. 12. Salkhala Series.

The Lesser Himalaya in the Indian part of the Himalaya (Fig. 2-B), is tectonically delineated on the south and north by the Main Boundary Thrust and the Main Central Thrust respectively. This tectonic zone has been divided by the earlier workers into the Inner Zone and the Outer Zone. The former constitutes the unfossiliferous metasedimentary suite of Precambrian-Lower Cambrian and the latter is comprised of the Mesozoic-Lower Tertiary sediments. A thrust fault divides the Inner Zone from the Outer Zone.

In the Karakoram domain in Pakistan the geological and the tectonic setup is different from the rest of the Himalaya (Fig. 2-A). Here the Lesser Himalaya is tectonically bounded by the Main Boundary Thrust, as usual on the south but by the Main Mantle Thrust, a southern suture, on the north.

Earlier, Fuchs (1975) had differentiated the Inner and the Outer zones of the Lesser Himalaya in Pakistan as the Abbottabad Zone and the Islamabad Zone respectively. Keeping in view the geological and the tectonic changes brought in this sector of the Indo-Pakistan subcontinent by the discovery of the Kohistan Island arc intervening the Indo - Pakistan and the Eurasian plates, two suture zones and the recognition of the Lesser Himalayan lithofacies west of the Indus river (besides the Attock-Cherat-Range by Tahirkheli, 1970), it has become imperative to enlarge the notion of the inner and the outer zones of the Lesser Himalaya in Pakistan to provide a representation to the new geological setup.

With this view in mind, the author has decided to redesignate the inner zone, earlier named the Abbottabad Zone to Hazara Zone and the Outer Zone earlier called as the Islamabad zone, to Kala Chitta zone. Actually it is the Mesozoic-Tertiary sedimentary rocks of the Kala Chitta Range which rim the Hazara-Kashmir Lesser Himalaya (Hazara Zone) along its outer periphery, and extend through Islamabad-Murree-Galiat-Muzaffarabad to the western limb of the Hazara-Kashmir syntaxis and terminate near its apex. Probably in the western limb of the syntaxis these rocks are faulted for some distance and reappear in Kashmir where in the Pir Panjal Range a Triassic to Eocene sequence is again developed.

In the Kala Chitta Range, the following rocks sequence has been established:-

Margala Hill Limestone	- Early Eocene
Patala Formation	- Late Palaeocene
Lockhart Limestone	- Palaeocene
Kawagarh Marl	- Late Cretaceous
Samana Sukh Formation -	
Daulatmar Limestone-	Middle Jurassic
Kioto Limestone	
Chak Jabbi Limestone	- Middle Triassic
Mianwali Formation	- Lower Triassic

Some of these formations have restricted distribution and do not display a consistant extension in the east. But the ones which are involved in the outer zone of the Lesser Himalaya in Hazara and Kashmir are the Daulatmar Limestone, Kawagarh Marl, Lockhart Limestone, Patala Formation and the Marghala Limestone. All these formations have been given local nomenclature by Latif (1970) and others.

In the Hazara Zone the following rock types,ranging from the Precambrian to the Lower Cambrian have been included:-

Galdanian Formation
Hazira Formation
Abbottabad Formation
Tannakki Conglomerate
Tannawal Formation
Hazara Slates/Dogra Slates
Salkhala Series

The rocks of the Hazara Zone as mapped by the previous geologists in Hazara and Kashmir were not considered to extend to the Hindu Kush, west of the Indus River. But the geographical and geological domains of the Himalaya do not coincide. The Lesser Himalayan lithofacies belonging to both the Kala Chitta and the Hazara zones are found extending into the Hindu Kush which is discussed in detail elsewhere.

DESCRIPTION OF THE ROCK SEQUENCES

The rock formations differentiated in the Himalaya, Karakoram and Hindu Kush will be described here to introduce their lithology, contact relationship, fauna and any other distinguishing character which give them a separate status.The discussion in this chapter will cover the general characteristics of the rock formations based on cumulative observations including the sections other than the type area. Whereas, in the explanations attached with the figures more stress is given to their geological behaviour as observed in the sections under mention. Thus, there is a chance of minor overlapping which the author has tried to minimise.

THE LESSER HIMALAYAN DOMAIN

HAZARA ZONE

1. The Salkhala Series

Its type section is located in the upper reaches of the Nilam Valley east of Muzaffarabad, on the eastern flank of the Hazara syntaxis. A detailed lithological description of the outcrop exposed along the road section in the Nilam Valley is included in the explanation alongwith Fig. 12.

The Salkhalas form the stratigraphic base in the Lesser Himalaya. They are involved in the Nanga Parbat-Haramosh tectonics and constitutes a substantial part of the massif. The main rock type are slates, phyllites, various types of schists and paragneisses, sandstone, quartzitic sandstone and quartzites, semi-to medium crystalline limestones and marble, and minor conglomerate, which are intruded by the basic and acid igneous rocks. The migmatised horizons are associated with the more tectonized parts of the sections.

Among the basic intrusives, gabbro, dolerite and diorite are common. The granites of more than one phases alongwith pegmatite, aplite and vein quartz are frequently recored in the acid igneous domain. The basic intrusives are older except the older granite gneisses which are considered to belong to the Outer Zone of the Himalayan Crystallines and are placed in the Precambrian.

As already mentioned, the graphitic association with both the metasedimentary and igneous rocks is quite common in the Salkhalas which gives this sequence a dark grey to black colouration. Generally, epi-to kata-grade metamorphism is recorded in the sequence, with meso-grade rocks predominating. Sometime the epi-grade rocks occur in the highly tectonized zones which could be regarded as a result of retrograde metamorphism.

This is the general lithological picture of the Salkhala Series usually encountered towards the east of the syntaxis and on the southern margin of the Nanga Parabat-Haramosh massif. But elsewhere this lithology may have variations, as a result in some sections the Dogra Slates/Hazara Slates are misconstrued as the Salkhalas or vice versa.

The important sections, where the Salkhala Series are recorded west of the syntaxis in Hazara and outside are: i. Between Batagram and Thakot, ii. Between Besham-Karora and Besham-Dubair iii. In the Black Mountains of Middlemiss (1996) in the upper Hazara, iv. On the eastern flank of the Gandghar Range in the western Hazara, v. Topi-Gadun section in Swabi across the Indus river, vi. Shahkotabala Formation (Tahirkheli, 1970) in the Attock-Cherat Range, vii. On the southern flank of the Malakand Range and vii. The metasedimentary rocks recorded in the core of the Ghalanai anticline in Mohmand.

The rock types in all the abovementioned sections are dominantly pelitic and indicate an excessive carbonaceous associations. In some sections, the contact between the Salkhalas and the overlying slates which are equivalent to the Hazara/Dogra Slates, is faulted as is the case in the type section, but in a few other sections gradational contacts have also been observed. Thus, the stratigraphic status of lithological units in these sections is yet to be established specially with reference to their placement in the Salkhalas or in the lower part of the Hazara Slates.

The age of the Salkhala Series is Precambrian. It is confirmed by the three Rb-Sr dates on the overlying Hazara Slates carried out by Crawford & Davies (1975) and are described subsequently.

2. The Hazara Slates

The first nomenclature used for the slate sequence of the Hazara Lesser Himalaya was the Attock Slates, imported by Waagen and Wynne (1872) from the Attock - Cherat Range across the Indus in the west. Subsequently, Middlemiss (1896) called them the Slate Series of Hazara. The Dogra Slates of Wadia (1930) and the Hazara Slates are the stratigraphic equivalents, which change their names across the Hazara syntaxis. Thus the Hazara Slates have no type section of their own, and the slates sequence exposed between Authmuqam and short of Nauseri in the Nilam Valley east of the syntaxis may be held as the type section of both the Dogra and the Hazara Slates.

During recent years, three more names have emerged for the slate sequence of Hazara. These are, the Hazara Slate Formation (Marks & Ali, 1961), Hazara Group (Latif,1970), and the Hazara Formation (Calkins et al.,1975). All these names have some significance but still the name "Hazara Slates" has more weightage because over two-third of the area in Hazara is characterized by this lithology.

The Hazara Slates include slates, phyllites and phyllitic schists being dominant with calcareos and siliceous partings. This lithology gradually enhances to various types of schists, para-gneisses, amphibolite and migmatites in the north lying closer to the northern edge of the Indo-Pakistan plate. Turbiditic features have deep imprints in this sequence and are more vivid in the epi-grade rocks. Burrovian type metamorphic zonation has already been confirmed in the Hazara Slates (Calkins et al, 1975), west of the syntaxis. Approximate locations of the isogrades, as studied by the author along the Karakoram Highway are chlorite grade between Abbottabad and Qalandarabad,garnet grade in the vicinity of Mansehra and Khaki, biotite grade in the vicinity of Shinkiari,the staurolite grade north of Batal, the Kyanite grade about ten km short of Batagram and the sillimanite grade north of Batagram upto a point about 15 km south of Thakot.

The granitic intrusions start in the garnet grade zonation and indicate progressive increase with the increase of metamorphism in the north as one moves closer to the Main Mantle Thrust, the southern suture.

The Hazara Slates have their counterparts located in the sections west of the Indus, outside Hazara. These are; the Manki Slates in the Attock-Cherat Range, Landikotal Slates in the Khyber mountains and several unnamed slate sequences located in the Malakand range, Swat, Dir and Mohmand areas. These slates occur near the leading edge of the Indo-Pakistan plate and have suffered intense deformation as a result of collision and subsequent stresses generated during suturing which have raised their grade of metamorphism. Meso-Kata zonations in the metasedimentary suite are quite frequent in the slates located in this belt.

Crawford and Davies(1975)had analysed three pieces of the slates as total rock samples by Rb-Sr method, which were collected from the low grade metamorphic belt of the Hazara Slates. The samples gave a model ages for two samples - 765 m.y. and for the third - 950 - m.y This confirms a Precambrian age for the Hazara Slates.

3. The Tanawal Formation

The Hazara Slates are overlain by a dominantly arenaceous sequence called by various names as, the Tanol Series, Lower Sandstone and Shale and Tanol Formation (Table-1). This sequence has erratic distribution outside the Tannawal area of Hazara and in some sections as the case is in the Sirban hill, the Tanawals are missing and the Hazara Slates are directly overlain by the Abbottabad Formation with a conglomerate bed at the base.

The Tanawal Formation has extensions in the east and west as isolated patches. In the west, it is developed in the Gandghar Range and extends across the Indus in the western limb of the anticlinal fold and is observed forming thick outcrops in the Gadun area. During previous work, the author had some reservations in placing it in the Precambrian because of their lithological resemblance with the Chamla quartzite of Buner, the Kala quarzite of Swabi and the Misri Banda quartzite of the Reef Belt which on the basis of fossils were placed in the Silurian-Devonian. But subsequent studies revealed that there are two types o quarzites, one belonging to the Silurian-Devonian and another to the Precambrian. The latter has association with the Hazara Slates, Dogra Slates and their equivalents on the east and west of the Hazara syntaxis.

The Tanawal Formation is comprised of quartzites, quartzitic schists and quartzitic sandstones with interbedded arenaceous phyllitic slates and conglomerates, which are intruded by the acid and basic igneous rocks. In some sections thin calcareous partings are also recorded near their contact with the Abbottabad Formation, a dominantly carbonate sequence.

Among the arenaceous rocks, arkosic wacke, subarkose, arenites and quartz arenites were differentiated. Among the minor intrusions epidiorite, porphyritic microtonalite, dacite, rhyodacite, pegmatite and quartz veins are the igneous rocks which form sills, dykes and veins. The basic igneous rocks are the earliest, followed by the volcanics and the acid igneous bodies. In the southern periphery of the Tannawal area, some evidences of hydrothermal emanations are observed in this sequence, which have induced lead-barite mineralization.

The Tanawal Formation on the northern and eastern fringes of its type section has association of granites. The Mansehra granite dated by K/Ar method (Le Fort, 1979) has yielded a Cambrian age. Thus, the Tanawal Formation on the basis of this date may be placed in the Precambrian.

4. The Tannaki Conglomerate

A conglomerate bed intervenes the Hazara Slates and the Abbottabad Formation specially in those sections where the Tanawal Formation is missing. In all the three sections in Hazara where the Tannaki conglomerate is recorded e.g. Tannaki village (type section), , Khote-de-Kabbar located at 8 km west of Abbottabad and near Mohamda Gali on the Abbottabad-Sherwan road, the Tannaki Conglomerate directly overlies the Hazara Slates.

The Tannaki Conglomerate is 40-60 m thick and is comprised of two lithologies; conglomerate at the base followed by red and maroon shales. In the conglomerate, clastics range in size from granules to cobbles with pebbles dominating in the sequence. The proportion of the constituent rocks in the Tannaki Conglomerate (Ghauri et al., 1977) in the type section are as follows: sandstones-64.5 %, siltstone- 3.6 %, quartz- 1.4%, quartzites 1.7%, slate-argillite- 19.3% and limestone/dolomite-8 · 7%.

PT-1 The Indus gorge upstream of Kamila in the Kohistan Island arc. The rocks exposed on both the banks are Bahrain pyroxene granulites, one of the oldest rock suites of the Kohistan sequence. A part of the Karakoram Highway is visible on the right bank which runs along the Indus valley.

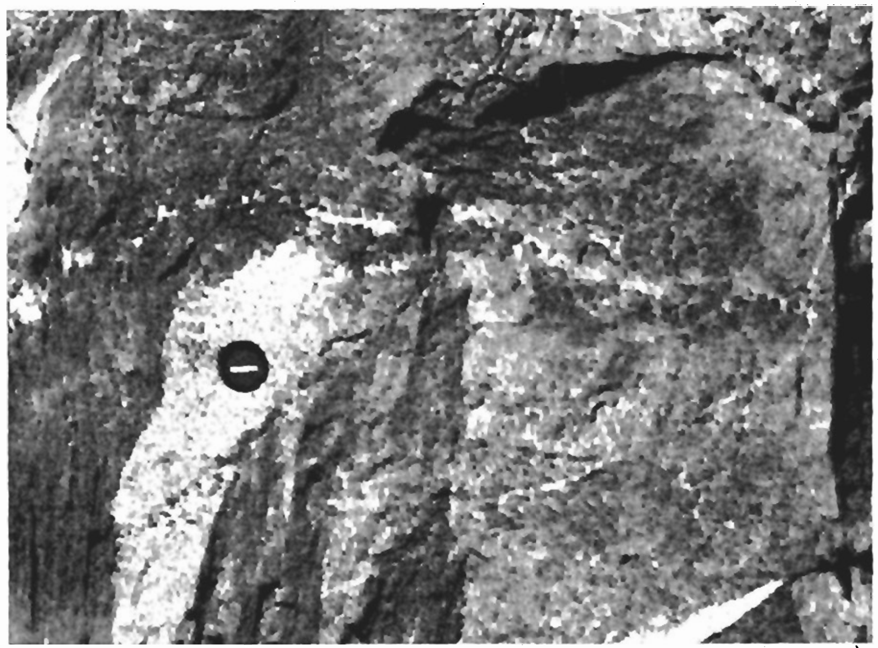
PT.2-3 Garnet clustering the felsic veins in the garnet granulites near Pattan. Garnet has pinkish colour and is essentially composed of pyrope - almandine - grossular mixture. Garnet granulites and Jijal ultramafics shara a common tectonic zone and together obducts onto the Indo-Pakistan plate along the Main Mantle Thrust, a southern suture zone.

Garnet granulite belongs to the high pressure granulite facies of the assemblage; garnet + diopsidic pyroxene + plagioclase + hornblende + quartz + rutile + clinoziosite.

PT-4 Melange exposed in the Main Karakoram Thrust Zone in Sissi Gol, northeast of Drosh in Chitral.

Melange is mormorized due to intense deformation and the fragments involved are of andesite, basalt and serpentinite. The latter being relatively softer has suffered more.


PT−1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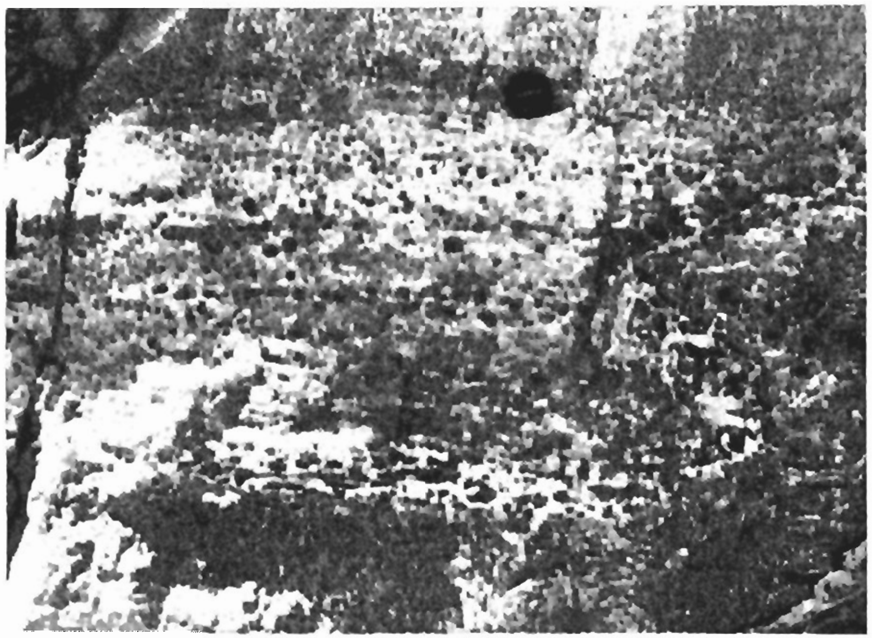
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Some of the earlier workers have correlated the Tannaki Conglomerate with the Tobra Formation, named by the previous workers as the Talchir Boulder Bed of the Salt Range, which lies between the Cambrian and the Permian. However, there is a marked difference between the lithology of the two rock units. In the former, all of the clastics are derived locally from the underlying Hazara Slates, whereas in the latter most of the clastics incorporated in the sequence are transported from the Indian shield from the southeast.

The conglomerate beds considered equivalent to the Tannakis are also recorded in the other slates occurrences outside Hazara. In the Manki Slates in the Attock - Cherat range, conglomerates equivalent to the Tannakis are located in two sections, one on the top of Raja Hodi tunnel, south of Khairabad and another in an isolated hillock on Jallozai-Manki road, west of Jabba Khattak (Tahirkheli,1970).

A conglomerate bed in the slates located on the western abutment of the Warsak Dam has also been reported by Ali et al.(1969). Another section, where the conglomerate bed is recorded is the Ghalanai anticline in Mohmand in the slates occupying the top of this structure and is considered equivalent to the Hazara Slates.

5. The Abbottabad Formation

A dominantly carbonate sequence, earlier called the Infra - Triassic by Middlemiss (1896), overlies the Tannaki Conglomerate in the Sirban hill section near Abbottabad. Elsewhere, specially in the sections located in the west, the Abbottabad Formation overlies the Tanawal Formation.

In the environ of Abbottabad, this formation is developed in the three isolated massifs namely, the Sirban, Kakul and Sobra located around Abbottabad in an area of about 200 sq. km. This formation has extension eastward towards Garhi Habibullah and westward towards Sherwan, Kacchi and the Gandghar Range.

The Abbottabad Formation has a variable thickness. It is about 450 m thick at Sirban, 700 m in Sherwan-Kacchi section occupying the southern fringe of the Tanawal area, 150 m in the vicinity of Garhi Habibullah and 80 m thick in the Pirthan section of the Gandghar Range.

In the Abbottabad section all the members of the Abbottabad Formation are exposed, whereas in the other sections the Sangar Gali and the Sirban members (Table-1) are more consistant in horizontal distribution than the other two.

Marks & Ali (1961-62) on the basis of their work, differentiated the Abbottabad Formation into the following five lithological units which were not assigned any names. These units from the bottom to the top are:

i. Basal Conglomerate,
ii. Lower slate and sandstone,
iii. Lower Dolomite,
iv. Upper shales and sandstone and,
v. Upper Dolomite.

Subsequently, Latif (1970) followed the same classification and assigned them the names, which from bottom to top are:

i. Tannaki Member,
ii. Sangar Gali Member,
iii. Mohmda Gali Member,
iv. Mirpur Member.

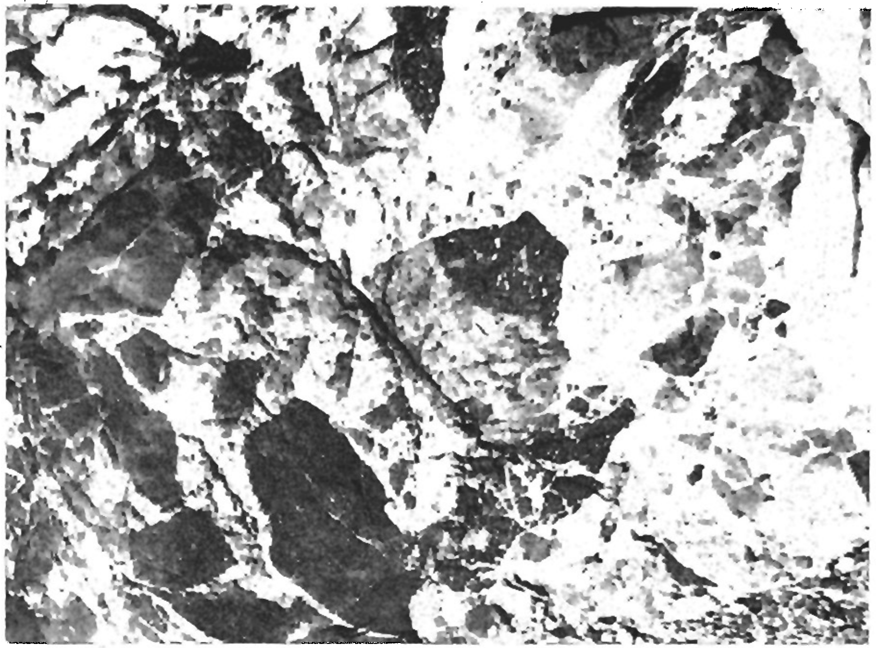
These units were placed under the Kakul Formation. The upper dolomite of Marks & Ali was retained as a separate formation to which he assigned the name Sirban Formation. Thus, Latif (1970) elevated the status of the Abbottabad Formation to a group.

PT-5 Another view of the melange in Sissi Gol further northeast of the previous section. The main fragments are basalt, andesite and serpentinite. An important feature in this melange zone is that it has been intruded by granite of late magmatic episode.

PT-6 Melange zone in the type section near Chalt in the Hunza Valley. The rocks of darker hue developed in the sharp ridge marked (1) contains serpentinite and ophicalcite representing the altered peridotite alongwith volcanic andesite and basalt. These are tectonically emplaced in the deep water oceanic sediments (2) consisting of phyllite and schists with subordinate conglomerate near the leading edge of the arc and interbedded fine grained limestone band.(3) is the southern marginal mass of Eurasian plate (Minapin Fm.) which obducts onto the Kohistan arc.

PT-7 A closer view of the above mentioned section along the road cut. All the rocks mentioned above are encountered in this section. Serpentinite zone is conspicuously marked because of its dark greenish hue.

PT-8 In the same section breccia, a product of cataclastic metamorphism was also recorded. Breccia contains angular cherty quartzite fragments which are cemented with siliceous matrix. Dessiminated hornblende is also associated with the matrix.



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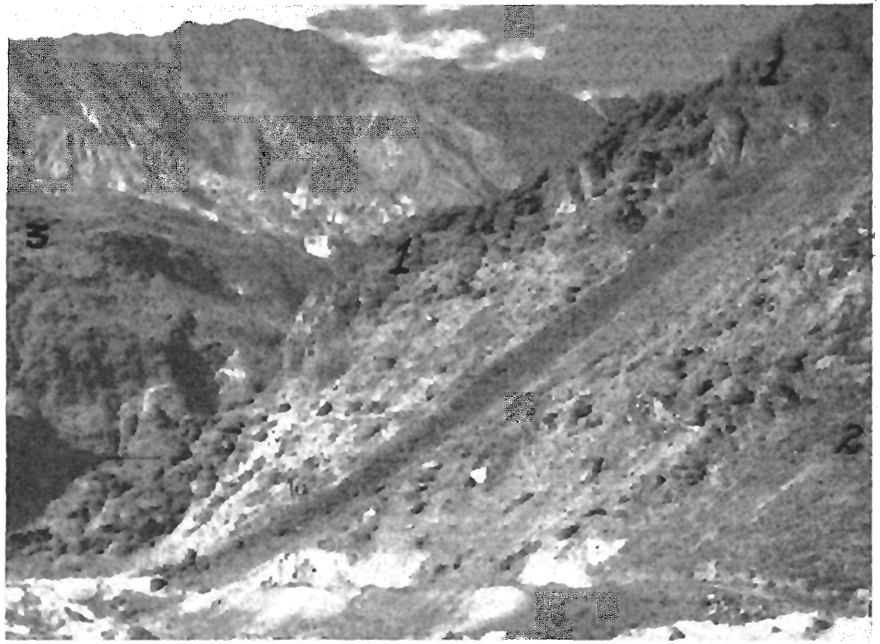

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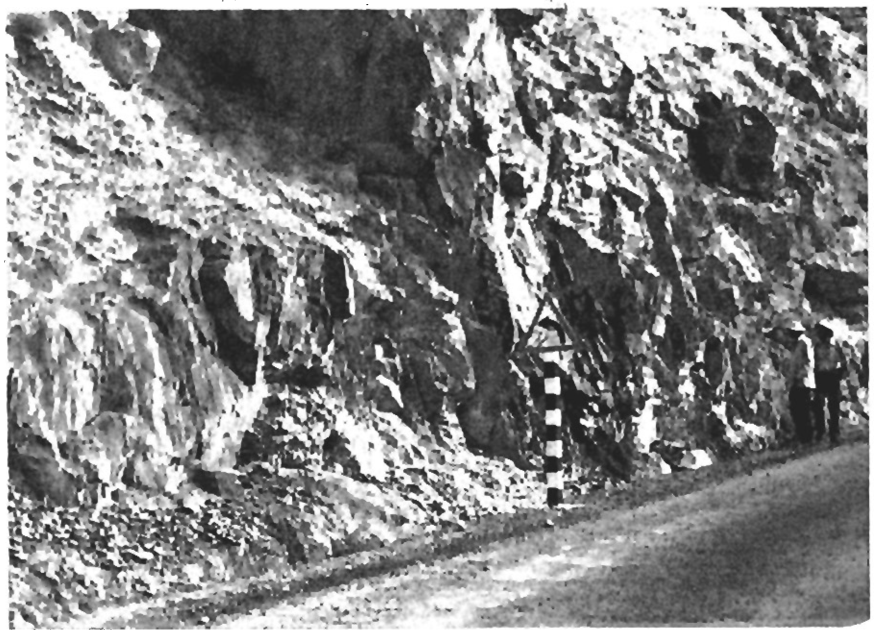

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The Sangar Gali Member which overlies the Tannaki Conglomerate comprises of red and purple sandstones and orthoquartzite with alternation of shales and slaty shales. The sandstones are hard, fine grained and break with concoidal fracture whereas the shales are well laminated and fissile with well developed cleavage, usually oblique to the beddings. Waagen and Wynne (1872) had reported a lithological resemblance of the Sangar Gali Member with the Purple Sandstone of the Lower Cambrian in the Salt Range. As mentioned earlier, there is a gradational passage of the Tannakis upward into the Sangar Gali Member

The overlying sequence is the Mohmda Gali Member which consists of dominant dolmitic limestone with subordinate sandstones and shales. At the base this sequence contains pale red to purplish red coarse sandstones which gradationally pass on to more calcareous rocks and ultimately merges with the semi-to medium crystalline, purplish grey dolomitic limestone at the top. In the calcareous part, chert is quite common and is usually emplaced along the bedding. This part of the section resembles with the dolomite of the Sirban section.

The Mirpur sandstone is thin to thick bedded, light grey to greenish-red and fine grained. The grains are angular to subangular and the cementing material is both pelitic and calcareous, the latter becoming dominant towards the top. Thus, its contact with the overlying Sirban dolomite becomes gradational.

The top sequence of the Abbottabad Formation has its type section located in the Sirban hill. Latif has given it a status of a formation whereas the other workers including the author recognise it as a member of the Abbottabad Formation. This sequence is comprised of dominantly dolomitic limestone and dolomite with sporadic shale and sandstone partings. The dolomite is thin bedded to massive and indicates colour variations which appears as light greenish grey at the bottom, dull grey to buff in the middle and red to pink near the top. It is medium to coarse and semi-to medium crystalline. Cherty bands are quite common and have extensive distribution as compared to the other members. Solution weathering has deep imprints on the dolomite beds, leaving behind ribbed and grooved features on the exposed surface.

6. The Galdanian Formation

Overlying with an unconformity is a sequence that is comprised of volcanic rock, heamatitic claystone and sandstone, oolitic heamatite and laterite with silty shales and varicoloured quartz breccia. This sequence is about 120 m thick in its type section and on the basis of lithology, a broad two-fold division attempted by the author at the type section is as follows:

i. Red nodular heamatitic claystone, volcanics rock, oolitic heamatite and laterite with shales-repeated several times.	40 m.
ii. Manganese oxide, red and purple sandstone and siltstone with varicoloured quartzite breccia and felsitic rocks and manganese oxide.	80 m.

Among the volcanics, rhyolite is common which is not present in every section. Fuchs (1975) had shown his doubt about the Galdanian to have volcanic association. He also asserted that the general lithology of the rocks point out to their being a product of subaerial weathering and cites the example of association of the heamatitic rocks. Latif (1970), on the other hand confirms the presence of volcanic rocks in the Galdanian sequence as has earlier been done by Verchere, Waagen & Wynne and Middlemiss (Table-1), and correlates the volcanic rocks with the Panjal volcanics of Kashmir.

The author's investigation of the Galdanian Formation in its type section confirms that, i. There is a pronounced stratigraphic break between the Sirban member and the overlying Galdanian rocks, and ii. The lithology of the rock assemblage in the Galdanian sequence suggests the derivation of bulk of the material through subaerial weathering. The preponderance of the heamatitic rocks and the siliceous breccia in the sequence are the improtant constituents indicative of this source and iii. The Galdanian has volcanic incorporation which is sporadic in occurrence and appears as lenses of rhyolite-felsitic rock association.

7. The Hazira Formation

A sequence consisting of grey and yellowish brown calcareous and shaly siltstone with subordinate dolomitic limestone partings at the base, has been differentiated as the Hazira Formation by Gardezi and Ghazanffar (1965). At the type section, it is about 300 m thick and its horizontal distribution is confined to about 300 sq.km area, in the east and northeast of Abbottabad in Hazara.

In the Sirban section, it overlies conformably(?) the Sirban Dolomite and in turn is unconformably overlain by the Daulatmar Limestone of Jurassic age. Latif (1970) has described the lower contact of the Hazira with the Abbottabad Formation at Nare-di-Gali as disconformable. The author based on his observations opts for the latter views.

Gardezi and Ghazanffar (1965) have indicated that the Galdanian may be partly or entirely replaced by the Hazira Formation. On the other hand, the author is of the view that the red lateritic bands and the coarse clastic associations with the Hazira Formation, point out to the subaerial weathering which continued during the deposition of Galdanian.

In the Sirban section of the Abbottabad Formation where the Hazira Formation directly overlies the Sirban dolomites, a fossiliferous horizon was recorded by Fuchs and Latif (in Fuccs, 1975), Latif (1973), Rushton (1973) and Fuchs & Motler (1975) who studied fossils from this locality and identified as Hyolithids (circotheca and Linevitus) and Heterectinilled spong (Chancelloria walcot) indicating a Cambrian age for this sequenne.

8. The Mansehra Granites

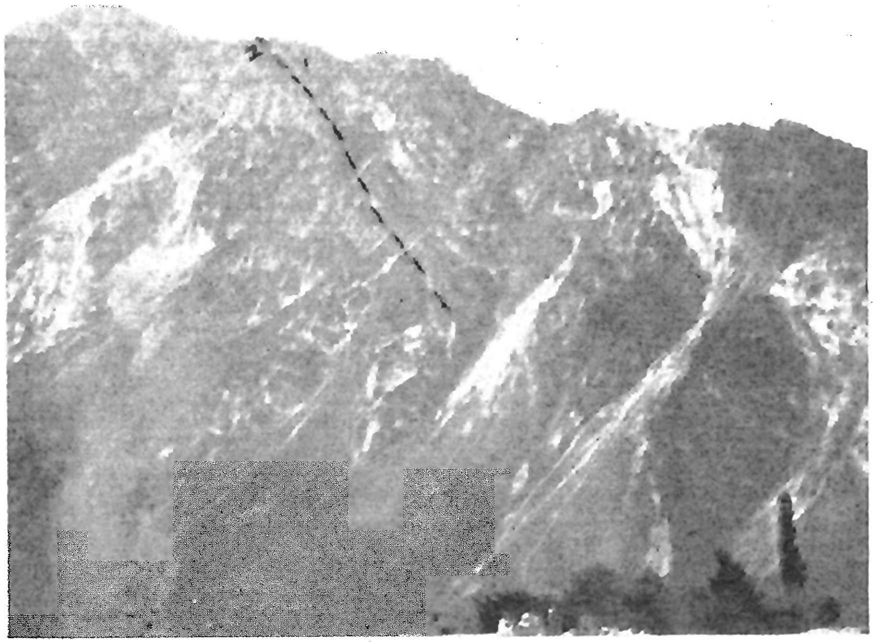
The granitic plutons have extensive distribution on the leading edge of the Indo-Pakistan plate. These are associated with the metasedimentary sequence of the Hazara zone of the Lesser Himalaya on the eastern and the western flanks of the syntaxis. In the west, the granitic plutons have extension to the west of the Indus into Gadun, Swat, Dir, Malakand and Mohmand forming isolated outcrops.

PT-9 A contact of the Yasin Group (1) with the underlying Rakaposhi Volcanic Complex (2) at the type section, near the Yasin Rest House, in the Yasin Valley. The base of the Yasin Group in this section contains conglomerate and over ninety percent of the clastics are derived from the underlying volcanic complex.

PT-10 A closer view of the basal conglomerate in the Yasin Group. This conglomerate is quite persistant and where the rocks are unfossiliferous it can work as a marker.

PT-11 The Yasin Group (1) in the Ishkuman Valley where it has a faulted contact with the Rakaposhi Volcanic Complex (2) at Yasin. The rocks dip towards north whereas in this section the dip is southerly. (3) indicates granite intrusions in the volcanic complex and (4) marks the river terraces which at places are two hundred meters high from the present river bed.

PT-12 The foothills on the northwestern fringe of Rakaposhi expose the rocks of the Yasin Group. The Main Karakoram Thrust passes over the frontal part of the village which lies in this zone. Rakaposhi in the back covered with ice, holds volcanic complex and thus forms its type section.



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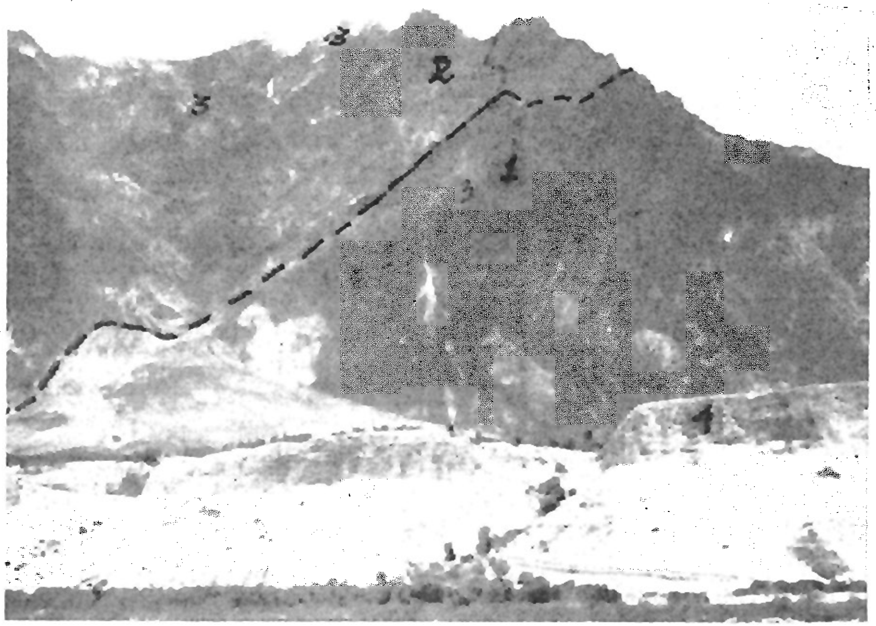

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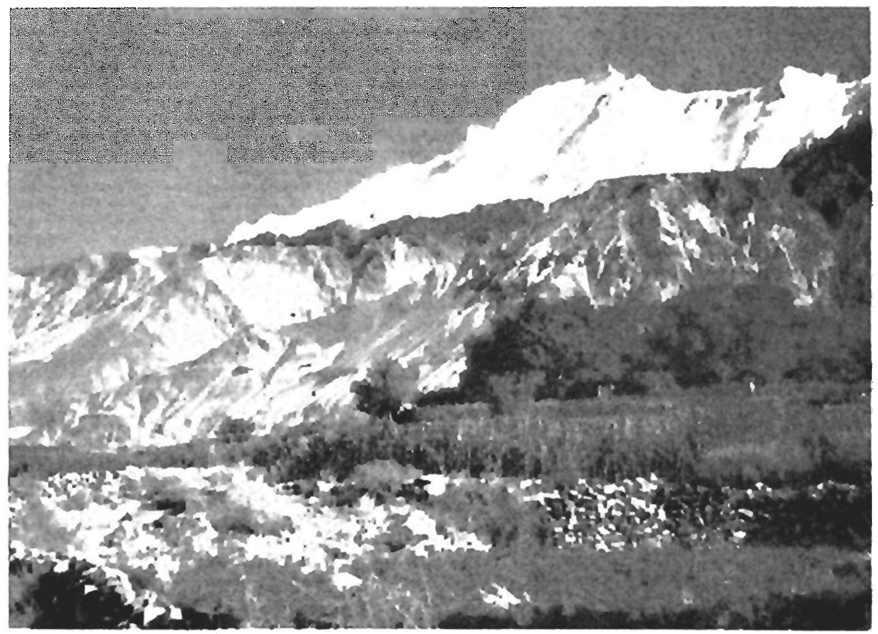


PT-12

The granites on the basis of texture, structure and composition are divisible into three categories: i. Augen gneisses, ii. Foliated gneisses, and iii. Normal or homogenous granites.

The first category is comprised of coarse to very coarse, dull grey to yellowish white and sub-equigranular with abundant mica including vermaculite. The augen structure is well pronounced in such type and incorporation of xenoliths are quite common. These granites indicate a concordant relationship with the country rocks and the contact is not very sharp. Besham-Karora granites and gneisses and the gneissic bodies found around Thakot, Oghi and Batagram belong to this type.

