KASHMIR JOURNAL OF GEOLOGY

Volume . 2 No. 1

1984

Institute of Applied Geology
University of Azad Jammu & Kashmir
Muzaffarabad (A.K.) Pakistan

KASHMIR JOURNAL OF GEOLOGY

Institute of Applied Geology
University of Azad Jammu and Kashmir
Muzaffarabad (A.K.) Pakistan

REFREES

Prof. F. A. Shams
Prof. M. A. Latif
Dr. M. Nawaz Chaudhry
Dr. Sarfraz Ahmad
Dr. S. R. H. Baqri
Dr. S. Hamidullah
Dr. Mubarik Ali
Dr. Azam Ali Khawaja
Dr. Khurshid Alam Butt
Mr. Riaz Ahmad
Dr. E. R. Gee
Dr. J. B. Auden

EDITORS **Syed Tayyab Ali**
Dr. Mohammad Ashraf

Published by: **Institute of Applied Geology University of Azad Jammu and Kashmir, Muzaffarabad Tel: 2706**

Printed by: **M/s Habib Press 24 Road, Lahore Pakistan. Tel: 63284 - 60351**

Price : Rs.50 (In Pakistan)

US $ 10/- (Foreign) includes Air Mail Charges

MESSAGE

The University of Azad Jmmu and Kashmir is passing through its early stages of development. It is heartening to know that the Institute of Applied Geology is bringing out the Kashmir Journal of Geology inspite of all shortcomings and difficulties. I congratulate Dr. M. Ashraf, Syed Tayyab Ali and other concerned for their efforts.

The area of Azad Jammu and Kashmir is rich from Geological point of view. It is hoped that the Institute will continue to expand its activities in Collaboration with other agencies engaged in this work. This will lead to the development of the area and make positive contributions to the subject.

DR. TAHIR HUSSAIN
Vice Chancellor

CONTENTS

PETROLOGY OF LOWER SIWALIK ROCKS OF POONCH AREA AZAD JAMMU AND KASHMIR

MOHAMMAD ASHRAF

Institute of Applied Geology Azad Jammu & Kashmir University
Muzaffarabad

M. NAWAZ CHAUDHRY

Institute of Geology University of the Punjab, Lahore.

ABSTRACT.– Sandstone (lithic arenites) and shale of Lower Siwalik of Poonch area have been studied petrographically, chemically and spectro-chemically. By comparing the overall compositions of these rocks and specially the types and compositions of the rock fragments in sandstone, it has been established that these rocks have been derived from the crystalline as well as sedimentary rocks lying due north towards the Pir Panjal Ranges.

INTRODUCTION

The Siwalik Group of rocks discussed in this paper are exposed in the western part of the Poonch District along the eastern bank of the Jhelum river. These rocks cropout between Kohala and Azad Pattan. The eastern contact runs in an irregular fashion from Hajira through Rawalakot to Dhirkot. The stratigraphic succession of rocks in the Poonch and Kotli areas is given in Table - 1

This paper is the first petrological study of its kind on the Lower Siwalik rocks of Poonch area. An earlier paper (Chaudhry & Ashraf, 1981) published on the petrology of the Middle Siwaliks of Kotli area, was the first study of its kind in Kotli. Geological work of a reconnaissance nature was however carried out in areas which now comprise Azad Jammu and Kashmir State, by Meddlicott (1876), Lydekker (1876) and Middlemiss (1896). Wadia (1928) carried out a much more detailed work on Poonch area and adjoining parts of the Punjab. He also prepared a geological map on one inch to four miles scale and studied the stratigraphy and economic geology of the area.

Wadia (1928) divided the Siwaliks of Kashmir into "Lower Plandri", "Middle Mang" and "Upper Sand Rock Stage". It may be noted that Plandri and Mang are both located in Poonch District.

The Stratigraphic committee of Pakistan (1973) has discarded the synonyms "Siwalik Series" of Oldham (1893) and Siwalik system of Holland (1973).

The Committee has formalised it as Siwalik Group and has subdivided it as follows:

Soan Formation . . . . Pleistocene
Dhok Pathan Formation. ..Pliocene
Nagri Formation. . . . . . . .Upper Miocene
Chinji Formation. . . . . . Middle Miocene

The above divisions cannot be easily applied to the Siwaliks of Poonch. The Siwaliks of Poonch have a different provenance from the Siwaliks of Potwar. Additionally the Lower Siwaliks of Poonch resemble the upper part of the "Murrees". Untill proper stratigraphic study of the area is carried out, Upper, Middle and Lower Siwalik classification will be retained.

GEOLOGY.

In the Poonch area, Lower Siwaliks and the lower part of Middle Siwaliks are exposed. The Siwaliks of Poonch, however, appear similar throughout. They are petrographically also indistinguishable.

The sandstones are coarse grained, thick bedded, massive and even pebbly. They are interbedded with hard and compact purple shaly/clayey rocks. Siwalik shales may also be brick red or lighter coloured. They may also contain pseudo-conglomerate beds, In this paper only the Lower Siwalik rocks are dealt with.

PETROGRAPHY

Sandstones

In the following the Siwalik sandstones will be dealt with as one petrographic entity. Fourteen samples were studied. The results alongwith averages and standard deviations are given in Table 2.

Texture and Structure:

These sandstones are medium to coarse grained and moderately compact. The grains are mainly of quartz, rock fragments, feldspar, and mica. The matrix is composed of clay, smaller grains and iron oxides. The cement binding material matter is calcite, chalcedony, and clay. These rocks are mainly lithic arenites.

TABLE - 1

STRATIGRAPHIC SUCCESSION OF ROCKS IN POONCH AND KOTLI

NAME OF FORMATIONS		AGE
Kotli Area	Poonch Area	
Alluvium	Alluvium	Recent to Sub-recent
Siwalik Group	Siwalik Group	Middle Miocene to Pleistocene
Murree Formation	Murree Formation	Oligocene to Lower Miocene
.... UNCONFORMITY		
	Kuldana Formation	Eocene
Margala Hill Limestone	Margala Hill Limestone	
Patala Formation	Patala Formation	Paleocene
.... UNCONFORMITY .... (marked by fire clay and baux ite/laterite)		
...	Gondwana Group	Premo-carboniferous
...	Panjal Trap	do
...	Agglomeritic slates & tuffs	do
.... UNCONFORMITY		
Abbottabad Group	Abbottabad Group	Cambrian
Dogra Slates	Dogra Slates	Pre-cambrian

Mineral Composition:

Quartz: It (X=25.43, S.D = 6.06) occurs mostly as medium to coarse and subangular to subrounded grains. Small subrounded to rounded grains also occur in the matrix.

Calcite: It (X=29.57, S.D = 6.30) is the main cementing material and is mostly fine grained but due to recrystallisation, medium to coarse grains are also encountered. It also occurs as detrital grains and fragments.

Chalcedony: It (X=4.89, S.D. = 0.74) mostly occurs as a cementing material. It shows radial, subradial, lamellar and salt and pepper structure.

Clay: It (X=4.89, S.D = 1.00) is the matrix material. It is fine grained and often from micro-crystalline to crypto-crystalline

Muscovite/Sericite: They (X=4.43, S.D. 1.74) occur as a part of the matrix. However, some muscovite (fine grained) occurs as a matrix material while the rest may be considered togather with grains.

Rock Fragments

The rock fragments are medium to coarse grained and from subangular to angular. The rock fragments are either quartzitic (X=3.43, S.D = 1.79) or cherty (X=9.43, S.D.= 2.82) or unstable ones described together as 'other rock fragments' (X=5.98,=4.00). The rock fragments are volcanic, phyllitic, shaly, calcareous and unstable sandstone fragments.

Haematite/Limonite: These (X=3.00, X= 1.47) occur as a cementing/or a matrix material. These are fine grained. Haematite may also occur as tiny grains. These are also found as finely dispersed matter, streaks, specks and veinlets.

K-feldspar: Both (X=2.64, S.D. = 2.95) microcline and orthoclase occur, as subangular and often elongate grains. These may show minor alteration to sericite or clay.

Chlorite: It (X = 2.86, S.D = 0.89) is an ubiquitous accessory mineral of the sandstone. It is green and moderately pleochroic from neutral green to medium green.

Table — 2

Petrographic Composition of Siwalik Sandstones of Poonch

Sample Nos.	PKA-77-MHN-204	PKA-77-MHN-206	PKA-77-MHN-207	PDT-77-MHN-213	PDT-77-MHN-214	PDT-77-MHN-215	PDT-77-MHN-216	PTL-78-MN-271
Localities	Kohala	Kohala	Kohala	Dhirkot	Dhirkot	Dhirkot	Dhirkot	Trarkhal
Coordinates	559063	561059	565069	584048	584048	632005	632005	877677
Rock types	Sandstone							
Quartz	30.0	20.0	32.0	10.0	28.0	20.0	25.0	30.0
Calcite	35.0	31.5	25.0	34.0	40.0	25.0	40.0	34.0
Muscovite/Sericite	6.0	8.0	2.0	6.0	5.0	3.0	3.0	3.0
Clay	5.0	5.0	6.0	7.0	4.0	4.0	6.0	6.0
Haematite/Limonite	2.0	2.0	–	4.0	3.0	4.0	–	3.0
Chalcedony	1.0	3.0	1.0	1.0	–	2.0	2.0	1.0
K-feldspar	5.0	1.0	2.0	11.0	–	–	–	1.0
Chlorite	3.0	2.0	3.5	3.0	1.0	4.0	2.0	3.0
Albite/Plagioclase	–	1.0	2.0	3.0	–	6.0	–	2.0
Magnetite	–	1.0	–	–	–	–	–	0.5
Tourmaline	–	2.0	2.5	–	2.0	1.0	1.0	1.0
Quartzitic rock fragments	3.0	3.0	3.0	5.0	3.0	9.0	3.0	2.0
Cherty rock fragments	7.0	13.0	11.0	9.0	10.0	13.0	12.0	5.0
Other rock fragments	–	5.5	8.0	2.0	4.0	7.0	2.0	8.0
Pyrite	–	–	–	–	–	–	–	0.5
Garnet	–	–	–	–	–	–	–	–
Pyroxene	–	–	–	2.0	–	–	–	–
Epidote	1.0	–	–	–	–	2.0	–	–
Biotite	2.0	2.0	2.0	3.0	–	–	4.0	–

Analysis at: Engineers Combine Limited, Lahore.

(Contd.)

Table — 2

Sample Nos.	PBH-78-AN-272	PTG-78-AN-273	PDK-78-AN-282	PTL-78-AN-283	PDK-78-AN-284	PDK-78-AN-255		
Localities	Bloch	Trarkhel	Dhirkot	Dhirkot	Dhirkot	Dhirkot		
Coordinates	027707	027707	678955	592042	882045	561058		
Rock types	Sandstone						X̄	S.D.
Quartz	32.0	28.0	26.0	30.0	23.0	22.0	25.43	6.06
Calcite	24.0	27.0	23.0	26.0	30.0	20.0	29.57	6.30
Muscovite/Sericite	4.0	4.0	4.0	4.0	3.0	7.0	4.43	1.74
Clay	4.0	4.0	5.0	4.0	4.5	4.0	4.89	1.00
Haematite/Limonite	4.0	5.0	4.0	3.0	3.0	5.0	3.00	1.57
Chalcedony	1.0	2.0	2.0	1.0	1.0	1.0	1.36	0.74
K–feldspar	1.0	2.0	5.0	2.0	3.0	4.0	2.64	2.95
Chlorite	4.0	[illegible]	3.0	2.0	2.5	3.0	2.86	0.89
Albite/Plagioclase	1.0	4.0	3.0	3.0	2.0	2.0	2.07	1.69
Magnetite	–	–	–	–	–	–	–	–
Tourmaline	1.0	1.0	2.0	3.0	1.0	1.0	1.32	0.87
Quartzitic rock fragments	3.0	4.0	2.0	3.0	2.0	3.0	3.43	1.79
Cherty rock fragments	6.0	10.0	13.0	6.0	7.0	10.0	9.43	2.82
Other rock fragments	12.0	5.0	8.0	10.0	12.0	12.0	5.98	4.00
Pyrite	–	–	–	–	–	–	–	–
Garnet	–	–	–	–	–	3.0	–	–
Pyroxene	–	–	–	–	–	–	–	–
Epidote	–	–	–	3.0	3.0	–	0.64	1.51
Biotite	3.0	–	–	–	3.0	3.0	1.57	1.50

Analysis at: Engineers Combine Limited, Lahore.