The second category consitutes fine to medium grained foliated gneisses which are dull white to light grey. These are rich in quartz and feldspar with subordinate sericite and some chlorite. Micas are relatively less developed.

These gneisses display subequigranular to equigranular texture and their contact with the country rocks is not sharp. This type includes the Mansehra granite, Chakdarra gneisses, Mingora gneisses, Ambela granite, Warsak granite, and Karakar granite.

In the last category the granites are white to light grey, medium to coarse and sub-equigranular to prophyritic. They are rich in feldspar and quartz, whereas black tourmaline and other accessories including the ores are quite common. This type usually forms discordant bodies and indicates a sharp contact with the country rocks. Most of such granitic bodies located in the Kohistan are included in this type. However, some of such granites which either intrude the earlier mentioned granites or occur as small isolated individual bodies within the metasedimentary sequence on the northern edge of the Indo-Pakistan plate, are included in this type.

In the stratigraphy of the Hazara Zone, the Mansehra Granite represents the syn-to late kinematic granitic plutons associated with the metasedimentary rocks ranging in age from the Precambrian to the Palaeozoic. Among them the Mansehra granite has yielded an age of 516 - my. by Rb-Sr method (Le Fort, 1979) and Mingora gneisses, dated by K-Ar method has given an age of 522 my. (Malluski, 1981). Thus both of them are placed in the Cambrian.

These granites are correlated with the latter phases of Pan African Magmatism which lasted from Precambrian to Cambrian periods.

THE KALA CHITTA ZONE

1. The Mianwali Formation

This formation has earlier been referred by Waagen(1879, 1878) as the Topmost Limestone and Dolomite Bed and the Lower part of the Mianwali Series by Gee (in Pascoe, 1959). It was first differentiated in Zaluch Nala in the Western Salt Range and in the Tappan Wah in the Khisort Range.

The Mianwali Formation has a variable lithology and consists of marl, limestone, sandstone, siltstone and dolomite. Its thickness is about 125 m. It has been divided into three members: the upper one is called the Narina Member, the middle one is the Mittiwali Member and the lower one is the Kathwai Member.

The upper contact of the Mianwali Formation is with the Tredian Formation and the Lower contact is with the Chak Jabbi in the Kala Chitta. Both the contacts are conformable and gradational.

Among the fossils, ammonites abound in this formation whereas a few bivalves, brachiopods, forams, ostracodes, crinoids, and conodonts were also recorded. Among the fossils identified are: Oweniles, Meckoceras, Ana-Kashmisites, Ophiceras Glyptophiceras, Ambites, Pesendomonotes Nucula, Rhyneonella, Bellerophon, and Spiriferina. It is assigned a Lower Triassic (Scathian) age.

2. The Chak Jabbi Limestone

In the old literature this formation has been named the Kioto Limestone by Cotter (1873) in the Kala Chitta and the Bagh Limestone by Fatmi (1966, 1968). The type locality displaying this sequence is located north of Chak Jabbi in the Kala Chitta Range. It consists of grey to light grey and thin to thick bedded limestone which on weathered surfaces looks brownish grey.

The upper contact of the Chak Jabbi Limestone with the Kingriali Formation is gradational and so is its lower contact with the Mianwali Formation. No recongnisable fauna have been recorded in this formation. Its thickness is between 30-35 meters. Based on its gradational contacts with the Mianwali and the Kingriali Formations, whose ages are confirmed on the basis of fossils, the Chak Jabbi Limestone has been assigned a probable Middle Triassic age.

3. The Samana Sukh Formation

The earlier names assigned to this formation are Kioto Limestone by Middlemiss (1896), upper part of Kioto limestone by Cotter (1933) and the Broch Limestone by Gee (1945). The type location of this section is situated northeast of Shinwari in the Samana Range, Kohat.

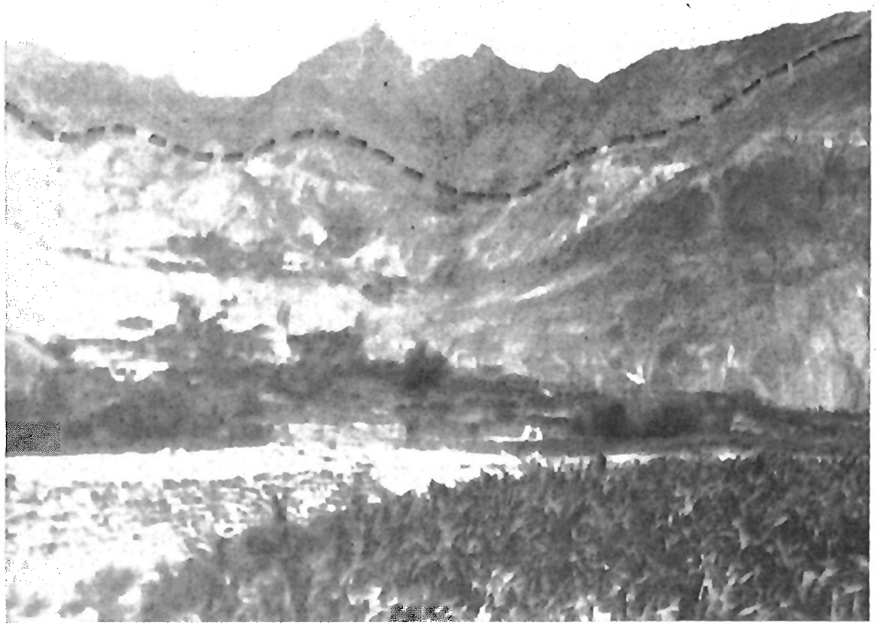
This formation is comprised of grey to dark grey, thin to thick bedded oolitic limestone with subordinate marl and calcareous shale partings. In the Kala Chitta Range and eastern Kohat, the limestone includes dolomitic and ferrugenous sandy beds. It is about 200 m thick in its type section and attains maximum thickness of 350 m in Kohat and Kala Chitta.

PT-13 A section located west of Chotarkhan in the Ishkuman Valley. The depression indicates the MKT Zone. The dotted line marks the northern edge of this zone in contact with the Eurasian plate.

PT-14 Again Yasin Group (1) exposed in the hillock behind the village. (2) marks the Rakaposhi Volcanic Complex. This section is located about five km west of Teru in the upper reaches of Ghizar Valley in the Karakoram.

PT-15 The Yasin Group exposed near Drosh in Hindu Kush. The dotted line marks the surficial trace of the MKT. (2) is the Yasin rocks which was named Orbitolina limestone by Hayden (1914) and (1)marks the Chitral Slates which are equivalent to the Baltit Group of the Karakoram.

PT-16 An outcrop of Rakaposhi Volcanic Complex with a yellow sulphide mineralized zone in the Ghizar Valley. Such gossans are very common features in the Karakoram and Hindu Kush, and some of them are reported to contain lead - antimony - zinc mineralization.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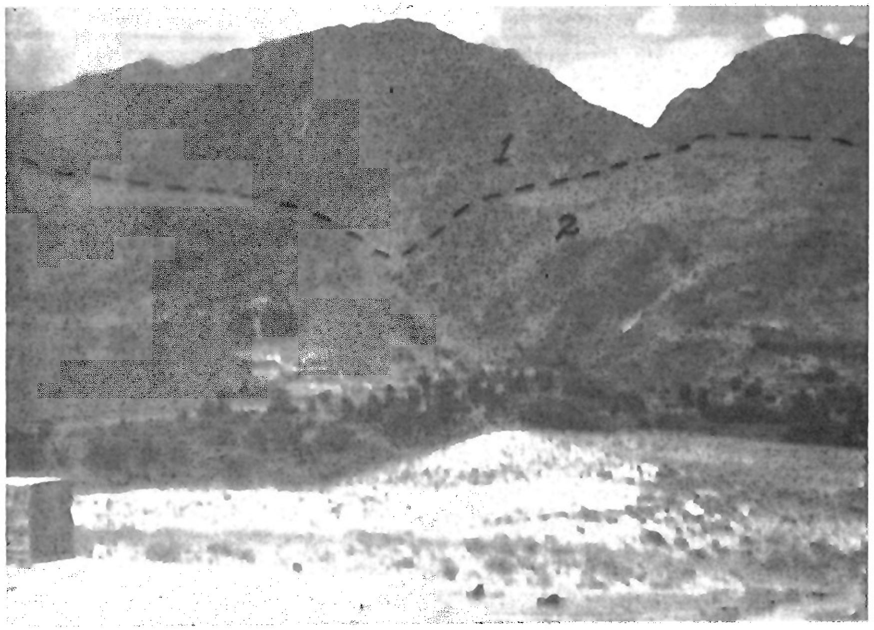


PT-15


PT-16

Its upper contact with the Chichali Formation (Late Jurassic) is disconformable whereas the lower contact with the Shinwari Formation is transitional. It is fossiliferous and contains brachiopods, bivalves,gastropods, ammonites and crinoids. Among the ammonites, Fatmi (1968, 1972) has identified: Reineckeia Cheffātion, Obtusicostites, Hubertoceras; Brachiopod; Somalirynchia nobelis; Bivalves; Homomya Arotosrea.

This formation is assigned a Middle Jurassic age. It is correlated with the Daulatmar Limestone of Hazara(Calkins et.al. 1975) and the Chiltan Limestone of Baluchistan.

4. The Kawagarh Marl

This formation was earlier designated as Kawagarh marls by Day (unpublished), sublithographic limestone by Davies (1930), Darsmand limestone by Fatmi & Khan (1966), Darband Limestone by Khan and Ahmad (1966) and Satu Limestone by Calkins et al.(1968). The first name was adopted by the Stratigraphic Committee of Pakistan with its type section located north of Kala Chitta in the Attock district.

Its main lithology is comprised of dominant dark grey marl and calcareous shales with nodular argillaceous limestone partings which weather to light grey or brownish grey.

In its type locality, the Kawagarh Marl has two members: the upper one is named the Tsukail Tsuk Limestone and the Lower is called the Challor Silli. It has a variable thickness: 50-60 m.at the type locality, 100-120 m.at Samana and the western Kohat and 80-180 m. in Hazara.

The upper and the lower contacts of the Kawagarh Marl with the Hangu Formation (Palaeocene) and with the Lamshiwal Formation in Kohat and Hazara respectively are disconformable.

The Kawagarh Marl is poor in fossils. Some Ammonites and Forams are recorded in the calcareous shales and limestone. The fossils identified are: Globotruncana, Heterohelix, Pseudolexterin and Globortalites (Latif,1970). It is placed in the late Cretaceous (Late Coriacian to Campanian) with the Pab Sandstone, Mughal Kot Formation and Parh Limestone of the Axial Belt and the Lower Indus Basin.

5. The Lockhart Limestone

The earlier names assigned to this formation were the Hill Limestone by Wynne (1873),Nummulitic Series by Middlemiss (1896), Khairabad Limestone by Gee (1933) and the Tarkhobi Limestone by Eames (1952). Its type locality is Fort Lockhart, Samana Range, Kohat.

Its main lithology is comprised of light grey to grey,thin to thick bedded, at places massive limestone which gives a rubbly appearance and is brecciated. The basal part contains dark grey to bluish grey flaggy limestone which is fossiliferous. In Hazara, its counterpart is dark grey to black with marl and shale intercalations. In some sections, the limestone is bituminous and emits a fetid smell. Its thickness is variable: 50 m.at the type section, 70 m.in the Salt Range, 250 m.in the Kala Chitta and 80-240 m.in Hazara.

The Lockhart Limestone has got conformable and transitional contacts with the upper Patala Formation and the lower Hangu Formation. It is fossiliferous and contains forams, corals, molluscs, echinoid and algae. The fossils identified constitute Lockhartia Conditi, L. Haimei, Miscellania Miscella, Operculina Patalessis (Bhola, Nagappa, 1952): sp. vulvulina geci (Haque, 1965). On the basis of faunal evidence, it is assigned a Paleocene age. It is correlated with the Mari Limestone of Hazara and the Bara Formation,the Dungan Formation and the Pakhshani Formation of the Axial Belt and Baluchistan.

6. The Patala Formation

This formation was earlier known as a part of the Nummulitic Formation by Waagen &Wynne (1872), part of the Hill limestone by Wynne (1837) and Cotter (1933), Patala Shale by Davies and Pinfold (1937) and Tarkhobi Shale by Eames (1952). Its type section is located in Patala Nala in the Salt Range.

The main rock constituents of this formation are shale and marl with subordinate limestone and sandstone. The coal seams are locally associated with the shales. Its thickness encountered in various sections is as follows: at the type locality-90 m.,at Khewra eastern part of the Salt Range - 25 m., Surgarh Range southern eastern Kohat - 30-150 m., in Kala Chitta and Hazara 25-30 m.

Its upper and the lower contacts with the Nammal Formation and the Lockhart Limestone respectively, are transitional. It is fossiliferous and contains forams, moluscas and ostracodes. The fossils identified are: Actinosiphon tibetica, dandotica Discocyclina ranikotenesis, Lockhartia conditi, Nummulites globlus and Globigerina Linaperta (Smout and Haque, 1965) and Latif (1970). On the basis of faunal evidence, this formation is placed in the Late Palaeocene in Hazara and Palaeocene to Early Eocene in the Kohat-Potwar Basin.

It is correlated with the Kuza Gali Shale of Hazara (Latif, 1970). Lakhra Formation in Sind and the upper part of the Dungan and Rakhshani Formations in Baluchistan.

7. The Marghala Hill Limestone

The earlier names assigned to this formation are Nummulitic Formation by Waagen and Wynne (1872), an upper part of the Hill Limestone by Wynne (1873) and Cotter (1933) and part of the Nammulites Series by Middlemiss (1896). Its type section is located at Shahdarra, Marghala Hills southeastern Hazara.

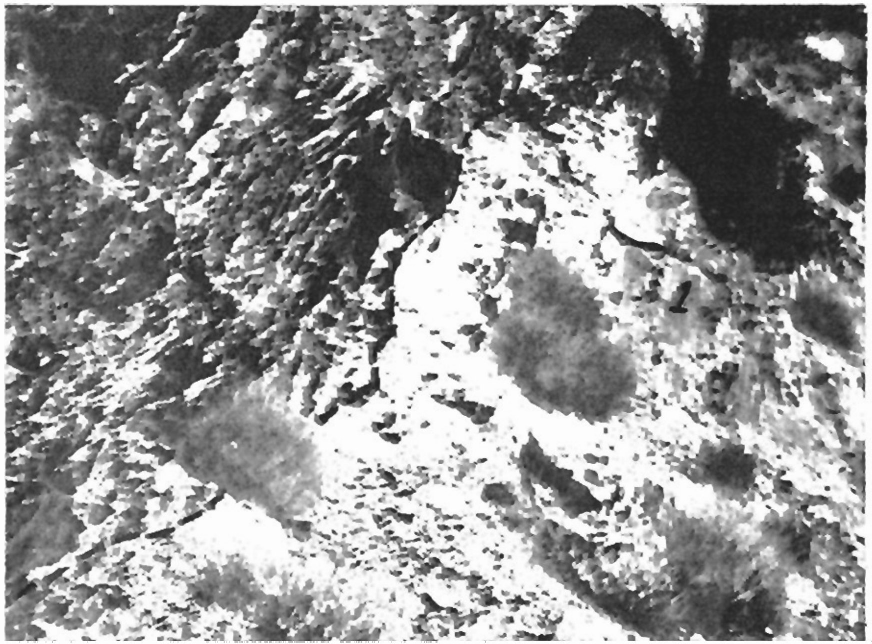
It consists of thick bedded to massive grey limestone weathering to pale grey. It is fine to medium grained, nodular with subordinate grey to brownish grey marl and greenish brown shale intercalations. It is fossiliferous ~~and its thickness~~ at the type section is about 80 m.

PT-17 A fault contact between the Rakaposhi Volcanic Complex (1) and the Yasin Group (2) exposed on the eastern bank,downstream of Chalt in the Hunza Valley.

PT-18. A section showing Rakaposhi Volcanic Complex in the Ghizar Valley. This picture was taken to locate an old jeepable road which was used by the author in 1957.

PT-19 Rakaposhi Volcanic Complex, besides flows, also contains tuffs. This picture shows foliated tuffaceous rocks located at about three km north of Sor Laspur village along the road leading to Mastuj.

PT-20 Basalt in Rakaposhi Volcanic Complex showing a deformed aplite veinlet. This section is not far off from the MKT in the Hunza Valley.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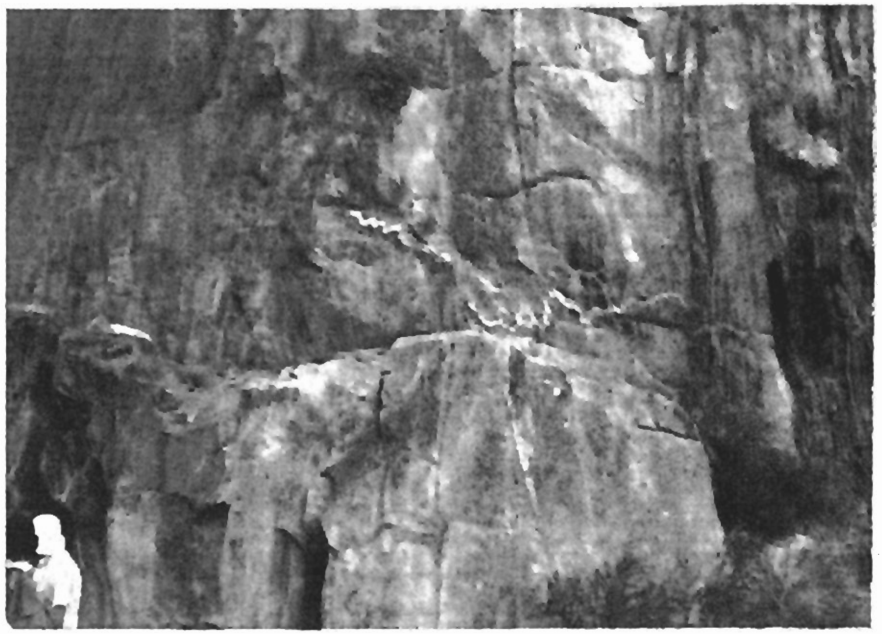

PT-20

The upper contact of the Marghala Hill Limestone is conformable with the Chorgali Formation (Early Eocene) and so is its lower contact with the Patala Formation. The fossils identified are Assilina granulosa and Lockhartia conditi, on the basis of which an Early Ecoene age is assigned to this formation.

The Marghala Hill Limestone has a wide range in distribution and is well developed in Hazara, Kala Chitta, eastern Kohat and the northern parts of Potwar.

HIGHER HIMALAYA

The Nanga-Parbat Gneisses

When the folio on the geology of the Nanga Parbat-Haramosh massif is opened, two important features appear in bold lines. Its intricate tectonics and metasomatic granitization of batholithic dimension. Wadia (1932), Misch (1935c, 1949) and Desio (1960, 1976) have already made substantial contribution on these problems.

A brief mention has already been made on the Lesser Himalayan sequence in the Nilam valley alongwith figure-8, which has extension toward the north into this massif. The rock assemblage which has made a principal contribution to the Nanga Parbat mass belongs to the Hazara zone, which in the decending order of abundance includes the Dogra/Hazara slates, flaggy quartzite and quartzitic schists, Salkhala Series, crystalline limestone and marble. Thus, the major part of the rocks involved are the earlier two. The Salkhalas, being more carbonaceous have resisted alteration and retarded the process of granitization a phenomenon also noticed by Misch (Fig.8).

On the southeastern margin of the Nanga Parbat, some volcanic flows and tuffs are also involved in the mass. Misch considers them to belong to the Indus volcanics. The composition of these volcanics is similar to those exposed in the vicinity of Dras. These volcanics also indicate some incorporations of the Deosai volcanics, the main occurrance of which is not far from the massif. The proportion of the volcanics when compared to the sediments, constitute a negligible part of the Nanga Parbat mass.

The involvement of the volcanics in the mass is a definite indication of their being older than the Nanga Parbat tectonics and thus Misch is justified in assigning them a Cretaceous age. The Deosai volcanics and the volcanics associated with the Dras ophiolitic belt, on the basis of fossils found in the trapped sediments have already been placed in the Cretaceous (Wadia, 1932a).

Misch has mentioned the intrusions of norites, hypersthene diorites and locally dunites, which he considers to be contemporaneous with or slightly younger to the Indus ophiolitic belt. The recent studies (Tahirkheli and Jan, 1978; Tahirkheli et al. 1979; Jan, 1979; Bard et al. 1979) hold that these rocks belong to the Kohistan arc and are developed on the fringes of both the limbs of the NP-H loop forming a thin rim around the massif on the eastern, northern and western sides. Their sequential order from the inner to the outer sides is as follows: The Kamila Amphibolite, Bahrain Pyroxene Granulites and Deshai Diorites. The hypersthene diorite mentioned by Misch is retrograde after granulites and has already been reported by Jan (1979) and Tahirkheli (1981) in the Indus Valley section and in the vicinity of Kalam in Swat, located on the west of the Nanga Parbat massif.

The dunite is associated with the Main Mantle Thrust, the southern suture earlier recorded by Misch as the extension of the Indus Fault. The ultrabasic bodies are quite frequently encountered intruding the Kohistan mass along this zone, the largest one is exposed at Jijal, which is their type section(Tahirkheli and Jan, 1978). The age assigned to these rocks by Misch is Late Cretaceous - Lower Tertiary. Only the ultrabasic part of the rock assemblage may be conveniently accommodated in this range of time but the other two rock formations i.e. Kamila amphibolite and the pyroxene granulites form the base of the Kohistan sequence and range in age from Jurassic to Early Cretaceous. Thus the volcanics are younger to both of these rock formations.

The selective granitization is a common feature in the Nanga Parbat-Haramosh massif and Misch considered some primary factors to be responsible for retarding this process. He mentions the presence of carbonaceous matter in the Salkhala sediments to be one of the check points in this process. The author considers that alongwith this factor, variations in deformation had left behind low thermal profiles within the Nanga Parbat mass, where adequate heat was not generated to promote the process of granitization. These zones are very conspicuous in the massif and are distinguished by hosting the epi-grade rocks.

The biotite gneisses have an extensive distribution in the Nanga Parbat massif, suggesting that granitization occured between garnet-biotite isogrades. Further rise in thermal gradient is not indicated in this zone, which could have altered the biotite. Misch's outer granitization zone corresponds to this horizon.

The core of the NP-H anticline where migmatites are frequent, marks a highly tectonized zone of the massif and P-T gradient has reached sillimanite-isograde. The sillimanite-bearing gneisses have already been reported in the upper reaches of the Kaghan valley which indicates their extension from the Nanga Parbat massif. This is the zone where Misch had mentioned injection of potash feldspar in the form of hot solutions. This zone correlates with the Inner granitization zone of Misch.

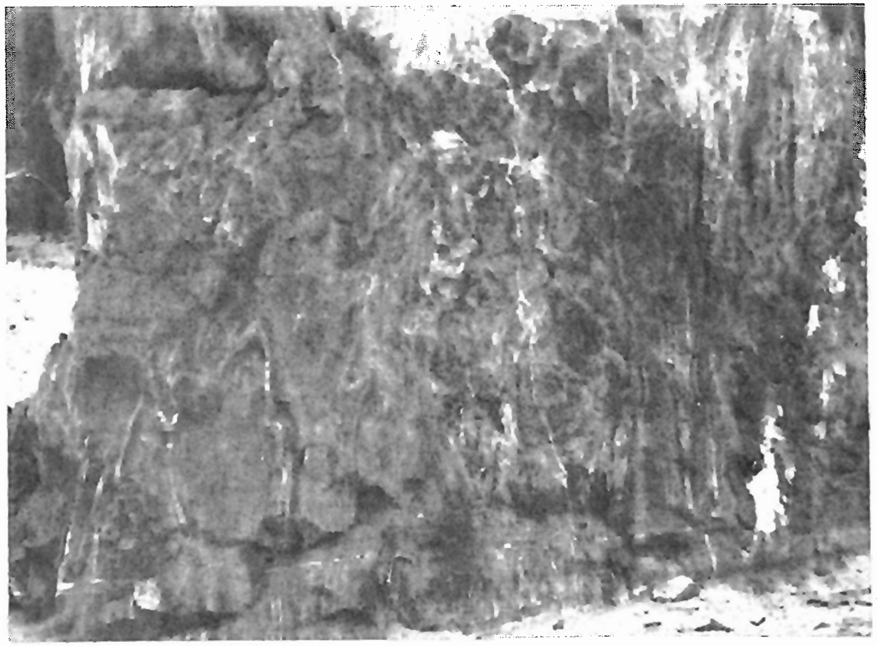
Keeping in view the involvement of the Hazara zone sediments in the Nanga Parbat massif, a Precambrian age assigned to the Nanga Parbat gneisses is quite justified.

PT-21 Deformed serpentinized basalt in the Rakaposhi Volcanic Complex in the Hunza Valley. Some pillows are also involved in the deformation.

PT-22 Fresh morain derived from the Rakaposhi Volcanic Complex near Sandur Top.

PT-23 Boudinage structure developed in the basalt, in the Hunza Valley.

PT-24 Epidote veining in the metavolcaniclastics, Hunza Valley.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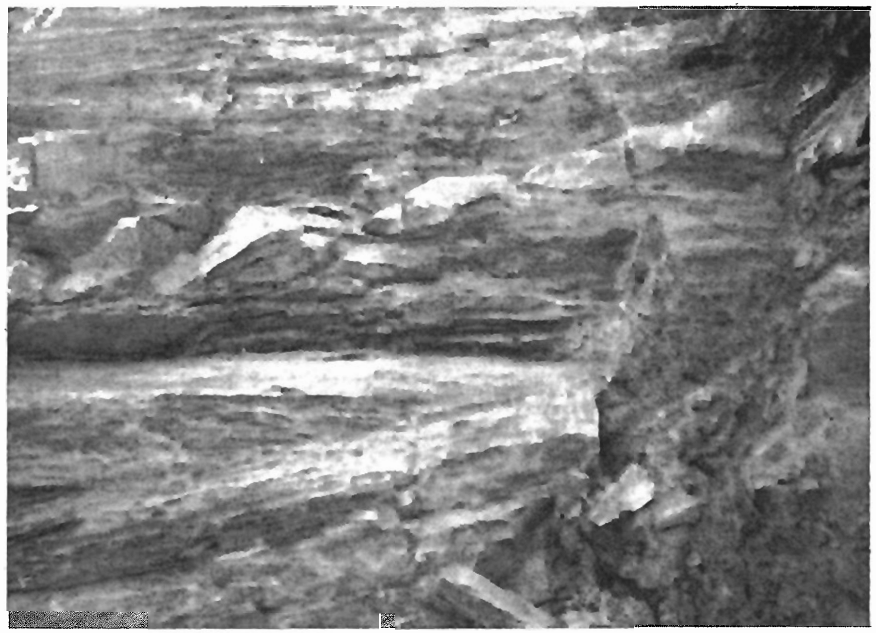
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PT-24

HINDU KUSH

1. The Chitral Slates

The Baltit Group of the Karakoram, considered to be the stratigraphic equivalent of the Chitral Slates, is already described in the Hunza Valley section alongwith figure 16. A brief mention about the Chitral Slates is also made in the regional geological setup of this publication.

The Chitral Slates remained isolated in the regional geological mosaic of the Karakoram-Hindu Kush domain. In the published literature, the sections in the Chitral Valley, downstream and upstream of the Chitral town were mainly limelighted. The author's traverses through the Ghizar Valley, over the Sandur Top, along the Sor Laspur Valley and in the Mastuj Valley have provided him a chance to have a closer look at several important sections of these slates, to appraise their lithological characteristics and ascertain their stratigraphi cbehaviour across the geographical border of the Hindu Kush and Karakoram.

As has already been mentioned, the Sor Laspur Valley section throws ample light on the sympathetic relationship of the Baltit Group, previously mapped in the Karakoram as the Darkut Group, and the Chitral Slates in the Hindu Kush. They laterally merge with each other, without any tectonic or stratigraphic break.Besides,both of these sequences form the southern marginal mass of the Eurasian plate and are traversed by a lineament common to both, called the Main Karakoram Thrust - the northern suture which passes on their southern edge and has thrown them over the Kohistan arc.

Lithologically, the Chitral Slates range from slaty shales to phyllitic schists and greenschists. In metamorphic grade in general they rarely surpass the garnet isograde. In the more tectonized zones, some para-gneisses have been noticed but these have sporadic distribution and usually constitute a very localized part of the sequence. On the southern edge, along the contact with the Main Karakoram Thrust zone, more intensely tectonized part of the Chitral Slates is exposed,where deformation has produced tightly squeezed foldings in these rocks. Otherwise, in general these slates are isoclinally folded with the limbs dipping towards north and northwest.

A thick marble bed named Gahiret Marble is associated with the Chitral Slates with a conformable contact in the Chitral Valley and extends northeastwards towards Mastuj. Besides numerous other semi-to medium crystalline limestone and marble beds occur as isolated partings within the slates. The arenaceous partings in the Chitral Slates are also noteworthy.

Among the igneous intrusions, dolerite, gabbro and diorite are present, the former being more common. Leuco-and melano-granitic bodies, form isolated plutons in the slates, but none attains a batholithic dimension like the ones encountered in their counterparts in the Karakoram.

The Chitral Slates were held to be Permain because of fossils reported by Tipper (1921) in a limestone band in the Chitral Gol. However,the subsequent workers could not confirm this find.The Permian beds in the Hindu Kush are already reported and none of them is lithologically comparable with the Chitral Slates.Another age assigned to the Chitral Slates is Cretaceous by Calkins et. al. (1975), based on the contact relationship. Again in the Hindu Kush, two isolated Cretaceous domains are encountered, one located on the north and another towards the south of the Chitral Slates. Their lithology is also quite distinct which does not match in any sense with the Chitral Slates. Moreover, the new regional tectonic model, created after the discovery of the Kohistan arc on the southern fringe of the Hindu Kush-Korakoram domain, also does not support a Cretaceous age for the Chitral Slates.

The Chitral Slates are overlain by the Lower Devonian sequence in the Mastuj Valley, thus these can be safely placed in the Pre-Devonian. Across the border in Afghanistan, these slates are mapped as Precambrian. Keeping in view, the geographical and stratigraphical relationship of the Pamir Knot in the north (Fig. Ia), it is postulated that this domain may have an extension of Precambrian rocks belonging to the Badakhshan Massif.

With these views in mind, the author proposes a Precambrian-Lower Palaeozoic age for the Chitral Slates and their equivalent i.e. the Baltit Group in the Karakoram, till such time an authentic evidence is in hand to alter this sequential order.

2. The Broghil Formation

A new stratigraphical sequence near Broghil, on the northern tip of Chitral, has been established on the basis of fossils. This sequence is placed in the Middle Ordovician (Talent et al.,1979). A detailed description of this sequence is given alongwith figure 20.

3. The Lun Shales

A large part of the area, located between the Tirich and Mastuj valleys, is underlain by greenish grey to dark grey splintery slaty shales and slates with subordinate quartzite and limestone partings. This sequence was earlier described by Hayden (1915), who considered it probably to be of Carboniferous age. Subsequently, Desio (1966) assigned it the name "Lun Shales", and described them as " a thick series of paper-and needle-shales and quartzites which represent the upper stratigraphical series of the Shogram Formation " He correlated this sequence with the Pamir Limestone,thus attributing it to the Carboniferous.

The Lun Shales sequence exposed in the Shogram hillock was latter examined by Talent et.al (1979), who reported <u>Irisdistrophia</u> Iris ? (Barrande), <u>Strophochonets</u> sp., <u>Atrypa</u> ? sp., <u>Prosoptychus</u> cf. plebius (Perner), <u>Dalmanites</u> sp nov., cf. <u>Phacops</u> and <u>Monographus</u> cf. <u>Uniformis</u>. On the basis of this fauna, the Lun Shales are assigned a probable Earliest Devonian(Lochkovian) age. Talent has reported some tectonic slivers of the late Devonian rocks incorporated in the Lun Shales in Barum Gol and Owin An sections. The Lun Shales are again faulted against the Chitral Slates in the vicinity of Phasti and the Cretaceous carbonates in the Krinj - Shogor sections.

PT-25 Sandur Top is over 4500 m high and is located on the Western tip of Karakoram. It has about 50 sq. km plain area with a beautiful lake which breeds trouts. The rocks around are those of Rakaposhi Volcanic Complex.

PT-26 Another view of Sandur Top. Its grassy ground holds several polo fields. People say that Sandur has the highest polo grounds in the world.

PT-27 A settlement over the glacial terrace (3) in the upper reaches of the Ghizar Valley. Most of the morainic material in the terrace has been derived from the Rakaposhi Volcanic Complex (1). The bedded outcrop (2) is that of Ghizar Molasse first differentiated by Tahirkheli (1981) and is correlated with the Hemis Conglomerate of Ladakh (Frank et al., 1974). The yellow colouration indicates a source from sulphide zone which are quite common in the volcanic complex.

PT-28 Again a thick morainic deposit along the Hunza Valley, upstream of Chalt.

PT-25

PT-26

PT-27

PT-28

4. The Shogram Formation

This section is synonymous with the fossiliferous Devonian sequence of Chitral. It is located in a hillock exposed on the southeastern slope, overlooking the Shogram village, which lies on the opposite bank of the Mastuj river. Desio (1966) has selected this section as a type locality of the Devonian rocks and defined its lithology and fauna.

The Shogram Formation can be divided lithologically into three broad units: a lower massive dolomite,a middle unit of bedded dolomite with fossiliferous limestone and black shale., and an upper quartzite.An approximate thickness of this section in the Shogram hillock is 800 meters.

The lower contact of the Shogram Formation with the Cherun Quartzite (Stauffer, 1969), is a well marked unconformity. Its upper contact is faulted against Lun Shales. Besides, a number of small faults traverse the sections which are usuallly parallel to the strike of the beds.

Some of the fossils, earlier described by Reed (1922) in the Shogram section are as follows: Actinopteria ? Victrix C. Reed, Spirifer Verneuili Murch, Spirifer reshunenisis C. Reed, Athyris hudlestoni c. Reed, Athyris Chitralensis c. Reed, Polypora hudlestoni C. Reed, alveolites(?) ramosa Roem, Orthis striatula Schloth Var., Fistulipora Shugramensis c. Reed, and Stromatoporella aff. granulate Nich,.

Desio (1966) confirms three palaeontological horizons in the Devonian sections (including Shogram) in the Mastuj Valley i.e. i. Lower dolomitic limestone with Crinoids ii. a middle limestone with Corals and iii. upper limestone with Brachiopods.

On the basis of fossil assemblage, the Shogram Formation is largely held to be Late Devonian. Desio has mentioned 600 m thick limestone and quartzitic sandstones beds beneath the Shogram Formations to which he, on the basis of coral fauna, places in the Middle-Upper Devonian transition zone. Thus Hayden, Reed and Desio, do not confirm the presence of the Lower Devonian rocks in Chitral.

Talent et al.(1979) sampled most of the Devonian outcrops, including the Shogram section and on the faunal basis, have confirmed the presence of Lower Devonian horizon in the Mastuj Valley.

5. The Parpish Limestone

The earliest known section in Chitral where Permo-Carboniferous rocks were reported is a thick escarp-forming limestone about 4 km northeast of the Parpish village. Tipper (Pascoe, 1923, P. 38) found fusulinids in this limestone which was traced for 12 km along the strike to the watershed of Phasti Gol. Other sections from where he collected fusulinids are on the northwest side of Tirich Gol and near Khot Pass, 13 km northeast of Buni.

Desio (1966) reported Permian fusulinids (Pseudofusulina and Nankinella) in a black fossiliferous limestone, which he suspected to have been derived from a fault slice within the Devonian sequence.

Stauffer also mentioned some sections where he found fusulinids.One is located 4 km east of Jumshill village and another lies in the upper reaches of Reshun Gol.

Talent et al.(1979) recorded fusulinid limestones in the Mastuj Valley between Nol and Kuragh, and along the left flank of Tirich Gol across Atrak and Rosh Gols. The latter belt, he thinks may have extension towards Baroghil-Shewa Shur area.

In the Karakoram-Hindu Kush domain, the section where Permo-Carboniferous sequence is confirmed on the basis of fossils, is located at Darkut which the author considers to be a Hindu Kush lithofacies. From the old literature, it appears that no detailed work is done on the fusulinids and other Carboniferous fossils, though Permian beds are reported from many sections.To trace the extension of the Darkut Group into Chitral, it is necessary that all the sections where fusulinids were earlier reported may be investigated. This may also help in tracing the new horizons.

6. The Zait Limestone

A thick sequence of massive black dolomitic limestone, weathering to grey and incorporating nearly 6 m thick pisolitic ironstone, is introduced as Zait I imestone by Talent et al. (1979). This limestone has quite an extensive distribution and occurs on the left flank of Mastuj Valley along th Reshun-Kuragh road between Torman Gol and Zait. It extends northeast across Zait Gol towards Memuk and southwest towards Girim Lasht.

In Zait Gol the limestone rests on Early Devonian sandstone, the contact appears to be sedimentary. The samples from Zait Gol sections were studied for conodonts by Molloy who idenified: Anchignathodus typicalis,,A. cf. typicalis, A. isarcicus, Lonchodina triassica, L. inflata L. cf. inflata. Prionodina mulleri and Ozarkhdina sp.

According to Talent, this fauna represent the zone Anchignathodus typicalis at the base of the Triassic,somewhere between the Otoceras and ophiceras ammonoid zones of the Griesbachian,probably on the presently known fauna.He mentioned some astray fauna from the floats and some in-situ containing identifiable cf.Bellerophon and Syringopora giving a board range of Silurian-Permian. However, on the basis of circumtantial evidence, Talent suggests that it may include horizons on either side of Permian-Triassic boundary.

7. Krinj Limestone

A thick platform type carbonate sequence is exposed along the Lutkho River east of Shoghor. Desio (1959) and Talent et al.(1979) have named this sequence as Krinj Limestone which has yielded fossils. It is massive, grey to black, partly crystallized and contains patches of white calcite which appears to be altered fossil remains, Tipper had reported Hippurites in this limestone in the Lutkho Valley.

PT-29 A distant look of the Ladakh Intrusives earlier called Ladakh Granodiorite Batholith by Ivanac et al.(1956). The light coloured rocks are diorite/granodiorite/granite whereas the darker ones are basic sills and dykes. This section is located about 25 km upstream of Skardu in Baltistan.

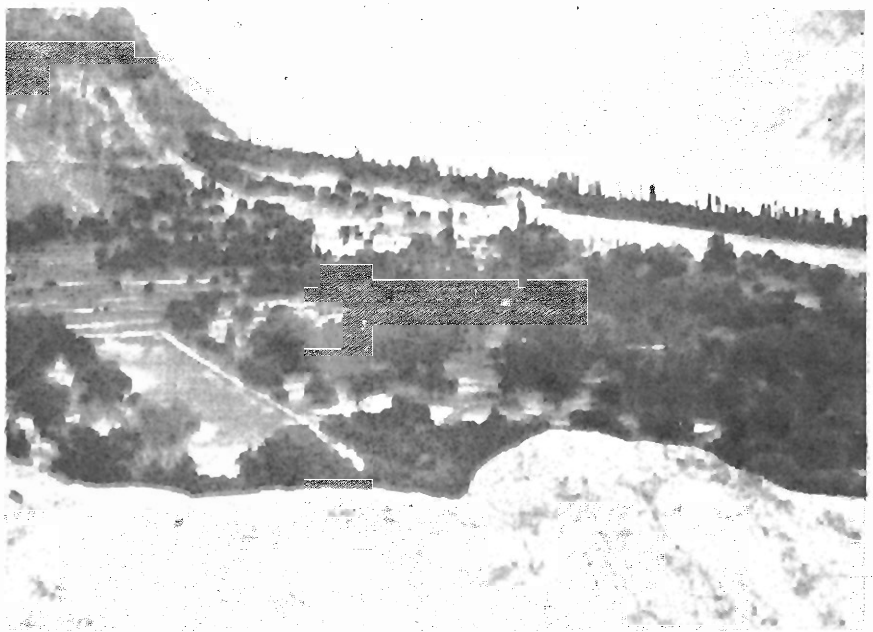
PT-30 Another view of the Ladakh Intrusives in the Ladakh Range in Baltistan.

PT-31 Khaplu village located in the Shyok Valley. This picture was taken from a thick morain deposit occuring on the eastern fringe of the village at an elevation of about 3000 m. The rock outcrops on the left are those of Ladakh Intrusives and on the right besides the "Ladakh", Rakaposhi Volcanic Complex is also developed. MKT passes on the right side of the Shyok Valley and is not visible in this section.

PT-32 Shyok Valley upstream of Khaplu gorge. This part of the valley is glaciated and spreads in about 70 sq. km area.
(1) iridicates folded Yasin Group dipping towards north and (2) is an outcrop of the Ladakh Intrusives.

PT-29

PT-30



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PT-32

The limestone bed strikes northeast and has vertical dips. Its actual thickness should be between 500-600 m but due to folding and faulting it apparently looks much more than this. Its contact with the underlying Chitral Slates is faulted. The northeastern extent of this limestone in Chitral is marked as far as Partsan. It laterally merges with the conglomerate and red Reshun shales between Phasti and Reshun.

Desio (1959) reported Orbitolina discordia and huppuritids in this limestone in the vicinity of Krinj mine. He mentioned its extension into Bombret and Barir valleys. Conaghan (in Talent et al. 1979) however,paid a visit to this section but could not find any fossil. He reported the contact of the Chitral Slates and the Krinj Limestone to be disconformable.

Another location of the Cretaceous limestone in Chitral is in a section along Buni Gol in Mastuj Valley. In this section, the limestone is fossiliferous and many Hippurites have been collected.

Talent has introduced another Cretaceous limestone outcrop in Rash Gol from where Hippurites were collected. This outcrop extends along the right flank of the Rash Gol for 3 km upstream of its confluence with the Tirich Gol.

The Krinj Limestone constitutes an important element in the Cretaceous stratigraphy of Chitral in the Hindu Kush. Most of the clastics in the conglomerate, named Awi Conglomerate, are derived from this carbonate bed. Thus the Krinj Limestone forms a basal bed of the Reshun sequence in a separate basin of deposition, already discussed alongwith figure 6.

8. The Awi Conglomerate

A conglomerate bed overlain by red and maroon shales, was earlier referred to as Reshun Formation by Mcmahon and Huddleton (1902).Hayden (1915) named this sequence as Reshun Conglomerate. So far the type section of this sequence is held to be Reshun situated in the Mastuj Valley. In this section, the sequence is bounded by two major faults which put it in direct contact on one side against the Devonian carbonate rocks and on the other side against the Chitral Slates.

In this sequence, the conglomerate and the maroon shales form two separate mappable units. Thus to give them separate stratigraphical entities the author proposes to shift the type section of the conglomerate part of the sequence to Awi and the shaly part to be retained at Reshun and named the Reshun shales.

At Reshun, the thickness of the conglomerate bed is between 350-400 m. It forms a conspicuous belt extending towards northeast from Parpish - Nol -Reshun to Awi. The latter section is selected to be its new type locality where the conglomerate outcrop occurs on the eastern bank of the Mastuj river and overlies the Chitral Slates with a great hiatus and have a faulted contact.

This sequence has an extension in the upper reaches of the Yarkun river and from the distant location it can be easily isolated because of its distinct texture and colouration. At Awi, the slate breccia is encountered at the base of the conglomerate.

Hayden has already reported preponderance of pebbles and cobbles of grey and white limestone and quartzite. Conaghan (in Talent et al., 1979) has conducted pebble counts to appraise its lithological assemblage in the conglomerate constituents at Awi and records: carbonate-44%,volcanic rocks-32%, quartzite - 16%, siltstone-4% and chert/quartz-4%.

The author had re-examined this section in 1981 and a general assemblage of the above stated lithology in the conglomerate formation indicates the carbonate, quartzite and siltstone predominating at the basal part and the volcanics usually becoming excessive in the upper part of the sequence. This suggests an existence of two provenances at different times from where the clastics were derived. The earlier source was confined to the Krinj Limestone - Parpish Limestone, Shogram Formation and The Chitral Slates, the contribution from the former (orbitolina - bearing clastics) exceeds the latter two. Subsequently, the major source providing the clastics was the Rakaposhi Volcanic Complex which contributed the volcanics.

The proportion of the clastic assemblage in the Awi conglomerate is variable. The Rakaposhi Volcanic Complex being located closer to this sequence at Awi has higher representation than the other sections in the southwest where the carbonate clastics become dominant. The Awi Conglomerate in the non-volcanogenic Cretaceous domain of Chitral in the Hindu-Kush by virtue of its stratigraphic position and incorporation of Orbitolina - bearing carbonate clastics may be placed in the post-Aptian, somewhere between Albian and Companian.

9. The Reshun Shales

A redbed sequence consisting of maroon shales and siltstone with calcareous and sandy partings forms a very conspicous association with the Reshun conglomerate. This bed has a tectonic contact with the conglomerates and as has earlier been viewed by Talent et al. (1979), this faulting coud be the result of different competency of the two juxtaposed units.

The previous workers have retained the redbed sequence as a part of the conglometate. This bed shows a consistant development alongwith the conglomerate, has a different lithology and forms a mappable unit. Thus the author considers this sequence to be given an independant status in the frame of the Cretaceous stratigraphy of the Hindu Kush.

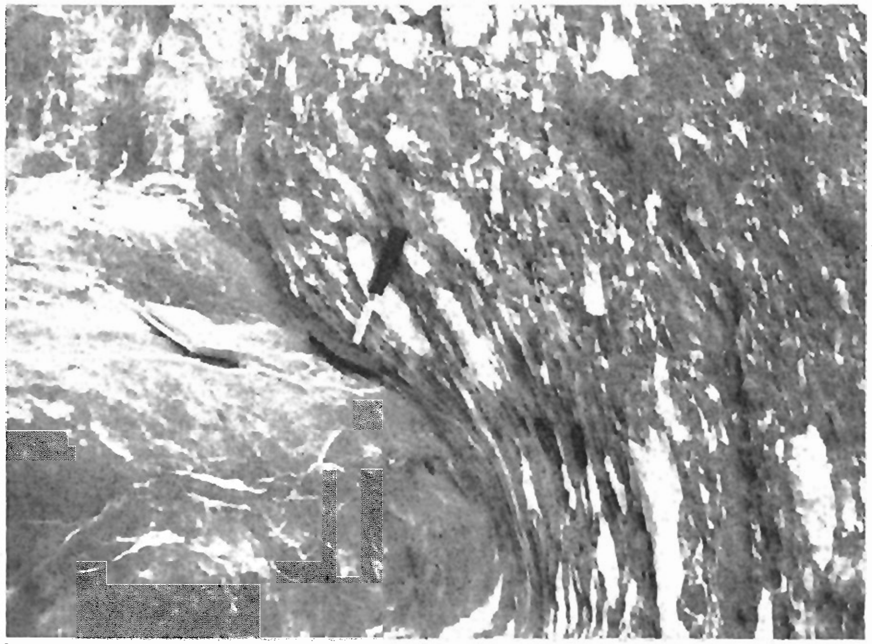
Another point pertaining to this sequence is its stratigraphic position with respect to the conglomerate bed. Talent has discussed this proposition in detail and has supported a younger age for the redbed. This view is appealing because in most of the sections which were investigated by the author in the vicinity of Nol, Reshun, Buni and Awi, the redbed is found overlying the conglomerate, though in some sections due to intense deformation its contact relationship with the conglomerates is in Jeopardy.

Most of the early workers consider the Reshun sequence to be the continuation of the Yasin Group, already described by Hayden (1915), Ivanac et al.(1956), Desio et al.(1964) and others in the Karakoram. Their stratigraphic status has already been discussed by the author (Fig. 7). These two Cretaceous occurrences in the Hindu Kush and Karakoram constitute two separate belts, the former has extension from the west and the latter has association with the shrinking Tethys trapped between the Kohistan island arc and the Eurasian plate. These belts were separated by a ridge formed by the Chitral Slates and the overlying Devono-Corboniferous rocks. Thus the Reshun sequence and the Yasin Group may be considered coeval,but both had inherited separate basins of deposition.

PT-33 This picture bespeaks of a great push which has generated this type of deformational features in the melange where it has come in contact with the leading Eurasian Mass along the northern edge of the MKT zone. Stretching in the pebbles and twisting of melange around a competent bed are remarkably displayed. Location is near Chotarkhan in the Ishkuman Valley in the Karakoram.

PTS-34-35 The blueschists zone in the vicinity of Shangla in Swat. This zone occurs in association with the marginal mass of the Indo-Pakistan plate, earlier named the lower Swat-Buner Schistose Group by Martin et.al.,(1962) who placed them in the Palaeozoic. Tahirkheli(1980) considers these rocks to be an extension of the Inner Zone of the Hazara Lesser Himalaya of Precambrian age. The main rock types in this zone are pelitic - psammitic schists, crystalline limestone, marble and glaucophane schists. This zone is subducted under the Kohistan Island arc along the southern suture zone, named the Main Mantle Thrust. Exact extent of this zone has so far not been delineated but along the road section which cuts across the strike of the rocks, blueschists forming isolated pockets are encountered between Topsin and Shangla Pass, in a distance of 6-8 km.

PT-36 The folded metasediments of the Indo-Pakistan plate near the sole of the Main Mantle Thrust. First the rocks were folded and then the fold was tilted towards the thrust zone. The axis of the fold is parallel to the MMT. This structure is the product of the MMT accident and is located 2 km short of Jijal on the Karakoram Highway.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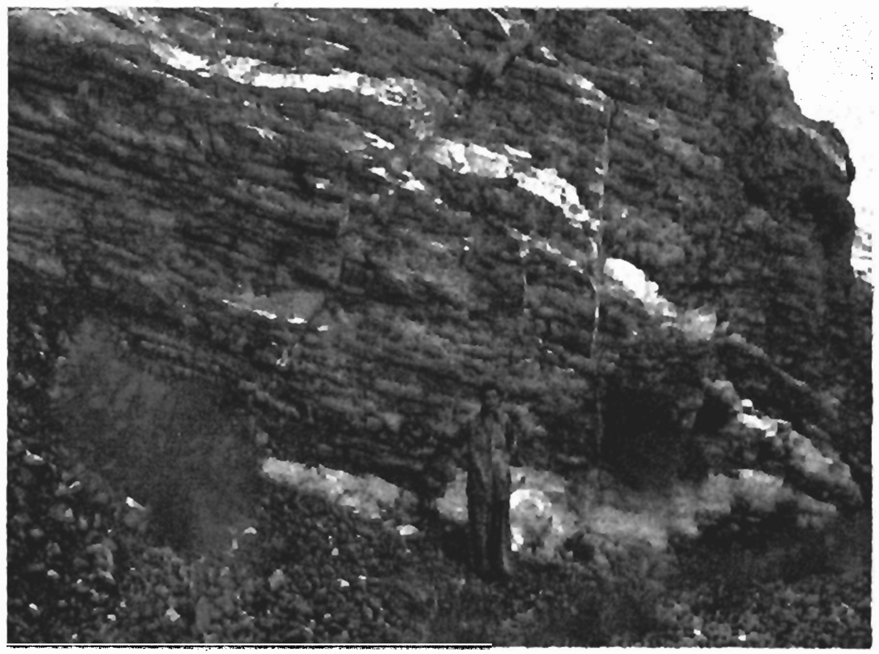
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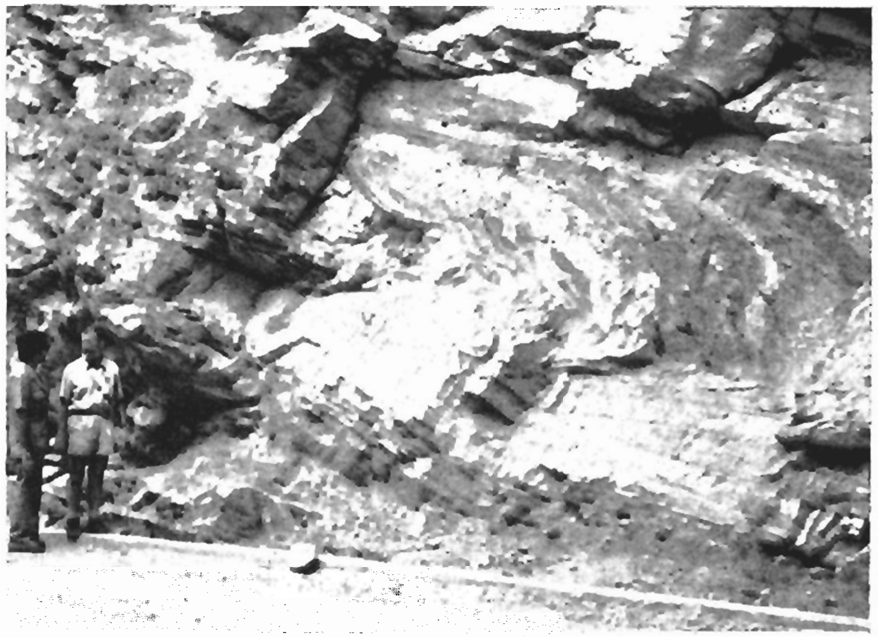
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The author proposes to separate the redbed sequence from the conglomerate and name it the Reshun Shales with its type section located near the Reshun village. Its age problem is still controversial because of lack of faunal evidence.The underlying conglomerate bed has yielded Orbitolina and Talent has reported their forms close to O minuta or O Parva within the Reshun Shales, suggestive of an Early Cretaceous(Aptian-Albian) age.This age is not significantly different from the broad Aptian age already advanced for the underlying Krinj Limestone and the Awi Conglomerate. Probably these Orbitolina- bearing pebbles were introduced into the shale sequence from the underlying conglomerate bed.

On the basis of only these evidences it will be unfair to assign an authentic age to the Reshun Shales at this stage. An arbitrary placement of this sequence is suggested between the Upper Cretaceous and Lower Tertiary.

10. The Tirich Mir Granites

In Hindu Kush, as mentioned elsewhere also, the granites have sporadic distribution and except a few, most of them do not constitute mappable bodies. The Tirich Mir pluton constitutes one of the largest acid igneous emanations in Chitral which composed the main curst of the Hindu Kush.

The acid plutons in the Hindu Kush range in composition from granodiorite, being the oldest to 2-3 phases of granites followed by pegmatite, aplite and veins quartz. Atleast one phase,that of leucocratic granite may be synchronous with the latter phase of magmatism in the Karakoram. This granite is associated with the Neogene orogeny and intrudes the southern marginal mass of the Eurasian plate, the Main Karakoram Thrust zone and the Rakaposhi Volcanic Complex both in the Karakoram and Hindu Kush.

Light to dark grey, medium to coarse and subequigranular to equigranular granites, having discordant contact with the countray rocks usually represent the younger granite phases,emanated during post continental collisional period. The older granites may be recognised by their light colouration and foliation. These are medium grained, inequigranular and are concordant to the regional structure. The Tirich Mir pluton incorporates this variety.

When compared with the granite occurrences encountered on the Indo-Pakistan plate margin, the Hindu Kush granites are relatively less deformed and are younger in age. In the former, the granites, as old as Cambrian are encountered whereas the oldest granitic bodies, so far proved in the Hindu Kush by isotopic determination belong to Triassic.

Desio (1976) has reported a Rb/Sr date of 114 m.y on one granodiorite sample from the Tirich Mir Massif, placing it in the Lower Cretaceous and belonging to the pre-continental collisional period. A fission track age on one of the granitic phases associated with the Chitral Slates in the Sissi Koh adjacent to the northern edge of the Main Karakoram Thrust zone gave 100 my (Zeitler et al.,1981).

Dasio has also reported three Rb/Sr determinations on the granite samples collected from Tolemo-i-Bali and Ghandak in the Afghanistan part of the Hindu Kush,located 380km apart from Tirich Mir. These samples have yielded an age around 215 my, thus placing them in the Lower Triassic. On the basis of these dates Desio considered the western (Afghanistan) and the eastern(Chitral) Hindu Kush to belong to different tectonic zones.

The granites of Chitral part of the Hindu Kush have not been studied in detail to provide a vivid picture on their regional distributive pattern.There is a basic need to decipher their petrology,structure and age for correlation purpose.The meager data in hand favours a separate stratigraphical entity for the acid igneous magmatism of the Hindu Kush and the author suggests to group them under the Tirich Mir Granites.

KARAKORAM

The geographical domain of the Karakoram incorporates the northern segment of the Kohistan zone.After the establishment of an ancient island arc on the southern flank of the Karakoram, the Kohistan zone now constitutes a separate geological entity. Its northern limit extends to the Main Karakoram Thrust,the northern suture alongwhich the Eurasian mass obducts onto the Kohistan sequence. Thus geologically, the Baltit Group and its stratigraphic equivalent, the Chitral Slates should form the southern limits of the Karakoram and Hindu Kush respectively which coincide with the southern edge of the Eurasian plate.

While preparing the stratigraphical scheme of the Karakoram, its geological limit has been transgressed by incorporating the Rakaposhi Volcanic Complex, Yasin Group, Chalt Ophiolitic Melange, Ghizar Molasse and the Ladakh Intrusives which geologically form part of the northern Kohistan.

If this stratigraphic scheme was based on the regional geological frame, then the following sequence should find accommodation in the Karakoram.

4.	Main Axial Batholith	Eocene-Pliocene
3.	Darkut Group	Devono(?)-Permocarboniferous
2.	Broghil Formation	Middle Ordovician
1.	Baltite Group	Precambrian-Lower Palaeozoic
	Main Karakoram Thrust ------------------	

The problem of geological and geographical division is also encountered in the Hindu-Kush. Whole of Chitral, Dir and the western portion of Swat geographically form part of the Hindu Kush. But this region, from south to north embraces three geological provinces: the northern marginal mass of the Indo-Pakistan plate, the Kohistan Island arc and the Hindu Kush with which coincides the southern limit of the Eurasian plate. Here again the Main Karakoram Thrust delineates the geological boundary of Kohistan with the Hindu Kush.

PT-37 A road section showing the lithology of the Minapin Formation, forming the base of the Baltit Group at its type section in the upper reaches of the Hunza Valley. The rocks are dominantly pelitic with common carbonaceous bands and yellow sulphide zones emitting sulphurous smell. Earlier, Wadia (1932), Desio (1963), Gansser (1964) and Stauffer (1968), because of typical lithology had considered these rocks belonging to the Salkhala Series, the Lesser Himalayan lithofacies.

PT-38 This picture was taken in the lower part of an obducted zone where the Eurasian plate come in contact with the Kohistan arc along the Main Karakoram Thrust. The rocks involved are the Minapin Formation. Here the pegmatite vein is involved in the deformation and is twisted like a rope.

PT-39 Mastuj Valley downstream of Awi. Tirich Mir the highest peak in Hindu Kush, surrounded by clouds, is also visible. The rock outcrops on the right are of Devonian age and those on the extreme left belong to the Chitral Slates.

PT-40 A flourishing village of Hindu Kush in Mastuj valley named Buni. The rock outcrops on the back of the village belong to Reshun Group.


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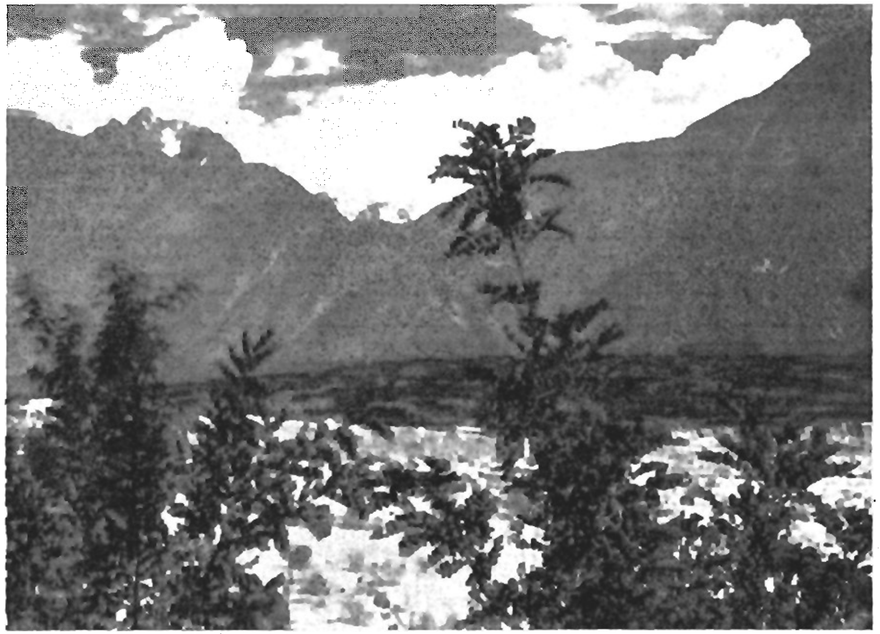
PT−39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The lithological characteristics and correlation of the Baltit Group and the Chitral Slates in the Karakoram-Hindu Kush domain have been discussed alongwith Figs. 7 and 16. An assignment of Precambrian-Lower Palaeozoic age to these sequences remains insecure because of lack of authentic evidences in support of this view. For this purpose, the author will like to probe the geology of the eastern and western extents of these formations across the border in Ladakh and Afghanistan respectively, where already Precambrian and Palaeozoic rocks have been mapped.

In Afghanistan (western Hindu Kush), three publications will be referred. One by Kafarskiy and Abdullah (1976), second by Walfart and Wittekindt (1980) and the third is a geological map (without date) of Afghanistan. Former deals with the geology and tectonics of the northern part of Afghanistan adjacent to Chitral and the second paper attempts a regional correlation and includes northeast Afghanistan and north Pamir. The third one is a geological map of Afghanistan compiled by the Geological Survey of Iran.

Kafarskiy and Abdullah mentions the Precambrian rocks spread over Badakhshan and Wakhan which are represented by gneisses, crystalline schists, amphibolites, quartzites and marbles. These areas are located on the NNW of Pakistan and the rocks are correlateable with the Precambrian rocks of Chitral.

The following stratigraphic scheme produced by Walfart and Wittekindt, pertains to the northeastern Afghanistan, indicates the Precambrian rocks and is reproduced here for correlation purpose.

		NE Afghanistan	Hindu Kush	Karakoram
KABUL FORMATION	2.	Nuristan-Kabul-Khost-Badakhshan: Crystalline schists, quartzite, gneisses and marble app. 5500 m thick.	Chitral Slates: slates, schists, gneisses and marble.	Baltit Group: slates, schists gneisses and marble.
	1.	Nuristan-Kabul: Garnet-cordierite-biotite-sillimanite-schists and gneisses; app. 5000 m thick.		

A greater part of the Chitral Slates in the western Chitral is concentrated in the Kafiristan territory. The western stretch of Kafiristan across the border in Afghanistan is named Nuristan. Thus both belong to the same geological province. The upper storey of the Kabul Formation is lithologically correlatable with the Chitral Slates, which continue across the border without any stratigraphic and tectonic break.

In the geological map of Afghanistan, compiled by the Geological Survey of Iran, the northeastern part of Afghanistan adjacent to Chitral has been shown to contain a big chunk of Precambrian rocks. This belt is located between Lat: 34° and 36° and envelops the terrain underlain by the Chitral Slates in the northern Pakistan. The rocks described in the Precambrian are mica schists, greenschists and gneisses and no nomenclature has been assigned to this sequence.

From this account of the geology across the border it appears that in the western Hindu Kush the Precambrian sequence has already been established. These rocks are separated on lithological basis, and as the case in Chitral, are overlain by the fossiliferous upper Palaeozoic sequences.

In the eastern Karakoram, the rocks analogous to the Baltit Group are mapped in Ladakh but the age assigned to them is considered arbitrary in the sense that no fossil has been reported to authenticate their placement in the Palaeozoic.

Sharma and Kumar (1978) discuss a rocks sequence. named the "Northern Crystalline" which extends between Murkha-Zanskar confluence and Mankhar in Ladakh. Tectonically, this sequence has been considered to form an uplifted block. A few remnants of Permo-Carboniferous rocks are found overlying the crystallines which are considered to have been deposited during marine transgression. The rocks are comprised of various types of schists, marble, quartzite schists, gneisses and amphibolite with small eclogite bodies emplaced in the core and on the northern flank of the crystallines. Kumar (1978) have noticed high pressure mineral assemblage towards Sumdo where Verdi et. al. (1977) have reported the occurrence of blue schists rocks. These rocks are intruded by two types of granite, one is massive and another is porphyritic and foliated.

Another belt named the "Southern Crystalline" occurs on the southern margin of the Kioto Limestone and is comprised of quartzites, low to high grade schists, gneisses with granite intrusions. These two belts of the crystalline rocks are placed in the Precambrian. These rocks occur on the south of the Indus Suture zone and thus appear to form the base of the Tethyan Zone of the Himalayan domain.

Another conspicuous belt of the crystalline rocks, grouped under "Palaeozoic Metamorphic", are differentiated on the north of the Indus Suture zone in Ladakh. The rock types are carbonaceous phyllite, chlorite-talc schists, crystalline limestone, quartzite and amphibolite. These rocks are intruded by the two mica granite, named Tegar Granite by Sharma & Gupta (1972), which has been correlated with the Karakoram Axial Batholith of Desio (1974) and the Main Karakoram Batholith of Tahirkheli (1980).

The lithology of the rocks and their association with the granite, correlated with the Main Karakoram Batholith provide a supportive evidence to correlate them with the Baltit Group. Sor far, no fossils have been reported from this sequence. On what basis this metamorphic sequence has been placed in the Palaeozoic, is a question still open for discussion. The author considers these metamorphics to be an extension of the Baltit Group into Ladakh in the eastern Karakoram. The thickness of these rocks is considerably reduced in Ladakh and their behaviour before truncation east of Pangong Tso is still to be ascertained.

PT-41 Another view of deformation of the rocks near the leading edge of the Eurasian plate and again the rocks involved are Minapin Formation in Hassanabad stream in the Hunza Valley.

PT-42 A conglomerate bed near the leading edge of the Kohistan arc. The clastics are mostly comprised of quartz with clayey matrix. The pebbles are subangular and some of them are stretched. The locale is near Chalt in the Hunza Valley.

PT-43 A zigzag fairweather jeepable road descending from the Sandur Top and leading to the Sor Laspur village. The hillock on the front is composed of Rakaposhi Volcanic Complex.

PT-44 An ophiolitic melange section in the Main Karakoram Thrust zone. Here the igneous rocks have a faulted contact with the flyschoid rocks.
(1) is comprised of serpentinite, andesite, basalt, cherty brecciated quartzitic sandstone and ophicalcite, whereas (2) constitutes slates, phyllites, phyllitic schists with minor arenaceous and calcareous partings. The hills in the distant front expose the Minapin Formation of Baltit Group occupying the leading edge of the Eurasian plate.

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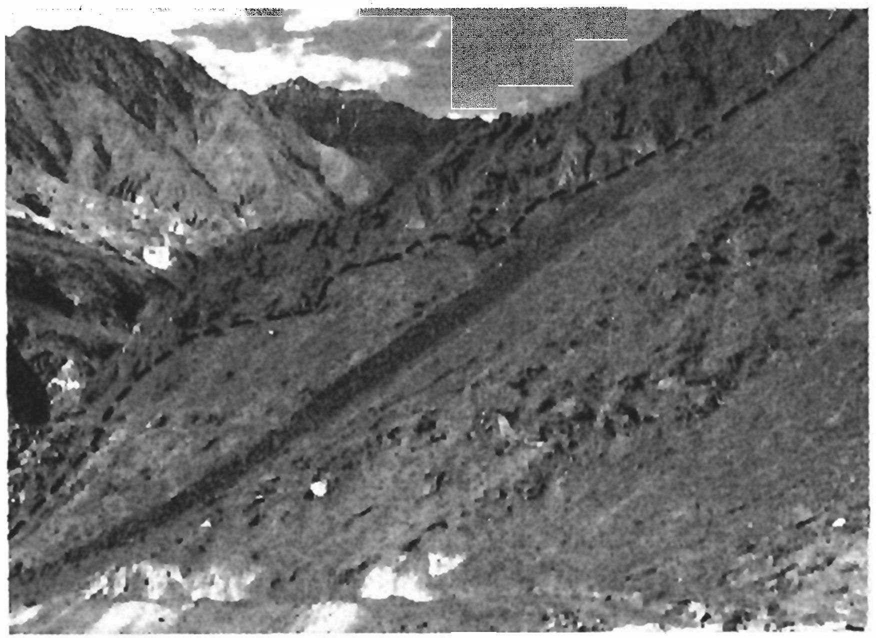
PT—43



PT—44

A has been discussed elsewhere, Desio had reported a K-Ar date of 8.6 my on one sample collected from the Main Karakoram Batholith in the Hunza Valley. While this manuscript was being given a final shape, some new dates were conveyed to the author through Windley and Jan (1981), which were determined by D. Rex in Leicester University.

These samples were collected from a widely scattered area; two from the main mass of the batholith and one from an isolated granitic body in the Minapin Formation, which was considered analogous to one of the acid igneous phases associated with the Main Karakoram Batholith. The locations and the K-Ar dates on these samples are as follows.

1.	A sample collected from the Yasin Valley, downstream of Darkut village near the northern edge of the mass.	4.7 my
2.	North of Minapin village from a granite body which intrudes the metasedimentary sequence of the Baltit Group.	17 my
3.	From the main body of the Karakoram batholith near the core of the mass, in the vicinity of Gulkin village in the upper part of the Hunza Valley.	52 my

In the Shigar Valley in Baltistan, two K-Ar determinations are reported by Matshushita et.al. (1965). These samples are from a magmatic body located near Dassu, known as Dassu Gneiss. One sample is from a pegmatite and another is from a leucocratic granite which are related to the younger magmatic episodes associated with this mass and are considered analogous to the magmatism associated with the Main Karakoram Batholithic. These have yielded dates of 27 and 30 my respectively.

From these dates the Main Karakoram Batholith reveals a protracted multi-phase magmatism which started from the Late Eocene and lasted till Early Pleistocene.

The Darkut section has been discussed in Fig. 5. The author has followed the stratigraphic scheme of Desio (1963) and the Devono-Permocarboniferous sequences of the Upper Hunza valley has been placed under this group. These formations are: 1. Passu Slates, ii. Gircha Formation, iii. Kilik Formation and iv. Misgar Slate. A brief lithological description and age assigned to these formations are given below.

The Passu Slate occupies the southern part of the Tethyan zone in the Karakoram and has a tectonic contact relationship with the Main Karakoram Batholith and the Gujal Dolomite, lying on the south and north respectively. It has a maximum thickness of about 1500 m. The slate and phyllitic slate are dominant with dark grey limestone and yellowish grey quartzite intercalations. A part of the slate is also arenaceous. No fossils have been reported in the slate which has tentatively been placed in the Upper Palaeozoic.

The Gircha Formation was reporated as a mappable unit by Desio (1963). Clark (in Ivanac et.al., 1956) has also described this formation under the name of Khaiber Series. This formation is comprised of a complex sequence of alternating argillaceous-arenaceous-calcareous beds, forming thick outcrops in Lupghar, Chapursan and Abgorch valleys. This formation attains a maximum thickness of about 4000 m.

The upper part of the sequence dominates in dark argillites with thin limestone-dolomite intercalations. In the lower part light coloured, thick bedded to massive sandstones with calcareous-arenaceous slates intercalations are dominant. The calcareous part of the sequence contains brachiopods, corals, bryozoans and foramaniferas which were referred to the lower Permian age.

The Kilik Formation is comprised of dominant limestone and dolomite with thin partings of light grey arenaceous slate and red quartzite, This formation is developed in a linear belt between the Misgar Slates and Gircha Formation on the northeast and southwest respectively. It is about 200 m thick and Desio (1966), on the basis of crinoidal stems has assigned it a Devonian-Lower Carboniferous age. He also correlated this sequence with the Shogram Formation of Hindu Kush in Chitral.

The principal outcrops of the Misgar Slates occur in Babar, Kilik, Gonduri, Giraf and Khunjerab valleys in the Upper Hunza in the Karakoram.It is about 3500 m thick and consists of a monotonous sequence of light to dark grey slate and phyllitic slate with intercalation of siliceous and calcareous partings, which at places become quite thick.

A conspicuous feature in the Misgar Slates is the frequent occurrences of igneous intrusions: dolerite, gabbro, pegmatite, aplite and quartzs-syenite are most common. The basic igneous intrusions are older and the acid bodies are younger.

No fossil has so far been reported from the Misgar Slates. The igneous intrusions, specially the basic sills are not encountered in the rock formations of the northern Karakoram. By virtue of this criterion the Misgar Slates should be considered an older sequence than those which do not contain such igneous bodies.

Most of the previous workers have attributed a broad Palaeozoic age to the Misgar Slates. Among the sequences discussed above, the author considers the Misgar Slates to be the oldest.

In the Hindu Kush, the following Palaeozoic sequences of Chitral will be placed under the Darkut Group: 1. Zait Limestone (Permian-Triassic), ii. Parpish Limestone (Permo-Carboniferous), iii. Shogram Formation (Late Devonian) and iv. Lun Shales (Early Devonian).

THE KOHISTAN DOMAIN

A large part of Kohistan remained unexplored till very recent time, as a result, this stretch of terrain was shown blank on the first geological map produced by the Geological Survey of Pakistan (Bakr and Jackson, 1964). The earliest introduction to the geology of Kohistan started appearing in the Peshawar University publications during 1965, which subsequently included a regional geological map produced by Tahirkheli and Jan (1978), showing Kohistan as an ancient island arc trapped between the Indo-Pakistan and Eurasian plates.

Kohistan altogether constitutes a distinct geological domain with respect to the adjoining rock sequences of the Himalaya and Karakoram-Hindu Kush. Thick calc-alkaline suite, tectonically displaced metasedimentary sequences, widespread acid and intermediate magmatism and bounded on the north and south by the two the sutures, delineate this terrain as a separate geological province. Earlier, Desio (1964) had recognised Kohistan as a separate tectonic zone of the Karakoram.

A brief description of various rock units composing the Kohistan sequence is intended in the following pages. Some of the rocks of Kohistan have received attention alongwith the diagrammatic sections while describing the type areas.

PT-45 In the upper reaches of the Ishkuman Valley, looking towards the Ishkuman Village. The outcrop exposed behind the village are those of Darkut Group which forms southeastern extent in the Karakoram.

PT-46 Shyok gorge upstream of the Indus-Shyok rivers confluence. This section displays a typical lithology of the Ladakh Intrusives in the Ladakh Range. The light coloured rocks are granodiorite-granite and the ones giving a darker hue are the basic sills and dykes.

PT-47 Sometime accessibility to water becomes problem for the villages located away from the glaciers and the main streams. Here eight km long water channel is seen passing along the steep slope of the Rakaposhi Volcanic Complex in the Hunza Valley. A small fold with the flanks dipping to the north and south is exposed near the river bed.

PT-48 A morning view of the Rakaposhi from the International Karakoram Expedition camp at Baltit.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1. The Jijal Complex

This complex is located on the southern margin of the Kohistan Island arc adjoining the Indo-Pakistan plate, between Jijal and Pattan. It covers between 150 and 200 square km area on the eastern and the western banks across the Indus river; the larger part is exposed on the latter. Tectonically this complex is delineated by the two major faults; the Main Mantle Thrust separates it from the northern marginal mass of the Indo-Pakistan plate and the Pattan Fault marks its boundary with the Kamila Amphibolites.

The Jijal Complex is comprised of two lithologies, an ultramafic suite called the Jijal Ultramafics and the garnet granulites named after Pattan. Their emplacement at the present site is tectonic which is intimately related with the MMT accident. Jan et.al.(1981) have reported a structural disharmony between the ultramafics and the granulites. According to them, the ultramafic rocks have intruded the granulites as solid material capable of plastic flow after both were metamorphosed at different sites, before their lift to the present position.

The garnet granulites are thin bedded to massive, medium to coarse and are locally porphyroblastic. They belong to the high pressure granulite facies of the assemblage: garnet + diopsidic pyroxene + plagioclase + hornblende + quartz + rutile + clinoziosite (Tahirkheli et.al. (1979).Jan (1979) has classified the granulites into plagioclase- bearing (basic to intermediate) and plagioclase-free (ultrabasic to basic) types. Out of the 17 assemblages which Jan had studied, plagioclase + garnet + clinopyroxene + quartz + rutile is the most prevalent.

Garnets usually cluster the felsic part of the mass and are comprised of almandine-pyrope and grossular mixture; the tenor of the latter two are unusually high which is indicative of high pressure conditions. The other factors which favour such conditions are the high density of granulites ranging from 3·3 - 3·5 compared to less than 3·0 of the surrounding rocks, large amount of Al_2O_3 in the clinopyroxene upto 9·9 per cent (after Jan), amphiboles and orthopyroxenes However, Jan had reported that the Al-vi/Al-iv ratios (about 1:1) and the presence of higher Tschermark's component coupled with lower acmite and jadeite components in the clinopyroxenes suggest that pressures were lower than those of eclogite facies. Thus they consider the rocks to have equiliberated within the P-T ranges of 12-14 kb and 670 -790 °C.

The ultramafic part of the Jijal Complex is represented by diopsidites; peridotites, dunites and websterites, which are varyingly subjected to serpentinization, being more pronounced near the marginal parts involved in shearing. The texture and petrography of the ultramafic rocks suggest that they are alpine type in nature. The lack of plagioclase and garnet, and low Al_2O_3 content of their pyroxenes led Jan & Howie (1981) to consider an intermediate pressures for the ultramafic rocks, suggesting the equilibrium conditions in the granulite facies at 8-12 kb and 800 - 850 °C.