Albite/Plagioclase: These occur (X=2.07, S.D = 1.69) as small subhedral grains.

Other Minerals: Pyroxene, biotite, epidote, and magnetite are rare accessories.

Shales:

TEXTURE AND STRUCTURE:

The Siwalik Shales are fine grained and from poorly to moderately laminated. Some of these should in fact be called 'mud stones'. Still others should be considered as clays. These may at places contain medium grained quartz and calcite. Their petrographic composition is given in Table-3.

Mineral Composition:

Clay: It (X= 47.80, S.D = 10.62) is the predominant material. It is fine grained and often microcrystalline to cryptocrystalline. It belongs predominantly to the illite group, however, some kaolinites and smectite group clays also occur. It is intimately admixed with sericite.

Quartz: It (X= 20.80, S.D = 13.22) is an essential constituent of shales/clays. It is mostly fine grained. Some medium grains also occur. It may form irregular and elongate aggregates of streaks parallel to the planes of lamination.

Calcite/Dolomite: These (X = 18.60, S.D = 9.07) are ubiquitous and as a whole essential minerals. Calcite is predominant. It occurs mostly as fine and often microcrystalline and cryptocrystalline matter, however, recrystalised areas may contain medium and even coarse carbonate grains. Detrital grains are also present.

Haematite/Limonite: These (X = 5.20, S.D = 2.59) occur mostly as important and ubiquitous accessory minerals, assuming occasionally the status of essential minerals. These occur mostly as extremely fine and dispersed matter. These may however also occur as streaks and veins. Haematite may also occur as discrete anhedra.

Albite/Plagioclase: Only two samples contain tiny elongate anhedra subhedra of albite/plagioclase. In one sample it is 0.5% while in the other it is 3.0%.

Muscovite/Sericite: Muscovite (X = 5.80, S.D = 4.38) occurs as fine to medium flakes while sericite occurs exclusively as fine flakes. These occur mostly along the planes of lamination. Sericite is intimately admixed with clay.

Other accessory minerals which may or may not occur are chlorite magnetite, tourmaline and epidote.

CHEMISTRY

Sandstones:

Ten samples of Siwaliks sandstones were analysed chemically. The results are given in Table -4. The SiO_2 (X = 49.85, S.D = 7.22) contents range from 42.07 to 59.51%; those of Al_2O_3 (X = 8.77, S.D = 2.52) range from 3.78 to 13.42%; those of CaO (X = 16.12, S.D = 4.05) range from 11.35% to 20.30%; those of I/L (X = 15.63, S.D = 4.72) range from 0.85% to 23.60%; those of MgO (X = 2.71, S.D = 1.15) range from 1.69 to 5.50% and those of Fe_2O_3 (X = 4.87%, S.D = 1.46) range from 2.71% to 7.42%. The K_2O (X = 1.42, S.D = 0.40) and Na_2O (X = 1.14, S.D = 0.60) contents range from 0.90% to 1.17% respectively. These are carbonate rich sandstones.

SPECTROCHEMISTRY

Sandstones:

Five samples of Siwalik sandstone were analysed spectrochemically. The results of the spectrochemical analysis are given in Table-5. The ZrO_2 contents range from 0.01% to 0.03%, Vanadium ranges from 0.002% to 0.01%. Ba from 0.03 to 0.08%, Cr from 0.01% to 0.02%, Mo from 5ppm to 20ppm (in 4 samples), Y from 10 to 20 ppm (except one sample in which it is absent), S_o 2ppm to 5ppm (in 4 samples, Cu from 1ppm to 5ppm, La from 10ppm to 50ppm (in 3 samples, being absent in 2 samples), Ni and Co less than 10ppm and Pb less than 50ppm.

Shales:

Four samples of Siwalik shales/Clays were analysed spectrochemically. The results are given in Table-6.

The contents of ZrO_2 range from 0.014% to 0.02%, of V from 0.008% to 0.01% and of Ba from 0.03% to 0.08% and Cr is 0.01% in all the samples. The contents of Mo in all the samples are 5ppm, of Y is 10ppm, of Sc 2ppm, of Ni-Co 10ppm, of Pb 50ppm. The contents of Cu range from nil to 20ppm.

ORIGIN

In order to understand the provenance of Poonch Siwaliks, it is essential to understand the type and nature of rocks, lying to the north and north-east, in the districts of Kotli and Poonch towards Pir Panjal Range.

Briefly, the rocks exposed from oldest to the youngest are the Precambrian Dogra Slates, mainly black and grey slates with carbonaceous horizons and basic volcanics (the Dogra Trap). These are exposed mainly in the Poonch areas.

These are followed by poorly developed Abbottabad Group in Poonch (thin limestone and quartzite beds) and good development of Sirban Formation's thick cherty dolomites and thin quartzites in Kotli area. It also contains dispersed and poor Pb-Ni-Co mineralised zones. In Poonch following an unconformity, agglomeritic slates and tuffs of Upper Carboniferous are exposed followed by the Upper Carboniferous Panjal Trap consisting mainly of basalts with subordinate andesites. In Poonch Panjal Trap is followed by Gondwana Group schists, phyllites and quartzites of Permo-Carboniferous age. This is followed by unconformably overlying Patala Formation of Paleocene age. Patala Formation in this area is composed of khaki, dark grey and black shales with subordinate interbedded limestone which is in turn overlain by Margala Hill Limestone of Eocene age. The unconformity in the Kotli area is marked by bauxite and fireclay. In Poonch rocks equivalent to Kuldana Formation are also present. Then follows with an unconformity Murree Formation composed of alternating red sandstone and shale. Rarely some marly calcareous beds may also occur. The Murrees are overlain by the Siwaliks.

The Siwalik sandstones of Poonch area have been studied carefully and compared with the older rock formations in order to determine their provenance. This sandstone has derived cherty and carbonate rock fragments from the Cambrian dolomite, quartzite fragments and quartz from the Cambrian quartzite while the volcanic fragments and green cherty pieces have been derived from the Panjal Trap. The other constituents of these sandstones are schists, phyllites and carbonaceous phyllites which are derived from the Gondwana, and the slate fragments from the Dogra Slates. Some material may also have been derived from the granites to the north (microcline and tourmaline). Some shale, carbonaceous shale and limestone pieces may have been derived from Patala Formation shales and Margala Hill Limestone. But fossil evidence for their derivation from the Tertiary rocks is still inconclusive. The resemblance of Lower Siwaliks to Upper Murrees may be due to derivation of a part of sediments from the Murrees.

Trace elements study of Siwaliks shales and sandstones conforms to the above interpretation. Ni, Co, Cr, Cu, and V are derived from the volcanic zones. Pb, Mo, and Ba are derived from the granites and the mineralised zones in the Cambrian dolomites. Rare earth elements are derived from volcanics of alkaline affinities.

Chaudhry and Ashraf (1981) have shown a provenance for Kotli Middle Siwaliks more or less similar to the Lower Siwaliks of Poonch. Lower and Middle Siwaliks have been derived from the same positive area to the north and northeast towards the Pir Panjal Range during late Miocene to Middle Pliocene. These deposits are of continental origin. For depositional environments of Dhok Pathan in Surghar the reader is referred to Abbasi et. al. (1983).

Studies carried out on the Siwalik rocks of Azad Kashmir and the Punjab show that different blocks (lateral variation) of Siwaliks have been derived from source area differing in rock compositions to varying degrees. Vertical variations due to different source rocks for Siwaliks of Surghar Range have been proposed by Abid et al. (1983). It may therefore be concluded that there are vertical and lateral petrographic variations due to provenance in the Siwaliks. The sandstones are unlike the Siwaliks sandstones described by Krynine (1948) as schist arenite from northern India.

REFERENCES

Abbasi, I.A., Abid, I.A., & Khan, M.A., (1983). Statistical study of Dhok Pathan Formation, Puki Oudikhel, Surghar Range, Karak. *Geol. Bull., Univ. Peshawar,* Vol. 16, p. 85.

Abid, I.A., Abbasi, I.A., Khan, M.A., &, Shah, T.M. (1983). Petrography and geochemistry of the Siwalik sandstone and its relationship to the Himalayan orogeny. *Geol. Bull. Univ. Peshawar,* Vol. 16, p. 65.

Chaudhry, M.N., & Ashraf, M., (1981). Petrology of Middle Siwalik rocks of the Kotli area, Azad Kashmir. *Geol. Bull. Univ. Peshawar.* Vol. 14, p. 183.

Chaudhry, M.N., & Ashraf, M. (1980). The Volcanic rocks of Poonch District, Azad Kashmir. Spec. Issue, *Geol. Bull. Univ. Peshawar.* Vol. 12, pp. 121-128.

Lydekker, R., (1876). Notes on the geology of Pir Panjal and neighbouring Districts. *Rec. Geol. Surv. India,* Vol. 9, p. 155.

Middlemiss, C.S., (1896). The geology of Hazara and Black Mountains. *Mem. Geol. Surv. India,* Vol. 26, pp 302.

Meddlicott, C.S., (1896). Notes on the sub-Himalayan Series in Jammu Hills. *Rec. Geol. Surv. India, Vol. 9, pp 49.*

Wadia, D.N., (1928). The geology of Poonch State (Kashmir) and adjacent portions of the Punjab. *Mem. Geol. Surv. India,* Vol. 2, p. 2.

William, H., Turner, F.J., Gilbert, C.M., (1953). Petrography. W. H. Freeman Co., San Francisco, U.S.A.

Table — 3

Petrographic Composition of Siwalik Shales/Clays of Pooneh

Sample Nos.	PKA-77-MHN-205	PKA-77-MHN-209	PDT-77-MHN-212	PDT-77-MHN-217	PDT-77-MHN-219A		
Localities	Kohala	Kohala	Dhirkot	Dhirkot	Dhirkot		
Coordinates	561059	566058	584048	632005	651984		
Rock types	Shales					$\overline{X}$	S.D.
Quartz	18.0	15.0	8.0	20.0	43.0	20.80	13.22
Clay	44.0	44.0	63.0	53.0	35.0	47.80	10.62
Calcite/Dolomite	20.0	25.0	25.0	20.0	3.0	18.60	9.07
Haematite/Limonite	8.0	3.0	3.0	4.0	8.0	5.20	2.59
Albite/Plagioclase	–	3.0	–	–	0.5		
Chlorite	–	–	–	–	2.5		
Muscovite/Sericite	10.0	10.0	–	3.0	6.0	5.80	4.38
Magnetite	–	–	1.0	–	1.0		
Tourmaline	–	–	–	–	0.5		
Epidote	–	–	–	–	0.5		

Analysis at: Engineers Combine Limited, Lahore.

Table — 4

Chemical Composition of Siwalik Sandstone of Poonch

Sample Nos.	PKA-77-MHN-204	PDT-77-MHN-216	PTL-78-AN-270	PTL-78-AN-271	PBS-78-AN-272	PDK-78-AN-282	PDK-78-AN-283	PDK-78-AN-284	PTL-78-AN-273	PDK-78-AN-285		
Localities	Kohala	Dhirkot	Trarkhel	Trarkhel	Bloch	Dhirkot	Dhirkot	Dhirkot	Trarkhel	Dhirkot		
Coordinates	55.9063	632005	864686	877677	027707	678955	592042	882045	027707	561058		
Rock types	Sandstone										$\bar{X}$	S.D.
SiO_2	43.20	43.52	44.51	43.88	53.59	59.51	58.09	42.07	58.94	51.23	49.85	7.22
TiO_2	0.43	0.43	0.00	TR	TR	0.00	TR	0.00	0.24	0.26	0.14	0.19
Al_2O_3	10.79	9.68	13.42	7.19	8.50	7.95	8.14	3.78	10.05	8.17	8.77	2.52
Fe_2O_3	3.09	2.71	7.42	5.93	5.67	3.79	4.03	5.70	5.54	4.82	4.87	1.46
MgO	2.24	1.69	1.92	2.83	3.22	3.47	0.83	5.50	2.16	2.26	2.71	1.15
CaO	19.68	20.36	14.34	19.17	13.53	11.35	12.84	17.70	7.84	14.41	15.12	4.05
Na_2O	0.80	0.48	1.17	0.93	0.73	1.17	1.07	0.73	2.44	1.92	1.14	0.60
K_2O	1.24	1.35	1.40	1.16	1.16	1.40	1.38	0.90	2.35	1.82	1.42	0.40
I/L	18.52	19.39	15.31	18.31	12.99	10.85	11.94	23.60	10.45	14.93	15.63	4.27
Total:	99.99	99.51	99.49	99.40	99.59	99.49	99.32	100.07	100.01	99.82		

Analysis at: Engineers Combine Limited, Lahore.