Jan and Howie (1981) have excellently dealt with the mineralogy, geochemistry and petrography of the Jijal Complex and for a detailed and an exhaustive digest on these problems, the author will recommend the interested readers to go through this paper.

2. The Metasedimentary Sequences

The Kohistan domain holds several metasedimentary sequences, some of which constitute mappable units but many occur as small isolated pockets in association with the igneous rocks. Mention has already been made about these sequences by the earlier workers but their stratigraphic status and correlation of some still remain obscure.

The Yasin Group, Drosh Orbitolina Limestone, Thalichi Bed, Burji La Formation, Kalam Group, Dir Group and Kandia Schists are well coined nomenclatures assigned to the mappable metasedimentary sequences in the published geological literature of the northern region. All of them belong to the Kohistan domain.

The Yasin Group was previously mapped as an oval-shaped isolated pocket in the vicinity of Yasin, but the recent work of the author has extended its domain to the Hindu Kush and Baltistan, respectively lying towards west and east. Its extension is uninterrupted over the northern edge of the Kohistan arc and is directly involved in the MKT accident.

The southern contact of the Yasin Group is with the Rakaposhi Volcanic Complex, which is faulted and in many sections the lower part of the sequence interbeds with the volcanic flows.

A variable lithology is indicated in the rock assemblage of the Yasin Group. The main rock constituents are slates, phyllite, schists, quartzitic sandstone, semi-to medium crystalline limestone and conglomerate. Pre-to post-kinematic magmatic intrusions of acid and basic igneous rocks are quite common. At the type section sedimentary features are retained by these rocks. But in the vicinity of Nange Parbat-Haramosh loop, garnet-staurolite grade metamorphism is recorded in the pelites. This change in grade is quite vividly marked in the Yasin outcrops exposed in the Hunza, Hispar and Shigar valleys which surround the loop. Elsewhere, the maximum metamorphism imparted in the rocks of Yasin does not exceed garnet grade, which could be as a result of their involvement in the MKT.

While this text was being prepared for the press, a short trip was made to Hunza to introduce geology to Ellen D.Mullen and Bob Lawrence(Oregon State University,U.S.A)and Arif Ghauri from Peshawar University. During this visit, a remarkable tectonic feature was observed near the contact of the Yasin Group with the Rakaposhi Volcanic Complex. This section is located between 600-650 meters above Jaffarabed village along a steep nala, 8-10 km upstream of Chalt. Here a 40-60 meters wide zone contains migmatitic gneisses and garnet-staurolite schists. The deformational features encountered in this part of the section appeared alien to the Yasin Group, which was not observed elsewhere through its length and breadth. All the abovementioned geologists had unanimous view to brand this part of the sequence as an exotic block, either derived from the Eurasian marginal mass or from the core of the Nanga Parbat-Haramosh anticline. The earlier view has support from an existence of garnet-staurolite grade metamorphism in the Eurasian marginal mass, named the Minapin Formation. The latter view gains ground on the basis of author's observations along Astor and the Indus valleys road sections where the migmatitic gneisses of this type were recorded near the core of the Nanga Parbat-Haramosh anticline. It is probable that this block had received a tectonic lift from either of the sites, during the MKT accident and subsequent stresses generated during suturing helped in cementing its relations with the host rocks.

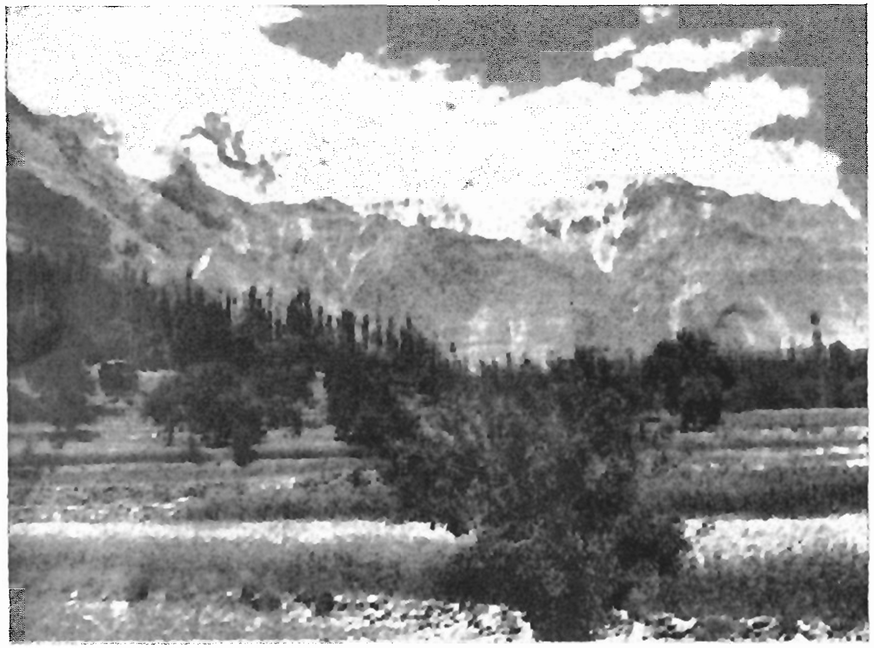
The Drosh Orbitolina Limestone forms the westward extension of the Yasin Group in the Hindu Kush in Chitral. This section was first described by Hayden (1915). Here the Yasin sequence is comprised of slate,phyllite, phyllitic schist, semi-crystalline limestone and conglomerate. The last mentioned rock occupied the base of the sequence and are sheared near the contact with the Rakaposhi Volcanic Complex in the vicinity of Mirkani, an easily accessible section along the road south of Drosh. In the Sissi Koh section, 3-4 km north of Drosh, the green and maroon slates are interbedded with the volcanic flows, which in composition range from andesite to rhyodacite. The Yasin rocks, in general retain sedimentary features in this section, except in a narrow belt along the MKT zone, where relatively higher grade of metamorphism is encountered. For a further detail on the Yasin Group, the reader is recommended to go through the description of Fig.10.

PT-49 Terrace cultivation on the northern slope of Rakaposhi in the Hunza Valley.

PT-50 The rocks belong to the Ladakh Intrusives in the hills in the vicinity of Gilgit. The light coloured patch near the skyline is that of a terrace deposit, which constitutes the second level located between two and three thousands meters elevation.

PT-51 The famous Karakoram Highway passing through the Hunza Valley, which has changed the socio-economic complexion of this region once considered to be unsympathetic and forbidden terrain.

PT-52 A few millimeters drift could have cost three lives. This mishap occurred in the upper reaches of Sissi Gol, northeast of Drosh in Chitral. This part of the road runs in the Main Karakoram Thrust zone. The boulder in front is derived from the melange.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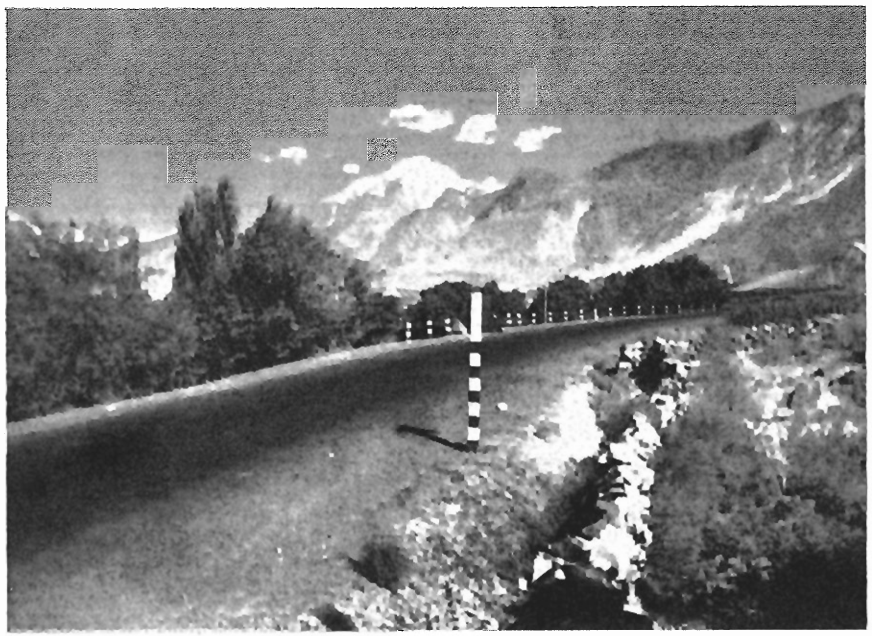
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The Thalichi Bed is long known as an extension of the Salkhala Series, a lesser Himalayan lithofacies into the Karakoram. Wadia (1932a), Misch (1935) and Gansser (1964) have made special mention of this bed and discussed its lithological characteristics and structural trends.

This bed forms an isolated outcrop on the western bank of the Indus river downstream of the Gilgit-Indus confluence between Thalichi and Jaglot. It strikes northwest with dips ranging from 60°to 85°. The eastern extension of the bed is cut by the Main Mantle Thrust which has influenced its structure.

The main rock type include slate, phyllite, graphitic schist, mica schists, garnet schist and para-gneisses with arenaceous alternations being dominant and followed by semi- to medium crystalline limestone and marble. These rocks are intruded by the Ladakh Intrusives, as a result,the contact metamorphic effect is more pronounced along the margin. Between Thalichi and Jaglot Gah, this bed is thick, folded into a syncline and is easily accessible on the road sections. Its westward extension is traceable short of the army post,4 km east of Gilgit. Another lithologically similar outcrop is developed on the northern bank of the Gilgit river at the mouth of Bagrot stream, which has a faulted contact with the rocks of the Ladakh Intrusives.

The new tectonic model of the northern segment of Pakistan with Jurassic-Cretaceous Kohistan arc intervening the Indo-Pakistan-Eurasian plates,does not accommodate the old concept to relate the Thalichi bed with the Precambrian Salkhala Series. The higher proportion of carbonate association with the Thalichi Bed also negates the actual lighology of the Salkhalas as recorded at their type section. Thus the Thalichi Bed belongs to the Kohistan domain and in age may range from Jurassic to Cretaceous. The garnet-amphibolite facies metamorphism in the Thalichi Bed is caused by the MMT accident, Nanga Parbat-Haramosh tectonics and subsequently by injectons of several acid to basic intrusive phases associated with the Ladakh Intrusives with which it has got an intimate relation.

The Kalam and Dir Groups have got their type sections located in Swat and Dir, west of the Nanga Parbat-Haramosh loop and have extensions towards west across the border into Afghanistan. Matshushita (1965) first assigned the name Kalam Group to a metasedimentary sequence in the vicinity of Kalam. He correlated this sequence with the Darkut Group of Ivanac et al. (1956) in the Karakoram,thus assigning it a Permo-Carboniferous or Early Mesozoic- ages.

Ataullah (in Jan et al., 1971) considered the fossil assemblage from the Kalam Group to be asphroid or thamnastereoids, the septa of the individual corallite becoming confluent with one another and suggested their marked resemblance with the Missisipian-Pensylvanian corals.

Jan et al. (1971) had also studied the fossil assemblage from the Kalam section and confirmed differentiating columnals of crinoid and a few fragments of fusulinids (?). They considered the age of the Kalam Group to be Carboniferous, thus placing the underlying quartzites and other metasedimentary rocks to be Silurian-Devonian.

The Dir Group was differentiated by Tahirkheli (1979), which on the basis of fossils was placed in the Palaeocene-Lower Eocene. Latter, based on detailed investigation, he produced three-fold subdivision of the Kalam Group, namely Karanduki Slates, Deshan Banda Limestone and Shou Quartzite. The Dir Group is divided into two parts, the lower one is called the Baraul Banda Slate and the upper one is Utror Volcanics.

Among these sequences, the Baraul Banda Slate and the Deshan Banda Limestone have yielded fossils.The dates assigned to Kalam Group(PermoCarboniderous)had intrigued the author while conceiving a new tectonic model for the northern Pakistan, with Kohistan being created as an island arc. For this purpose the author had considered a Cretaceous age for this sequence.

Many thanks to karig (1981) from Cornell University, USA, who as a specialist on the island arc with his many yeards of experiences in the Far-East, happened to visit Swat Kohistan. During his investigation of the Utror Volcanic, he found a limestone clast in a loose block of volcanic conglomerate, west of Kalam which contained coral fragments. John Wells, one of the world's experts on coral from Cornell had studied this sample and discarded the earlier view of assigining them Palaeozoic/Permian age. He identified the coral to be Rhabdophyllia sp, a genus that ranges from Middle Jurassic to Cretaceous.

Such fossiliferous limestone clasts were earlier reported from the Utror Volcanics, which the author considers to have been derived from the Deshan Banda Limestone forming the middle sequence of the Kalam Group. This age coincides with the Intraoceanic subduction in front of the moving Indo-Pakistan plate during Late Triassic-Early Jurassic periods. The earliest flow can safely he placed in the post-Middle Jurassic and thus the Utror Volcanics are the oldest and constitute the main arc of Kohistan.

The Karandoki Slates occupy the base of the Kalam Group and their type section is located about 2 km south of Kalam. The basal part of the bed is comprised of muscovite schist which grades upward to phyllitic schist and slates. The slates are grey, green and maroon coloured.This bed is in direct contact with the quartz diorite on the south,as a result chilled and backed margins with hornfelsic texture form a thin rim.

Overlying the slate sequence with a gradational contact is a light grey bed of limestone named after Deshan Banda, which is its type section. This limestone is between 35-45 m thick, thin bedded,fine textured and semi- to medium crystalline. Fossils have been reported earlier but the recent discovery of Rhabdophyllia sp(Karig,1981)in the limestone,a genus that ranges from Middle Jurassic to Cretaceous has overlapped the earlier views of assigning this bed a PermoCarboniferous age.

The Shou Quartzites occupy the top of the Kalam Group and constitute the thickest sequence in this sedimentary assemblage. The quartzites have an intrusive contact with the Deshai diorites on the south and a faulted contact with the Baraul Banda Slates on the north. In the type section along the Shou stream, the quartzites are folded and form a broad anticline with limbs dipping 30°-35°towards north and south. This bed has an extension towards the west and has been traced along the Shringal Valley upto Baraul Banda in Dir.

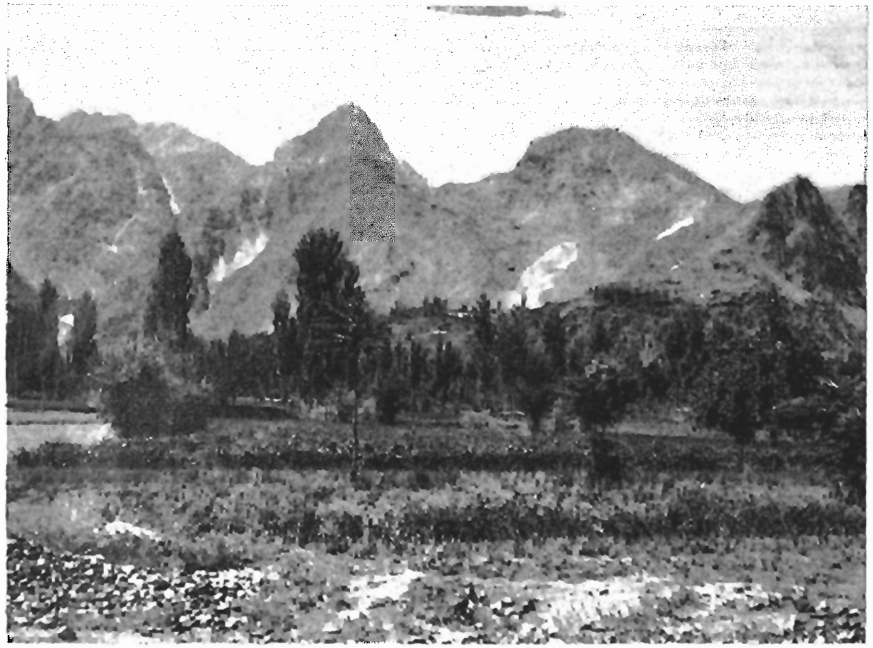
The Shou Quartzites are light to dark grey on fresh faces and brownish grey on the weathered surfaces. They are thin to thick bedded and fine to very fine textured. The grains are angular to subangular and cherty matrix is also recorded.Horizontal and verticle fractures have common occurrences in this bed. Some of these fractures and their ancillaries are filled with pegmatite and quartz intrusions. Banding and gradational features are well pronounced.

PT-53 Sanoghar village in the Mastuj Valley in the Hindu Kush. The outcrops behind expose the Chitral Slates.

PT-54 An aerial view of Chitral town, exposing the type section of the Chitral Slates.

PT-55 Pre-to Synkinematic acid igneous Veinlets in the Precambrian Slates on the northern slope of Malakand ridge.

PT-56 A quarry in Mansehra granite in the vicinity of Mansehra in Hazara. This granitic body intrudes the Precambrian marginal mass of the Indo-Pakistan plate and is of Cambrian age.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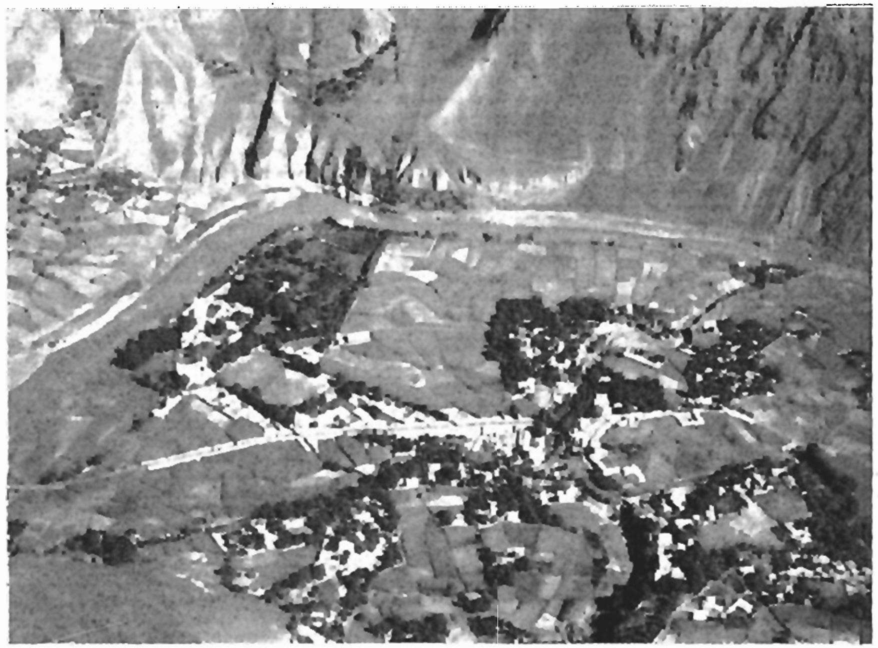
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The Dir Group has been isolated from the Kalam Group for two reasons. Firstly, the spatial and vertical distribution of its both formations have vast extents in Dir and secondly due to long span of volcanic episodes in the Utror Volcanics, which started during Late Jurassic and its last phase terminated during Eocene-Early Oligocene periods.

The Dir Group has two-fold division, a sedimentary sequence known as the Baraul Banda Slates and a dominantly volcanic part named the Utror Volcanics. Both of these rocks have been described alongwith Fig. 17.

The Kandia Schists are located in the strike direction to the east of the Kalam Group, in the Kandia stream which is one of the major tributaries of the Indus in Kohistan. These sediments form an isolated outcrop and were first described by Jan et al.,(1970).

The rock assemblage is comprised of dominant slates, phyllitic schists, quartz schists, mica schist, garnet schist and gneisses. These sediments hold subordinate calcarceous and arenaceous partings.

The contact of the Kandia Schists is with the amphibolites which according to Jan surround this sequence.

The stratigraphic position of the Kandia Schists because of their anomalous relationship with the amphibolite becomes doubtful as metasedimentary incorporation also occur in the amphibolites. If this sequence is held to be sedimentary then on the basis of lithology it should be correlated with the Karandoki Slates, forming the basal part of the Kalam Group. Otherwise, the Kandia Schists could belong to the Kamila Amphibolite and represent its metasedimentary incorpotations which has already been reported in this sequence.

3. The Rakaposhi Volcanic Complex

This complex holds a very important position in the geological mosaic of Kohistan island arc. Its rock types and their lithology bespeak of its origin as a thick oceanic crust formed in the trapped Tethys, between the converging Indo-Pakistan and Eurasian plates. It is developed on the northern periphery of the arc and its extension has been traced uninterrupted through Hindu Kush and Baltistan across the Afghanistan and Indian borders on the west and east repectively. Its behaviour before truncation across the borders is not ascertained, but from its intimate association with the Kohistan it appears to follow the east-west limits of the arc.

The maximum thickness of the complex is recorded in the central part of Karakoram-Kohistan, in the Hunza Valley its type section, and in the Ishkuman and Yasin valleys, which cut across the foliation, enabling an indepth view of its lithology and structure.

A wide range of lithologies have been encountered in the volcanic complex. There are volcanic flows and tuffs, metasedimentary incorporations and syn-to post kinematic magmatic intrusions. All these rocks are haphazardly intermingled with a confused mixture which provide an incoherent picture of the mass.

The flows constitute basalt, andesite, dacite and rhyolite. Their assemblage is variable and many sections do not hold all. Pillows are quite conspicuous in the basalt, which are usually deformed along the smaller axis. The deformation in the pillows shows a progressive increase towards north, suggestive of their involvement in the MKT accident. Serpentinization and epidotization form well defined metamorphic scars in the volcanic suite.

The tuffaceous beds are traceable throughout in the complex and include biotite schis, thornblende schist,schistose amphibolite,hornblende-epidote schist and actinoliteThe southern margin of the complex in contact with the Ladakh Intrusives in the Hunza Valley and elsewhere shows a volcanogenic succession in 60-80 m wide chilled zone which contain metamorphosed rocks rich in hornblende, epidote and serpentine minerals. The agglomerates with the fragments of andesite, aphanitic basalt, red and grey chert, quartzite, tuffaceous slate and marble are also encountered alongwith these rocks.

The metasedimentary incorporations include slates, phyllitic schists, quartzite, semi-to medium crystalline limestone and marble. They usually occur in thin isolated pockets but some forming thick beds are also recorded. Three of these to be mentioned are, a marble bed near Ashret along the road to Drosh in Chitral, another marble bed 3-4 km north of Shigar village in Baltistan and a bed of quartzite and phyllitic schist along the road between Gakuch and Gopis in the Ghizar Valley.

The metasedimentary incorporations have undergone both contact and dynamic metamorphism. A substantial part of the amphibolite present in the complex may be attributed to the alteration of calc-alkaline rocks incorporations of the metasediments though as mentioned earlier, a considerable part of volcanogenic rocks are also involved.

The Rakaposhi Volcanic Complex was placed in the Triassic by the earlier workers. But the recent studies conducted on these rocks have revealed fossils of the Cretaceous age. The two localities from where fossils were discovered are the Tissar section located on the western bank, upstream of Shigar and another occurs near Shamran in the Ghizar Valley. In the former Globotruncana was identified and in the latter Thaninasteria matshushitai was discovered (in Matshushita et al., 1965),on the basis of which this complex is placed in the Lower Cretaceous.

The magmatic intrusives in the complex include gabbro, diorite, dolerite, hornblendite and pyroxenite in the mafic suite whereas acid to intermediate igneous rocks are represented by granodiorite, granite, pegmatite, aplite and vein quartz. Pyroxenite and hornblendite are thin and have a very limited distribution, and are considered to have formed by the segregation in the mafic rocks.

Atleast three granitic phases are differentiated. Two of them are leuco-and malanocratic post-kinematic intrusives which have been derived from the Ladakh magmatism. The earlier workers have reported the leucocratic granite to belong to the last granitic phase in the Karakoram but in the Yasin Valley melanocratic type was found to post-date the former. The third variety is trondjhemite which is synkinematic and appears to be the oldest among the acid igneous domain. Some pegmatite, aplite and vein quartz appear to constitute the remobilized parts of the mass and form syn-to late kinematic veins and dykes in the complex. The basic igneous rocks, in general, are the oldest and occur as pre-to synkinematic sills and dykes.

The Rakaposhi Volcanic Complex is involved in the regional structure and is isoclinally folded with the limbs with moderate dip towards the north. The foliation trend swings from southeast in Baltistan to east-west in the Hunza, Ishkuman and Yasin valleys to southwest in the west near Afghan border.

The complex is varyingly metamorphosed. The central part of the mass in the vicinity of the Nanga Parbat-Haramosh loop shows relatively higher grade of metamorphism. Here garnet-amphibolite facies metamorphism is observable. Elsewhere greenschist-garnet grade metamorphism is usually recorded.

The Rakaposhi Volcanic Complex is between 3000 and 4000 m thick at its thickest sections and grandually thins towards east and west. Its type section in the Hunza Valley covers the highest elevation of Rakaposhi, a sister peak of the Karakoram chain for which a new momenclature is proposed for this complex.

PT-57 Banded para-gneisses in the apex zone of the Hazara-Kashmir syntaxis in the upper reaches of the Kaghan Valley. Some of these gneisses are sillimanite - bearing indicating their association with the katazone.

PT-58 Foliated Kamila Amphibolite bed exposed in the Indus Valley downstream of Skardu. This bed is associated with the eastern limb of the Nanga Parbat-Haramosh loop and extends southward towards Astor.

PT-59 A view of Karimabad, a nothern part of the Baltit town. The old Palace of Mir of Hunza is visible occupying the commanding position in front of the gorge. This palace is now turned into a Museum. The rock outcrops behind are those of the Main Karakoran Batholith.

PT-60 The author along with one of his colleagues is scanning the rocks of Baltit Group in the Hispar Valley. Here the rocks of Minapin Formation are exposed and this section occurs in the apex zone of the Nanga Parbat - Haramosh anticline.


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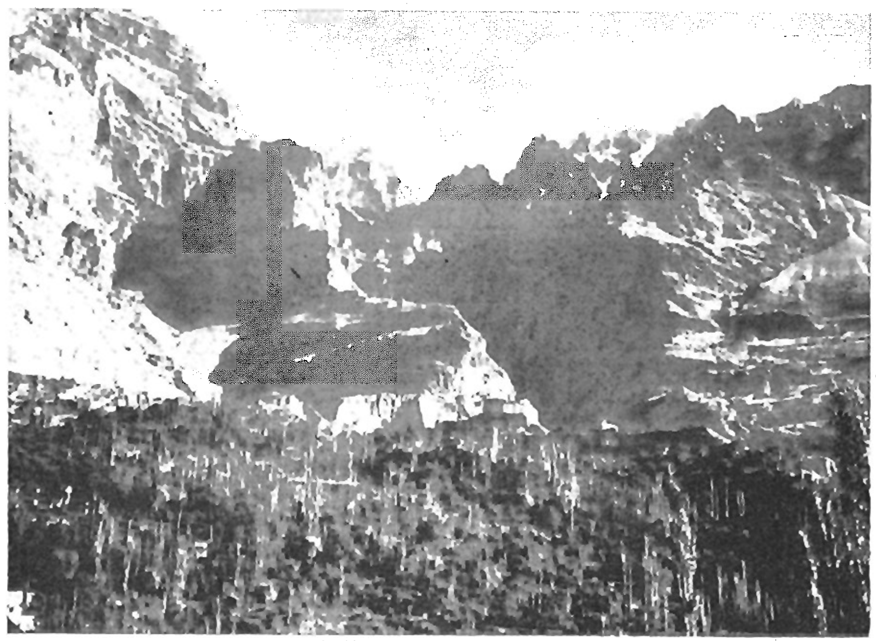
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The Rakaposhi Volcanic Complex, as mentioned earlier has an uninterrupted extension and form an isolated domain from the other two formations of Kohistan, the Kamila Amphibolites and Utror Volcanics. The former hosts a substantial part of volcanogenic element in its lithology and the latter is dominantly volcanic with flows predominating. The Kamila Amphibolites are involved in the Nange Parbat-Haramosh loop. The Indus Valley section, between Skardu in the east and the Indus-Gilgit rivers confluence in the west, cut across this loop. The western loop is traceable near Hanuchal village and the eastern one is located west of the bridge over the Indus, downstream of Skardu.

The Rakaposhi Volcanic Complexon the other hand passes north of the apex zone and is not involved in the folding. This structural feature is in support of isolating the volcanic complex from the Kamila Amphibolites.

4. The Kamila Amphibolite

This amphibolite belt is located on the southern margin of Kohistan and is in direct contact with the Indo-Pakistan marginal mass along the MMT zone, except in those sections where ultramafic rocks intervene. Its northern contact is with the pyroxene granulites and both of these rocks are involved in the Nanga Parbat-Haramosh tectonics. Its maximum thickness is recorded towards west of the Nanga Parbat in the Swat and Dir parts of Kohistan.

East of the Nanga Parbat, the Kamila amphibolites after looping around the Nanga Parbat - Haramosh anticline reappears in the eastern flank of the fold, cut across the Indus Valley and extends southward towards Astor along the western margin of the Deosai Plateau. Here, it becomes thin and has been differentiated as noritic group by Misch(1977) and Astor metabasites by Casnedi & Ebblin (1977).

The Kamila amphibolites constitute part of an oceanic crust which is the product of an intraoceanic subduction in the fore-arc basin of the Kohistan Island arc, thus it forms the base of this arc. The lithology of the amphibolites is variable which include three main types i. massive and homogenous, ii. banded and sheared and iii. a bedded variety. These are the products of prograde metamorphism of the basic and intermediate plutonic and volcanic rocks which were associated with the oceanic sediments and tuffs.

The massive variety is rich in hornblende and is derived from gabbros and diorites of two types, tholeitic and calcalkaline. Its is medium to very coarse textured and lacks foliation. At places, specially along the contact with the pyroxene granulites some addition of pyroxene is noteworthy in the amphibolites which is considered to be the prograde metamorphic product after amphibole. This variety constitutes nearly 40 percent of the whole mass by volume in this formation and because of matching lithology it is characterized as amphibolite.

The banded variety mostly incorporates tuffaceous material. This variety is usually confined to the tectonized zones near the base of the sequence involved in deformation produced by obduction onto the Indo-Pakistan plate.As a result,it is banded and has developed shearing, well pronounced along the Indus Valley where the lower part of the section is exposed.

The bedded variety is not as common as the other two. But in some sections its presence is very conspicuous, as is recorded south of Sassi village in the great Indus bend, north of Chilas. This variety represents the metamorphosed sediments which now appear as chlorite schist, mica schist, graphitic schist, garnet schist and light coloured fine to medium textured amphibolite.

The Kamila amphibolites are inturded by syn-to post kinematic magmatic intrusives which represent both basic and acid igneous rocks. Gabbro, diorite and doierite are some of the basic intrusions which are the earliest magmatic bodies and are usually found as pre-and syn-kinematic sills and dykes. In the acid-intermediate domain tonalite, granodiorite, granite, pegmatite, aplite and vein quartz are common, which are younger to basic magmatic bodies and occur as syn-to post-kinematic veins, sills and dykes, Trandjomite constitutes one of the granites and among the minor acid igneous bodies some may represent the remoblized parts of the mass. Pyroxenite and hornblendite are also recorded in the amphibolites and belong to the Jijal ultramafics which intrude the amphibolite along the MMT zone. But some of them which occur as minor showings could be the product of segregation of pre-to synkinematic basic sills and dykes.

Garnet has a fairly common distribution in the Kamila amphibolites. The second and third varieties relatively host higher proportion of garnet, which are usually found clustering the felsic part of the intrusions. Garnet as large as 4 cm across is not uncommon in the amphibolite which imparts a porphyritic texture. The geochemistry of the garnet assemblage in the amphibolites indicates the presence of three types; almandine, spessartine - almandine and grossular; the latter is usually found in the calcareous horizons.

Jan (1977), while discussing the modal composition of the amphibolites from Swat has reported amphibole 32-93 %, plagioclase 0.1-26.8%, opaque minerals trace - 4.5%,beside the other accessories. Some amphibolites include biotite, muscovite, garnet and a few have margarite, clinopyroxene, carbonate and green spinel.

Thick masses of amphibolites are also present in the pyroxene granulites, which are quite frequent in occurrence near the contact with the Kamila amphibolites. This part of the amphibolites represent a retrograded type and shows a gradational passage between the two rocks without any break.

5. The Ghizar Molasse

The widespread occurrence of intermontane basins are evidenced in the northern region where fresh water sedimentation analogous to the Siwaliks had taken place. This sedimentation left behind thick piles of shales, sandstones and conglomerate, occupying isolated pockets which are deformed because of their involvement in the younger orogenic movements emanating during Miocene-Pleistocene periods. Some of such known molasse deposits are the Karewas in Kashmir, Hemis molasse of Ladakh, Jalipur molasse near Chilas and a few others lying scattered in the Hindu Kush and Baltistan which are yet to be brought on record.

In the Ghizar Valley, west of Gilgit in the Karakoram, a thick pile of fresh water sediments consisting of sandstone and conglomerate are found overlying the Rakaposhi Complex. This molasse deposit was isolated by Thirkheli (1981) and named after Ghizar.

Here the main rocks encountered are fresh water conglomerate and sandstone. The sandstone is coarse to very coarse which forms a binding material in the conglomerate too. The common clasts are angular to subangular suggesting a near source. The lithology of the conglomerate constitutes slates, quartzites, semi-to medium crystalline limestone, marble, granite, basalt, andesite, dacite and rhyolite, indicating the provenance to the southern marginal mass of the Eurasian plate. Some conglomerate pebbles are found interbedding with the rhyolite indicating their involvement in the latest volcanic episodes (?).

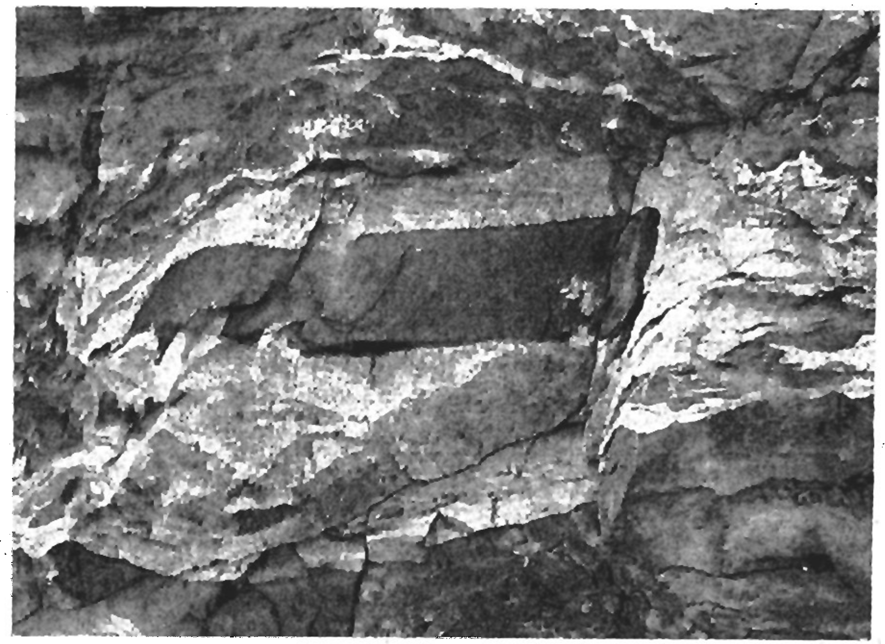
PT-61 In Nauseri section (Fig.13) above the Main Boundary Thrust there is about 250-300 m thick sequence which has different lithology than the Dogra Slates. It contains greenschists, para-gneisses and mixture of arenaceous and calcareous rocks. This sequence is equated with the Permo-Triassic rocks of the Pir Panjal. In this picture one of the rock components of this sequence is slown which is tuffaceous.

PT-62 Retro- and prograde metamorphism is usually observable along the contact of the granulites and amphibolites. In this section some patches of retrograde granulite are observed which become enriched in hornblende and altered to amphibolite.

PT-63 A garnet schist bed in the slates sequence considered equivalent to the Hazara Slates, near Landakai in the Swat Valley. Garnet is mostly spessarite and constitutes about 60-70 percent of the whole mass in this bed.

PT-64 A view of the surficial trace of the Main Karakoram Thrust in the Yasin Valley. Here the thrust zone has split and got squeezed, showing red and maroon Yasin Group forming northern edge of the Kohistan Island arc subducting under the Minapin Formation of Baltit Group,occupying the leading edge of the Eurasian plate. The ophiolitic melange has very tiny showings and appears to have been disrupted or become localized at places which are not easily accessible.


PT—61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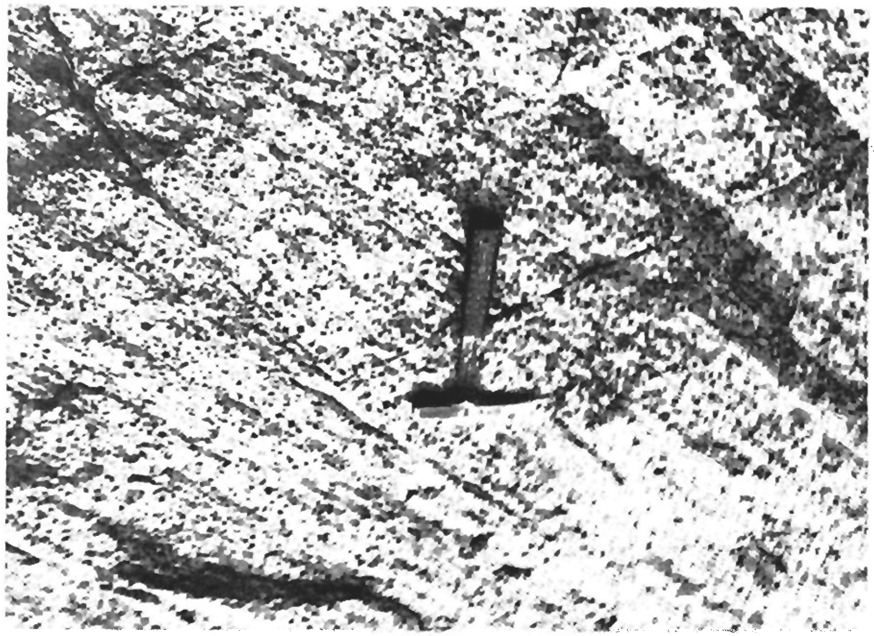
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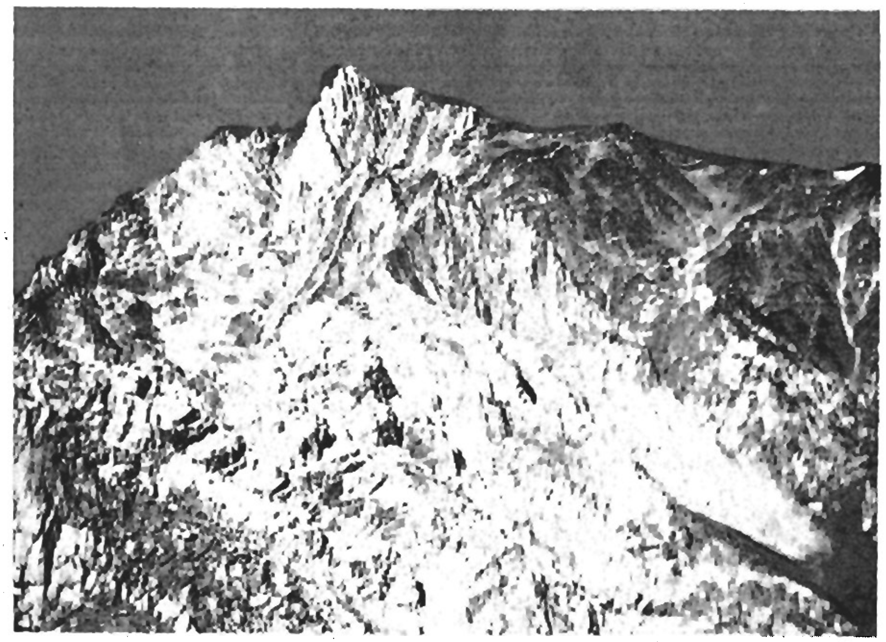

PT—64

So far, the Ghizar molasse has not been mapped in detail. This description is based on the results of three isolated sections in the Ghizar Valley upstream of Gopis. The lithology of the clastics suggest their derivation from the north after the MKT accident, as a few remants of the ophiolitic malange were also recorded in the conglomerate.