Table — 5

Spectrochemical Composition of Siwalik Sandstone of Poonch

Sample Nos.		PKA-77-MHN-206	PKA-77-MHN-207	PDT-77-MHN-213	PDT-77-MHN-214	PDT-77 MHN-215
Localities		Kohala	Kohala	Dhirkot	Dhirkot	Dhirkot
Coordinates		561059	565069	584048	584048	632005
Rock type		Sandstone				
ZrO_2	%	0.012	0.012	0.035	0.02	0.01
V	%	0.002	0.002	0.01	0.01	0.01
Mo	ppm	5.0	5.0	20.0	5.0	5.0
Y	ppm	10.00	10.00	20.0	10.00	–
Sc	ppm	2.0	2.0	5.0	2.0	2.0
Cu	ppm	1.0	2.0	5.0	5.0	5.0
La	ppm	–	–	50.0	10.0	10.0
Ni-Co	ppm	<10	H 10	<10	<10	<10
Pb	ppm	<50	< 50	<50	<50	<50
Ba	%	0.03	0.03	0.08	0.05	0.3
Cr	%	<0.01	0.01	0.01	0.01	0.01
Sn	ppm	–	–	<10	–	–

Table — 6

Spectrochemical Composition of Siwalik Shale/Clays of Poonch

Sample Nos.		PKA-77-MHN-209	PDT-77-MHN-212	PDT-77-MHN-217	PDT-77-MHN-219
Localities		Kohala	Dhirkot	Dhirkot	Dhirkot
Coordinates		566058	584048	632005	651984
Rock types		Shales			
ZrO_2	%	0.014	0.014	0.02	0.014
V	%	0.01	0.01	0.008	0.01
Mo	ppm	5.0	5.0	5	5
Y	ppm	10.0	10.0	10	10
Sc	ppm	2.0	2.0	2.0	2.0
Cu	ppm	5.0	5.0	5.0	2.0
La	ppm	10.0	10.0	30	10
Ni-Co	ppm	<10	<10	<10	<10
Pb	ppm	<50	<50	<50	<50
Ba	%	0.08	0.05	0.05	0.03
Cr	%	<0.01	<0.01	<0.01	<0.01
Sn	ppm	<10	20	<20	–

Analysis at: PINSTECH

Kashmir Journal of Geology *Vol 2 No. 1, 1984*

GEOLOGY, PETROGRAPHY AND SPECTROCHEMISTRY OF GONDWANA ROCKS OF POONCH DISTRICT, AZAD KASHMIR

M. NAWAZ CHAUDHRY
Institute of Geology, University of the Punjab, Lahore
&
MOHAMMAD ASHRAF
Institute of Applied Geology, University of Azad Jammu & Kashmir, Muzaffarabad

ABSTRACT.– Geology, petrography and spectrochemistry of Gondwana group metaconglomerates, quartzites and schists have been described and discussed. Ten modal analyses of Gondwana metaconglomerate bed, four modal analyses of Gondwana schists, five spectrochemical analyses of Gondwana metaconglomerate and two spectrochemical analyses of Gondwana schists are presented for the first time from Poonch. The geological and petrographic evidence supports the view (Wadia 1928) that the Gondwana Group of rocks were deposited under continental conditions. It has been further suggested that the environment of deposition varied from oxidising to reducing. The upper Haveli Tehsil of Poonch with Agglomeritic slates and tuff, Panjal Trap and Gondwana Group of rocks belongs to the Kashmir geologic province while the remaining part (with the Palaeozoic rocks missing) should be grouped with the Hazara province. The two contrasting provinces are separated by the great boundary fault.

STRATIGRAPHY

A geological map of the upper Haveli Tehsil of Poonch showing the location of the Gondwana Group of rocks is presented as Fig. 1.

The stratigraphic sequence of rocks in the Poonch District is given as table 1 and briefly discussed by Chaudhry and Ashraf (1980). In this table the stratigraphy of the Kashmir Province as well as the Hazara Province is given together. In this table the stratigraphy of the adjoining Kotli area is also presented which like most of Poonch (except upper Haveli Tehsil) is a part of the Hazara Province.

It is not the purpose of the present paper to give details of stratigraphy of Poonch, however stratigraphic features of Gondwana group are being presented.

GONDWANA GROUP:

Authorship: The name was proposed by Medlicott in 1872 is an unpublished portion of his report on the Satpura basin, and first published by Feistmantel (1877). Wadia (1928) tentatively assigned to the "Gondwana System" a great thickness of moderately metamorphosed shales, argillaceous sandstone and quartzites occuring on the southwest side of the Pir Panjal, which in their sedimentary characters unmistakably suggest their formation under fresh water conditions and which overlie the agglomeritic slates conformably and the older Dogra Slates with a distinct unconformity generally marked by an extremely coarse boulder conglomerate at the base (Wadia, 1928).

Many bands of Gondwana are exposed between Kalamula and Hillan in the Batar Valley.

The Dogra Slates are overlain unconformably by a well sorted meta-conglomeritic bed consisting essentially of quartz pebbles of white to milky white colour with subordinate phyllitic layers. The quartz pebbles are well rounded and have fairly good sphericity. The percentage of quartz pebbles varies from 50 to 70% in most of the localities visited, e.g. eastern escarpment of Kalamula, Paje-di-Gali and northern area of Maili.

Meta-conglomeratic bed is succeeded by arenaceous phyllitic and sandy slates of black, green to grey colour overlain by massive or flaggy quartzites of white and pale variegated colours.

GEOLOGY

The Gondwana Group is an important and conspicuous unit of the upper Haveli Tehsil. It is composed of slightly to moderately metamorphosed argillites, argillaceous sandstones and quartzites with a metaconglomerate towards the base of the series. The series is cut by a few altered basic dykes. The phyllitic matrix of the basal conglomerate contains heavy minerals like magnetite, pyrite and zircon. Further search may reveal other useful heavy mineral concentrations.

The boulder bed has an argillaceous matrix which is phyllitic and even schistose. The matrix may contain heavy minerals like magnetite, pyrite and zircon etc. The pebbles, cobbles (and even boulders) which occur in the bed are composed of fairly pure quartz, much of which appears to be vein quartz. The boulder bed gradually passes upwards into the overlying argillaceous and sandy metasediments.

The Gondwana Pelite-Psammites are fairly variable and alternate beds are either rich in quartz or contain significant argillaceous matter (now recrystallised). These beds show colour banding in buff, grey, cream, white, pale grey and light green shades. Cross bedding is very common, leaf impression and plant organic matter is present in some layers. Rapid facies changes are common.

Table–1

STRATIGRAPHIC SEQUENCE OF KOTLI AND POONCH AREAS

KOTLI	POONCH	
Alluvium	Alluvium	Recent to subrecent
Siwalik Group	Siwalik Group	Middle Miocene to Pleistocene
Murree Formation	Murree Formation	Oligocene to L. Miocene
.... Unconformity		
	Kuldana Formation	)
		) Eocene
Margala Hill Limestone	Margala Hill Limestone	)
Patala Formation	Patala Formation	Paleocene
.... Unconformity		
Unconformity marked by Fire clay and Bauxite)		
	Gondwana Group	Permo-Carboniferous
	Panjal Trap	Upper Carboniferous
	Agglomeritic Slates and Tuff	"
.... Unconformity		
Abbottabad Group	Abbottabad Group	Cambrian
Dogra Slates	Dogra Slates	Pre-Cambrian

PETROGRAPHY

Metaconglomerate

TEXTURE AND STRUCTURE: It is conglomeratic. The pebbles and cobbles are subrounded to rounded but stretched due to metamorphism. The groundmass is phyllitic and even schistose. The modal composition is presented in Table–2.

MINERALOGY:

Quartz: It ($\bar{X}$ = 68.45, s.d = 6.63) ranges from 60.0 to 78.0% generally composed of fairly pure quartz grains. This appears to be vein quartz. These grains are well interlocked. They are from fine to medium grained. The quartz grains which occur in the groundmass are also fine to medium. All the quartz grains show moderate to strong strain extinction.

Muscovite: It ($\bar{X}$= 14.08, s.d. = 4.56) ranges from 9.0 to 25.0%. It occurs mostly in the groundmass. It is fine to medium grained. It alongwith other micaceous minerals, imparts foliation to the rock. The medium flakes may sometimes be poikioblastic.

Biotite: It ($\bar{X}$=6.12, s.d. = 5.59) occurs in seven out of ten samples and in them it ranges from 0.2 to 14.0%. It occurs as fine to medium flakes. It occurs associated closely with muscovite. It is generally brownish green and moderately pleochroic from light brownish green to brownish green. Its presence in the rocks suggests a biotite grade of regional metamorphism.

Chlorite: It ($\bar{X}$= 5.10, s.d. = 3.28) occurs in nine out of ten samples and in them it ranges from 2.0 to 12.0%. It occurs from fine to medium flakes. It is green and pleochroic from neutral green to green. It shows anomalous interference colours.

Magnetite: It ($\bar{X}$= 2.25, s.d. = 1.90) occurs in seven out of ten samples and in them it ranges from 1.0 to 5.0%. It occurs mostly as anhedral to subidioblastic grains and their aggregates. It may show marginal alternation to haematite/limonite.

Haematite/Limonite: They ($\bar{X}$= 1.45, s.d. = 1.21) occur in eight out of ten samples. Haematite may occur as grains. Haematite/limonite occur as stains, specks and irregular aggregates. They also occur as weathering/alteration products, specially of magnetite and pyrite.

Pyrite: It occurs in three samples (3.0 to 5.0%). It is from anhedral to subidioblastic. It occurs as fine grains which show alternation to haematite/limonite.

Apatite: Tiny apatite grains occur in four out of ten samples. Three samples contain 0.5% and one sample contains 1.0% apatite.

Zircon: One sample, PML-77-FSH-114, contains 2.0% zircon. Zircon is subhedral to eumorphic and occurs as fine to medium crystals.

Other Accessories: Other accessories which may or may not occur are sphene, tourmaline, garnet, epidote, K-feldspar and carbonaceous matter.

Schists/Phyllites:

Four samples of the schistose rocks were studied petrographically. The results are given in Table–3.

TEXTURE AND STRUCTURE: The rocks are phyllitic to schistose. They are hypidioblastic.

MINERALOGY:

Quartz: It ($\bar{X}$= 70.50, s.d. = 3.11) occurs as small to medium grains which may occur either as discrete grains or as streaks and irregular elongate aggregates. It ranges from 68.0 to 75.0%.

Muscovite: It ($\bar{X}$= 16.25, s.d. = 3.95) ranges from 13.0 to 22.0%. It occurs from fine to medium flakes, which alongwith other micaceous minerals impart foliation to the rock.

Biotite: It ($\bar{X}$= 1.75, s.d. = 2.22) occurs in three out of four samples and in them it ranges from 1.0 to 5.0%. It is brownish green and pleochroic from light green to brownish green.

Chlorite: It ($\bar{X}$= 2.75, s.d. = 2.22) occurs in three out of four samples and in them it ranges from 2.0 to 5.0%. It occurs as fine to medium flakes which are green and moderately pleochroic from almost neutral green to medium green. It shows inky blue interference colours.