In one of the earlier papers, the author had suggested its correlation with the Hemis conglomerate of Ladakh. Yet the evidences lack to confirm the last volcanic episode of the Rakaposhi Volcanic Complex to be as young as Eocene. Moreover, structurally the Ghizar molasse is not as involved in deformation to be placed so old. More investigations are underway to answere these questions.

6. The Ladakh Intrusives

These rocks are dealt with alongwith Fig. 18, while describing the geology along the Shigar Valley in Baltistan. It has already been mentioned that the felsic (dominant) to mafic rocks composition of this batholith belong to a multicycle magmatic phases. According to three K/Ar dates available (Res, 1981) in the vicinity of Gilgit from this batholith, its age ranges from 50 to 19 my. In other words, the first magmatic epiode had started during the Lower Eocene and the last pulsation occured in Miocene-Pliocene periods. The Younger age may not represent the last magmatic phase because this age is derived from granite and the Ladakh Intrusives show several post-granitic phases of felsic and mafic sills and dykes. Thus the termination of magmatism in the Ladakh Intrusives may be held to be younger to 19 my.

The Ladakh Intrusives hold many amphibolite bodies within its mass which have been studied in detail in the outcrops located in the vicinity of Gilgit. These amphibolites are either derived from the sediments which as mentioned earlier form isolated incorporations within the batholith or possibly represent calcalkaline volcanics, trapped within this mass during the intrusions of the Ladakh Intrusives into the Rakaposhi Volcanic Complex evidences support. Field the latter source.

The lit-par-lit injections of pegmatite and aplite veins and veinlets (Fig. 8) are noteworthy in the Ladakh Intrusives, upstream of the Gilgit-Indus rivers confluence. Towards east, in the vicinity of Hanuchal and Sassi villages, the horizontal veins predominate which follow the east-northeast foliation trend of the Ladakh Intrusives. Some of the felsic veins intrude the western limb of the Nánga Parbat-Haramosh anticline. Thus there appears to be more than one generations of the felsic veins. Some are younger to the MMT accident and subsequent wedging of the Indo-Pakistan marginal mass into the Kohistan island arc. This type has extension from the batholith into the pyroxene granulites and amphibolites. The second type envelops those which follows the foliation parallel to the Nânga Parbat-Haramosh loop. In the MMT zone, in the gorge 6-8 km upstream of Sassi village, the suture zone is well demarcated by the discordant foliation of this type of felsic veins in the Kamila amphibolites from the foliation imparted in the Nanga Parbat gneisses; in the former the foliation trend is horizontal and in the latter it is vertical.

The third type of the felsic veins represent the remobilized part of the rocks involved in the MMT accident and the Nanga Parbat-Haramosh tectonics which have haphazard distribution and some are noticed cutting the earlier mentioned veins.

7. The Lawarai Granites

Beside the Ladakh Intrusives which hava a batholithic dimension, the Kohistan island arc hosts several isolated granitic bodies which belong to different magmatic episodes. These bodies are widely scattered and form Late to post-kinematic intrusives within the Kohistan calcalkaline and metasedimentary sequences. Some of these magmatic bodies which have been differentiated and find mention in the earlier literature are, Kamila granite, Gabrial granite, Dadrel granite, Diwangar granite, Warai granite and a few others.

The granites of Kohistan have not been studied in detail. Their petrology, geochemistry and geochronology have still to find an adequate place in the published literature. Some of these granites, specially those mentioned above form mappable bodies but there are many which occur as isolated small intrusions.

In general these granites are leucocratic, medium to coarse, equi-to sub-equigranular and non-foliated, though some have developed structure on the fringes. The smaller granitic bodies contain xenoliths and a few appear to be the products of metamorphic crystallization.

The granites have a sharp and discordant contact with the surrounding rocks. Some of them are trondjomitic with K-feldspar either missing or is present in small quantity. However, the proportion of the normal granites remains much higher. Some of these granites may be considered synchronus with the last magmatic phases of the Ladakh Intrusives but the others post-date this magmatic episodes, which include pegmatic-aplitic phases also.

In one of the earlier publications (Tahirkheli, 1979) the author had suggested to group them under the Kohistan granites. But as the name Kohistan has become synonymous with the island arc, its tectonic setup and lack a type section, therefore this view is revised to assign them the name Lawarai Granites after an important pass in Dir, where granite is exposed on the road section.

The Lawarai Granites include all the granitic magmatic bodies of the Kohistan island arc albeit the Ladakh Intrusives which have been given a separate entity. In age these may be placed in the post-Eocene with the intrusive episodes culminating during Miocene-Pliocene periods.

8. The Chalt Ophiolitic Melange

The ophiolitic melange of the Karakoram and Hindu Kush has already received attention alongwith Fig. 16, while describing the Hunza Valley section. Chalt, located in the Hunza Valley has been selected to be its type section-which due to an easy access enables a very through grasp on its lithology and tectonics. Here the magmatic rocks occur in two isolated tectonic slivers on the northern and southern edges of the melange zone which are separated by a thick flyschoid sequence consisting of slates and phyllitic schists being dominant alongwith thin intercalating argillaceous limestone and silty bands. In the vicinity of magmatic rocks talc schists, calc schists and serpentine schists are also recorded.

In the magmatic part of the melange zone andesite, serpentinite, basalt, ophi-calcite and rarely peridotite are the common rock types encountered in this assemblage. The siliceous breccia composed of angular pieces of quartzite with siliceous matrix and incorporating dessiminated amphibole is also associated with this part of the melange sequence.

On the northern edge of the melange zone, the magmatic sliver is overlain by a thin sequence of flyschoid rocks consisting of slates and phyllitic schists with subordinate argillaceous limestone and conglomerate. This part of the section is in contact with the Eurasian mass which obducts onto this sequence.

The clastics represented in the conglomerate belong to the meterial derived from the underlying Yasin Group. These are usually subangular to subrounded, suggestive of their source located nearby. In some conglomerate quartz predominates. The presence of stretched pebbles in the conglomerate is noteworthy. The conglomerate bands in this part of the melange zone suggest their origin during back-arc spreading.

PT-65 A granite quarry near the road at Malakand. The Malakand granite is leucocratic, nonfoliated and post-kinematic.

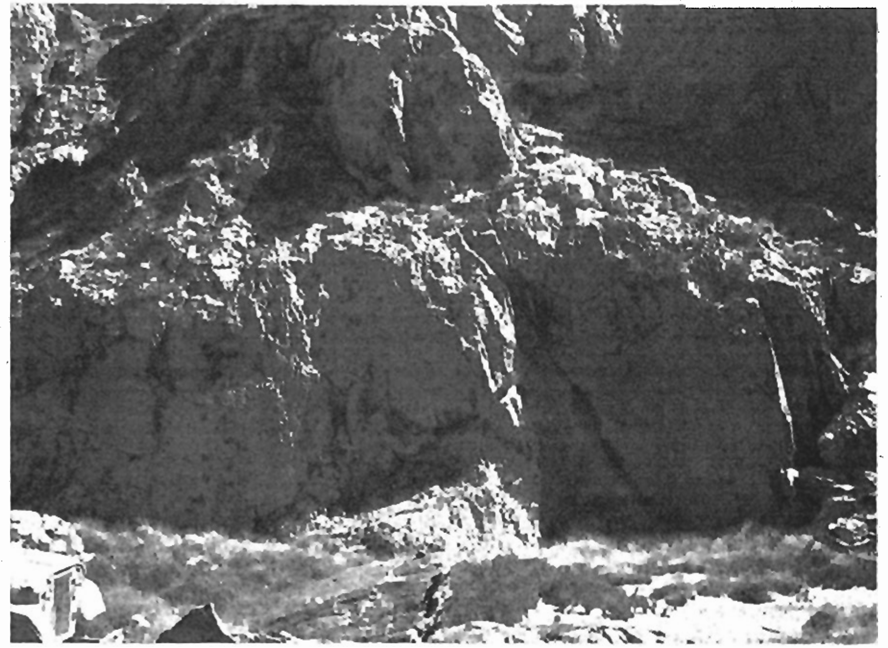
PT-66 Nanga Parbat gneiss exposed near the road in the Indus Valley downstream of Skardu.

PT-67 The Greenschists Bed between Brehnis and No1 upstream of Chitral, earlier described by Calkins, Stauffer and Desio. The former considered this bed to be equivalent to his Greenstone Volcanics now named the Rakaposhi Volcanic Complex, whereas the second author placed it as the oldest sequence underlying the Chitral Slates.

This author considers the greenstone bed to be a part of the Chitral Slates and places it somewhere between the middle and Lower part of the sequence.

PT-68 A quarry in the Malakand granite. The granite is non-foliated and is post-kinematic and intrudes the Precambrian slates sequence of Malakand which are correlatable with the Hazara Slates in the east. The contact is Conspicuously marked in the right corner.


PT−65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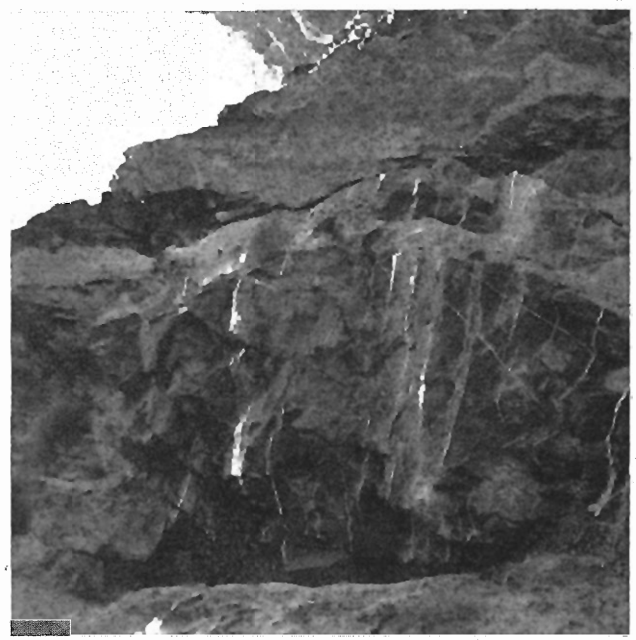
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PT−68

Near the contact with the Eurasian mass, the leading edge of the melange incorporates breccia which represents meterial derived from both Kohistan arc and the Eurasian plate and was formed during their collision. Plate 33 displays one of such sections in the Ishkuman Valley in the Karakoram.

As mentioned elsewhere, a complete classical sequence of ophiolitic melange is not encountered anywhere in the Karakoram and Hindu Kush. It occurs as isolated pockets and is dimentered as a result of their involvment in the MKT accident. The important sections where the ophiolitic melange was studied in the Karakoram and Hindu Kush, from west to east, are as follows:

1. Along Sissi Koh stream,upstream of Drosh in Chitral district. In this section the flyschoid rocks are crushed along their northern contact with the Eurasian mass and appear as a well defined fault gouge. It incorporates pockets of andesite, basalt, serpentinite, ophicalcite and some cherty breccia.

2. In the Sor Laspur Valley, the melange zone occurs in the vicinity of Rehman downstream of Sor Laspur village. Here the melange zone is squeezed and is littered with lenticular bodies of serpentinite, andesite, basalt and ophicalcite.

3. In the Yasin Valley, the Sondhi stream upstream of the Yasin village demarcates the surficial trace of the MKT and in its upper reaches holds squeezed pockets of melange which escaped erosion.

4. In the Ishkuman Valley, the melange zone is well displayed along the stream east of Chotarkhan village. Some derived material from the melange zone is recorded in the stream alluvials. The section located on the northern edge of this stream hosts the melange zone.

5.In the Hispar Valley trending east-west and passing across the apex zone of the Nanga Parbat-Haramosh anticline, the melange zone is located on the southern side of the valley which is accessible through several small side valleys. The glacial morrain filling these valleys contain material derived from the melange zone.

6. In the Shigar Valley, the northern and the southern stretches of the melange zone is recorded respectively in the vicinity of Tissar and in the upper reaches of Shigar stream, east of Shigar village.

7. In the Hushe Valley, the melange zone is recorded along the stream just north of Machelu village, which is situated in the Yasin Group zone.

8. From here, the MMT zone passes along the southern fringe of the outcrop boardering the northern side of the glaciated Shyok river valley and is partly eroded. The Shyok Valley spreads in over 100 square km area upstream of Khaplu. The squeezed MKT zone is visible along a steep nala in the outcrop east of Khaplu which is the easternmost section of the Karakoram examined by the author.

The Shangla Blueschists

The first recognition of the glaucophane-bearing schists was reported in some samples by Shams (1972) in the vicinity of Topsin in the Main Mantle Thrust zone, northeast of Khawajakhela in Swat. Subsequently, Desio (1977) further elaborated on this occurrence and stretched this zone further east towards Shangla Pass. Further studies of the rocks along the MMT zone in widely scattered area in Hazara, Dir, Swat and Chilas districts have shown the development of glaucophane in the schistose rocks associated with the subduction zone Most of these occurrences are in the form of tiny showings and none compares in extent with the Topsin-Shangla section which is exposed along the road-cut and provides an excellent view of this zone in about 30 square km area.

The blueschist occurs in a melange zone forming the top sequence of the subducted part of the Indo-Pakistan plate in contact with the Kamila Amphibolites of the Kohistan island arc. The Jijal altramafics have uninterrupted extension towards this zone and their western termination is marked on the southern slope of the Shanglá crest. Here these are represented by serpentinized harzburgites and dunites which form thin tectonic slivers in the melange

The Indo-Pakistan plate marginal mass in association with the blueschists has greenschist lithology. It is comprised of chlorite schists, epidote-albite-schists, epidote-quartz-feldspar schists, epidote-actinolite schists, actinolite-talc schists, magnetite-chlorite-actinotite schists, and graphitic schists. Besides, semi-to medium crystalline limestone and quartzite form thin partings within this sequence. These rocks according to Martin et al. (1962) belong to the Lower Swat-Buner Schistose Group which were placed in the Palaeozoic. The author considers these rocks, forming the marginal mass of the Indo-Pakistan plate to be an extension of the Inner Zone of the Lesser Himalayan lithofacies which are located in their strike direction in the east in Hazara and Kashmir. Thus this sequence is correlated with the Salkhala Series-Hazara/Dogra slates of the Precambrian age.

Shams (1977) observes that the Shangla blueschists have developed as a result of soda metasomatism on the original lithologies of the greenschists. He considers that soda activity took place in two stages; first when the blue amphibole was formed and second when the albite porphyroblasts were grown. The amphibole was identified earlier as crossite of the riebeckite-glaucophane series by Shams which was confirmed on the basis of chemical composition and structural formula with the known minerals. The hypersodic composition of the blueschists relate them with the metasedimentary type which are usually found emplaced along the fossil trench associated with the plate subduction zone.

In the Topsin-Shangla area, besides glaucophane-bearing schists, the other high pressure minerals associated with the melange are epidote and piemonite which have relatively restricted development than the former. Brecciated rocks which incorporate blueschists and serpentinite, with pods and boudins point put to deformations which this zone has been subjected. The blueschists are usually found interealated with the greenschists and in some sections their contacts appear tectonic.

Shams (1979) reports a K/Ar date on muscovite from a metasedimentary type blueschist located in the vicinity of Topsin to have given an age of 84 + 1·7 my., placing it in the Upper Cretaceous. This age compares favourably with the Indo-Pakistan plate-Kohistan arc collision and subduction of the former along the Main Thrust zone as envisaged by Tahirkheli et al. (1979).

The blueschist facies metamorphism from the Topsin-Shangla area along the Main Mantle Thrust in Swat in Pakistan (Shams, 1972, Desio, 1977) is the first record in the Indo-Pakistan subcontinent which has given due weightage to the school of thought favouring the Indo-Pakistan-Eurasian collision and considering the Indus Suture in India and the Main Karakoram Thrust and the Main Mantle Thrust, the northern and southern sutures respectively in Pakistan to represent major zones of crustal subduction. This evidence was further supported by the discovery of another glaucophane-bearing schists in the Indus Suture zone in the Kalra nala, a north flowing tributary of the Indus SE of Leh in Ladakh by Virdi et al. (1977). Here glaucophane occurs in the basic rocks of the ophiolitic melange zone which is comprised of a sequence of feebly deformed and metamorphosed lavas, interbanded pyroclastics and lenticular serpentinites.

EVOLUTION OF KOHISTAN ISLAND ARC

The Himalayan domain in the NW Pakistan has a different tectonic setup than the rest of the Himalaya, has already been discussed alongwith Fig. 2. This distinction is marked by the Juxtaposition of an island arc in between the Indo-Pakistan and Eurasian plates.

The paleomagentic and spreading data in the Indian ocean suggest that the Indo-Pakistan plate began moving towards Eurasia at least 130 my. ago. This convergence resulted in an intraoceanic subduction in front of the Indo-Pakistan plate which paved may for the birth of this arc, north of the subduction zone.

The Kalam Group in Kohistan holds the oldest marine sediment which was involved in the earlier stages of the arc build-up.The middle sequence of this group, called the Deshan Banda Limestone contains corals among which Rhabdophyllia sp has been identified (Karig, 1981), which range in age from Middle Jurassic to Middle Cretaceous. This evidence also favours the time of intraoceanic subduction. The Utror volcanics which form part of the Dir Group thus constitute the main arc of Kohistan, the earliest phases of which were generated during the Upper Jurassic time.

In the Lower Cretaceous time, the Kohistan island arc had formed an independant domain and was moving ahead of the Indo-Pakistan plate. During this period, thick mass of an oceanic crust was formed in the trapped Tethys in the back-arc which is overlain by a shelf type sedimentary deposit known as the Yasin Group.

Among the marine sediments, the Baraul Banda Slates are the youngest which have yielded fossils and are placed in the Palaeocene-Lower Eocene. Whether this marine sequence was deposited in the fore-arc basin or had direct connection from the west is still being debated. If we accept the earlier view, then the timings of the Indo-Pakistan-Kohistan arc collision and suturing are to be lagged behind which is not commensurate with the general epinionheld by many geologists.

The Baraul Banda Slates have association of intermediate-acid volcanic flows which suggest the last phases of the volcanic activity in the main arc to have continued to the post-Palaeocene period.

The Gondwanic microplates which were disintegrated during northward drift in the Palaeo-Tethys had swarmed around the southern margin of the Eurasian plate. A chain of such fragments are observed northeast of the Zagros Fault in Iran, some of which are popularly known after Lut (Iran), Kabul (Afghanistan), Pamir (Central Asia) and Chaghai(Pakistan). This belt of "Central Domain" was responsible for complete annihilation of the Palaeo-Tethys. These microplates were involved in subduction under Eurasia during the Kimmerian orogeny along the Palaeo-Tethys suture which is marked by the Hercynian eugeosynclinal deposits (flysch and volcano-sedimentary) with volcanics and ophiolites, and are involved in an intense late Triassic folding.

Between Afghanistan and Tibet the Palaeo-Tethys suture follows the Pamir syntaxis and thus the eastern Hindu Kush and the western and Central parts of the Karakoram, according to Stocklin (1979) are not involved in the Triassic suturing. Recent discovery of a microplate with an upper Gondwanic plants (Sharma et al.) north of the Indus Suture in Ladakh in the eastern Karakoram necessitate to review the marking of the surficial trace of the Triassic suture in this part of the Central Asia.

The Kohistan Island arc started achieving its configuration after the termination of the Kimmerian orogeny in the Neo-Tethys, nevertheless it should have received its effect during the earlier stages when intraoceanic subduction was taking place.

If one traces the history of volcanic arc buildup between Zagros and Ladakh, one encounters two periods of lave flows; the earlier one is of Jurassic age and is associated with the Palaeo-Tethys suturing. This volcanic belt is located on the north of this suture and has a limited distribution. The latter volcanism has started after the advent of the Neo-Tethys and this arc system was built on the southern edges of the Gondwanic microplates. In Afghanistan, the Kandhar volcanics and in Pakistan the Sanjrani volcanics are two of them which were developed on the southern edge of Kabul and Chaghai microplates respectively.

The Kohistan arc constitutes three volcanic episodes; two of them are associated with the oceanic crust in the fore-arc and back-arc basins and the third one which is considered to be the oldest forms the main arc of this domain. The latter, as mentioned earlier based on the trapped fossil indicates initiation of volcanism during upper Jurassic, whereas the earlier named the Rakaposhi Volcanic Complex has yielded Lower Cretaceous fossils in the trapped sediments.

The doubling of the Indus Tsang Po Tectonic Line in Ladakh marks the eastern extent of the Kohistan arc. Its northern and southern contacts respectively are welded with the Eurasian and the Indo-Pakistan plates along the Main Karakoram Thrust and the Main Mantle Thrust, the two sutures which were earlier mapped as Shyok Fault and Indus Fault. Some of the earlier workers including Klootwijk et al. (1979) have differentiated Ladakh as a separate arc. The author considers Ladakh as an extension of the Kohistan arc which is supported by their inheriting a similar geological environment and forming a single tectonic domain.

Both the sutures are involved in the regional tectonics, emanating after welding of the arc with the two plates. The southern suture is structurally more deformed than the northern one. It hosts one of the major tectonic scars of the region,namely the Nanga Parbat-Haramosh syntaxis whereas the northern suture is twisted in a bow-shaped bend; both of these structures verge towards south, indicative of having shared north-south directed stresses generated during various orogenic episodes. The post-suturing tectonic episodes appear to have a larger share in structural indentations. These episodes have started during Early Tertiary and achieved culmination during Neogene, which records maximum severity in the Himalayan orogeny.

The Lower Cretaceous (Barremian-Aptian) Period after the deposition of the Yasin Group, marks the closure of the Tethys in the back-arc. The initial contact of the arc with the Eurasian plate is postulated in the Upper Cretaceous and completion of suturing phase during Late Cretaceous-Early Tertiary. In the fore-arc the Palaeocene Baraul Banda Slates in the Dir Group, support the arc-Indo-Pakistan plate contact during the Late Palaeocene-Early Eocene. This evidence remains valid if the Palaeocene slates are considered to represent the last remnant of the shrinking Tethys in the fore-arc basin.

After the isolation of the Kohistan arc, its first contact was with Eurasia or with the Indo-Pakistan plate. The earlier view held by the author (Tahirkheli et al., 1979) was in favour of its first contact with the Indo-Pakistan plate. Mattauer et al. (1979),Bard et al.(1979) and Klootwijk (1979) had also supported this view. In one of his latter publications, the author deviated from this view which was necessitated by the presence of the Baraul Banda Slates (Palaeocene-Lower Eocene) near the fore-arc basin, pointing to collapse of the southern basin during post-Eocene, or in other word indicating a later contact with the Indo-Pakistan plate.

However, there are evidences which favour the first contact of the Kohistan arc with the Indo-Pakistan plate and then together colliding with the Eurasian plate. One of such evidences supporting this view is the geological maps incorporating regional tectonics produced by Bakr and Jackson (1964), Gansser (1980) and Desio (1964) which show the disruption of the apex of the Nanga Parbat-Haramosh syntaxis by the Main Karakoram Thrust. This suggests that the MKT is formed subsequent to the MMT, when both Indo-Pakistan plate and the Kohistan arc together collided with Eurasia.

However, there is no intention to close this issue with the meager evidences now in hand. I will leave this problem open till more concerete evidences are gathered to enable adequate weightage for accepting either of the views.

PT-69 Machelu Village located in the Hushe stream in Baltistan. The snowy peak behind belongs to the Masherbrium Group of the Karakoram.

PT-70 A veiw of the Mingora Emerald Minc Swat. It is located near the northern margin of the Indo-Pakistan plate in a fault zone named the Main Marginal Fault which disturbs .the Precambrian rocks and indicates serpentinite association.

PT-71 A section between Nol and Brehnis in the Mastuj. Valley in Chitral,showing the Chitral Slates underlying the Devonian sequence.

PT-72 The hillock exposed in front is near Chakdarra Fort at the confluence of the Panjkora and Swat rivers. The rocks on the right of darker hue belong to the slates sequence of Malakand. These rocks are in contact with the Chakdarra foliated granite on the west. The foliation trend in both the rocks are the same i.e. northeast-southwest. A picket is noteworthy which is named after Sir Winston Churchill, who had spent some time in this picket as a young Lieutinent correspondent during 1880s, when the British forces and the local tribes were at war.

THE INTERPRETATIONS OF IMPORTANT GEOLOGICAL SECTIONS

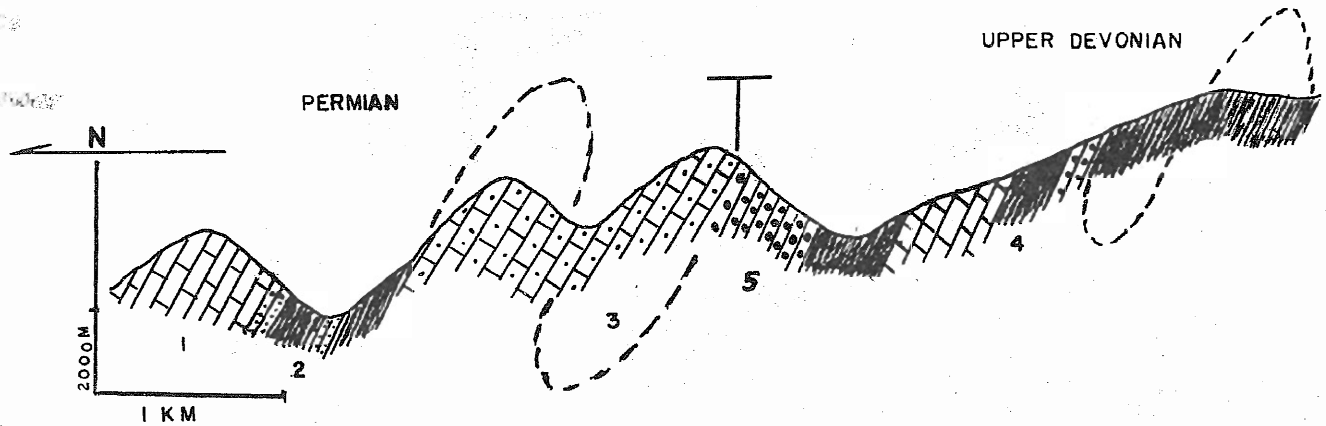
A major part of the northern terrain in Pakistan is geologically covered by reconnaissance type of work, as a result many of its important sections are not properly limelighted due to lack of detailed interpretation. The published literature on these sections contain small scale maps, as a result, a sketchy picture is represented which create problems in understanding their geological setup in the regional frame.

The author has tried to overcome this difficulty by preparing diagrammatic sketches of all these sections incorporating detailed informations on their geology. Each section includes a detailed description of its rock formations and discusses their major structural features. All these diagrammatic sections are prepared under the context of plate tectonics which include the evolution of an island arc intervening the Indo-Pakistan and Eurasian plates.

The Broghil section of Hayden (1915) is located towards the west (Fig.20) which was measured by Talent and Tahirkheli in 1973. In this section two main lithologies of rusty brown carbonate - siltstone (4-5 m) and fine grained quartzites (over 300 m) were placed by Talent et al.(1979) in the Ordovician, a first record in the stratigraphy of Pakistan. This age was based on several species of conodont found in the carbonate-siltstone sequence.

During a subsequent visit, the author tried to locate the Ordovician rocks in the Shewa Shur section. As much of the area is under glacier and the Yarkun gorge forbids an easy access to the outcrops across the river, it was not possible to extend the investigation further south which exposes older part of the sequence and is expected to hold the Ordovician rocks. But my observations based on the regional structure and the strike of the beds between Broghil and Shewa Shur, it is expected that the Ordovician rocks of Broghil have extension in the foothill zone, south of Shewa Shur. Thus as considered by Talent et al.(1979) the Upper Devonian rocks are not faulted against the Ordovician carbonate, siltstone and slates in Shewa Shur area.

FIG. 4



SECTION EIGHT KM. WEST OF SHEWA SHUR
NE TIP OF PAKISTAN

1. Light grey, thin to thick bedded limestones 2. Slates with alternations of siltstone and yellowish brown limestone, 3. Dark grey to black semi-crystalline limestone, thin bedded, jointed and containing carbonaceous pockets, 4. Slates, phyllitic schists, with siltstone and yellowish brown limestone intercalations, 5. sandstone and quartzitic sandstone incorporating minor silty bands.

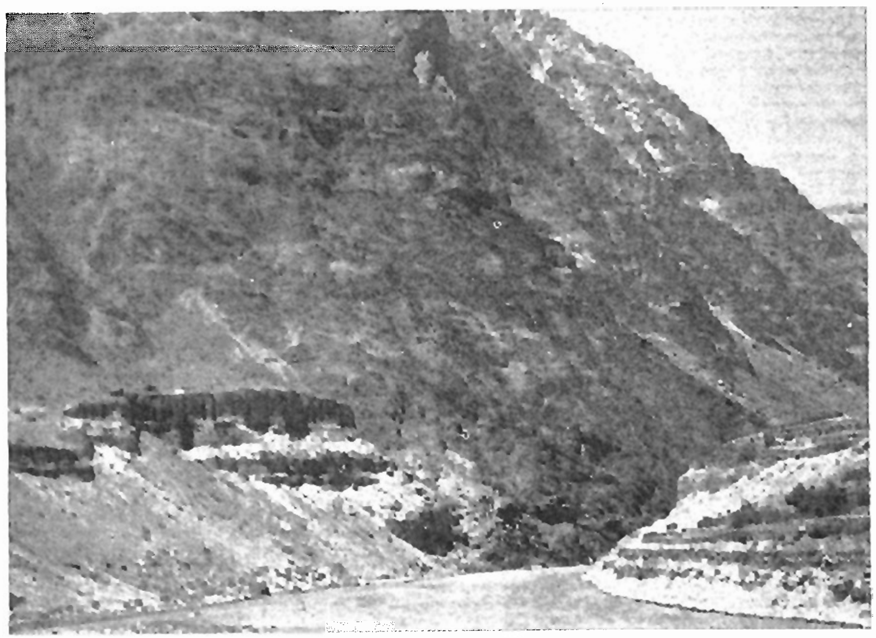
The Shewa Shur section is located at about 25 km northeast of Broghil in Chitral near the northern edge of Pakistan. Geographically this part constitutes the northwestern margin of the Karakoram but its geological domain is shared by the Hindu Kush (west), Wakhan area(north) and Karakoram(east). Reed(1911) had first reported an Early Devonian fauna from this section. Hayden (1915), subsequently further elaborated and incorporated Middle Devonian to Permian rocks also The belt incorporating this section extends from the Hindu Kush to the Karakoram and as the dip of the beds is northwards it is expected that its younger part may be lying in the Wakhan-Pamir area.

Earlier, I.H. Grant had sampled this section at Shewa Shur. Most of his fossils came from a dark grey and black limestone, which is compact and is semi - to medium crystalline and occasionally fossiliferous. The samples were studied by Reed(1911) who identified the following species:-

Proctus chitralensis C.Reed
Polytropis Gnillieri (Oehl) ?
Pterinea sp.
Spirifer cf. robustus Barr
Spirifer aff. Canaliferus Valence,
Spirifer sp.
Liorhynchus sp.
Stropheodonta? sp.
Orthothetes hippony schnur
Orthothetes? sp
Productella? sp.
Thamnicella? sp.
Striatopora cf. vermicularis McCoy
Crinoid Stems.


PT－69


PT－70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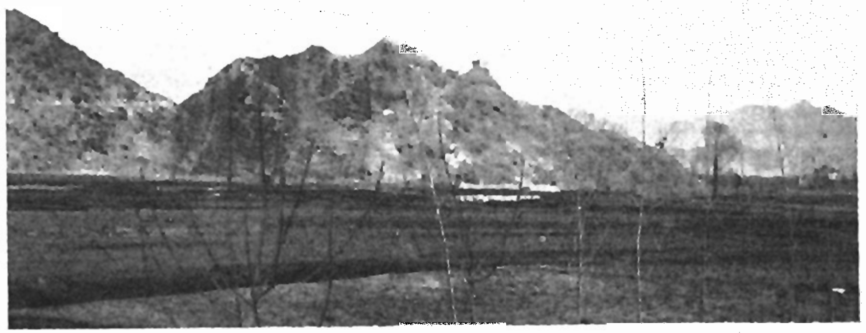
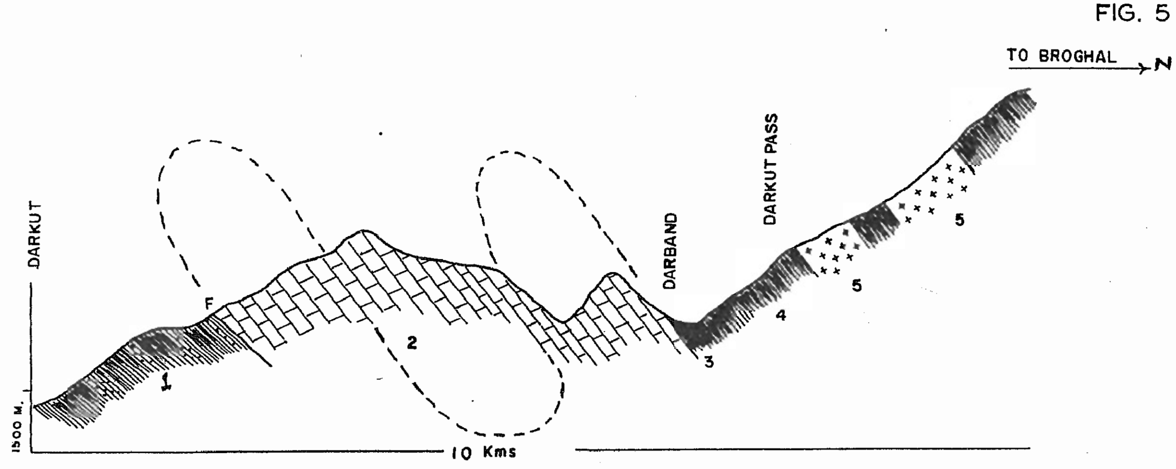

PT－72

On the basis of these identifications, Reed concluded that the species indicate a Lower Devonian age and the fauna consist of an intermixture of species possessing Bohemian and the north European affinities. Hayden had made a mention of the presence of Fusulina limes tone in the right bank of the large glacier (author could not visit this part where he contends the presence of the Ordovician bed), southeast of Shewa Shur - which he had earlier recorded in the Broghil section which yielded an Upper Devonian fossil.

This belt extends south-eastwards, north of the Main Karakoram Batholith into the Upper Hunza Valley where Desio (1964) and Desio and Martina (1972) have described the rock types and their fauna.

Gaikushi section is located in the upper reaches of the Yasin Valley in the western karakoram. This sequence occurs on the northern side of the Main Karakoram Batholith and costitutes the type section of the Darkut Group of Hayden (1915) and Ivanac et al. (1956) who first recorded Permo-Carboniferous fossils in the limestone bed near Darkut village. On the basis of this find the latter authors mapped the rest of the metasedimentary sequences of this region as Darkut Group which so far is being considered to form the oldest sequence in the Karakoram.



SECTION ALONG GAIKUSHI STREAM BETWEEN DARKUT & DARKUT PASS, UPPER REACHES OF YASIN VALLEY

FIG.5

1. Slates, phyllitic schists with subordinate siliceous bands. 2. Light grey to yellowish brown semi-crystalline limestone, thin to thick bedded, siliceous with sporadic chert. Weathered faces show grooved feature. Its lower contact with the slates is disturbed. Near the top it becomes thin bedded. Black carbonaceous bands are recorded near the top. This limestone bed is sparingly fossiliferous and has yielded Fenestella, Rhombopora R. Lopidodendroids, indicating a Permo-Carboniferous age. This limestone sequence constitutes the type section of the Darkut Group (Ivanc et al. 1956). 3. A slate bed having a normal contact with the underlying limestone and incorporating 8-10m thick carbonaceous band at the base. 4. Slates, phyllites and phyllitic schists having a similar lithology as encountered at the base of the sequence in I. 5. Darkut Pass Granodiorite.

This section has its importance because it is the only section in the Karakoram and Hindu Kush where the Carboniferous sequence was established by the early work. At Darkut, this Group is located on the northern side of the Main Karakoram Batholith and its eastward extension has been traced upto Ishkuman village in the Ishkuman Valley. As mentioned earlier, the Palaeozoic-Mesozoic sequences of the Hindu Kush extend eastward into the Karakoram and already have been mapped by Desio and Martina (1977) in the upper reaches of the Hunza Valley. The westward extension of the Darkut Group is recorded in the vicinity of Chamarkhand in the Yarkun Valley upstream of Mastuj. Thus the Darkut Group is a part of the Hindu Kush lithofacies which has extension in the Karakoram. Recently, Casnedi (1979) has also reported a thick flysch like formation of the Carboniferous age between the Hindu Kush and Karakoram which coincides with the location of the Darkut Group.

PT-73 A view of the melange zone in the Sissi Gol section near Drosh in the Hindu Kush. Here green coloured serpentinite lense emanates from the associated ophicalcite, both representing the altered peridotites.

PT-74 Epidotization is a very common feature embedded in the Karakoram-Hindu Kush rocks which is related to the alpine orogeny. Here the scars of epidote are vividly marked in the rocks of the Rakaposhi Volcanic Complex in the vicinity of Lawari Top in the Hindu Kush.

PT-75 Minor acid igneous intrusions in the pelitic rocks on the southern slope of the Malakand hill. Due to contact metamorphism the pelitic rocks are changed to hornfelses.