Magnetite: It ($\bar{X}$= 3.13, s.d. = 3.47) also occurs in three out of four samples and in them it ranges from 1.5 to 8.0%. It occurs as small anhedra and their tiny aggregates.

Haematite/Limonite: They ($\bar{X}$= 0.50, s.d. = 0.41) also occur in three samples only (0.5 to 1.0%). They occur as specks, stains and tiny grains.

Zircon: One sample, PHN-77 – MFW-155, contains 0.5% tiny zircon crystals.

Other Accessories: Other accessories which may or may not occur in these rocks are clay (secondary), apatite, tourmaline, garnet, carbonate, K-feldspar and carbonaceous matter.

CHEMISTRY

One sample, PKM-77-AS-76 was analysed (Table-4). Its compostion is given as 75.95% SiO_2, 9.61% AL_2O_3, 7.86% Fe_2O_3, 1.55% K_2O and 0.91% each of CaO and MgO.

SPECTROCHEMISTRY

Gondwana Boulder Bed: Five samples were analysed by spectrochemical methods. The results are given in Table-5. The contents of $Zr0_2$ range from 0.01 to 0.014%, those of La range from 10 ppm to 100 ppm, those of Y range from 5 ppm to 20 ppm, those of V range from 0.008 to 0.01% and those of Cu range from 5 ppm (in four samples) to 100 ppm.

Lead occurs in four out of five samples. In one sample it is 50 ppm and in three samples it is 50 ppm. Sc (10 ppm) occurs in one sample while Mo occurs in two samples (5 ppm and 10 ppm). The 100 ppm La contents are anomalous.

Schists/Phyllites: Two samples were analysed spectrochemically. The results are given in Table-6. They contain Zr02 0.14% and 0.02%, La 50 ppm each, Y 10 ppm each, Mo 5 and 10 ppm, V 0.04%, Sn nil and 50 ppm, Pb 50 ppm each and Cu 5 ppm each. The analyses do not show anomalous results. However, 0.14% $Zr0_2$ value is interesting.

DISCUSSION AND CONCLUSION

Spectrochemistry throws some light on the origin of these rocks. They contain zirconium and rare earth elements which are likely to have been drawn from rocks of acid to intermediate and alkaline affinities. Presence of Pb, Mo, Sn indicates acidic component. The presence of V & Cu shows some contribution from rocks of basic affinities. The metaconglomerate and the base of the Gondwanas is a metamorphosed glacial deposit. This bed contains pebbles, cobbles as well as boulders. The matrix is schistose. It is a very hetrogeneous deposit and represents a metamorphosed boulder clay. The overlying beds are now composed of schists, phyllites and impure arenaceous beds. The arenaceous beds retain well marked cross-bedding. Leaf and plant fossil impressions are found preserved at a number of places. Carbonaceous schists are also found. Rapid facies changes are common at place. All these features support the view (Wadia, 1928) that these are definitely land deposits. Unlike most of the Gondwanas in Peninsular India, these rocks in Poonch have been well folded and metamorphosed to greenschist facies (See petrography).

The Pir Panjal Range in Poonch as elsewhere in Kashmir is an important geological boundary (Wadia, 1928). This range passes through Poonch and divides it into two distinct geological domains. The eastern part of Poonch is a part of the southwestern limb of Pir Panjal and therefore part of the Kashmir Province where Gondwana have developed extensively which are a part of the well developed Palaeozoics of Kashmir. The rest of the Poonch has the Palaeozoic unconformity (Table 1) – (the stratigraphy of Kotli is similar to the southwest Poonch). Coal deposits have not been found in Poonch.

Extension of continental Permian coaliferous deposits is indicated in boreholes from parts of northwestern and western Punjab (Mirza, unpublished work). These rocks are unmetamorphosed. Existence of a large number of outliers is proposed as linear features of continental Permian equivalent also of Damuda group of India. These basins bounded by faults are likely to contain not only high grade coal, but also iron rich sediments. The geotectonic position of these outliers is such that the Gondwanic rocks (unlike Poonch) are likely to be unmetamorphosed and uneffected by strong folding. Gondwanic elements have been known from Poonch for quite some time. However new information on the extension of Gondwanic elements in Pakistan (specially Punjab) is being furnished. This will help define more precisely the limits and boundaries of Gondwanic and Tethyian elements.

REFERENCES

Chaudhry, M. N., and Ashraf, M., (1980). The volcanic rocks of Poonch District, Azad Kashmir. *Proc. Intern. Commit. Geodynamics,* Grp-6, Mtg Peshawar, Nov. 23-29, 1979: spec. Issue, *Geo. Bull. Univ. Peshawar,* Vol. 13, p. 121-128.

Feistmantel, (1877). Fossil Flora of the Gondwana System. Pol. Indica, Vol. 2. Part 2.

Medlicoott, H.B., (1872). Report on Satpura basin. Unpublished report.

Wadia, D.N., (1928). The geology of Poonch State, Kashmir and adjacent portions of the Punjab. *Mem. G.S.I.,* Vol. VLI.

Fig. 1 GEOLOGICAL MAP OF UPPER HAVELI TEHSIL (POONCH DISTRICT), Topo sheet NO. 43 $\frac{K}{1}$

M.A.Kiani Illustrator

Table — 2

Petrographic Composition of Gondwana Boulder Bed (Metaconglomerate)

Sample Nos.	PKM-77-AS-76	PML-77-FSH-114	PML-77-FSH-115	PML-77-FSH-115	PML-77 FSH-119	PRI-78-NH-235	PRI-78-NH-237	PRI-78-NH-238	PRI-78-NH-240	PRI-78-NH-241		
Localities	Kalamula	Maili	Maili area	Reji Maili area	Reji-Maili area	Reji	Reji	Reji	Reji	Reji		
Coordinates	221927	252913	252913	269913	269913	272918	272918	272918	272918	272918	$\overline{X}$	S.D.
Quartz	71.0	77.5	74.0	63.0	78.0	68.0	65.0	60.0	60.0	68.0	68.45	6.63
K-feldspar	–	–	–	–	–	–	–	–	2.0	–		
Muscovite	12.0	12.8	9.0	25.0	12.0	15.0	9.0	16.0	15.0	15.0	14.08	4.56
Biotite	3.0	0.2	–	–	–	12.0	14.0	10.0	12.0	10.0	6.12	5.95
Haematite/ Limonite	3.0	1.0	1.0	–	0.5	3.0	1.0	3.0	–	2.0	1.45	1.21
Magnetite	–	4.0	5.0	–	3.5	–	3.0	4.0	2.0	1.0	2.25	1.90
Pyrite	5.0	–	3.0	–	3.0	–	–	–	–	–	1.10	1.85
Chlorite	6.0	2.0	5.0	12.0	3.0	–	7.0	5.0	7.0	4.0	5.10	3.28
Garnet	–	–	–	–	–	0.5	0.5	–	0.5	–	0.15	0.24
Tourmaline	–	–	–	–	–	0.5	–	–	–	–	–	
Apatite	–	0.5	1.0	–	–	0.5	–	–	0.5	–	0.25	0.35
Epidote	–	–	2.0	–	–	–	–	1.0	0.5	–	0.35	0.67
Sphene	–	–	–	–	–	–	–	–	0.5	–		
Carbonaceous matter	–	–	–	–	–	0.5	0.5	1.0	–	–	0.20	0.35
Zircon	–	2.0	–	–	–	–	–	–	–	–		

TABLE 3

Petrographic Composition of Gondwana Schists/Phyllites

Samples Nos.	PHN-77-FS-31	PML-77-FSH-113	PHN-77-MFW-155	PML-77-MFW-160		
Localities	Hillan	Sangla Nala-Mai-area li area	Hillan	Sangla		
Coordinates	Out of toposheet	252913	307947	256915		
Rock types	Biotite-Mica-Schist	Chlorite Mica-Mica Schist.	(Biotite)-Chlorite-Mica Schist.	(Biotite)-Chlorite-Mica Schist.	$\overline{X}$	S.D.
Quartz	70.0	68.0	69.0	75.0	70.50	3.11
K-feldspar	–	5.0	2.0	–		
Muscovite	22.0	15.0	15.0	13.0	16.25	3.95
Biotite	5.0	–	1.0	1.0	1.75	2.22
Haematite/ Limonite	0.5	–	0.5	1.0	0.50	0.41
Magnetite	1.5	3.0	–	8.0	3.13	3.47
Pyrite	1.0	–	–	–		
Chlorite	–	5.0	4.0	2.0	2.75	2.22
Carbonate	–	–	5.0	–		
Garnet	–	0.5	–	–		
Tourmaline		1.0	–	–		
Apatite		0.5	–	–		
Carbonaceous matter	–	1.0	–	–		
Clay	–	1.0	3.0	–		
Zircon/Rutile	–	–	0.5	–		

TABLE — 4

Chemical Composition of Gondwana Boulder Bed (Metaconglomerate)

SSamples No.	PKM-77-AS-76
Localities	Kalamula
Coordinates	221927
Rock Type	Gondwana boulder bed
SiO_2	75.95
TiO_2	0.00
Al	
Al_2O_3	9.61
F	
Fe_2O_3	7.86
MnO	0.00
MgO	0.91
CaO	0.91
Na_2O	0.00
K_2O	1.55
I/L	3.14
Total	99.96

TABLE — 5

Spectrochemical Composition of Gondwana Boulder Bed (Metaconglomerate)

Samples No.s		PKM-77-	PML-77-	PML-	PML-77-	PML-77-		
Localities		Malamula	Maili	Maili area	Reji-Maili area	Reji-Maili area		
Coordinates		221927	252913	252913	269913	269913	$\bar{X}$	S.D.
ZrO_2	(%)	0.01	0.014	0.014	0.014	0.01	1.79	
La	(ppm)	10	100	20	20	50.00	45.83	
Y	"	10	10	20	10	5	11.00	5.48
Mo	"	–	5	10	–	–		
V	(%)	0.008	0.050	0.040	0.010	0.010	0.02	0.02
Sc	(ppm)	–	–	–	–	10	–	
Pb	(ppm)	50	50	50	50	–		
Cu	"	100	5	5	5	5	24.00	42.49

TABLE 6

Spectrochemcal Composition of Gondwana Schists/Phyllites

Sample Nos.		PML-77-PSH-113	PML-77-MFW-160
Localities		Sangla Nala Maili Area	Sangla
Coordinates		252913	256915
Rock types		Chlorite-mica Schist	(Biotite)-Chlorite-Mica Schist
ZrO_2	(%)	0.14	0.02
La	(ppm)	50	50
Y	"	10	10
Mo	"	5	10
V	(%)	0.02	0.04
Sn	(ppm)	–	50
Pb	"	50	50
cu	"	5	5

A NEW STRUCTURAL INTERPRETATION OF THE HAZARA KASHMIR SYNTAXIS SOUTHERN HIMALAYAS, PAKISTAN

PAUL BOSSART, DOROTHEE DIETRICH, ANTONIO GRECO, ROBERT OTTIGER & JOHN G. RAMSAY

Geological Institute, ETH-Zentrum
CH-8092 Zurich, Switzerland

ABSTRACT.– The stratigraphic and structural features of the Hazara Syntaxis are described. The principal lithological features of the geological formations are reviewed and a special type of rhythmic sedimentation which characterises the structurally lowest Murree formation is described in detail. The region is one of overthrust and shear zone tectonics associated with the development of at least two superimposed sets of major folds and associated minor structures (Microfolds, cleavage, vein systems and various types of lineations related to rock strain or intersection of planar structures). It is concluded that the syntaxis results from an early set of nappe units developed by southwestward overthrusting of a previously metamorphosed (Himalayan) rocks followed by the formation of a large shear zone structure and finally by the transport of overthrust units from northwest to southeast.