PT-76 Leucogranite intrusion in the Rakaposhi Volcanic Complex in the Yasin Valley.

Darkut Group is located on the north of the Main Karakoram Batholith and Desio(1963) had suggested that this group should incorporate,(a) Passu Slate,(b) Gircha Formation, (c) Kilik Formation and (d) Misgar Slate (Kazmi,1951),all of them located in the Upper Hunza Valley, north of the batholith. To support his view,Desio mentions that the correlation between the typical Darkut sequence located between the Darkut village and the Darkut Pass, the above-mentioned formations have indicated a similar faunal assemblage of Brachiopods,Bryozoans and Fusulinids of the Permian age which were also recorded by Hayden,Clark,Kazmi and Ivanac et al.Thus he assembled the other metasedimentary rocks of the Karakoram under the Dumurdo Formation,type section of which is located in the Braldu Valley in Baltistan.

The Darkut sequence at its type section has yieded the following fossils:-

Fistulipora Yasinesis Reed 1925

Batostomela sp. Fenestella sp.A

Polypora ?

darkotenesis (Reed) 1925

Rhombopora cf. lepidodendroides Meek 1872

Thaminscus sp.

Acanthocladia sp.

Crinoidea gen. Ind.

Orthotetidate gen.Ind.

Euomphalus of parvus Waagen 1880

Hyolithidae gen.et.sp.

This whole fauna suggest an Upper Carboniferous/Lower Permian age.

On the basis of these observations two things have become clear. One is the confirmed existence of the Carboniferous rocks in the Hindu Kush and Karakoram about which the previous work does not elaborate. Secondly, the Baltit Group incorporating the metasedimentaries of the Karakoram which Ivanac et al.(1956) has placed in the Darkut Group has different stratigraphic status and the author considers them older than the Permo-Carboniferous. This view gets further confirmation in the two other sections,across Sanoghar and between Nol and Brehnis in the Mastuj Valley, where the Chitral Slates considered equivalent to the Baltit Group are found underlain unconformably by the Devonian rocks. This evidence dismisses the earlier age assignments of Permo-Carboniferous,Permian or Cretaceous to these rocks by the previous workers.

FIG-6.

1. Chitral Slates = Baltit Group, 2. Marble bed incorporated in the Chitral Slates which was differentiated as Gahirat Marble by Calkins et.al.(1969), 3. Conglomerates, 4. Maroon argillaceous bed. 1-2 are Precambrian to Lower Palaeozoic and 3-4 belong to the Reshun Group of the Cretaceous-Lower Tertiary age.

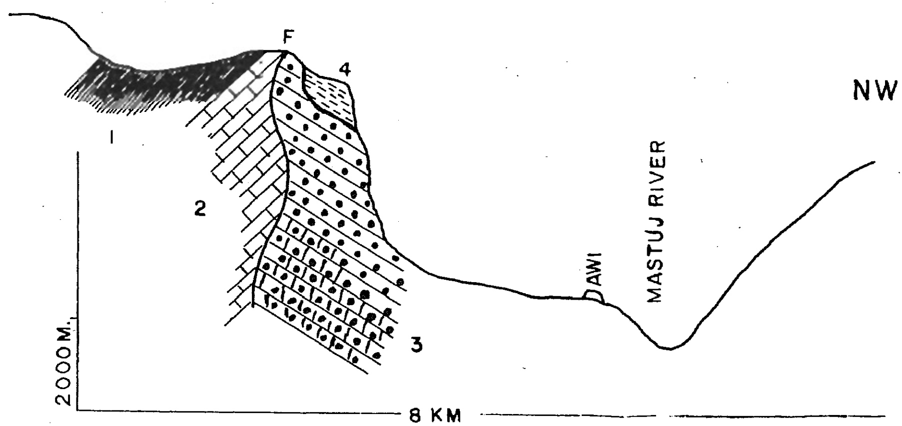
Awi section is located downstream of Sanoghar village in the Mastuj Valley. Here the Precambrian slates and crystalline limestones have a faulted contact with the Reshun Group of the Cretaceous - Lower Tertiary age.

The Reshun Group has two lithologies, conglomerate at the base and overlain with a faulted contact by the red and maroon agillaceous bed. This group is considered equivalent to the Yasin Group of the Karakoram though they indicate some lithological differences.

The Yasin Group and the Reshun Group had two different basins of deposition, the former encircled a volcanic arc and has volcanic rock associations whereas the latter was formed in a linear Tethyan arm in the Hindu Kush which had extension from the west.Both of these basins were separated by the Precambrian-Palaeozoic rocks forming a ridge which separated them from each other.

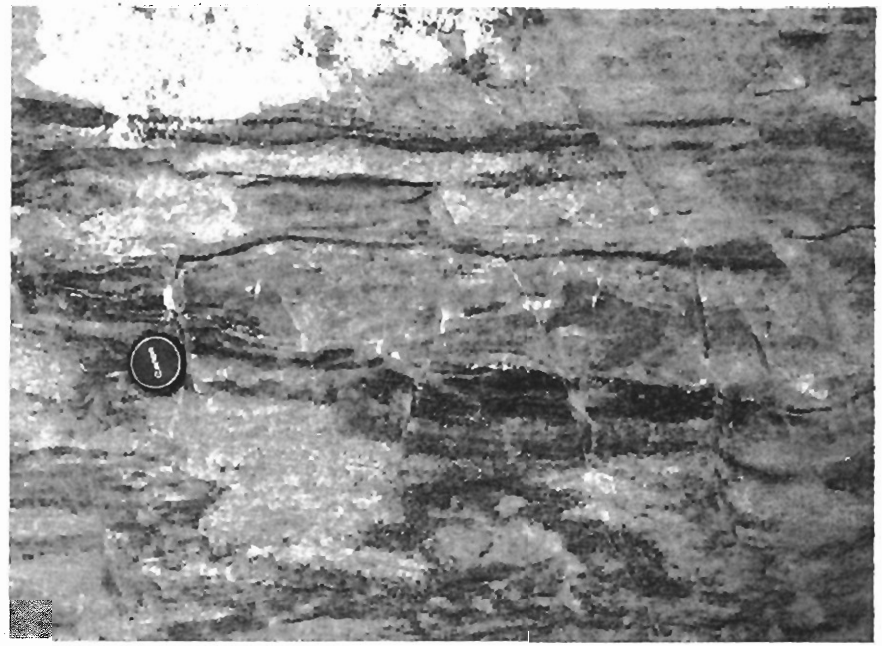
The Awi structure is the product of the neotectonics emanating during the formation of the Pamir syntaxis. How much this structure is influenced by the MKT accident is yet to be appraised.

FIG. 6



AWI SECTION DOWNSTREAM OF MASTUJ


PT—73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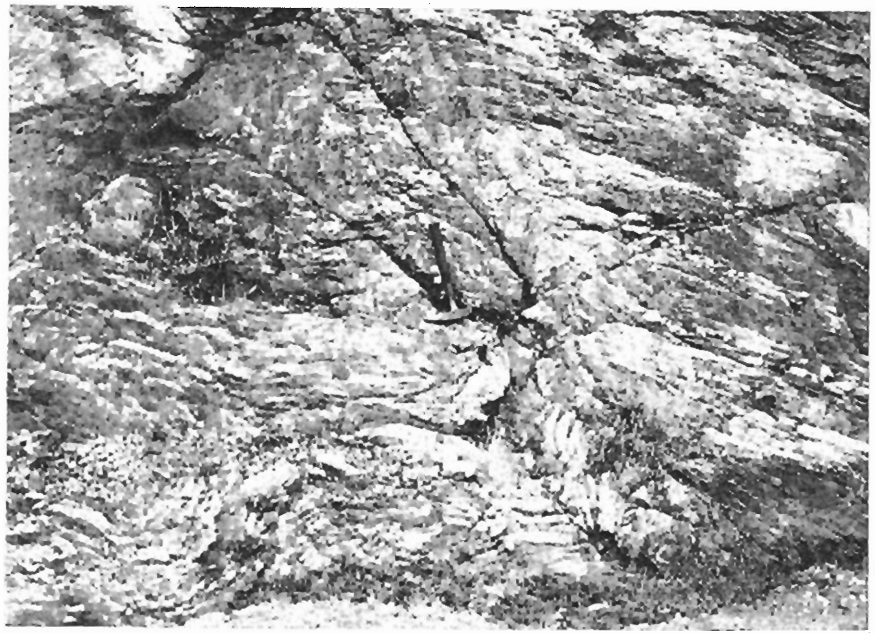
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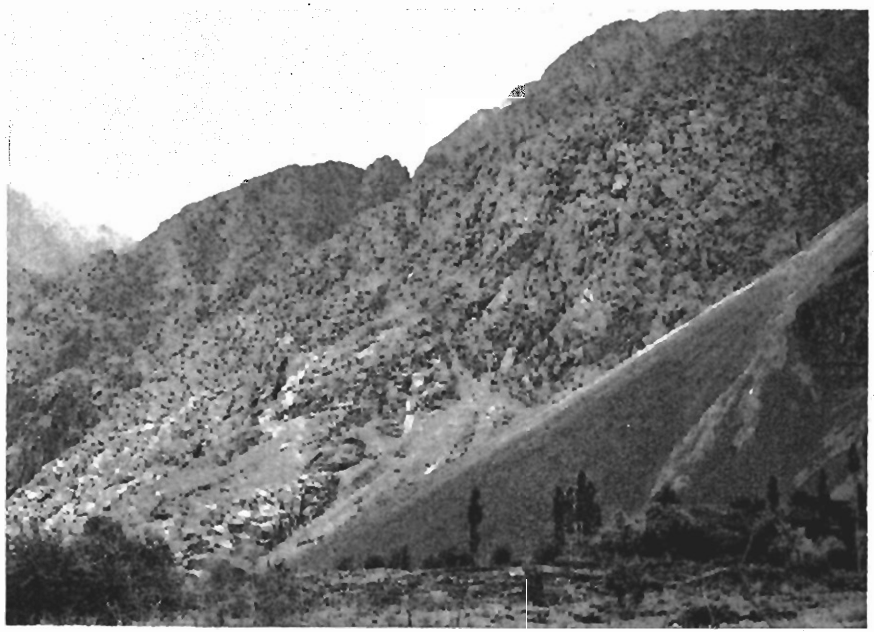
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FIG. 7

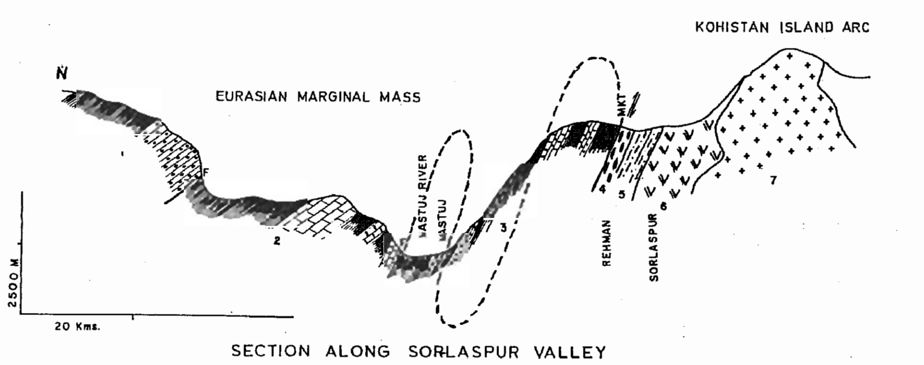


FIG.-7.

1. Reshun Group of Cretaceous - Lower Tertiary age. 2. A sequence consisting of slate and limestone which the author considers to be incorporated in the Darkut Group (Ivanac et, al., 1956) of Permo-Carboniferous age. The base of this sequence may have the Upper Devonian rocks. 3. A thick sequence of the slate (dominant) with limestone and sandstone partings which in Chitral was mapped as the Chitral Slates and in Gilgit area as Darkut Group (Ivanac et al., 1956), Baltit Group (Stauffer,1968) and Dumurdu Formation (Desio, 1963). The author retained the name Baltit Group for both the sequences which laterally merge with each other in the Sor Laspur Valley and are placed in the Precambrian-Lower Palaeozoic age.

The Sor Laspur section has its own importance, because it is located along a profile which geographically demarcates the boundary of the Karakoram from the Hindu Kush. Here the rocks of the Karakoram and Hindu Kush laterally merge with each other, indicating sharing a common geological domain from the Precambrian to the Cretaceous, of course with some intervals of non-depositional periods.

The Kohistan sequence in this section is comprised of the Ladakh Intrusives,Rakaposhi Volcanic Complex, Yasin Group and the Chalt Ophiolitic Melange, which subducts the Eurasian plate along the Main Karakoram Thrust. The Ladakh Intrusives terminate just southwest of the Sor Laspur village and beyond that in the Hindu Kush only sporadic granitic bodies are located, none of them attaining a batholithic dimension.

Another important feature is the occurrence of two isolated belts, exposing the rocks of the Lower Cretaceous (Yasin Group-5) and the Cretaceous-Lower Tertiary periods (Reshun Group-1). This indicates the existance of two basins where sedimentation was taking place simultaneously, atleast during the Cretaceous period: One basin formed the shrinking Tehtys trapped between the Kohistan Island arc and the Eurasian Plate during the last phases of convergence and the second basin formed a linear Tethyan arm, having extension from the west into the Hindu Kush and Karakoram. These two basins were separated by a Precambrian - Palaeozoic ridge which was raised and did not permit them having any direct link with each other.

The Darkut Group of the Permo-Carboniferous age has extension into this area and part of the thick slates and limestone sequence (2), north of Mastuj may incorporate these rocks.

FIG-8:

1. Ladakh Intrusives on the northern fringe of Deosai Plateau. 2. Burji La Formation which has yielded <u>Orbitolina.</u> 3. Deosai Volcanics. 4. Katzarah Formation containing metasediments alongwith metavolcaniclastics. 5. Bahrain Pyroxene Granulites. 6. Kamila Amphibolites. 7. Nanga Parbat Gneisses (Precambrian). 8. Thalichi Sediments. 9. Quartz Diorites. 10 A Ladakh Intrusives outcrop upstream of the confluence of the Gilgit-Indus rivers, showing lit-par-lit injections of aplite and pegmatite.

The Nanga Parbat - Haramosh massif forms the western termination of the Higher Himalaya in Pakistan. Wadia (1932) and Misch (1935,1936,1949) considered it to constitute the promontory of the Indian basement having Precambrian rocks in its core. With the discovery of Kohistan as an ancient island arc and the two sutures, one of them the MMT encircling this massif, the geological and tectonic positions of the Nanga Parbat - Haramosh massif has become more clear.

If one approaches the Nanga Parbat from the Nilam Valley in Kashmir towards south,it becomes easy to grasp the stratigaphic relationship between the Hazara-Kashmir Lesser Himalayan lithofacies (Hazara Zone) and the Nanga Parbat gneisses. The Hazara Zone in this area constitutes three main lithologies with an approximate estimate in the assemblage as: Salkhala series/Dogra Slates-70 percent, quartzites and other psammitic partings- 15 percent, carbonates consisting of medium crystalline limestone and marble - 7 percent, and the igneous intrusions-8 percent. These are the rock types which in highly metamorphosed form constitute the main mass of the Nanga Parbat - Haramosh massif.

The metasediments show progressive increase in metamorphism from the northern edge of Kashmir and Hazara to the north near the southern fringe of the massif. After entering the domain of the massif the grade of metamorphism further increases and the rocks are variably changed to para-gneisses, quartzitic schists and marble. This zone parallels the limbs of the anticline or in other words forms the leading edge of the protruding Indo-Pakistan plate which subducts the Kohistan arc along the Main Mantle Thrust. Towards the core of the fold, due to intense metamorphism mesozonal to katazonal rocks and migmatitic gneisses become dominant which have been thoroughly studied and already described by Misch (1949).

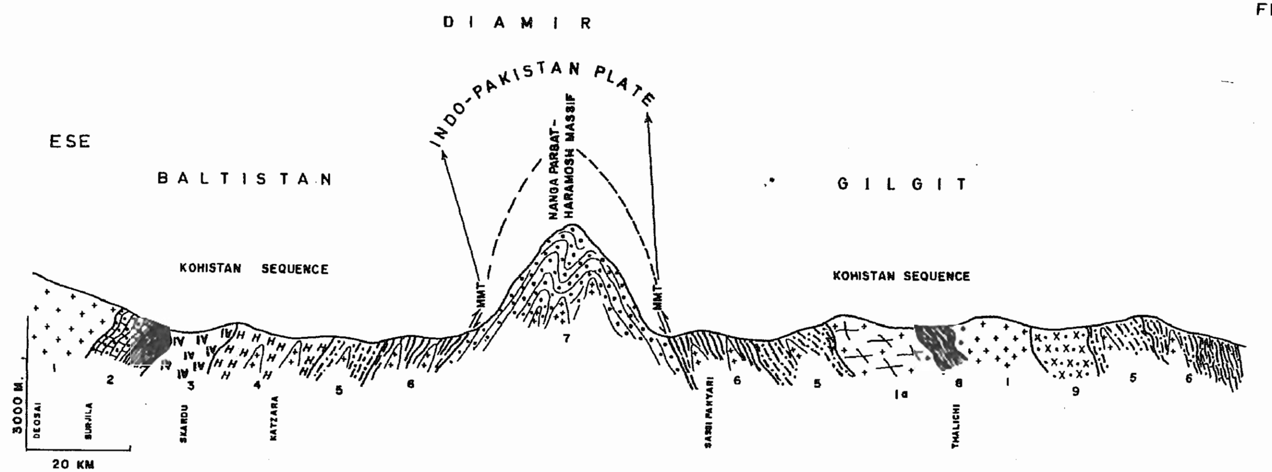
PT-77 The compact foliated gneisses with synkinematic acid igneous intrusives. A boudinage structural feature is well displayed. This section is located near the apex of Hazara syntaxis uprtream of Kagharn Valley.

PT-78 A banded and folded amphibolite ontcrop which forms a part of the Dogra/Hazara slates in the apex zone of the Hazara syntaxis.

PT-79 A veiw of the Ghizar Valley upstream of Gopis. In this section the Ghizar river traverses the Rakaposhi Volcanic Complex.

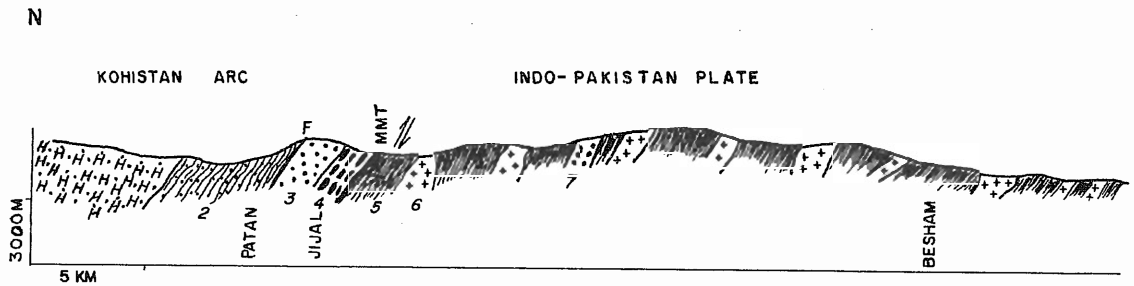
PT-80 A closer look at the Darkut Group near its type section in the upper reaches of the Yasin Valley. In this part of the sequence the carbonate rocks dominate.

FIG. 8



SECTION ALONG THE INDUS RIVER ACROSS NANGA PARBAT- HARAMOSH MASSIF

FIG. 9



SECTION ACROSS THE LEADING EDGE OF INDO-PAKISTAN PLATE AND KOHISTAN ALONG THE KARAKORAM HIGHWAY

FIG-9:

1. Kamila Amphibolites 2. Bahrain Pyroxene Granulites 3. Pattan Garnet Granulites (type section) 4. Jijal Ultramafics (type section) 5. Metasedimentary assemblage ranging from slates to para-gneisses with fairly extensive distribution of graphitic material and occasional presence of medium crystalline limestones and marble. In lithology these beds resemble with the Salkhala Series of the Hazara Zone of the Lesser Himalaya 6.Synkinematic leuco-type granites form lip and tongues in these sediments
7. Conglomerate bands in the sediments are recorded which contain granite pebbles among the clastics.

Between Besham and Pattan, a very interesting geological section is exposed along the Karakoram Highway. This is the section where the Main Mantle Thrust was first deciphered and demarcated.

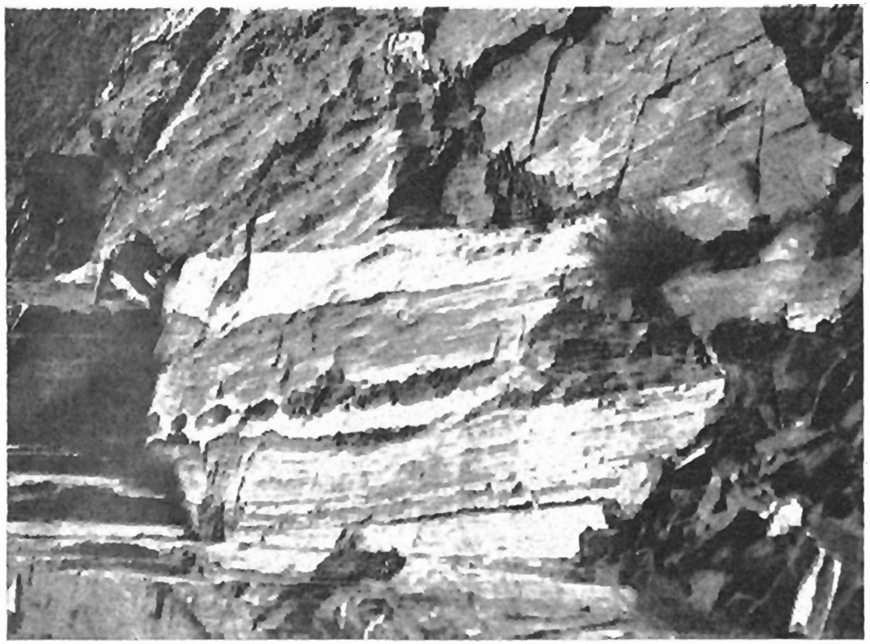
The marginal mass of the Indo-Pakistan plate is comprised of slates, quartzite and crystalline limestone ,placed in the ascending order of abundance. The slates sequence ranges from phyllitic slates to various types of schists and para - gneisses. In the more tectonized zones,amphibolite schists and gneisses are also encountered. The graphitic bands in the slates are quite common and have consistant distribution.

The carbonate bands are associated with the slate sequence and range from medium crystalline limestone to marble.The quartzite , besides forming separate beds also occur as siliceous partings within the slates. Sporadic bands of conglomerate have also been noticed in the metasedimentary sequence which among the clastics also contain granite pebbles.

This mass is intruded by the synkinematic granites forming lips and tongues within the metasedimentary sequence. There are 2-3 phases of granitic emanations and atleast one of them is Cambrian or older which is based on the evidence of dating conducted on the granites intruding the marginal mass of the Indo-Pakistan plate at Mansehra in Hazara and near Mingora in Swat. This phase may belong to Pan African magmatism which remained in force from the Precambrian to the Early Cambrian periods Besides,numerous basic and acid igneous rocks in the form of sills, dykes and veins, strew the metasedimentary rocks. Some phases of granitic emanations have induced sulphide mineralizations which are in investigation stage

The rocks described above are developed on the leading edge of the Indo-Pakistan plate which subducts the Kohistan Island arc along the Main Mantle Thrust.

The Kohistan sequence, from the north to the south in this section exposes pyroxene granulites, garnet granulites and Jijal ultramafics,the last named has its type section located at Jijal along the Karakoram Highway.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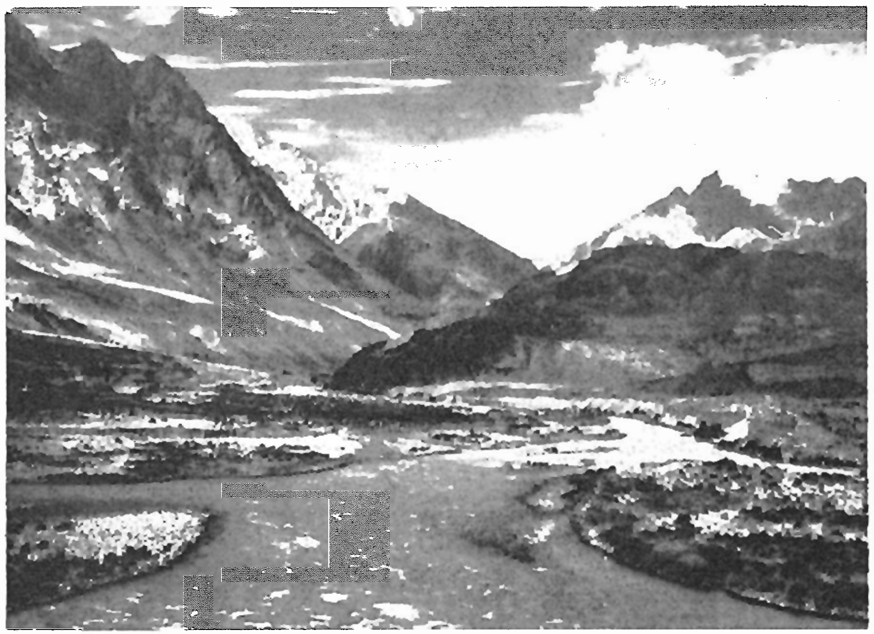
PT−78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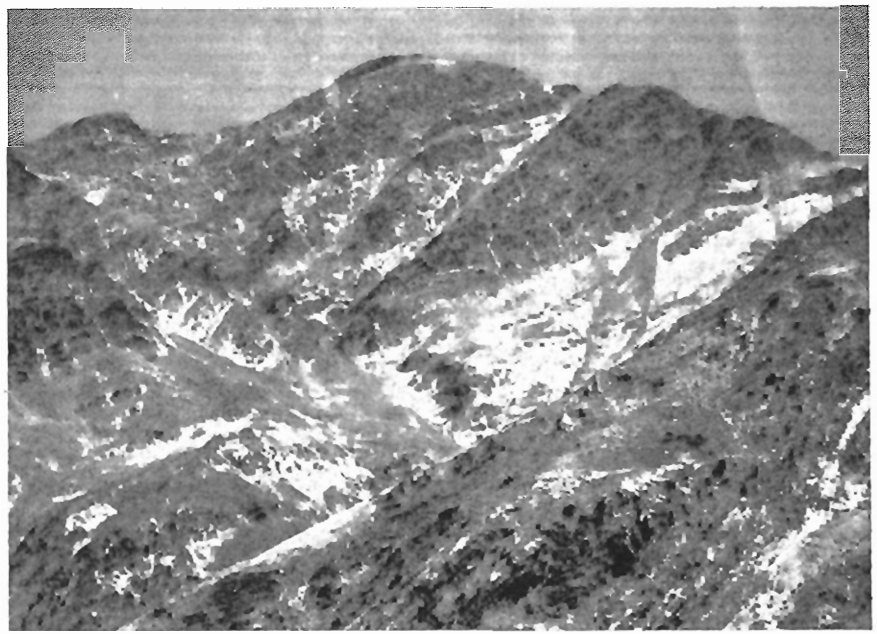
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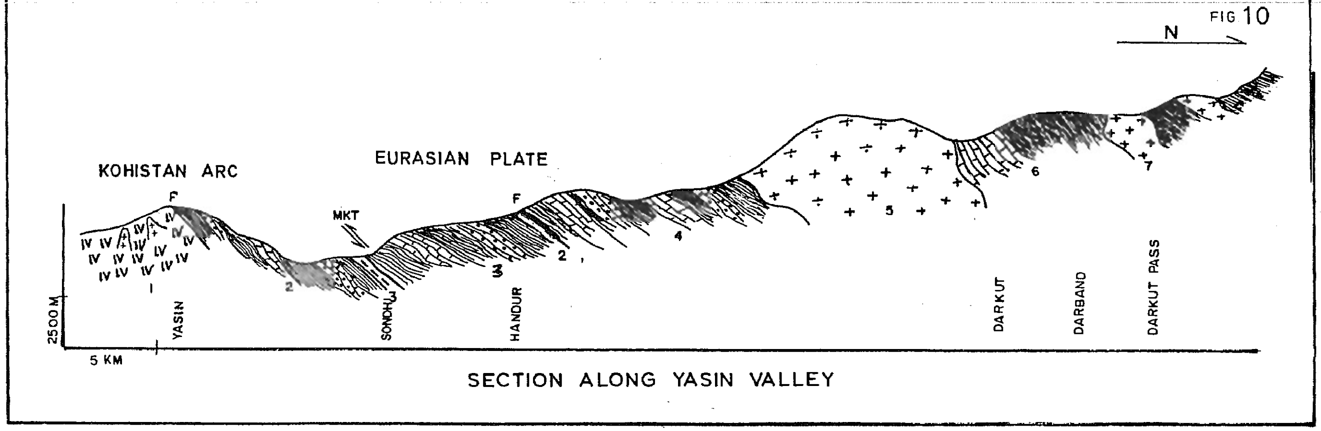


FIG-10:

1. Rakaposhi Volcanic Complex 2-3 Yasin Group in its type section
4. Baltit Group 5. Main Karakoram Batholith 6. Darkut Group of Permo-Carboniferous age at its type section 7. Darkut Pass Granodiorite of Ivanac et al. (1956)which the author considers as part of the Main Karakoram Batholith.

The Yasin Valley in the western Karakoram is well coined in the geological literature, firstly because it exposes the type section of the Lower Cretaceous sediments and secondly the Darkut Group which yielded Permo-Carboniferous fossils, is located in the upper reaches of this valley.

The Yasin Group is one of the well known fossiliferous lithofacies of the Karakoram and has been studied by many workers since 1914,(Hayden, 1914, Ivanac et.al.1956,Desio, 1959, Matshushita 1955, Casnedi 1980, Talent et.al. 1979, Tahirkheli 1979, and others).

The Yasin Group was mapped by the earlier workers in two isolated outcrops, one in the Yasin Valley and another in the west between Yasin and Sor Laspur valleys,but the author has found this group to cover much larger area than was envisaged by the previous workers. It extends as a continuous east-west trending, 5-6 km wide linear belt in the Karakoram and southern Hindu KushIn the Hindu Kush the Orbitolina Limestone Bed,earlier described by Hayden (1914) near Drosh is incorporated in this group.

A variation in the lithology of the Yasin Group is conspicuously marked in the karakoram and Hindu Kush. Its typical red and green hues associated with the basal bed are persistant. It is also not fossiliferous everywhere. It lies unconformably with a tectonic contact over the Rakaposhi Volcanic Complex and this relationship remains consistant everywhere. On the northern side, the Yasin Group has again a tectonic contact with the Chalt Ophiolitic Melange and is involved in the MKT accident.

Desio (1963) had proposed a three- fold division of the Yasin Group,based on lithology in the Yasin ValleyThe upper one is comprised of dominantly pelitic rock and was named Taus Shales, the middle is dominantly arenaceous and was called Manich Sandstone and the Lower is comprised of shales, limestones, conglomerates with interbedded volcanics and was named Gojalty Formation. As the lithology of the Yasin Group is variable, this division does not hold good everywhere.

The Yasin Group in the type section in the Yasin Valley is comprised of slates, limestones, quartzitic sandstones and conglomerates. Volcanic rocks interbed with the lower part of the sequence which ranges in composition from basalt-andesite-dacite-rhyodacite-rhyolite to agglomerates.

The slates range from phyllite to phyllitic schists with occasional siliceous and calcareous partings. Sporadic graphitic patches within the slates have also been recorded. The lower to middle parts of the sequence predominate in the slates which indicate turbiditic features.

Quartzitic sandstones dominate in the middle and the upper parts of the section in the Yasin Valley. These are grey, medium to fine and have angular to subangular quartz grains cemented in siliceous matrix.

The limestones are semi-to-medium crystalline, light to dark grey, thin bedded and are fossiliferous. At Yasin, the limestones have sporadic occurences, usually forming thin bands in the slates horizon. Elsewhere, for instance south of Chotarkhan in the Ishkuman Valley, near Chalt in the Hunza Valley and at Machelu in the Hushe Valley section of Baltistan. the limestones are quite thick and incorporate bands of light grey marble.

The conglomerates in the Yasin Group occur in more than one horizons. In the type section at Yasin, one of the conglomerate beds occurs at the base, marking an unconformity with the underlying Rakaposhi Volcanic Complex. The detritals in the conglomerate, beside incorprating slate , limestone and sandstone contain over ninety percent of the volcanic rocks derived from the underlying formation.

Some of the fossils identified in the Yasin Group are:

Horiopleura cf. Camberti, Eugyra Cotteani,Eugyra cf. E.neocomiensis, Calmophyllia cf. C. gracillis, Thecosmilia sp., Isastrea cf. 1. Eeqularis, Orbitolina bulgarica, Orbitolina discoidea Gras and Thasunasteria deudroides. These fossil assemblages have already been reported by the previous workers and confirm a Lower Cretaceous (Barremian-Aptian) age for the Yasin Group. The Main Karakoram Thrust zone passes along the Sondhi stream which demarcates the boundary between the Eurasian plate and the Kohistan Island arc. But some ancillary tectonic arms of this thrust have also been recorded within the Eurasian mass. One of them, exposed in the valley is located across the Handur village in the Yasin Valley.

PT-81 Pyroxene Granuelite in a section near Chilas in the Indus Valley.

PT-82 Bahrain Pyroxene Granulite in a section upstream of Bahrain in the Swat Valley.

PT-83 Tannakki Boulder Bed, exposed on the road section in the Sirbon hill, about ten km west of Abbottabad near Khote-di-Kabar in Hazara. The components consists of slate, siltstone, sandstone/quartzite which were derived from the underlying Hazara Slates or Tanol Quartzites. The clastics are badly sorted, are rounded to subrounded and show glacial scratches. These were correlated with the Talchir Boulder Bed of the Salt Range by the earlier workers. This view is now being contested by the recent workers who consider the Tannakkis as a normal basal conglomerate.

PT-84 A closer look of the Bahrain Pyroxene Granulite in a section in the Indus Valley, upstream of Kamila in Kohistan.

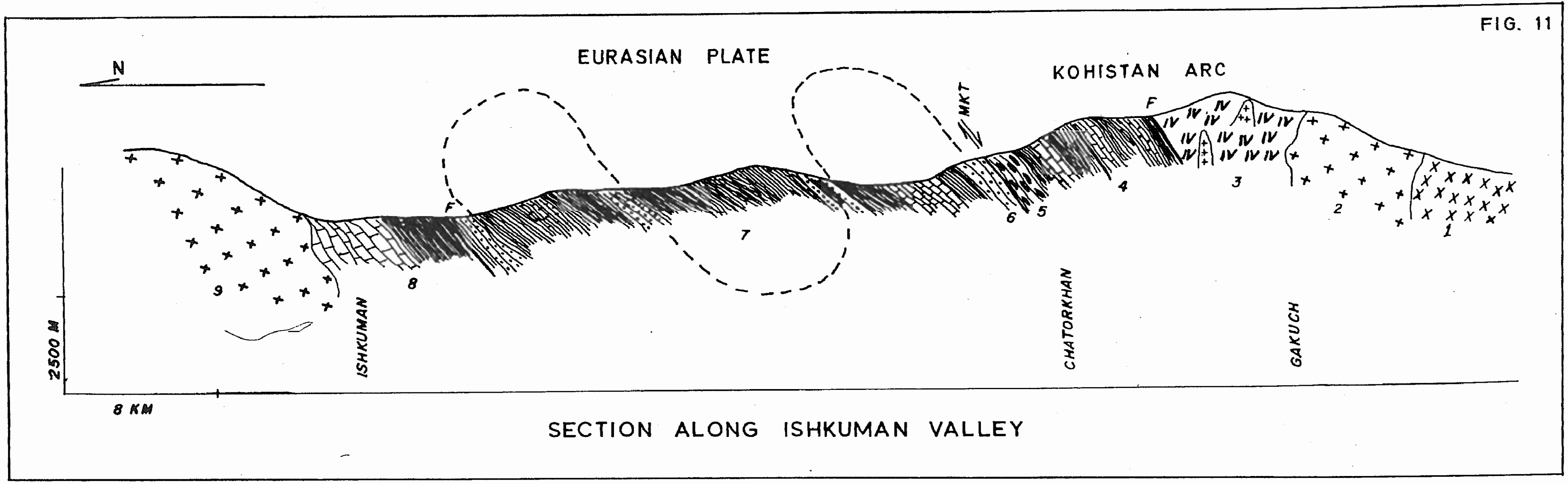


FIG-11:

1. Quartz Diorites 2. Ladakh Intrusives 3. Rakaposhi Volcanic Complex 4. Yasín Group 5. Chalt Ophiolitic Melange 6-7. Baltit Group 8. Darkut Group 9. Main Karakoram Batholith.

In the Karakoram and the southern Hindu Kush the regional strike swings from east-south-east to west-south-west and the dip changes from northeast to the northwest. In the Ishkuman Valley the dip of the beds, unlike the other sections in the Karakoram-Hindu Kush is towards south. This dip direction persists in the sediments as far as their contact with the Main Karakoram Batholith in the north. This change in inclination of the beds has also effected the Main Karakoram Thrust, indicating a tectonic episode emanating subsequent to the MKT accident after the completion of the suturing phase.

This tectonic episode cannot be called a regional because its effect has been imparted in a limited area. The Pamir syntaxis is the nearest locale to this section, which has achieved its final tectonic configuration during Neogene period. It is possible that some tectonic turbulance emanating from this orogeny has travelld to the south and effected this area. If this view is accepted then this phenomenon should have happened prior to the emplacement of the Main Karakoram Batholith which forms a thick mass intervening the Pamir and the Ishkuman Valley and is capable to shield the migration of such stresses from the north.

The rocks of the Baltit Group in the Ishkuman Valley are quite thick and their metamorphic grade is lower than the ones encountered in their type section in the Hunza Valley. The main rock types are slates,phyllites and phyllitic schists with subordinate semi-crystalline limestones, sandstones and conglomerates. These are intruded by the basic and the acid igneous sills and dykes. Carbonaceous bands in the pelitic part of the sequence are quite noteworthy.

In the upper reaches of the Ishkuman Valley, the rocks of the Darkut Group are exposed in the hillocks behind the Ishkuman village. Probably these outcrops form the southeastern termination of the Darkut Group in this part of the Karakoram. However, the extension of the Darkut Group is envisaged in the Tethyan Folded Belt in the northern Karakoram, north of the Main Karakoram Batholith.

The Ishkuman Valley provides a very interesting section to illustrate the tectonic scars which are the products of the collisional tectonics and stresses generated during and after suturing. This section is located 2-3 km north of Chotarkhan stream on the eastern bank of the Ishkuman river.