INTRODUCTION

The large scale tectonic structure of many mountain chains is often characterized by features which might be termed structural re-entrants or syntaxial bends where the main linear trends of folds and faults show a marked deflection from the regional line. Various ex-planations have been put forward to account for such syntaxial bends, some necessitating discontinuities of the deeper parts of the crust others requiring relatively superficial geometric modifications at high tectonic levels. Because of the recurrence of such features we were of the opinion that it would be scientificially profitable to in-vestigate the structural geological features of one such bend using the techniques of modern structural geology. We chose for this in-vestigation a well exposed and previously investigated syntaxis, the Hazara syntaxis, exposed in the southern Himalayan region of Azad Kashmir in Pakistan. The Hazara syntaxis consists of a complex series of overlapping nappes made up of various Precambrian, Palaeozoic and Mesozoic formations which have been overthrust on a group of predomi-nantly red-brown coloured clastic sediments, the Murree Formation of Tertiary age. Previous work in this region (Calkins et al., 1975) had indicated that it might be possible to measure the finite strain state (Wadia, 1931; Tahirkheli Khan, 1982) of the deformed rocks and determine the finite strain ellipsoid forms through the region, and to evaluate the significance of the small scale folds, cleavages and lineations. In this paper we set out the preliminary results of these new structural studies and give an account of their tectonic significance. Current and future work is being undertaken to evaluate further the geometric problems and to evaluate various geophysical parameters of the rocks (Palaeomagnetism, magenetic anisotropy). The new data presented in his paper have primarily resulted from a remapping of the region. The northern apex zone of the syntaxis has been remapped in considerable detail (Bossart and Ottiger) while the data from the central and southern part have been developed by local detailed mapping linked by reconnaissance traverse investigations (Dietrich, Greco, Ramsay).

In carrying out this work we have received assistance in many ways; geological, logistical and social, from a number of Pakistan geologists. Without this assistance our work could not have gone for-ward. In particular we wish to give our special thanks to Professor Khan Tahirkheli, Syed Tayyab Ali and Mir Abdul Latif and to the members of staff of the University of Azad Kashmir at Muzaffarabad and at the University of Peshawar. Not least we would like to thank the many students of the University of Azad Kashmir for their help and friendship during the course of the work. We wish also to thank the ETH Zurich for providing funds for this research (Forschungsprojekte Nr. 0.330.060.33/9 and 0.330.084.48/4).

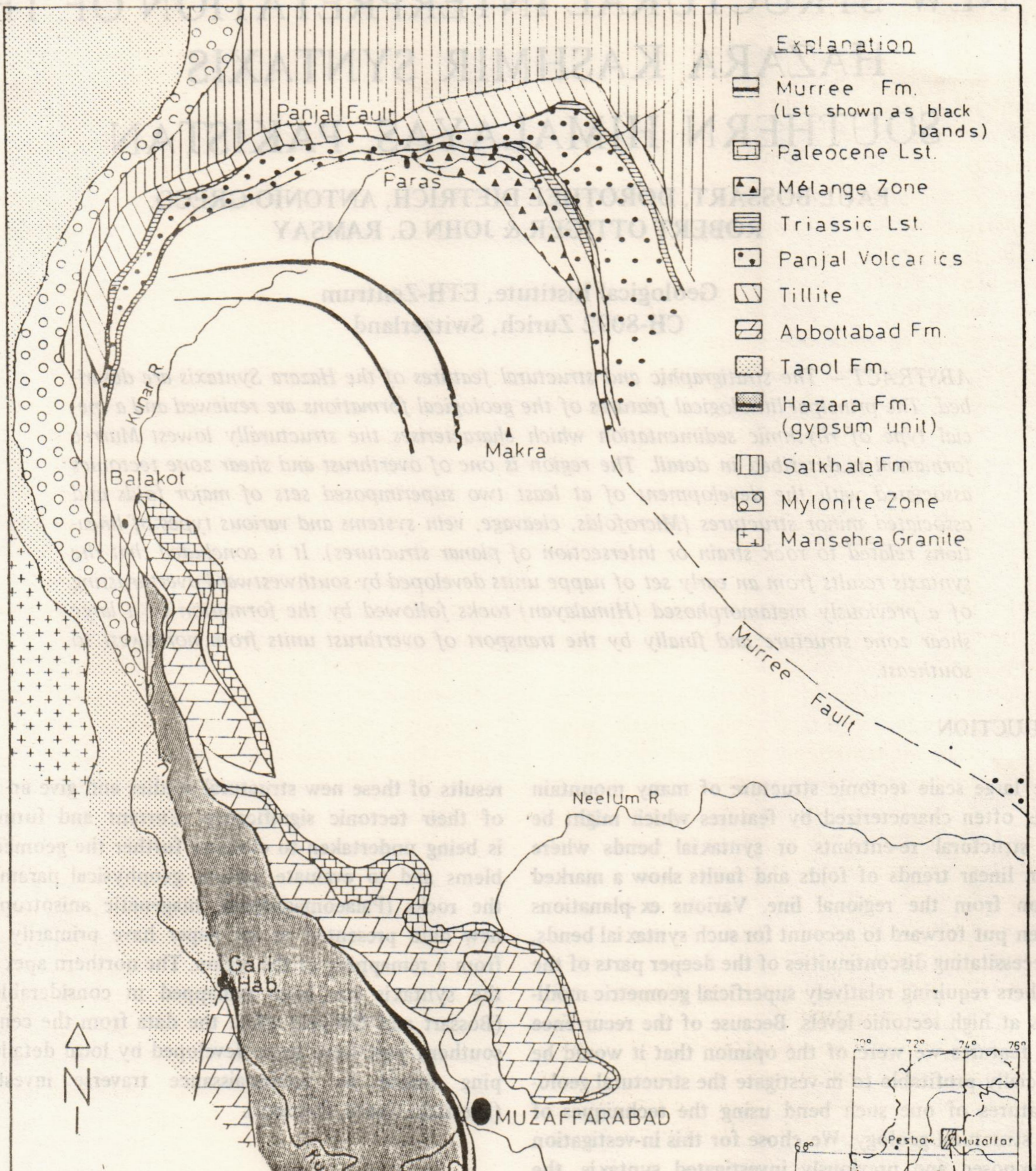

Explanation
Murree Fm.
(Lst shown as black bands)
Paleocene Lst.
Mélange Zone
Triassic Lst.
Panjal Volcanics
Tillite
Abbottabad Fm.
Tanol Fm.
Hazara Fm.
(gypsum unit)
Salkhala Fm.
Mylonite Zone
Mansehra Granite
Panjal Fault
Paras
Kunhar R.
Makra
Balakot
Murree Fault
Neelum R.
Garhi Habib
MUZAFFARABAD
Jhelum R.
Neelum R.
0
km
10
Peshaw
Muzaffar
ISLAMABAD
Lahore
Karachi
Fig: 1

Fig : 2

BOSSARD ET AL

STRATIGRAPHY OF THE APEX REGION

The apex region of the Hazara-Kashmir Syntax is divisible in three, lithologicall as well as structurally different units (Fig. 1)

Unit 1: The Cambrian and Precambrian formations of the outermost rim

Unit 2: The upper Palaeozoic and Mesozoic formations between the Murree and the Panjal Fault

Unit 3: The Tertiary formations of the core of the apex region.

The outermost rim consists of the Cambrian and Precambrian rocks of the Hazara Zone where one finds the following formations: Salkhalas, Hazara formation, Tanol formation, Abbottabad formation.

PRECAMBRIAN AND CAMBRIAN FORMATIONS

Salkhalas

These rocks are mostly located on the eastern limb and in the hinge region of the Hazara Kashmir-Syntax is where they build up parts of the Pir Panjal Range and the mountains of the upper Kaghan Valley. On the western limb they can be traced as a narrow strip as far as the south of Hassa.

The type locality is located in the upper part of the Neelum Valley on the eastern flank of the syntax is (near Dhudnial). One finds there sltes, phyllites, schists, gneisses, quartzites and marbles of Precambrian age cut by tourmaline pegmatite dykes. The main feature which enables them to be distinguished from the overlaying Dogra slates is the abundance of graphitic material.

In the studied area the rocks are strongly metamorphosed (amphibolite facies) and show well marked deformation features which will be discussed later.

Hazara slate formation

Black and grey phyllitic slates, weathering brown and dark green, are the most important lithological units of the Hazara slate formation (Marks and Muhammad Ali, 1961). In this slate unit, fine to medium grained, thick bedded graywacke sandstone are also found. In the mapped area the principal sedimentary structure observed is a thin alternating lamination of clay and silty size material, but locally graded bedding can be found. Around Muzaffarabad other lithological units are distinguishable: a gypsum unit and a limestone unit appear to lie in conformable stratigraphical position with the surrounding slates. However, the relationships of the slates with the eastern dolomitic-quartzitic unit on the contrary may be tectonic, because open folding and imbricate faulting systems, which can be related to the southward movement direction of the Hazara formation along the Murree Fault, are found.

The sedimentary structures of the slates (fine lamination, bottom marks, slumps, graded and cross bedding), and the considerable thickness of the formation suggest a turbidite, flyschoide character of the sedimentation. Thicker graywacke sandstones are probably related to somewhat more proximal sedimentation or to a local increase of the input of more coarse detritic material. Changes in depositional environments are suggested by the presence of limestone and some arenaceous banks, and the formation of gypsum in shallow marine environment.

It the study area, the relationships between the Hazara formation and the other mapped formations are tectonic. The gypsum and limestone units lie in conformity with the slates, but the lack of fossils does not allow any direct dating of the formation. A Late precambrian age has been suggested by previous workers (Marks and Muhammad Ali, 1961; Muhammad Ali, 1962; Gardezi, 1968; Calkins et al., 1975).

Tanol (Tanawal) formation

In the studied area one can find the rocks of this formation west of the Panjal Fault, from the Batrasi Summit area, over the slopes of the lower Kaghan valley, up to Musaka Musallah. At the type locality (Tarbela), Offield, Calkins and Ali subdivided this formation into four units: basal conglomerate, lower quartztie, schists, upper quartzite.

At the Garhi Habibullah region, however, one finds only medium grained quartzites and fine grained quartz-mica schists which, south of Balakot, pass into garnet mica schists. The grade of metamorphism increases from south to north, and the various combinations of the main mineral constituents result in a great variety of rock types. Of particular interest from the structural point of view are the garnet mica schists, with garnets showing snow-ball structure.

The age of these rocks is considered to be Precambrian.

Abbottabad formation

The core of the Muzaffarabad anticline, which can be traced from Muzaffarabad to Balakot, is composed, for the most part, of rocks of the Abbottabad formation. Calkins (1966) separated these rocks into three units: dolomite unit, black limestone unit within the dolomite unit, sandstone and conglomerate unit.

Chert-bearing dolomites predominate. These locally show well developed stromatolite structure. The characteristic cauliflowerlike shape of the stromatolites gives an excellent marker of the younging direction of the rock (Fig. 2). Other very important features are the quite abundant synsedimentary breccia layers which appear to have formed during storm periods, when the algal material became broken apart and redeposited. The deposition range of this Unit is supposed to be intertidal to possibly lagoonal.

The discovery of Cambrian hyolites (Latif, 1969) at the overlying Hazira formation suggests that the Abbottabad formation is of Cambrian or even late Precambrian age.

Mansehra granite

The rocks of the Salkhala, Hazara and Tanol Formation are intruded by the 516–16 my old Mansehra granite (Le Fort, 1979): a leucocrate granite with large porphyritic crystals of feldspar.

UPPER PALAEOZOIC AND MESOZOIC FORMATION

The Palaeozoic and Mesozoic rocks of the apex region form a rim whose northern boundary is represented by the Panjal Fault and the southern one by the Murree Fault. They are mainly composed of tillitic rocks, volcanics, and limestones.

Chushal formation: conglomerates and tillites

This formation has been divided into three different units, tillite, conglomerates and schists. The tillites are composed of slates, limestones, gneisses and tourmaline pegmatite components in a shaly matrix. In the Chushal region (near Shinu, Kagan Valley) one can observe a transition from tillites to conglomerates. Conglomerates are especially well developed in the region of the Chushal Katha. The components of up to twenty centimeters in diameter are gneisses, tourmaline pegmatites, quartzites, shales and limestones. At Phagna Katha the conglomerates pass laterally into a glaciofluviatile subarkose.

Graphite schists attain a considerable thickness along the Kaghan road east of Shino. The best outcrops of these graphitic schists contain much idiomorphic pyrite.

The rocks of these three subunits are comparable with those described by Middlemiss (1910) and Wadia (1931) called agglomeratic slates. During the present reinvestigation, however, no sign of volcanic material was identified.

The age of this formation is, according to the work of Bion and Middlemiss (1928) probably Carboniferous to Permian.

Panjal Volcanics

These predominantly dark green to olive coloured volcanics occur mainly in the greenschist facies, and are of intermediate to basic composition. The most characteristic feature of these rocks are the abundant amygdules and pipe vesicles filled with chlorite, epidote, or jasper and chalcedony. There is often a marked increase in the number of amygdules towards the top of a layer as a result of volcanic degassing and, by making a study of these, it has sometimes been possible to separate individual flows and their younging directions.

The Panjal volcanics show a normal stratigraphic contact with the overlying Triassic carbonates and at a few places one can observe an interbedding of carbonates and volcanic rocks (near Fridabad).

Triassic limestones and dolomites

These rocks mainly build up of two large bands, one at Fridabad and the other near Shino. They are yellow to grey weathering microsparitic, flaggy limestones which show a marked pyrite lineation. At Shino, one finds an dolomites and sparitic limestones. The quite abundant fossils are unfortunately in a very bad state of preservation and therefore not precisely determinable. These consists of crinoids, gastropods, bivalves and a few relicts of reptile bones (Mandi, Jalora Katha). From their general stratigraphic relationship one can assume a Triassic age.

The Melange zone

This zone covers the region between Paras and Malkandi, in the north-east of the apex region. Roughly one can distinguish six different subzones (Fig. 3):

1) black micritic limestones of upper Cretaceous age

2) Palaeocene and lower Eocene limestones (Lockart and Patala formation

3a) sparitic limestones of upper Permian to lower Triassic age

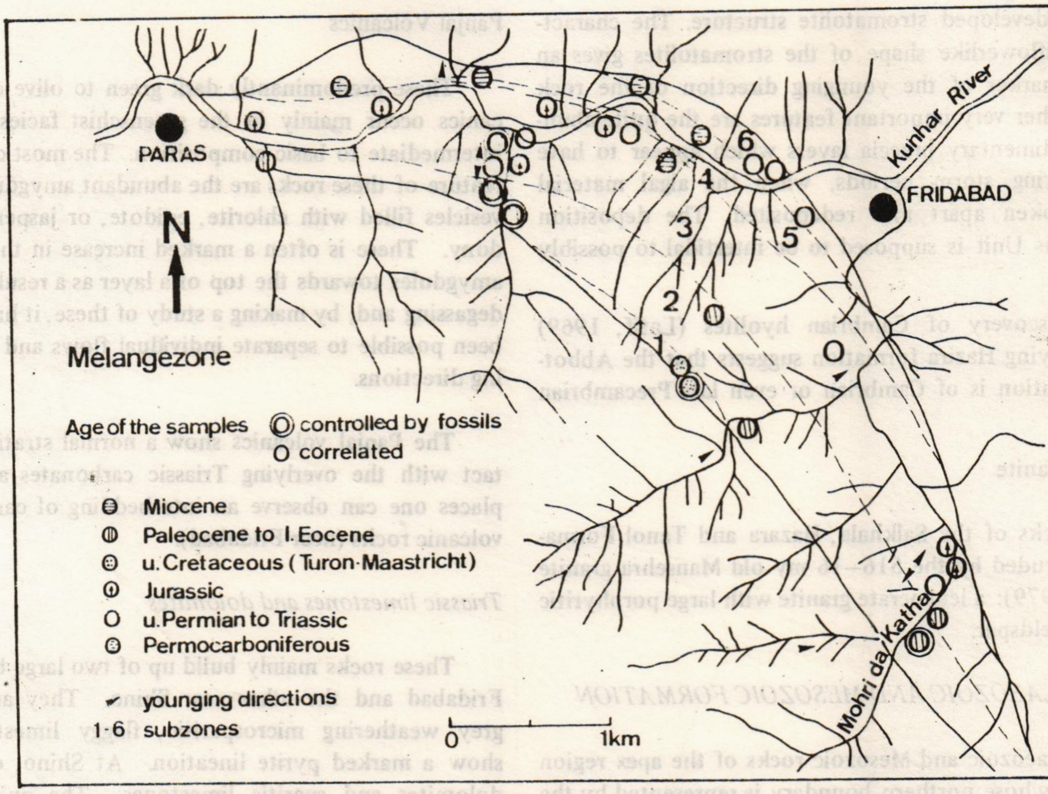
3b) oolitic limestones (Samana Suk), Jurassic

4) red shales of the Murree formation

5) a very heterogeneous group of arenites, pelites and marbles (Carboniferous?)

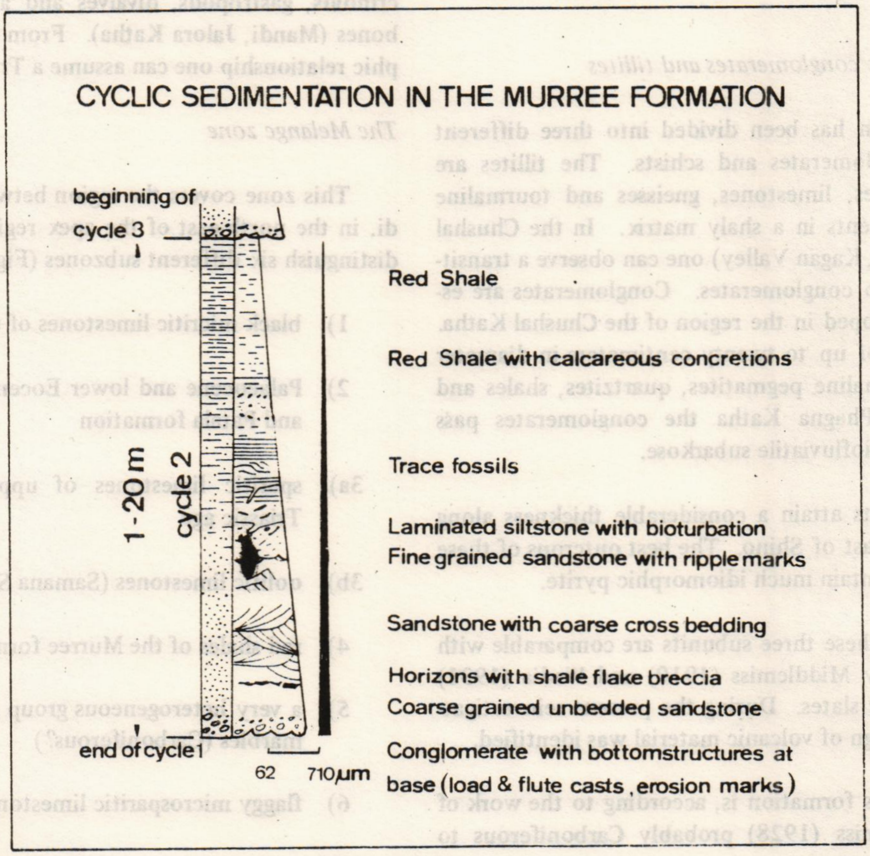
6) flaggy microsparitic limestones of Triassic age.

Closer investigation of these rocks, especially at the



PARAS
FRIDABAD
Kunhar River
Mohri da Katha
N
1
2
3
4
5
6
Mélangezone
Age of the samples ◎ controlled by fossils
O correlated
Miocene
Paleocene to l. Eocene
u. Cretaceous (Turon-Maastricht)
Jurassic
u. Permian to Triassic
Permocarboniferous
younging directions
1-6 subzones
0
1km

Fig: 3



CYCLIC SEDIMENTATION IN THE MURREE FORMATION
beginning of cycle 3
1-20 m
cycle 2
end of cycle1
62
710µm
Red Shale
Red Shale with calcareous concretions
Trace fossils
Laminated siltstone with bioturbation
Fine grained sandstone with ripple marks
Sandstone with coarse cross bedding
Horizons with shale flake breccia
Coarse grained unbedded sandstone
Conglomerate with bottomstructures at base (load & flute casts, erosion marks)

Fig: 4

Mohri da Katha, shows that the components are mixed in a very heterogeneous chaotic way. Huge blocks are separated by a black shaly matrix, the blocks showing no coherent stratigraphic relations to each other. This whole sequence is considered as a zone of a tectonic melange and not a stratigraphic succession.

TERTIARY FORMATION

The core of the Hazara Kashmir Syntaxis is mainly built up by the Tertiary rocks: the Lockart limestones, Patala Formation, Margala Hill limestones and the Murree Formation.

Lockart limestones, Patala formation, Margala Hill Limestones

The occurrence of these three formations is mainly restricted to the Muzaffarabad anticline and to a few outcrops east of Paras. One finds these black limestones with marly intercalations (Lockart limestones), marls and shales with intercalations of sandy limestones (Patala formation) and black nodular limestones (Margala Hill limestones), of upper Paleocene to lower Eocene age.

The main rocks forming the core of the syntaxis, however, are the green and red sandstones and shales of the Murree Formation.

Murree formation

The characteristic feature of these somewhat monotonous, continental to shallow marine (tidal flat) clastic series, is a pervasive cyclicity. The thickness of the different cycles fluctuates between half a meter . The cycles show a strong graded bedding (fining upwards) with grain sizes at the base between 710 and 250 microns and less than 62 microns at the top. The cycle represented in figure 4 is a schematic model of the main features shown by the cyclic strata.

The base is sometimes marked by a conglomerate with a considerable variation in the composition of the components as well as of the matrix. The most abundant components are reworked red shales from the underlying cycle. However, coarse grained channel fill deposits are not always present and the cycles then start with a greenish, coarse grained litharenite with well developed sedimentary structures at their base (flute casts, load casts, erosion marks and bioturbation structures).

These rocks are also characterised by coarse cross-bedding. The heavy mineral content shows some peculiarities. Locally, in small lenses and thin bands, one finds chromium spinel together with magnetite, zircon and tourmaline.

Together with the decrease of the grain size there is a change of the sedimentary structures to asymmetric current ripples and symmetric wave dominated ripple marks.

The next higher unit is composed of red, parallel laminated and strongly bioturbated, fine grained sandstones which in their turn pass into argillaceous silts, containing many calcareous concretions of up to a few centimeters in diameter appearing to represent a kind of a caliche horizon.

The top of a cycle is mostly built up by red and green shales which contain sub-spherical or ellipsoid reduction spots of diagenetic origin.

TECTONIC STRUCTURES

The structural map, Fig.5, gives a synthesis of the tectonic structures observed around the syntaxis.

Cleavage

Practically all the rock units in the region show at least one well developed cleavage. Orientation as well as intensity of the cleavage are related to the orientation and intensity of the strains which have affected the various units. The direction of the strike of the main cleavage and the intensity of cleavage development are indicated schematically in the map.

In the Murrees the cleavage strike trends fairly regularly in a northwestwards direction. The cleavage increases in intensity towards the apex of the syntaxis and from SW to NE across the syntaxis. Along the Neelum valley, and in the contact zone with the Murree thrust, along the westside of the syntaxis, the cleavage strike trends more westwards than that of the overall regional direction.

The cleavage is cut discordantly by the Murree thrust. In the lowermost Panjal units the cleavage strikes sub-parallel to the Murree thrust. In these units, as well as in the overlying Salkhalas, there exists a second cleavage testifying a polyphase deformation history. In the Hazara slates a well developed slaty cleavage is the most evident tectonic feature in outcrop scale. It is related to a strongly developed isoclinal folding of the slates. A second cleavage can be frequently observed N of the Kunar River, which crenulates the first phase cleavage. This crenulation cleavage is related to large open folds which refold the first phase isoclinal folds.