Here the leading edge of the Eurasian plate (Baltit Group) is in contact with the melange zone of the Kohistan arc. The melange,beside containing the fragments of serpentinite, peridotite (rare) basalt, andesite and some siliceous breccia representing the ophiolitic suite also incorporates fragments from the leading edge of the Eurasian mass containing slates,limestones, marble, sandstones and quartz. Their emplacement is tectonic which occurred during the time of collision of the Kohistan arc with the Eurasian plate.

The effect of subsequent stresses generated during and after suturing is visible in the stretched pebbles and twisting of the melange around a competent rock of the Eurasian mass. Studies are underway for a detailed assessment of this section. A photograph PT-32 of this section may be more informative to illustrate the composition, texture and structure developed in the melange zone.

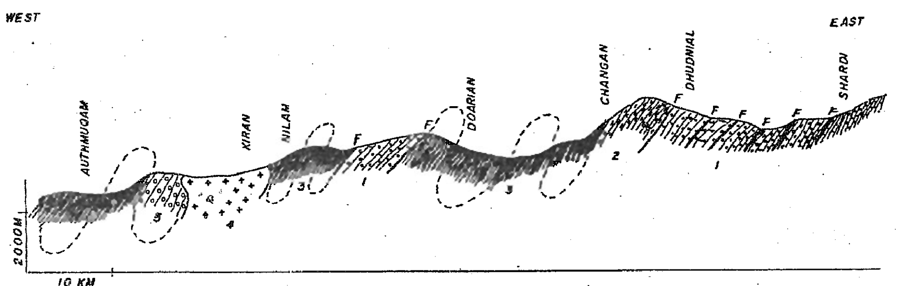
PT—81

PT—82

PT—83

PT—84

FIG. 12



SECTION ALONG NILAM VALLEY ON THE EASTERN FLANK OF HAZARA-KASHMIR SYNTAXIS

FIG-12:

1. Salkhala Series. 2. Garnet schist forming base of the Dogra Slates. 3. Dogra Slates 4. Kiran nonfoliated leuco-granite 5. A Sandstone Bed appears conspicuous because of its distinct lithology and considered as a part of the Dogra Slates.

The Nilam Valley Section (earlier called Kishenganga) is located on the eastern flank of the Hazara-Kashmir syntaxis. This section represents the Inner Zone (Hazara Zone) of the Kashmir Lesser Himalaya and the two well known formations of Kashmir,the Salkhala Series and the Dogra Slates have got their type sections located in this valley.

The Salkhala Series was first described by Wadia (1929) and it forms the basement of the Hazara Zone in Kashmir and Hazara Lesser Himalaya, which has been correlated with the Jatog and Chail series of the Indian Lesser Himalaya.

The typical sequence of the Salkhala Series in the Nilam Valley was observed along the road between Dhudnial and extending beyond Shardi. The name Salkhala did not suit to this sequence,because it is located over fifty km upstream of the Salkhala village which lies within the domain of the Dogra Slates.

The main rock assemblage in the Salkhala as appraised along the road section constitute approximately; pelites-65 percent, psammites-15 percent, carbonates-10 percent, conglomerates-3 percent and the rest includes acid and basic igneous sills and dykes.

Slates, phyllites, schists and para-gneisses constitute the pelitic part; flaggy sandstone and quartzitic sandstones represent the psammitic part whereas semi-to-medium crystalline limestones and marble form intimate association in the above-mentioned rock assemblage. The conglomerate bands are occasionally observed in the pelitic part which appear to have restricted distribution. Among the igneous intrusions, the main basic rocks which form the earlier igneous emanations are, gabbro ,dolerite and diorite whereas granites, pegmatites, aplites and vein quartz constitute the latter acid igneous phases.

This whole rock assemblage in the Salkhala Series has one unique lithological feature which distinguishes it from the overlying Dogra Slates and that is the preponderance of the graphitic material.

The rocks are tightly folded and the graphitic material has facilitated moverments along the slip planes of the bends. The axial plane foliations and the limbs of the folds are usually the most effected.

This resulted in creation of imbricate type of structures imparting local displacements in the form of small thrust slices which over-ride each other. This type of structure makes it difficult to discern normal order of superposition of the rocks constituting the Salkhala Series. The base of the Salkhala Series is not exposed whereas it has a tectonic contact with the over lying Dogra Slates.

The Salkhala rocks indicate variable metamorphism. It ranges from chlorite slates-green schists to foliated amphibolites with biotite-garnet zones occupying the intermediate position. Para-gneisses have a quite widespread distribution in the Salkhala assemblage and one of the samples collected from this area has indicated sillimanite. A part of the epi-grade zones may be associated with the retrograde metamorphism.

The Dogra Slates are stratigraphically equivalent to the Hazara Slates:the former name is assigned to a dominantly pelitic sequence in Kashmir located east of the syntaxis by Wadia (1929),whereas on the west of the syntaxis in Hazara these slates become the Attock slates of Waagen and Wynne(1879),which were subsequently named the Hazara Slates by Wadia(1929).

The other slate sequences considered equivalent to the Dogra - Hazara slates on the northern margin of the Indo-Pakistan Plate in Pakistan are the Manki Slates in the Attock-Cherat Range (Tahirkheli, 1970),Serikot Slates in the Gandghar Range (Tahirkheli ,1970 e), Landikotal Slates in the Khyber mountains (Tahirkheli, 1971) and several un - named slate sequences in Swat, Dir, Bajaur and Mohmand still awaiting stratigraphic formalization.

The Dogra Slates form a monotonous sequence of the dominantly pelitic rocks which have an extensive distribution than the other rocks of the Hazara Zone. They are thinly laminated,are light grey to greenish grey and range from slates to phyllitic schists.Thin intercalations of yellowish brown limestones and sandstones are conspicously marked. Graded bedding, worm track, flute cast and sole marks are some of the turbiditic features which are well displayed.

Gansser (1964) mentions interbedded altered lava flows incorporated in the Dogra Slates,which according to him is mostly changed to chlorite schists.In the Nilam Valley section and on the eastern flank of the syntaxis only one tuffaceous bed 30-50 m thick is identifiable which envelops the slates sequence and the author considers it to be an extension of the Panjal trap which can only justify the extension of the Pir Panjal Fault to the eastern limb of the Hazara - Kashmir syntaxis.

The Dogra Slates are not well cleaved. Dolerite sills are the most common basic intrusions.The acid igneous emanations are the latest which are represented by the veins and veinlets of quartz, pegmatite and aplite. The last two mentioned are not very common and are usually found near the contact with the magmatic bodies.

PT-85 Acid igneous apophyses in the Baltit Group near the contact with the Main Karakoram Batholith in the vicinity of Baltit town.

PT-86 Another View of the Salkhala rocks near Dudhnial in the Nilam Valley.

PT-87 A section exposing graphitic schists in the Salkhala Series in their type section in the Nilam Valley. Flow folding and a master joint are conspicuously displayed in the outcrop.

PT-8 A section in the Nilam Valley, shows the Dogra Slates at their type section where these were studied by Wadia during 1930s. This section is located in a tectonized zone on the top of the Salkhalas near Authmuqam in Azad Kashmir.

Chlorite grade metamorphism is indicated in the Dogra Slates, but in the tectonized zones, at places, it has culminated to garnet grade. In the Nilam Valley the garnet schist bed is marked intervening the Salkhala Series and the Dogra Slates between Changan and Dhudnial. Such occurences have been recorded in the other slate sequence,e,g.in the Hazara Slates (in the vicinity of Darband and Khaki),in the Landikotal Slates and in the slates exposed in Swat and Mohmand.

FIG-13:

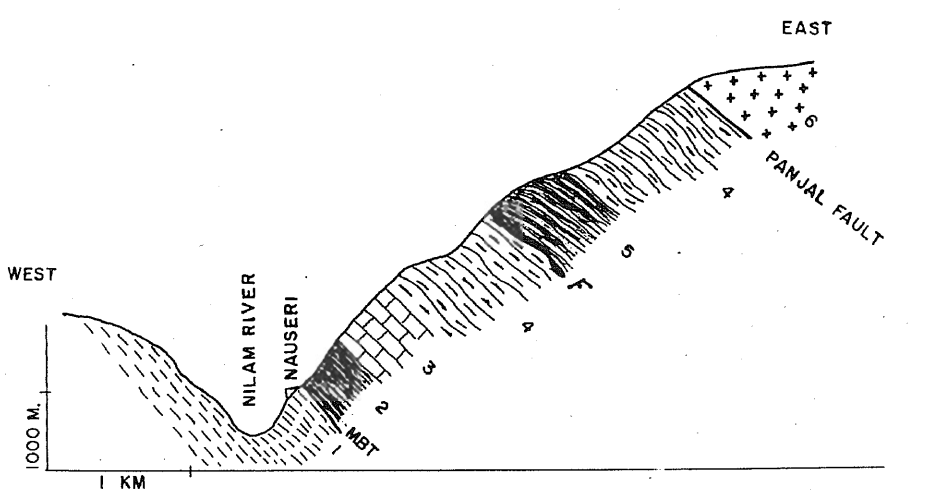
1. The Murree Formation. 2. 30-50 m thick bed showing greenschists type lithology. 3. Semi-to medium crystalline limestone 4. Para-gneisses 5. Dogra Slates 6. Para-gneisses 7. Non-foliated granite.

The rock types, exposed at the Nauseri section forming the eastern limb of the syntaxis have also different lithology than the ones encountered in the western limb.Here the two main lithological elements i.e. the Great Limestone of Wadia which used to be considered an Infra-Triassic and now placed in the Precambrian and the Permo - Triassic-Sabathus which represent the Outer Zone of the Lesser Himalaya in the Pir Panjal Range in Kashmir are missing. But in the western limb the Great Limestone and the rocks equivalent to Sabathus are encountered which have a thrust contact and extend southwest from Muzaffarabad to as far as the apex of the syntaxis in the northeast near Balakot.

On the other hand, the tuffaceous bed probably a representative of the Panjal Volcanics, developed along the eastern limb of the syntaxis is not traceable in the western limb.

These anomalies appear to be the products of the deformations produced by severe tectonics emanating during the building of the syntaxis which have disrupted these beds.

FIG. 13



NAUSERI SECTION IN NEELAM VALLEY, EAST OF HAZARA-KASHMIR SYNTAXIS

The Nauseri section was earlier mentioned by Wadia (1931) while discussing the geolgy of the Kishenganga (now named Nilam) and the Kaghan valleys. This section is located towards east of Muzaffarabad on the eastern flank of the Hazara - Kashmir syntaxis. The rock exposed in the sequence have typical lithology of the Hazara Zone of the Lesser Himalaya.

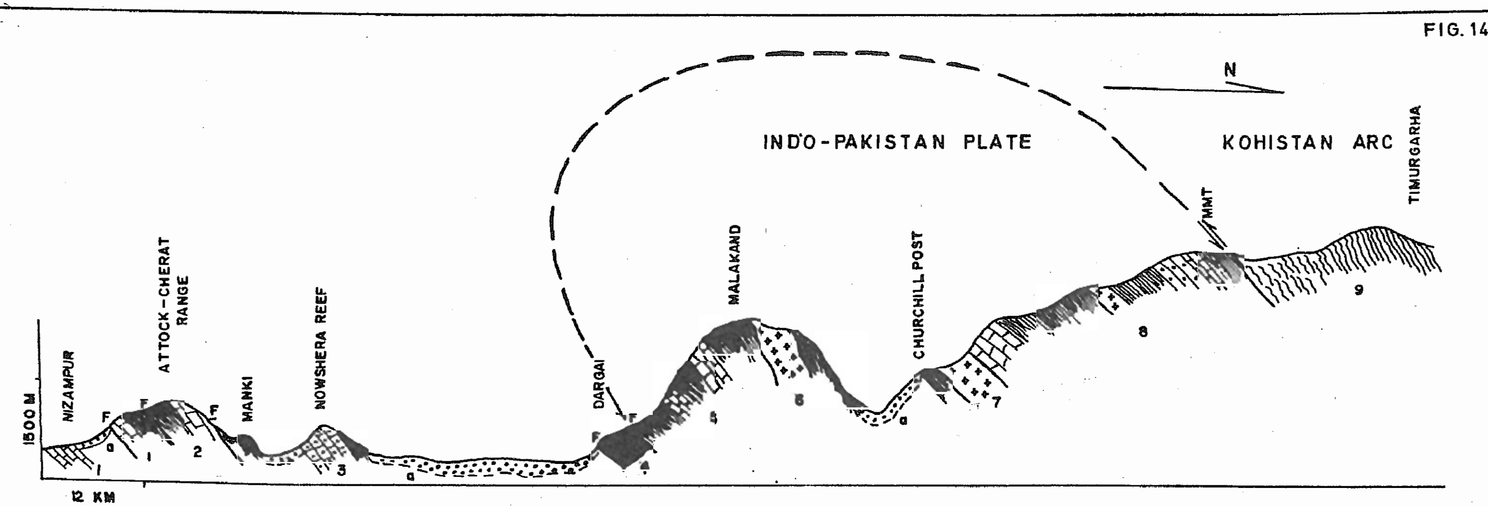
Two major faults traverse this section. One is the Main Boundary Thrust where the Murree Formation of Oligocene-Mid. Miocene age is thrust over by the metasedimentary sequence equivalent to the Hazara Slates/Dogra Slates of Precambrian age. The second is the Panjal Fault which extends from the Kashmir Valley, travels along the eastern flank of the syntaxis and terminates at the apex of this structure in the Kaghan Valley. Both of these faults are involved in the syntaxial tectonics.

The status of the Pir Panjal at Nauseri section is not clear. This fault in its type section in Kashmir (Srikantia,1973) dislocates the Precambrian Salkhalas-Dogra slates overlain unconformably by the Permo-Triassic sediments of the Tethys with extensive Panjal Volcanics, from the Permo-Triassic and the Sabathus sediments.

At Nauseri, except 30-50 m thick greenschists bed which is in thrust contact with the Murree Formation,no other rocks except Dogra Slates are recorded. It appears that the previous workers have extended the Panjal Fault to the eastern limb of the Hazara-Kashmir syntaxis because of the occurance of thin tuffaceous beds in association with the Dogra Slates.

FIG-14:

1. The Kala Chitta zone of the Lesser Himalaya with the rocks ranging from the lower Triassic to Palaeocene.2. The Hazara Zone of the Lesser Himalaya containing the four lithofacies: Hazara Slates = Manki Slates, Khattak Limestone = Langrial Limestone, Shakhai Limestone = Sirbon Formation and conglomerates equivalent to the Tannakki Conglomerate. 3. Nowshera Reef outcrop of the Silurian-Devonian age. 4. Dargai Klippe. 5. Metasediments considered equivalent to the Hazara Slates. 6. Malakand Granite. 7. Chakdarra Granite Gneiss 8. Undifferentiated metasediments corresponding to the Hazara Zone. 9. Kamila Amphibolites.



SECTION ACROSS ATTOCK-CHERAT & MALAKAND RANGES WEST OF HAZARA SYNTAXIS

The diagrammatic section across the Attock-Cherat and Malakand ranges is located in the Peshawar and Swat region, west of the Hazara-Kashmir syntaxis. Five major geological features discerned in this section for discussion are as follows:-

1. The Lesser Hazara Himalayan lithofacies are encountered in these ranges. In the Attock-Cherat range the rocks representing the Hazara and the Kala Chitta zones separated by a thrust fault are well marked. In the Hazara Zone, four formations equivalent to the Hazara Slates, Langrial Limestone, Tannakki Conglomerate and Abbottabad Formation are differentiated. In the Kala Chitta Zone a sequence from Lower Triassic to Paleocene is developed in the southern flank of the Attock-Cherat range which has extension in the south towards Nizampur.

   In the Malakand Range the metasedimentary sequence resemble with the rocks of the Hazara Zone. The grade of metamorphism increases from chlorite schists to amphibolite schists, from south to north, and matches with the unfossiliferous Lesser Himalayan sequence encountered north of Abbottabad in Hazara. The pelitic rocks of the Malakand Range on the southern flank also contain thick development of hornfelses usually surrounding the acid igneous intrusions which induced contact metamorphism. In the metasedimentary assemblage the schistose rocks predominate, followed by crystalline limestones and quartzites.

2. A Silurian-Devonian reef belt (Teichert & Stauffer, 1965; Stauffer, 1969) intervenes the Attock-Cherat and the Malakand ranges. This belt is exposed in three isolated outcrops on the northern bank of the Kabul river; two are located across the Nowshera and Akora Khattak towns and the third at Pir Sabak. The Akora Khattak outcrop has also been mentioned as Misri Banda by the earlier workers.

The reef belt has subsurface extension towards the west and reappears in two isolated outcrops in the vincinity of Tangi in the Hashtnagar plain (Tahirkheli, 1969) and in Ghundai Sar near Jamrud in the Khyber Agency.

At Nowshera the reef belt has been divided into four units (Ali et.al., 1969): i. Carbonate Rocks, ii. Reef Core, iii, Reef Breccia and iv. Misri Banda Quartzites. The first three are collectively known as the Nowshera Formation.

The reef belt exposed near Jamrud is also divisible in four units (Khan, 1969), which from top to bottom are: grey and yellowish grey dolomitized quartzites, ii. Reef Breccia, iii, Reef Core and iv. Phyllites and Crinoidal limestones. The age of the reef belt (Teichert & Stauffer, 1965) based on faunal evidences range from the Upper Silurian to Devonian.

3. An ultramafic body, about 300 sq km in dimension is exposed on the southern flank of the Malakand Range near Dargai. On the basis of its mode of emplacement in the framework of the regional tectonics, this body was considered to form a Klippe (Tahirkheli et al. 1979, Tahirkheli, 1980), sitting over the Precambrian slates sequence of the Malakand Range. Subsequent studies (Malinconico et al., 1980), based on two dimensional modelling of gravity and magnetic data near Dargai, upheld the earlier views confirming the Dargai ultramafics to form a 7km thick Klippe, which was lifted from the MMT zone during the southern accident.

4. The basic igneous sills are quite common in the rocks of the Hazara Zone in the Attock-Cherat Range. The acid igneous intrusions here are represented by lean quartz and aplite vienlets which cut across the structures and have sporadic distribution.

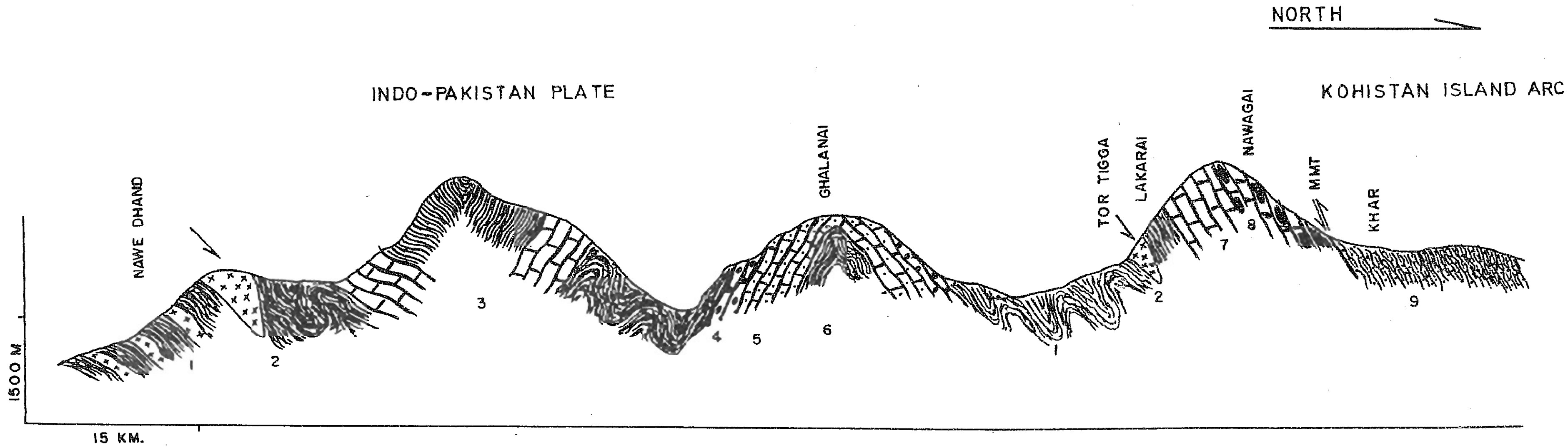
In the Malakand Range the basic sills are quite common and some of them are younger to the granitic phase. The acid igneous intrusions start from the base of southern flank of the range in the form of quartz, aplite, pegmatite and granitic veins which have transformed the slates in cantact to hornfels.

These veins are quite frequent in occurrence and represent pre-to post kinematic igneous episodes emanating during Neogene. In the outcrops exposed in the Swat Valley, large bodies of granitic intrusions are encountered. Two varieties of granites are differentiated; synkinematic granites which are foliated and post-kinematic granites which are non-foliated. Chakdarra gneisses fall in the former and the Malakand granite belongs to the latter category. Both the types of granites have different structure, texture and mineralogy.

One of the synkinematic granite gneisses exposed 3-4 km north of Mingora and considered equivalent to the Chakdarra gneisses, has yielded an age of 523 my by K/Ar method (Malluski, 1981). The Mansehra granite located in the same strike direction in Hazara in the east has given an age of 516 m.y by Rb/Sr method (Le Fort, 1979). Thus both of granitic bodies are of Cambrian age. Foliated granitic bodies are found intruding the maginal mass of the Indo-Pakistan plate and may belong to the Pan African magmatic episode which remained in force between the Precambrian and the Early Cambrian periods.

5. The surficial configuration of the Main Mantle Thrust in the Panjkora Valley, north of the Malakand is not well defined. However, in a road cut section, between 15-13 km short of Timurgarah, the amphibolites obducting onto the Indo-Pakistan plate are intensely deformed indicating 2-3 generations of folding. This structure is located within the Main Mantle Thrust zone and is the direct result of their involvement in the MMT accident.

FIG. 15



SECTION ACROSS GHALANAI, THROUGH MOHMAND, MALAKAND AND BAJAUR NEAR THE WESTERN BORDER OF PAKISTAN

FIG-15

1. Metasedimentary sequence with igneous intrusives, 2. An extension of the Dargai Klippe, 3. A metasedimentary sequence with slates (dominant) and semi-crystalline limestone, 4-5-6.sandstones, dolomitic limestones and the slates (dominant) forming the core of the Ghalanai anticline. These rocks form the oldest sequence in this section, 7. Medium crystalline limestone to marble which are the extension of the Mullaghori outcrops of the Khyber mountains in the southwest which are assigned a Permo-Carboniferous age. 8. Minor volcanic and ultramafic bodies associated with the marble bed near the top. 9. Kamila Amphibolites.

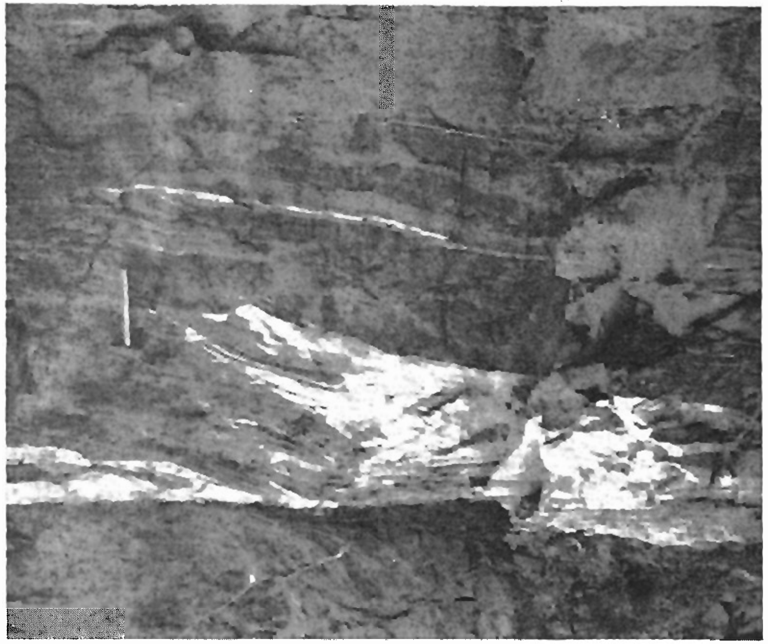
The Ghalanai section is located near the western border of Pakistan and geographically this part lies in the Hindu Kush. The marginal mass of the Indo-Pakistan plate here is correlatable with the Hazara Zone of the Lesser Himalaya,which is located in the strike direction towards the east.

There are two striking features in this section which are worth mentioning. One is the occurrence of the ultramafic bodies in two isolated zones,one near Nawe Dhand and another at Tor Tigga, and second is the presence of minor volcanic and ultramafic bodies strewing the medium crystalline limestone and marble beds just north of Nawagai.

The ultramafic body located near Nawe Dhand is the extension of the Dargai Klippe. Another ultramafic body exposed near Tor Tigga and those occuring north of Nawagai were earlier reported by Tahirkheli(1979). These bodies are located within the Main Mantle Thrust zone and their emplacement may be related with the MMT accident. However, these words may not be considered final because already an old lineament (FIG-21) has been recorded by Tahirkheli (1981) which runs along the MMT over the leading edge of the Indo-Pakistan plate and passes over the Mingora emerald mine and south of Karora in Swat. This lineament contains association of metamorphosed serpentinites. The Tor Tigga ultramafics occur in the strike direction towards the west and may be the westward extension of this lineament.

The road from Yaka Ghund to Ghalanai, more or less passes along the strike of the rocks, following the axial trace of the Ghalanai anticline,the limbs of which dip towards north and south. Here the slates, phyllites, schists and gneisses with calcareous-siliceous partings and frequent occurrences of graphitic bands are developed and form the core of the anticline. These rocks are intruded by gabbro, diorite and dolerite which are common among the basic suite, and pegmatite, aplite and quartz constitute the acid igneous suite. The basic rocks are synkinematic and are involved in the deformations whereas the minor acid bodies are generally post-kinematic.

The former assemblage forming the core of the Ghalanai anticline exhibits lithological resemblance with the Salkhala Series of the Lesser Himalaya and the latter may be equated with the Hazara/Dogra slates.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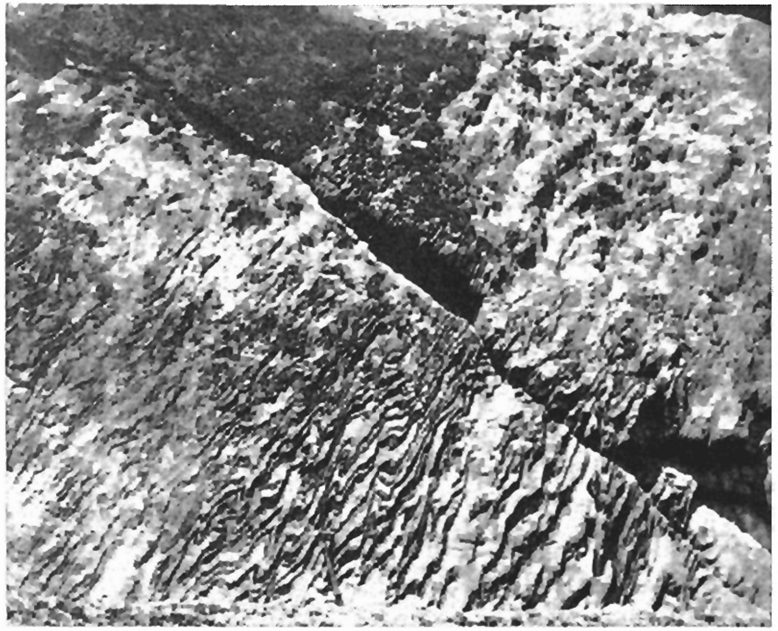
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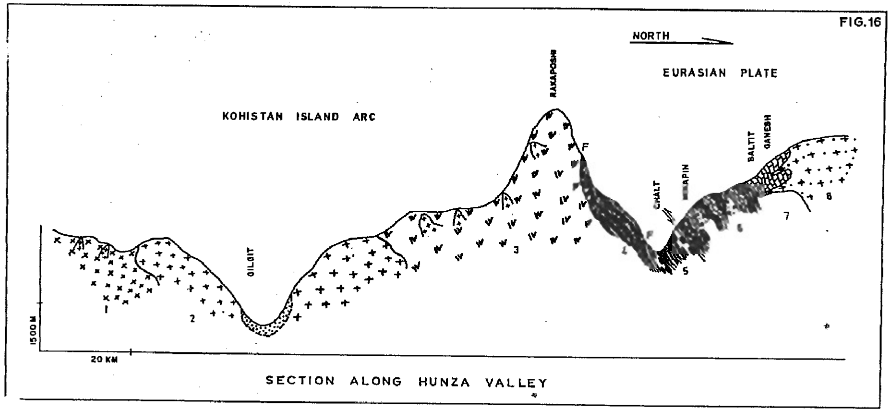


FIG-16:

1. Quartz Diorite, 2. Ladakh Intrusives 3. Rakaposhi Volcanic Complex, 4. Yasin Group, 5. Chalt Ophiolitic Melange, 6. Minapin Formation, 7. Ganesh Marble, 8. Main Karakoram Batholith.

The Hunza Valley traverses an important section of the Central Karakoram which exposes the type localities of the four lithofacies designated by the author as,1-Rakaposhi Volcanic Complex,2.Chalt Ophiolitic Melange,3. Baltit Group and 4. the Main Karakoram Batholith.

1. The Rakaposhi Volcanic Complex previously called the Greenstone Complex by Ivanac et al.(1965), the Greenstone Volcanics by Stauffer (1965) and the Volcanic Greenstone by Calkins(1969), covers a larger part of the Rakaposhi including its commanding peak, a sister mountain of the Karakoram chain. It has maximum exposure in the Hunza Valley indicating complete lithology.in an easily accessible area for which this section is selected as its type locality.

In the Rakaposhi Volcanic Complex, four main lithological elements comprising the whole mass are: i. the volcanic flows ranging from basalt-andesite-dacite-rhyodacite to rhyolite, ii. The meta-volcaniclastics consisting of greenschists, actinolite, chlorite schists, hornblend schist, amphibolite and agglomerates. In the latter, the fragments of andesite, red and grey chert, tuffs, marble and slates are usually encountered. This part of the complex is foliated and is criss-crossed by epidote veins, iii. the metasediments incorporate medium crystalline limestone and marble, quartzite , chert, slates and mica schists, iv.the igneous intrusions are mostly in the form of acid and basic sills and dykes. Leucocratic granite bodies, which belong to the last phases of the Ladakh Intrusives are quite common.In the Yasin Valley,melano-granite was found intruding the leuco-type, thus in the westerm Karakoram this granitic episode may be the latest. Besides, dolerite, diorite and gabbro are common among the basic igneous rocks whereas pegmatite, aplite and quartz veins represent the minor acid bodies.

2. The earlier work is calm on the occurrences of the ophiolitic melange in the Karakoram andHindu KushExcept cursory mentions made by Gansser (1979) and others, some workers had considered the Rakaposhi VolcanicComplex to have formed under a similar environment. Tahirkheli and Jan (1978) had first demarcated the northern suture in the Karakoram and Hindu Kush and named it the Northern Megashear. Subsequent studies by the author revealed a distinct ophiolitic melange zone (FIG.3) lying north of the Rakaposhi VolcanicComplex,between the Yasin Group(Kohistan)and the Baltit Group (Eurasian Mass). This zone forms a linear belt 4-16 km wide,stretching east-west direction, all along the karakoram and southern Hindu KushThe Shyok Fault (Gansser,1977) the Chalt-Hini fault(Desio.1964), and the Drosh fault (Hayden,(1914),all fall in this zone and are incorporated in the Main Karakoram Thrustthe northern suture which welds the Kohistan Island arc with the Eurasian plate and is the western extension of the Indus Tsaang Po Line.

The ophiolitic melange, in the MKT zone is disrupted and has become localized forming scattered pockets.Serpentinite is usually the most common rock encountered in this zone. The other rock types representing the ophiolitic melange are andesite, ophicalcite, basalt, cherty quartzite breccia, radiolarites and very rarely unaltered peridotites. The flyschoid rocks are also associated and in the more tectonized part, like the Sissi Gol section north of Drosh in the Hindu Kush,these are crushed and appear as fault gouge.

Again,Chalt in the Hunza Valley, is selected to be the type section of the ophiolitic malange in the karakoram because of its easy access and though not displaying a complete sequence, yet detailing a typical lithology. Here the fragments in the melange belong to more than one rock types unlike many other sections where only serpentinite is encountered. To study this section in detail the ophiolitic melange zone at Chalt displays from north to south the following sequential order.

a. 15-25 m thick flyschoid sequence which thrust under the Minapin Formation and delineates the northern tectonic contact of the MKT zone with the Eurasian plate. It constitutes slates, phyllites and phyllitic schists with alternations of siliceous and semi-crystalline argillaceous limestone. Thin conglomerate bands occur in more than one horizons and among the clastics, quartz usually predominates. Stretched pebbles in the conglomerates are noteworthy.

b. 20-30 m thick melange zone which incorporates serpentinite, ophicalcite, andesite, basalt and cherty quartzite breccia. This zone has tectonic contact with the flyschoid rocks.

c. 80-120 m thick dominantly flyschoid rocks which in ascending order of abundance contain slates,phyllites,phyllitic schists, talc schists, calc-schists with some erratic serpentinite incorporations. Semi-crystalline limestone and siliceous bands form thin partings in the schistose rocks. Conglomerates are also associated.

d. 15-20 m thick melange zone dislocated from b. having more or less the same lithology. Here periodotite lenses with well developed olivine crystals are also present.

e. 15-20 m thick flyschoid bed as described in a. which has a faulted contact with the Yasin Group.

3. In the first regional geological mosaic of the Karakoram produced by Ivanac et al.(1965) the metasedimentary sequence in the Karakoram was mapped as the Darkut Group which on the basis of fossils was assigned a Premo-Carboniferous age (FIG.5). Subsequently, Stauffer (1965) redesignated it as Baltit Group and Desio (1963) called it Dumurdu Formation. The type sections of the Darkut Group is located in the upper reaches of the Yasin Valley in the westren Karakoram; Baltit Group occurs in the Hunza Valley in the Central Karakoram and the Dumurdu Formation is located in Braldu stream in the Shigar Valley in Baltistan.

During a review of the earlier work, the author has come to the conclusion that the Darkut Group is a Hindu Kush lithofacies which has extended in the Karakoram from the west. This outcrop is cut by the Main Karakoram Batholith between Darkut and the Ishkuman Valleys and its last tip is exposed in the hillocks behind Ishkuman village in the Ishkuman Valleys Beyond this occurrence, it has not been recorded elsewhere, south of the Main Karakoram Batholith, though its presence in the folded Tethyan Belt in the Upper Hunza Valley is not disputed.

Thus,there appears to be no justification to incorporate all the metasedimentary rocks in the Darkut Group in the Karakoram which have neither yielded any fossils of this age nor the rocks have similar lithology. Therefore, the author has differentiated the Darkut Group from the rest of the metasedimentary rocks, forming the southern edge of the Eurasian plate which are involved in the MKT accident and obducts onto the Kohistan Island arc. The name Baltit Group of Stauffer(1965) has been retained and applied to the metasedimentary assemblage in the Karakoram, which also incorporates the Chitral Slates in the Hindu Kush.These rocks are placed in the Precambrian-Lower Palaeozoic, an age assigned to these rocks across the border in Afghanistan also.

The Baltit Group has a variable lithology, which may be the result of varying effects on it of the regional tectonics. The two major tectonic events which have effected these rocks are the Nanga Parbat - Haramosh looping in the Central Karakoram and the Main Karakoram Thrust which runs all along its length. Along the northern edge of the Baltit Group, the Main Karakoram Batholith has also imparted the scars of the contact metamorphism which are observable in many sections. All these metamorphic events have occurred at different time; the MKT accident being the earliest, followed by the Nanga Parbat - Haramosh tectonics and the last is the acid igneous magmatism along the main axis of the Karakoram.

Thus the main foci of the high grade metamorphism is concentrated in the close vicinity of the Nanga Parbat - Haramosh anticline and its effect is reminiscent in the Hunza Valley, Hispar Valley and in the upper reaches of the Shigar Valley. As one moves away from this maga-tectonic feature, the grade of metamorphism registers gradual decrease.

In the Hunza Valley, the garnet-staurolite grade metamorphism is recorded near the Minapin village. Though not yet confirmed, but some workers have indicated sillimanite isograde passing just south of this location where para-gneisses are developed. The Baltit Group in the Karakoram is located in an area where it has been influenced by both the dynamic and the thermal metamorphisms. The effect of the dynamic metamorphism is earlier which is likely to have an overprint of the latter thermal metamorphism. Still a line is to be drawn where the isogrades of the dynamic and the contact metamorphisms interfere with each other. Probably this zone may be located within 10-15 km south of the southern periphery of the Main Karakoram Batholith.

The Baltit Group is divided into two parts, the lower dominantly pelitic sequence is named the Minapin Formation and the upper dominantly carbonate sequence is called the Ganesh Marble.

The Minapin Formation is from 1500 -3000 m thick and consists of slates, phyllites, schists,para-gneisses and conglomerates alongwith alternations of calcareous and siliceous partings. Graphitic bands are quite common. According to a rough count, it consists of 70 percent pelites, 10 percent crystalline limestone, 8 percent psammites, 5 percent conglomerates, and the rest constitutes the igneous intrusions.

Among the schistose rocks, mica schists, quartz schists, garnet schists, staurolite schists, graphitic schists, calc-schists and talc-schists are noteworthy. Dolerite, diorite and gabbro intrusions are common among the basic igneous rocks whereas the acid igneous rocks are represented by the granites, pegmatites, aplites and quartz which in the vicinity of the Main Karakoram Batholith form apophyses within the Baltit Group.

These metamorphic rock assemblages are concentrated in the Central Karakoram in the periphery of the Nanga Parbat-Haramosh loop. Elsewhere in their strike direction in the east and west, slates, phyllites and phyllitic schists are the usual suite of rocks which dominate in the Baltit Group. In the immediate vicinity of the Main Karakoram thrust the rocks which are involved in the accident have suffered intense deformation and have developed complicated type of structures.In such sections the metamorphim has reached to garnet grade.

The conglomerates in the Minapin Formation occur in more than one stratigraphic horizons and show variations in texture and composition. Their thickness varies from a meter to over ten meters. The clastics are usually locally derived and constitute slate, limestone, marble, quartzite, quartz, granite and other igneous acid and basic rocks. Some of the conglomerates have got only quartz as clastics. The binding material is usually argillaceous but in some conglomerate bands siliceous material is also noted. On the basis of lithology and frequency of the conglomerate bands, the Minapin Formation can be further subdivided into more than one mappable units which awaits a detailed investigation.

The Minapin Formation is conformably overlain by a 80-120 m thick marble bed which is in contact with the Main Karakoram Batholith. The acid igneous apophyses emanating from this batholith intrude the marble bed and have induced gem mineralization which is currently being mined for gems by the Gemstone Corporation of Pakistan.