The overall cleavage pattern in the Murrees is that of a planar fabric related to the folding and overthrust history of the region. The tectonic units overlying the Murrees

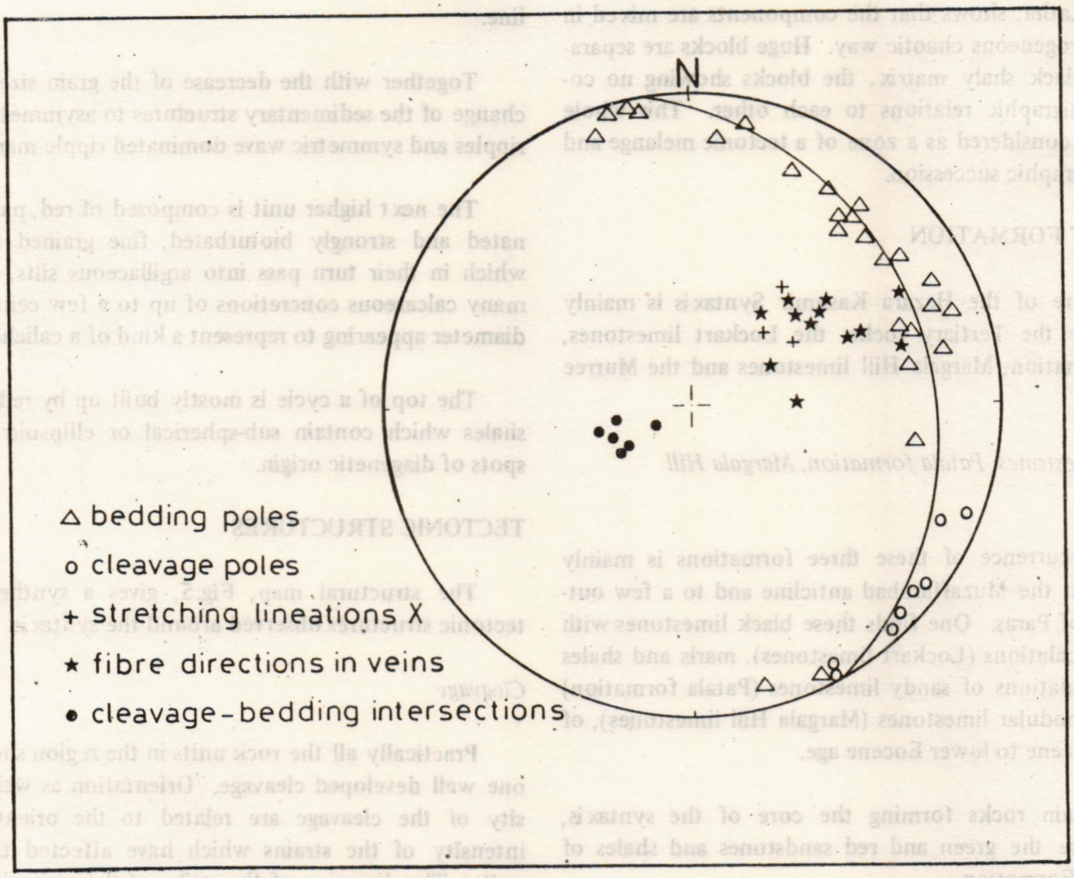


Fig: 6

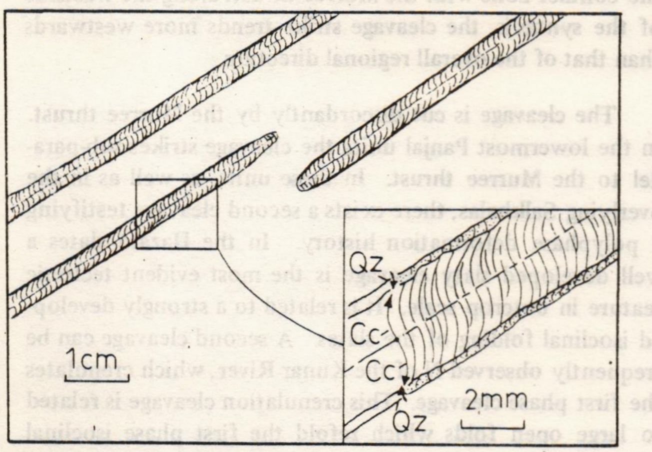


Fig: 7-A

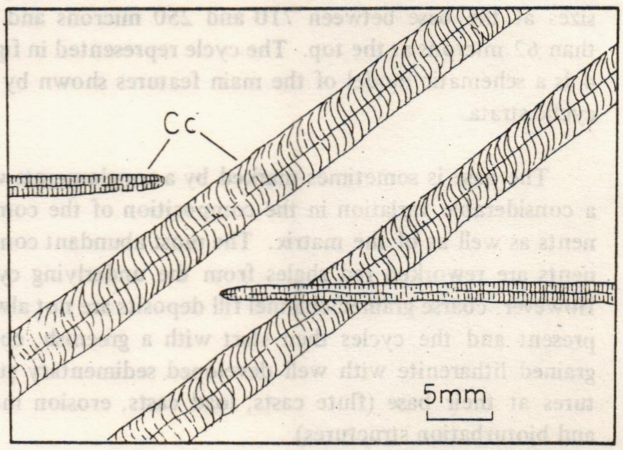


Fig: 7-B

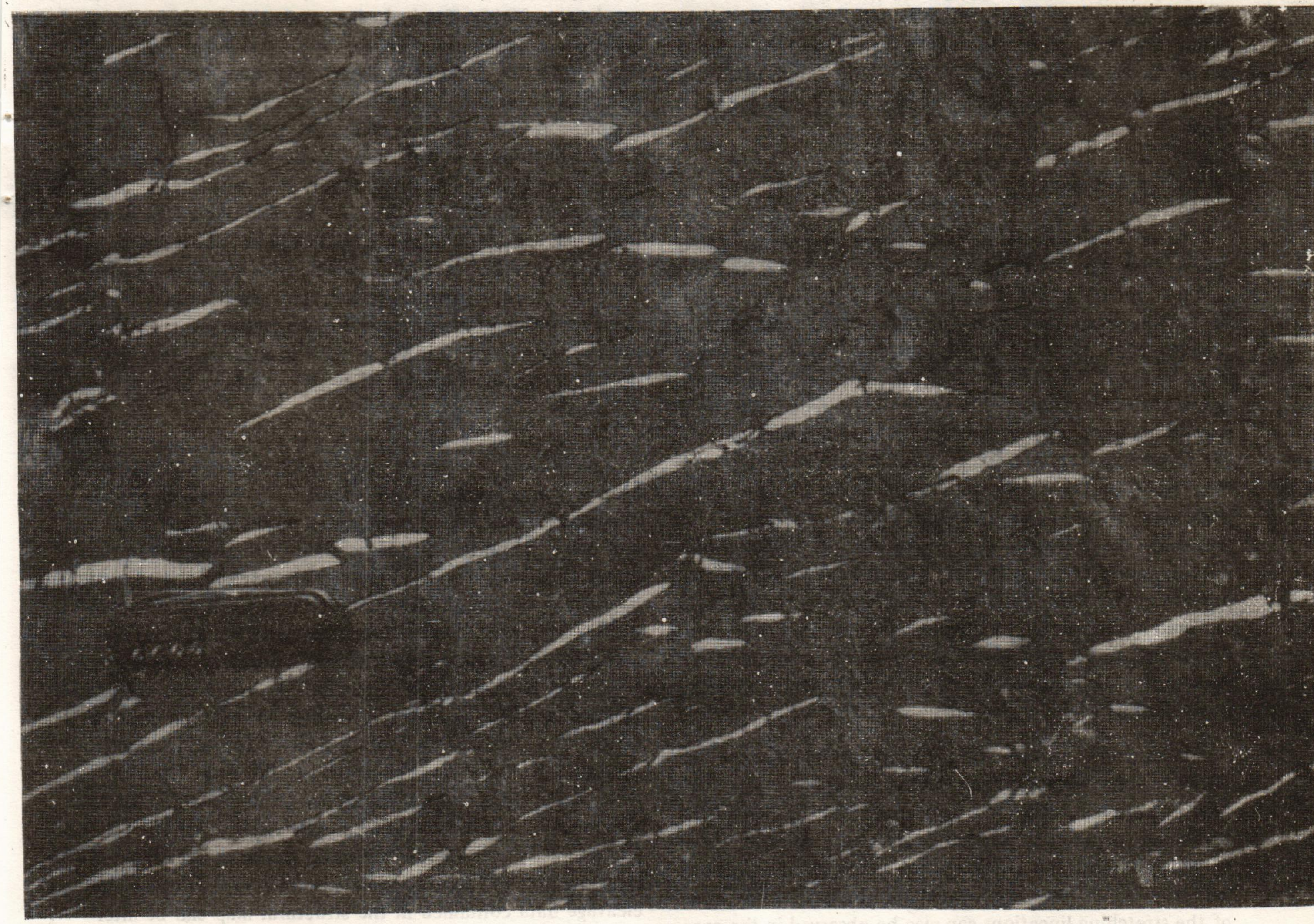


Fig: 8

bend slightly into a zone of high deformation W of Balakot. Confined post-thrusting deformation is responsible for this shear zone pattern emphasized so clearly on the structural map. The cleavage planes of these units bend also into the shear zone, that is, they are as well deformed and partially verprinted by it. The cleavage in the Murrees, on the contrary, appears only to be slightly deflected by the shear zone. The strike of the second cleavage present in the units overlying the Murrees cuts the shear zone fabric obliquely which indicates that this last cleavage is later than the shear zone.

Stretching lineations

Often on a cleavage plane there can be observed a stretching lineation. Where the finite strain state of a rock can be determined these stretching lineations are generally parallel to the finite extension direction in the rock, that is, parallel to the X-axis of the finite strain ellipsoid (with axes X Y Z). This is easy to demonstrate in the Murrees, where many examples can be found of stretching lineations parallel to the longest axis of deformed reduction spots. In the Hazara slates a stretching lineation can be found on the first phase cleavage planes. This lineation consists of an alignment of phyllosilicates and can be observed to be parallel to the extension direction of pressure shadow fibres around pyrite crystals, another feature of importance as a marker of the finite extension direction in a rock. For a tectonic interpretation of a region the stretching lineations can therefore be used to define an extension pattern in a rock unit, which is directly related to the kinematic history of these units.

Stretching lineation directions from the Murrees are shown in three stereoplots on the structural map. These are lower hemisphere equal area projections. The plunge of the stretching lineation is generally very steep towards NE, in accordance with the generally steep dip of the cleavage planes on which they are located. An overall NE-SW trend of the stretching lineations can also be observed in the overlying Panjal units, the Salkhalas and the Hazara slates.

In mountain chains which are characterised by a sequence of overthrusts, it is reasonable to assume simple shear as an overall type of deformation for the rock units involved in the chain. Since it is probable that the stretching lineation fabric in and around the syntaxis can be related to certain aspects of the overthrust history of the tectonic units, the strain pattern indicates a major transport direction of these nappes from NE towards SW.

Folding

Although in the Murrees small scale folds are rather uncommon in outcrop scale, a moderately well formed cleavage-bedding intersection lineation can be measured. It is well known that, where cleavage and fold formation are synchronous, the cleavage-bedding intersection lineation lies parallel to the fold axis. Measurements of these intersection lineations from three regions in the Murrees, the Kaghan valley, the Neelum valley and the Jhelum valley southeast of Muzaffarabad, are presented in three lower hemisphere stereoplots on the structural map, Fig.5. In these plots the intersection lineations may be compared with the stretching lineation directions from the same region. In the Jhelum valley the plunge of the intersection lineations is fairly low, in the Neelum valley it is steeper, and in the Kaghan valley it is very steep. The intersection lineations also show an increasing degree of preferred orientation from the Jhelum to the Neelum to the Kaghan valley, a feature which goes together with an increase in finite stratin state. The angle between the mean position of the intersection lineation and stretching lineation directions is 80o - 10^0 in the Jhelum valley, 40^0 - 50^0 in the Neelum valley, 0^0 - 10^0 in the Kaghan valley.