The marble bed, named Ganesh Marble is thin to thick bedded and is very coarse grained. This bed has been mapped in the accessible sections in the Hunza Valley. It could not be followed along the strike in the east and west because of difficult terrane but its boulders have been found as far as the Ishkuman Valley in the west and the Shigar Valley in the east which indicates the extent of distribution of the Ganesh Marble.

4. The Main Karakoram Batholith in the earlier literature is referred to as the Karakoram Granodiorite Batholith (Ivanac et al.,1956), Axial Batholith (Schneider, 1975) and the Axial Karakoram Batholith (Desio et al.,1972). The change in the nomenclature is desined because, besides granodiorite, other acid igneous rocks constitute a substantial part of the mass and are developed along the main crest of the range.

The Main Karakoram Batholith occupies the central domain of the Karakoram Range and its extent coincides with the east-west limits of the Karakoram. In the east, this batholith terminates at the "great divide", where the Indus Tsang Po Line bifurcates into two sutures in Ladakh, and in the west its extent is delimited by the Sor Laspur-Mastuj profile which demarcates the geographical boundary between the Karakoram and the Hindu Kush.

The Main Karakoram Batholith divides the northern Tethyan Folded Belt an extension of the Hindu Kush lithofacies ranging in age from the Ordovician ? (Desio et.al ., 1972. Talent et.al. 1979) to Cretaceous, from the southern Baltit Group (Precambrian-Lower Palaeozoic) and the Kohistan sequence (Mid.Jurassic-Late Tertiary).

The central part of the mass in the batholith has indicated some sign of foliations which appear to be more of a localized nature. However, on the margins of the batholith, foliations become more pronounced, paralleling the regional structural trends and deforming the veins and dykes which belong to the pre-deformational period.

Granodiorite constitutes the earliest intrusive in the batholith which is light grey to white, coarse to very coarse and semi-porphyritic. Among the mafic minerals biotite is dominant followed by subordinate hornblend. The former is partially altered to chlorite associated with iron oxide and titanite, whereas the latter is altered to epidote and calcite.

The other igneous bodies mostly in the form of veins and dykes, found intruding the granodiorite are the granites, at least of two phases, pegmatites (2-3 phases), aplite (2-3 phases) and vein quartz belonging to the acid igneous domain, and dolerite, diorite and gabbro forming the basic suite. Part of the acid igneous suite e.g., biotite granodiorite, granite of the first phase and the earlier phases of the pegmatites are older than the basic rocks and are involved in the foliations, thus belonging to pre-foliation magmatic episode.

The lithological and petrological differences between the rocks of the Main Karakoram Batholith and the Transhimalayan Batholith incorporating the Ladakh Intrusives also, have been referred to by Gansser (1979) and the other geologists. The rock types, the initial Sr 87/Sr 86 ratio as well as the isotopic ages stress that the younger Karakoram Batholith originated from a more continental crust in contrast to the Transhimalayan-Ladakh Batholiths, where an ocean crust was involved.

An absolute dating with the Rb/Sr method was carried out on the two granodiorite samples from the Hunza Valley by Desio et el.(1964), which gave an age of 8.6 m.y., thus placing the earliest magmatic episode in the Main Karakoram Batholith in the Pliocene.

This age is too young when compared with the ages of the two other batholiths,the Ladakh Intrusives and the Transhimalayan Batholith where the earliest magmtfic episode coincides with the Eocene.

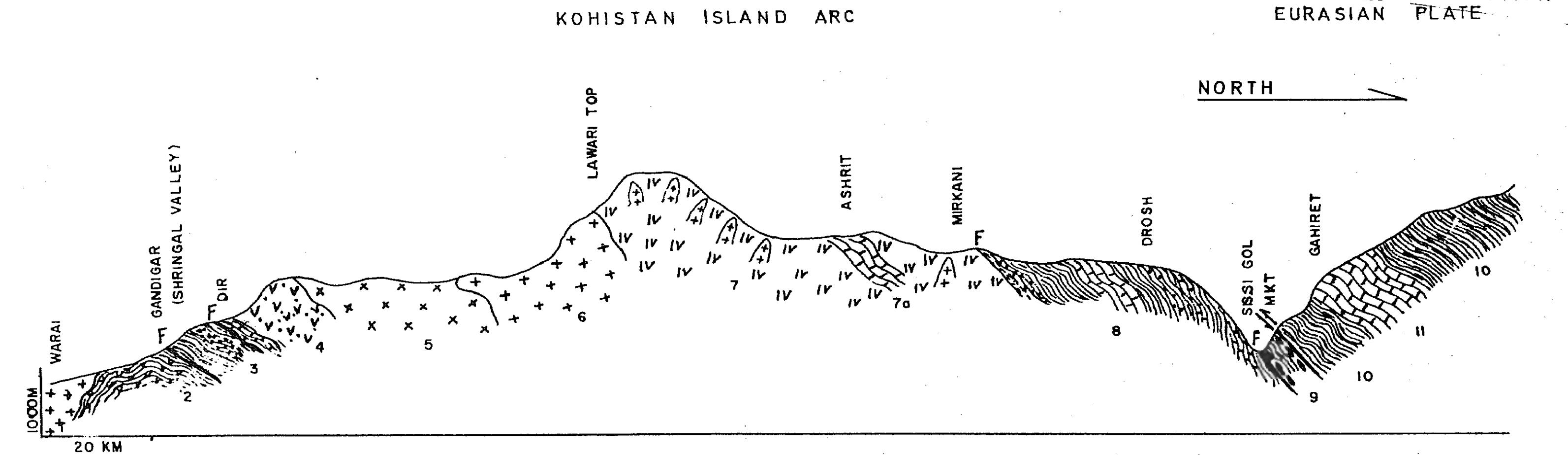
1. The Kalam Group has westward extension into Dir and its northern contact with the Dir group is faulted. This fault runs east-west direction along the Shringal Valley. The Kalam Group is divided into three mappable units by Tahirkheli (1979): i. Karandokai Slates - 120 m, ii. Deshan Banda Limestone - 35 m and iii. Shou Quartzites - 600 m thick. In Dir, the Kalam Group terminates west of Baraul Banda near the Afghanistan border.

In the type section near Kalam, the Kalam Group has its southern contact with the quartz diorites whereas in Dir it has a faulted contact with the Gandigar volcanics, which are comprised of tuffs and flows with incorporated metasedimentary rocks. Deformed serpentinized pillows in the basalt are common. The tuffs consist of greenschists, hornblend schists and amphibolites which are foliated and are criss-crossed by numerous epidote veins. The Gandigar volcanics are equated with the Kàmila Amphibolites.

2. The Dir Group has its type section located along the road to Dir, north of the Shringal Valley. It is comprised of two main lithologies (Tahirkheli,1979);i.the Baraul Banda Slates and ii. the Utror Volcanics.

The Baraul Banda Slates are a dominantly pelitic sequence which contain subordinate calcareous and siliceous partings. At the base, this sequence is faulted against the Shou Quartzites of the Kalam Group. The slates are light grey to greenish grey, thin bedded and indicate chlorite grade metamorphism.

FIG. 17



SECTION ACROSS LAWARAI TOP THROUGH DIR AND CHITRAL

FIG-17

1. Warai Granite, 2. Gandigar volcanics 3. Kalam Group 4. Dir Group,5.Deshai Diorites,6.Lawarai Granites 7.Rakaposhi Volcanic Complex, 8. Yasin Group incorporating the Orbitolina Limestone of Hyden (1914), 9. Chalt Ophiolitic Melange, 10. Chitral Slates = Baltit Group, 11. Gahirat Marble of Calkins et al.(1969).

The geological cross-section in Fig. 17 is located in the Hindu Kush near the Afghanistan border.In this section the Chitral Slates=Baltit Group,the Chalt Ophiolitic Melange,the Rakaposhi Volcanic Complex and the Yasin Group are found to continue westward uninterrupted through the Karakoram and the southern Hindu Kush (Fig.3). Thus these rock formations share a common geological domain in the Karakoram and Hindu Kush and extend together for some distance across the border in the east (Ladakh) and west (Afghanistan). Their stratigraphic and tectonic behaviour before truncation is not well spelt beyond the borders.

Towards the west,near the Afghanistan border,this sequence incorporates the tuffaceous rocks of the Utror Volcanics which are found interbedded with the slates sequence. Among the flows, dacite, rhyodacite and rhyolite interbed with the Baraul Banda Slates. The limestone bands in the slates have yielded Actinocyclina, Discocyclina, Distyconolids, Lokhartia and Nummulites atacicus which place these slates in the Palaeocene - Early Eocene.

3. The Utror Volcanics form a separate linear belt extending northeast-southwest direction respectively, between Kalam and in the vicinity of the Afghan border. Five main rock associations in the Utror Volcanics are: andesite, dacite, rhyodacite, rhyolite and welded tuff of ignimbrite type.

The Utror Volcanics form an arc of the Kohistan Island which originated as a result of intra-oceanic subduction during Jurassic-Cretaceous time(Karig,1981) has recently reported some corals in an entrapped limestone boulder in the volcanic rocks which ranged in age from the Jurassic to Early Cretaceous. This age very much coincides with the duration of the Intra-oceanic subduction and the evolution of the Utror Volcanic arc.

The volcanic activity in the Utror Volcanics did not end with the early eruption during Late Jurassic-Early Cretaceous. This view gains ground on the basis of presence of interbedded dacite, rhyodacite and rhyolite with the Baraul Banda Slates which on the basis of fossils have been assigned a Palaeocene age. This suggests that the last phases of the volcanism remaind active subsequent to the Indo-Pakistan plate-Kohistan Island arc collision during the Late Eocene - Early Oligocene periods.

4. The nothern contact of the Utror Volcanics is with the diorites. The diorite plutons have vast distribution in the central part of the Kohistan, between the western flank of the Nanga Parbat - Haramosh loop (Darel - Tangir area) and Lawarai Top in Dir. Their maximum expanse is between Kalam and the Ghizar Valley in Gilgit area which gradually truncates towards west in the vicinity of the Afghan border.

The type section of the diorites is Deshai, located in the upper reaches of Ushu near Kalam. On the basis of lithology, texture and structure, three types of diorites have been differentiated by Khalil et al.(1973) and Jan (1979). These are Gneissos Quartz Diorite, Orbicular Diorite and Smoky Diorite . Jan (1979) has added another variety and called it Laikot Diorite. Among them the quartz diorite is the oldest and the smoky diorite the youngest. Thus diorite plutonism represents more than one intrusive phases and some could be differentiates, retrograde after pyroxene granulites. Jan (1979) has already recognised one of them with strongly pleochroic hypersthene relics to be retrograde after pyroxene granulites.

The gneissose quartz diorite has more widespread distribution and the one which has contact with the Utror Volcanics north of Dir, is of this type.

The Ladakh Intrusives, like the Main Karakoram Batholith have a sympathetic relationship with the Karakoram because the development of this batholith is confined to the east-west extent of this range.

On the east, this batholith has extension into Ladakh and terminates east of Upshi, whereas in the west its last outcrop is seen southwest of Sor Laspur located near the western termination of the Karakoram. Its extension is uninterrupted except in the apex zone of the Nanga Parbat-Haramosh loop, where its mode of occurrence, because of inacessibility, is yet to be ascertained.

The Ladakh Intrusives between its type area in the Ladakh Range and in their westward extension have a complex and variable lithology. West of the Nange Parbat-Haramosh loop, the composition of the acid component range from tonalite-granodiorite-granite-pegmatite-aplite to quartz which are intruded by the basic sills and dykes of gabbro, hornblendite, diorite and dolerite. In this part, the acid igneous rocks in the batholith dominate and are older to the minor basic bodies. However, some of the late phases of the pegmatite, aplite and quartz are younger to the basic rocks which intrude them. Upstream of the Indus-Gilgit rivers conflunence, the Ladakh Intrusives indicate lit-par-lit type injection of pegmatite and aplite veins.

In the Deosai-Ladakh range in Baltistan, the Ladakh Intrusives indicate a relative increase in the basic igneous rocks where gabbro, hornblendite, diorite and dolerite tarnish their usual character by their excessive occurrences than were observed in the other sections located in the west. However, the acid to intermediate igneous composition of the batholith remains the same, ranging from tonalite-granodiorite-granite-pegmatite-aplite to quartz.

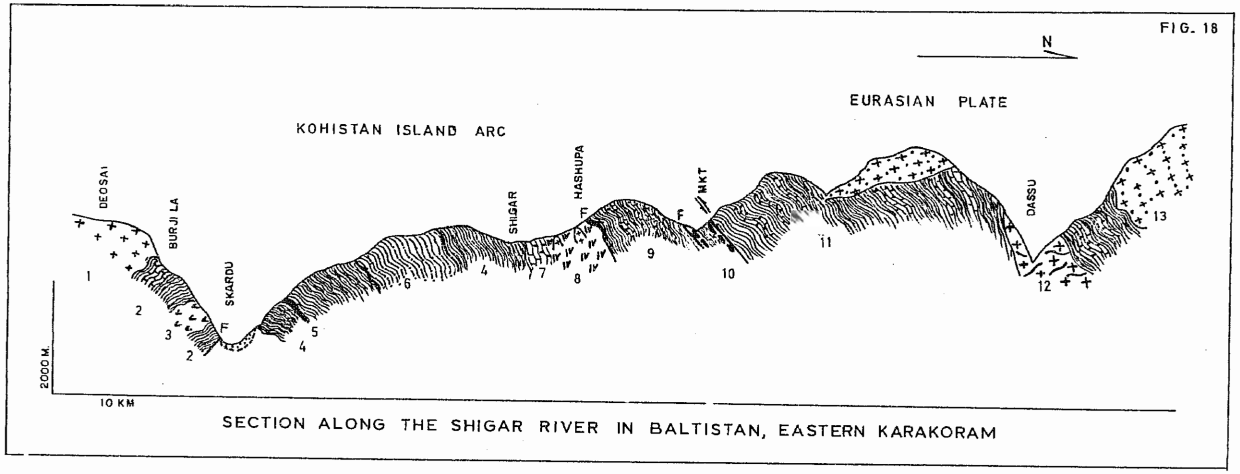


FIG-18
1. Ladakh Intrusives, 2. Burji La Formation, 3. Deosai Volcanics, 4. Katzarah Formation 5.A meta-gabbro dyke, 6. Amphibolite schists and gneisses (part of the Katzarah formation) 7. A marble band exposed at the base of the Rakaposhi Volcanic Complex, 2-3 km north of Shigar, 8. Rakaposhi Volcanic Complex, 9. Yasin Group, 10. Chalt Ophiolitic Melange, 11. Baltit Group. 12. Dassu Gneiss with pegmatite veins, 12. Main Karakoram Batholith.

The Shigar Valley section is located in Baltistan in the eastern part of the Karakoram. In this section the discussion will revolve around the Ladakh Intrusives, the Burji La Formation, the Deosai Volcanics, the Katzarah Formation, and the Dassu Gneiss.

1. The Ladakh Intrusives have earlier been named as the Ladakh Granodiorite Batholith by Ivanac et al.(1956), who had mapped the part of this batholith in the Gilgit area. Across the border in Ladakh, this batholith has been named Ladakh Granite and Gabbroic Intrusives by Sharma et al. (1978), Ladakh Intrusives by Frank et al.(1977) and Ladakh Batholith by several other geologists.

The Ladakh Intrusives occupy the northern part of the Kohistan Island arc. In the Gilgit area, on the north they intrude the Rakaposhi Volcanic Complex and some of the granite, pegmatite and aplite belonging to the last phases of this batholith occur as isolated bodies within the complex, the more common being postkinematic leucocratic granites and pegmatite-aplite. The southern contact of the batholith, in this area is with the quartz diorite, an older member of the Deshai dioritic pluton which hosts apophyses of granite, pegmatite and aplite emanating from the batholith along the junction. In the vicinity of Skardu in Baltistan, the northern contact of the Ladakh Intrusives is with the Burji La Formation and the Deosai Volcanics.

The Ladakh Intrusives do not belong to one major magmatic episode which is evident from their complex and variable petrological and mineralogical composition. The author's observations on this problem in Gilgit and Skardu area reveal, between 4-5 main igneous phases in the acid-intermediate igneous domain and 3-4 phases in the basic igneous suite.

The Ladakh Intrusives,like the Main Karakoram Batholith do not inherit much of structure. Some foliation trends are noticeable within the mass along its northern and southern margins. For instance, the section between Thalichi and Sassi Panyari, on the western tip of the Nanga Parbat-Haramosh loop in the Indus Valley, the Ladakh Intrusives with lit-par-lit injections indicate foliation swinging between east and north-east.

2. The Burji La Formation was first described by Desio (1964) who recorded Orbitolina from the limestone bed, thus assigning it a Cretaceous age. This section is located on the northern flank of Deosai Plateau, facing the Indus Valley near Skardu in Baltistan (Figs 2A and 3). The rocks strike east-west and are comprised of slates, phyllites, quartzitic sandstones with chert which look similar to the Shou quartzites of the Kalam Group, and thin bedded semi-to medium crystalline limestones occupying the top of the sequence. At the base of the limestone, a thin band of conglomerate is present. The Deosai Volcanics in some sections, specially south of Skardu, interbed with the Burji La Formation. This whole sequence may be between 300-400 m thick.

On the south, these rocks have got an intrusive contact with the Ladakh Intrusives and on the north these are interbedded with the Deosai Volcanics, which is not repeated everywhere. Thus the sharp terminations of the Burji La Formation on the north along the Indus Valley and on the east are the result of faulting. The east-west trending northern fault dislocates the Burji La from the biotite schists and gneisses of the Katzarah Formation.

Fossils have been collected from the limestone bed and a Cretaceous age,earlier assigned by Desio to this formation is confirmed.

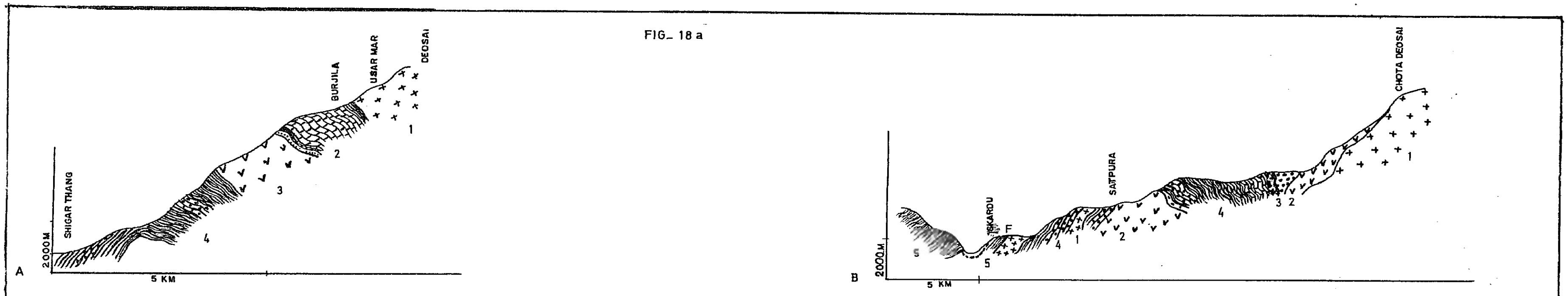
3 Deosai Volcanics were first studied by Wadia (1973) who had assigned them a Cretaceous age. These volcanics cover a substantial part of the Deosai Plateau on the west and southwest, and the one which is being described here is their minor extension which crop out on the northern fringe of the plateau.

The Deosai Volcanics are equated by the author with the main volcanic arc of Kohistan exposed at Utror in Swat Kohistan in the west. The Deosai - Utror volcanics were connected and once formed a single volcanic arc of Kohistan which was disrupted into more than one outcrops by the Nanga Parbat - Haramosh tectonics.

In the section under discussion,the composition of the volcanics range from andesite-dacite-rhyodacite to rhyolite which shows similarity in composition to the Utror Volcanics. They form isolated outcrops and as well as interbed with the Burji La Formation.They are older to the Ladakh Intrusives.The sediments in the Burji La Formation which have association with the Deosai Volcanics, are correlated on lithological basis, with the sediments of the Kalam and Dir groups.This evidence also favours to consider the Deosai-Utror volcanics to have once formed a single domain of the volcanic arc of Kohistan.

4. A sequence comprising of biotite schists and gneisses and amphibolites, about 1500 m thick is recorded on enterance to the Shigar Valley, which in the geological map (Fig.3) has been placed under the Katzarah Formation, a name earlier assigned by Desio (1963) to a suite of the metasedimentary rocks in the vicinity of Kartzarah, downstream of Skardu. These rocks lie on the strike direction towards west of the metasediments, associated with the Burji La Formation and the author considers them to be a part of this sequence.

The general strike of the rocks in this sequence swings between east and southeast and dip is north to northeast.The rocks are deformed showing intricate type folding. Migmatised zones are quite common and one such occurrence is located on the road section about 8-10 km upstream of Skardu. Epidote veining is frequently recorded.Acid and basic igneous rocks occuring as veins, sills and dykes are common. A meta-gabbro dyke associated with light coloured granite and micro-granite is quite prominent in the biotite gneiss zone, part of which is exposed on the road to Shigar. It has an extension across the Shigar Valley towards the west. The granite association with the meta-gabbro appears to belong to a late phase intrusion or may form its segregate.



SECTIONS A–B ACROSS NORTHERN MARGIN OF DEOSAI, SOUTH OF SKARDU

FIG-18-a

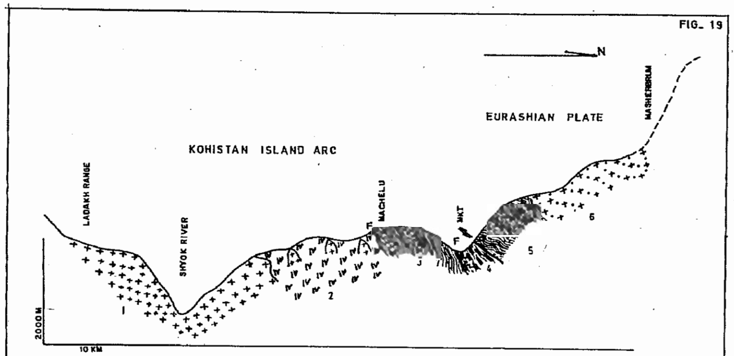
A 1. Ladakh Intrusives, Burji La Formation consisting of limestone and slates with a thin conglomerate band at the base.The light grey semi-crystalline limestone predominates which are sparingly fossiliferous.Among the fossils Orbitolina has been identified, as a result this formation is placed in the Cretaceous, 3. Deosai Volcanics 4. A sequence consisting of slates and quartzitic sandstone with thin limstone intercalations. These rocks on lithological basis are correlated with the Kalam Group which ranges in age from Mid. Jurassic to Early Cretaceous.

B. The earlier described section is again traversed north of Skardu along a Jeepable road. Here the rock types identified are:1.Ladakh Intrusives,2. Deosai Volcanics, 3. Morainic material which occupies an extensive area in this valley and a larger part of the road is built over these rocks, 4. Slates and limestone with quartzitic sandstone bands. In this section, the proportion of the limestone is diminished. This part of the metasediments are correlated with the Karanduki Slates and shou quartzites of the Kalam Group, 5. Katzarah Formation consisting of biotite schists and gneisses, amplibolite alongwith sporadic met-

The southernmost outcrop of this sequence is exposed on the southern bank of the Indus where it has an intrusive contact with the Ladakh Intrusives.On the north, this sequence has a faulted contact with the Rakaposhi Volcanic Complex.the fault passes 2-3 km north of the Shigar village. The amphibolite zone is bounded by the biotite schists and gneisses on the south and north and indicates a sharp contact. Amphibolite is foliated and contains needle like hornblende usually parallel to the foliation but some may cut across the foliation too.

This sequence has an extension across the Shigar Valley, east of the eastern flank of the Nanga Parbat-Haramosh anticline and in the east it has been recorded cutting across the Shyok Valley, downstream of the confluence of the Hushe stream. This sequence incorporates metavolcaniclastics also.

This Katazonal metamorphic sequence is located within the Kohistan Island arc, and is surrounded by epi-to meso-grades rocks. The deformation in the biotite schists and gnei-



SECTION DOWNSTREAM OF KHAPLU ALONG HUSHE STREAM IN BALTISTAN

FIG-19

The Hushe tributary of the Shyok river is located downstream of Khaplu and cuts across the strike of the rocks. Here the rock sequence exposed are 1. Ladakh Intrusives, 2. Rakaposhi Volcanic Complex, 3. Yasin Group, 4. Chalt Ophiolitic Melange, 5. Baltit Group and 6. Main Karakoram Batholith.

In the Kohistan Island arc amphibolite-granulite grade metamorphism has been recorded which is the product of a specific environment occuring during the formation of the Kohistan arc. But the biotite schists and gneisses and foliated amphibolite with migmatitic enclaves altogether give a different look when compared with the surrounding rocks in Baltistan. The amphibolite-granultite sequence in Kohistan is the oldest whereas the Katazonal rocks in Baltistan occur near the top of the Kohistan sequence.

The Burji La Formation and the Rakaposhi Volcanic Complex delineate respectively the southern and the northern contacts of these rocks which are metamorphosed to chlorite-greenschist grade. It could not be understood, why the regional tectonics were more effective on them than the surrounding rocks?

I tentatively consider this Katazonal enclave to be a foreign element incorporated in the Kohistan sequence. This fragment has either been derived from the Central Crystallines of the Indian Himalayan domain or it has been acquired from the Eurasian plate. It is too early to enforce my views with a fewer evidences at this stage and more work is needed to augment these observations.

5· In the earlier literature the name Dassu is familiar with the occurrence of pegmatite veins which had yielded aquamarine during the pre-independence days. Desio (1964) had first described the gneisses in the vicinity of Dassu which were assigned this name. Dassu gneiss zone is located in the Braldu stream near its confluence with the Shigar river in Baltistan.

The gneiss zone constitutes a granitic magmatic pluton within the Baltit Group. It is synkinematic and has developed foliations which follow the structural trend of the Baltit Group. In the central part of the body two mica granitic composition is evident. Foliation in the Dassu gneiss is more pronounced on the margins. The metasedimentary rocks surrounding the plutons indicate meso-to kata-grade metamorphism. The rocks encountered are garnet mica schist, garnet biotite schist and gneisses, garnet epidote-amphibole schists and amphibolite schists and gneisses.

The pegmatite bodies are found within the Dassu pluton and as well as in the surrounding metasedimentary rocks also. Most of the pegmatites are simple but a complex variety has also been recorded, which probably belongs to an earlier magmatic episode and bears gem minerals.

Two samples collected by Matshushita (1965) from Dassu pegmatites were treated for age determination by using Rb/Sr and K/Ar methods by Hayase (1965) which gave ages of 27 and 30 my. Thus the pegmatites, on the basis of these ages, appear to be the product of the Neogene orogeny, which places them older than the Main Karakoram Batholith, if the age determined by Desio (1972) of 8.6 my is accepted.

FIG-20

1. Hornblende Granite, 2. A sequence of flaggy quartzites, siliceous slates (dominant) and thin bedded dolomitic limestones, 3. A 4-5 m thick siliceous dolomitic bed in which Ordovician conodonts have been reported by Talent et al.(1979), 5. An angular unconformity, 6. Another thick sequence consisting of slates (60%), dolomitic limestone (35%) and flaggy quartzitic partings (5%), 7. Dolomitic limestones (dominant) with thin slaty partings, section beyond that constitutes a dominantly carbonate sequence, which falls close to the border and was not sampled.

The section is located about 3-4 km west-north-west of Broghil, across the Yarkun river. It was measured by Talent and Tahirkheli in 1973. The whole of the section shown here could not be measured because part of the northern stretch was located very close to the border.

This section has its importance in the stratigraphy of Pakistan. It records the first discovery of the Ordovician rocks with graptolites in Pakistan.

The pre-Devenian part of the section, measured from north to south, is as follows:

i. A dominantly slate sequence with flaggy quartzite partings and subordinate dolomite intercalations near the top. This stretch is sparingly fossiliferous. Talent reports Russophycus in the siliceous part.
ii. Thin bedded dolomitic limestone band which indicated siliceous pebble partings.
iii. A thick bed of flaggy and very coarse quartzite.
iv. This quartzite bed has extension towards the north but near the site of sampling, it is covered with thick scree.
v. A 4-5 m thick siliceous dolomitic limestone of rusty brown colouration in which Talent found conodont fauna,to be described below.
vi. Flaggy quartzites, dolomitic limestones and slates. This sequence is over 300 m thick and extends into the Yarkun gorge and is not accessible.

Talent et al.(1979) has reported the following conodont fossils:-

Rhynchonathodus divicata, Drepanodus homocuryatus, D. Suberectus? Amorphognathus Sp. and species of Cordylodus, Dichognathus, Oistodus and Tetraprionidodus. These fauna indicate a Middle rather than Late Ordovician age.

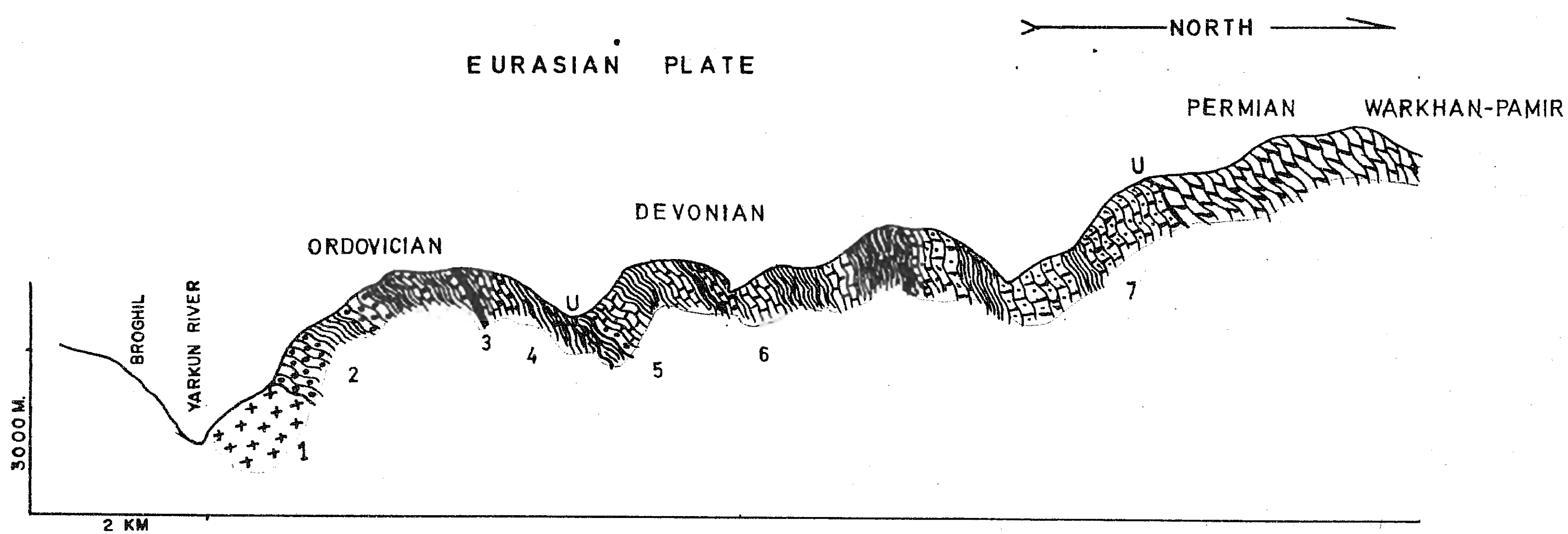
In the Devonian section,Hayden(1915) had collected badly preserved spiriferids and crushed corals. He considered the spiriferids to belong to Cyrtospirifer Veneuili and thus assigning the host rock a Late Devonian age. Reed (1922) because of Spirifer mediotextus differed with the early age and placed these bed in the Middle Devonian.

Our collection from the same stratigraphic horizon in 1973, yielded Cyrtospirifer (Talent et al. 1979) thus confirming Hayden's observations.

In an earlier geological map of the northern Pakistan, Tahirkheli & Jan (1978) had extended the Main Mantle Thrust from Shangla to Mingora. The reason for marking this thrust along this zone was the presence of surficial deformations in the rocks extending along this alignment together with the presence of altered periodotites mostly in the form of metamorphosed serpentinite and talc- cale schist emplaced in the fault zone.

During a review of the earlier work in the Swat Valley and across Shangla in the Alpurai-Karora area, the author has come up with some evidences which overlap the previous observations and need to be mentioned in the form of a preliminary information.

FIG_ 20



SECTION ACROSS YARKUN RIVER AT BROGHIL

FIG-21

1. Karakar Granite,2. Undifferentiated metasedimentary rocks equivalent to the Hazara Zone of the Lesser Himalaya, 3. Granite Gneisses which yielded an age of 523 my with K/Ar method, 4. Kamila Amphibolite, 5. Bahrain Pyroxene Granulite, 6. Deshai Diorites, 7-8-9. Kalam Groupi.Karandokai Slates, ii. Deshan Banda Limestone, iii. Shou Quartzites, 10-11. Dir Group: i Baraul Banda Slates, ii Utror Volcanics.

1.The marginal mass of the Indo-Pakistan plate in the Swat Valley displays a lithology which is identical to the unfossiliferous Lesser Himalayan sequence lying north of Mansehra in Hazara. The main rock types are slates, phyllites, schists with medium crystalline limestones and grey marble bands. Siliceous partings are indicated in the slates.

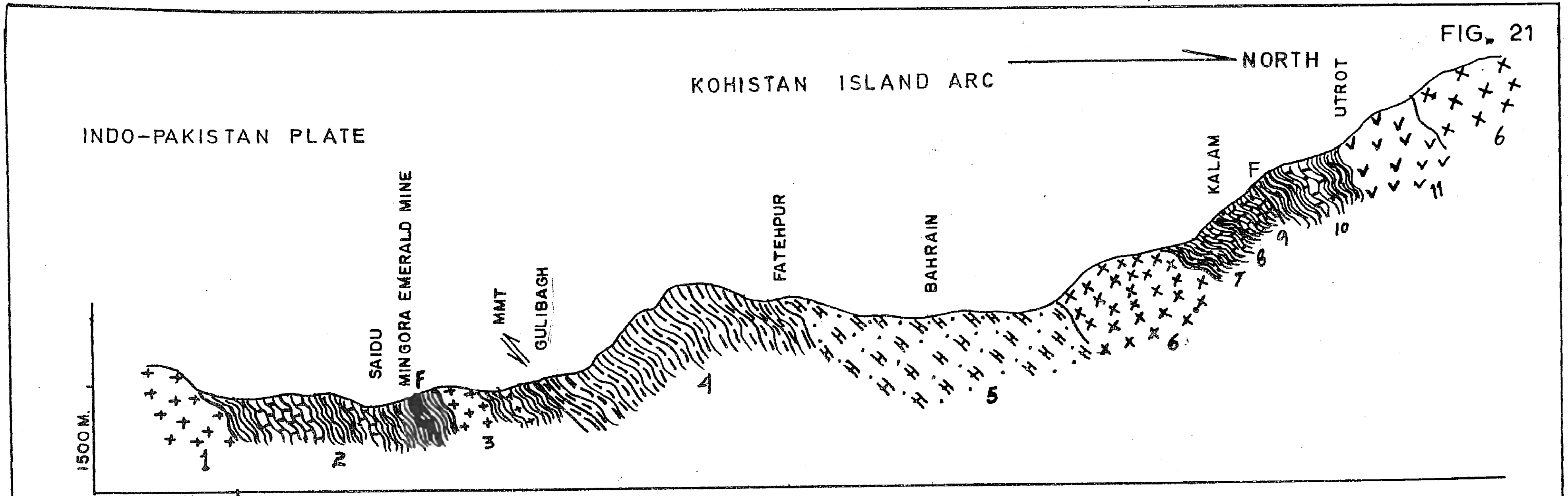
The schistose rocks include, chlorite schist, calc-schist, mica schist, talc-schist, garnet schist, staurolite schist, amphibolite schist and kyanite schist.

The grade of metamorphism ranges from chlorite to kyanite-amphibolite within a radius of 20-30 km.

There is a thick orthogneiss body located 2-3 km north of Mingora which has given a K/Ar age of 523 my (Malluskie, 1981). This body occurs near the leading edge of the Indo-Pakistan plate. As mentioned elsewhere also, the Mansehra granite emplaced in the similar type of rock formations in Hazara in the east has yielded an age of 516 my by Rb/Sr method (Le Forte, 1979).

The MMT zone has been shifted further north, about 2-4 km south of Gulibagh. The Mingora emerald mine, thus, is not located within the MMT zone, as used to be considered previously. There is another lineament running over the northern edge of the Indo-Pakistan plate, being more or less parallel to the MMT zone, which has dislocated the metasedimentary rocks of the Precambrian age. Thus this lineament is post-Precambrian in age - may be Lower to Middle Palaeozoic, a problem which is still under study to associate this faulting with one of the Palaeozoic or older orogenies. This lineament has indicated emplacement of metamorphosed serpentinites which are localized and occur in scattered pockets. The emerald mineralization of Mingora, Makhad and Gujjar killi is thus associated with this lineament. In the west, though the work has so far not been extended, but the Mohmand emerald mineralization which lies in its strike direction on the west may also be associated with this lineament.

Some interesting results on various aspects of this lineament are being awaited,yet from the meagre evidences in hand one can deduce either an existence of a Precambrian microplate on the northern edge of the Indo-Pakistan plate and this lineament marking an old suture, or it is also possible that this lineament has got deep roots, having access to the upper mantle which resulted in tectonic emplacement of the ultramafic rocks.



SECTION ALONG SWAT RIVER

2. The Pyroxene Granulites have their type section located in the Swat Valley. Their southern contact is with the Kamila Amphibolite and this zone passes very close to Fatehpur. On the south, the granulites are intruded by the quartz diorites between Bahrain and Kalam. At Fatehpur, on the road section some sign of retrograde metamorphism is indicated in the pyroxene granulites where the pyroxene is altered to amphibole. This is a usual feature along the contact of the Kamila amphibolite and the pyroxene granulites which is more pronounced further east of this section in the Indus Valley.

The pyroxene granulites are uniform in composition and are essentially composed of plagioclase, orthopyroxene and clinopyroxene with subordinate amounts of quartz, opaque minerals,apatite, amphibole, biotite and some garnet which has a local feature. They are leucocratic and show foliations which are more pronounced in the lower part of the mass.Layers and bandings are quite conspicuous,specially in the Indus Valley section and in the vicinity of Chilas. Pyroxenite and anorthosite usually frequent in the layers. The bands appear to represent the metamorphic segregates in the more tectonized parts but some could be the igneous layers modified by metamorphism. Jan (1979) considers the pyroxene granulites crystallized plutonically from an andesitic basalt magma in an island arc or a continental margin.These were metamorphosed to 800 C at 20kb.and finally intruded as crystalline flow in the country rocks which were passing through amphibolite facies metamorphism.

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