Regionally the most important major fold in the Murrees, the Muzaffarabad "anticline" shown in Fig.5, is emphasized in the structural map by the change of strike and dip demarkated by the bedding of the Murrees in the upper Kaghan valley. This fold is also clearly demarkated by polarity changes of the strata in the Neelum valley north of Muzaffarabad. Near Balakot this anticlinal structure has a fold axis plunging steeply towards northeast, whilst towards the Neelum valley the main fold axis is less steeply inclined and plunges at a low angle towards the east or southeast. The direction of this major fold axis changes therefore from being sub-parallel to the main overthrust direction in the Kaghan valley to being sub-perpendicular to the main overthrust direction in the Jhelum valley. The pattern of the intersection lineations can be cross correlated with the axis of this major fold structure. The bedding and cleavage data contained in the structural map can be interpreted as defining a very large elongated anticlinal dome structure, the cleavage showing an axial plane, fan-like distribution in this fold. Where the bedding and cleavage trends are parallel, the fold axis of the dome is horizontal (region to the northwest of the Makra peak). The two limbs of the structural dome are characterized by a change in the bedding-cleavage interrelationship. In the Kaghan valley the cleavage is more steeply inclined than the bedding, and the strike is clockwise relative to that of the bedding and cleavage are steep but the cleavage strike is anticlockwise relative to that of the bedding. The Cambrian strata between Muzaffarabad and Balakot represent the core of the Muzaffarabad fold structure (Calkins et al., 1975). Calkins et al. (1975, p. 23) describe the Muzaffarabad "anticline" and "sharply overturned southwest, and ... crossfolded". Crossfolding is evident from the map pattern

(Figs. 1 and 5). The structure is in effect an anticlinorium, and very complicated in detail. Fig.6 is a stereoplot containing data from a later synform in the Jhelum valley which is superposed across the anticlinorium. The location of this synform is indicated on the structural map. The stereoplot shows poles of bedding and cleavage planes which define a great circle. The measured bedding-cleavage intersections correspond well with the pole to the great circle, or the fold axis. This fold axis differs in plunge remarkably from the bedding-cleavage intersection lineations for the main phase deformation structures in the Jhelum valley as indicated in the stereoplot on the structural map. Fig.6 contains also three measurements of stretching lineation directions, or finite strain extension directions, from the fold limbs, as well as measurements of (fibre extension directions from veins, which correspond with the stretching directions. This indicates an oblique stretching of the fold limbs relative to the fold axis. All of these structural features are in accord with the structure being obliquely superposed on the main structures, and showing a later compression in a N-S or NNW-SSE direction.

In conclusion, the major fold in the Murrees appears to be an early structure which developed by layer compression originally sub-perpendicular to a southwestwards directed overthrust direction. During this main phase of overthrusting the fold axis was itself deformed, giving rise to the different intersection lineation patterns recorded in the Kaghan and Neelum valleys. It appears that, as the deformation increased, the fold axis rotated towards the maximum finite elongation marked now by the stretching lineation. This later shear deformation, localised in a zone west of Balakot, affected the core of the Muzaffarabad anticline. The azimuths of individual fold axes of this anticlinorium rotated in a clockwise direction and steepened, leading to the marked closed pattern of the strata at the north end of the anticlinorium in the apex of the syntaxis.

In the Hazara formation the principal fold axes are strongly dispersed, plunging towards N or S, as indicated on the stereoplot included in Fig. 5. An older, penetrative set of originally NNW-SSE trending folds is crossfolded by younger E-W directed folds. Observations in the Jhelum valley around Muzaffarabad show extremely variably oriented fold axes and cleavage-bedding intersections as a result of the interference of the two fold phases.

The Murree fault cuts the structures related to the Muzaffarabad "anticline" and must be, at least in part of its development, later than this structure. It also brings highly cleaved Hazara slates discordantly over the two sets of fold structures seen around Muzaffarabad, and therefore its final development as a fault surface must be late in the overall structural history.

Tectonic veins

In the Murree formation various system of calcite-and quartz-filled syntectonic veins exist. These veins were formed during the deformation history of the formation, because it can often be observed that they are sub-perpendicular to the long axes of strain ellipsoids defined by reductions spots, and therefore related to the principal deformation of the rock. Veins are particularly well developed in the apex of the syntaxis where the finite strains reach maximum values. Towards the south, for example in the Neelum valley where the finite strains are low, they are more rare. Most veins in the Murrees exhibit a fibrous structure. Measurements of fibre directions are important, because the fibres mark the opening path of the spreading vein wall rock and can therefore be used to reconstruct part of the deformation history of the surrounding wall rock (Durney & Ramsay, 1973). The growth geometry of the fibrous veins is usually composite: the central part of the veins consists of calcite fibres, whilst along the border exist thin seams of quartz fibres (Fig. 7A). The calcite fibres grow from a median suture towards the lateral suture between calcite and quartz fibres (antitaxial growth), the quartz fibres grow from the vein border towards the lateral suture between quartz- and calcite fibres (syntaxial growth) Some veins contain only calcite which is developed in an antitaxial manner (Fig. 7B). In the apex of the syntaxis vein systems with systematically changing lineation have been found. An earlier system of more steeply inclined older veins bends in a later system of flat laying younger veins (Fig.8). This rotation is also recorded in the sense of curvature of the fibres in the veins. The following facts must be considered for a tectonic interpretation of this rotation:

1) The vein formation is linked to the cleavage formation; this is clear from the study of thin secions. The material dissolved during the cleavage enhancement is partially redeposited in the veins.

2) Differences in rotation occur both within the cleavage (XY plane) and perpendicular to the cleavage (XZ plane). The sense of rotation deduced from the veins changes with the change of cross cutting relationships between the cleavage and bedding (Fig. 9).

The changes in incremental strain axes during the deformation show considerable complexity. Probably several equally plausible but different explanations can be made for the variation in directions in the XY-and XZ-plane, and we present below one explanation which appears to accord best with the variations seen in the major fold geometry and in the minor structures developed during folding.

First we will consider changes in strain history within

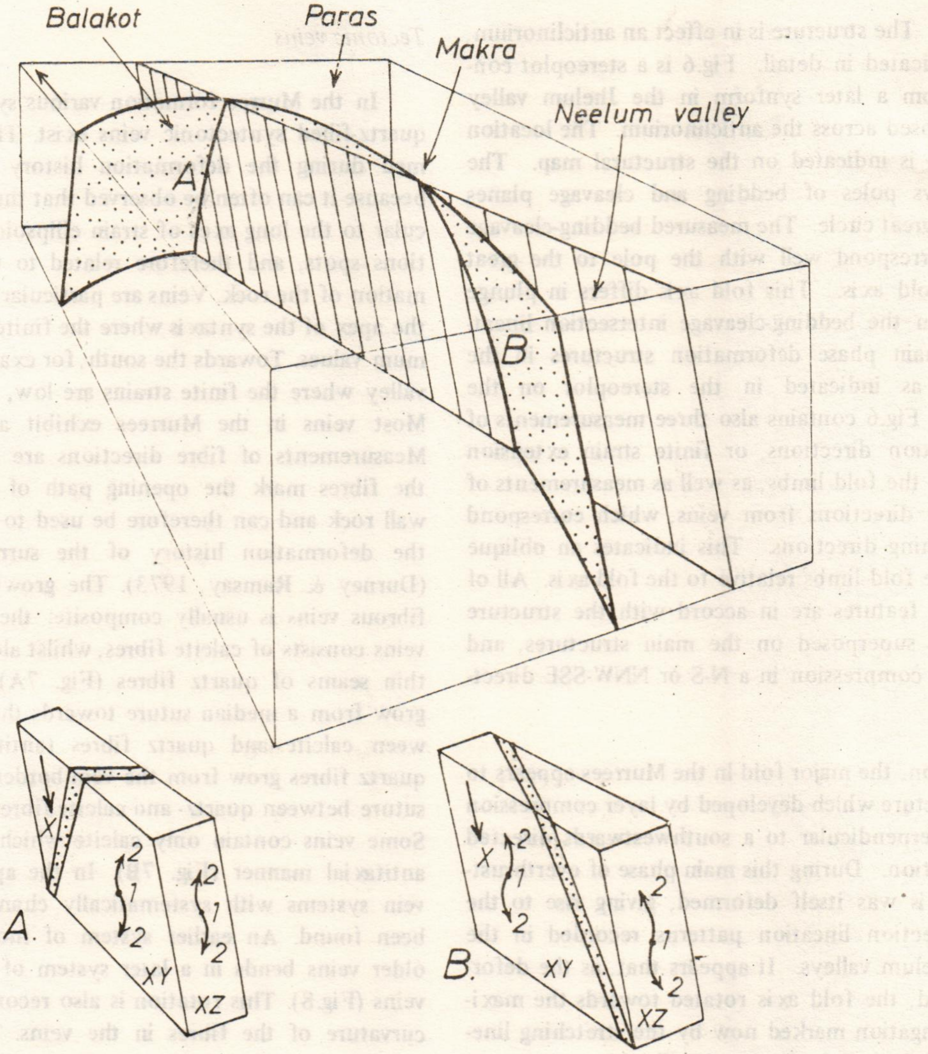


Fig: 9

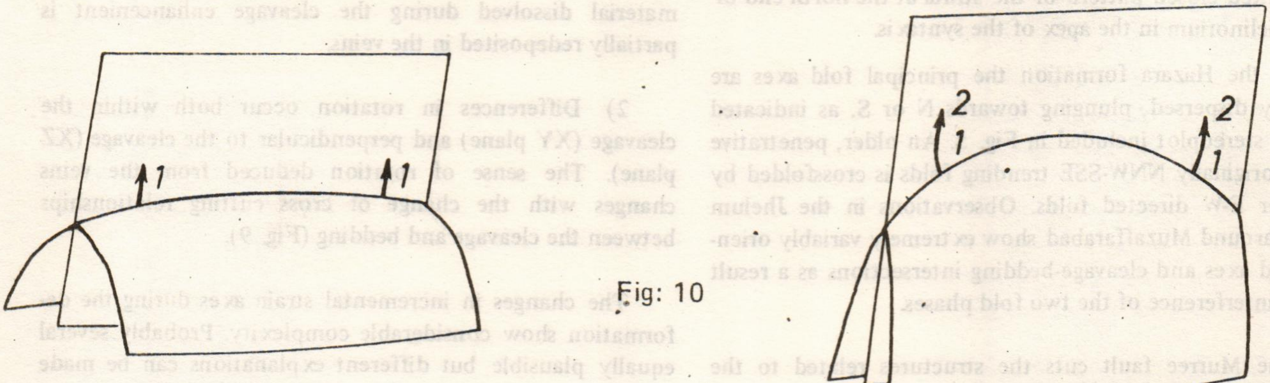


Fig: 10

the XY cleavage plane. In the northwesth of the syntaxis (Fig. 9, region A), where the cleavage strike is clockwise relative to that of the bedding, the incremental maximum strain changes show a clockwise sense (viewing the cleavage from the SE), whereas along the eastern side of the syntaxis (region B), where the cleavage strike is anticlockwise relative to that of the bedding the incremental strain axes change in an anticlockwise sense. Next, considering the changes in the XZ finite strain plane (perpendicular to the cleavage): looking NW along the cleavage these rotation senses are clockwise (region A) and anticlockwise (region B) respectively.

Because changes in the XY plane are systematically related to a change in cleavage-bedding intersection sense, and therefore to the overall fold axis direction, it seems likely that they are directly connected with the progressive evolution of the Muzaffarabad "anticline". These changes suggest that, as the fold evolved the domal nature of the main fold axis was accentuated by rotation of the fold axes (Fig. 10). The determination of the rotation sense in the XZ-planes is based on the cleavage plane being the frame of reference. If we assume instead the extension direction as a stable frame of reference during the formation of the vein system, the rotations observed indicate an opposite rotation of the rock unit containing the cleavage planes. Looking northwestwards along the limb the northwestern apex of the syntaxis (region A on Fig. 9) shows an anticlockwise bedding rotation, whereas in region B (in the Neelum valley) the bedding is rotated in a clockwise sense. These changes of strain history normal to the cleavage (XZ-plane) imply a type of torque-like rotation on the NE limb of the Muzaffarabad "anticline", with the axis of torque lying subhorizontally and in a NW-SE direction.

Mylonite Unit

Mylonites are found in a 1-5 km wide zone of ductile deformation along the western border of the syntaxis (Fig.5). This zone disappears towards the SW under the alluvium of the Mansehra valley. The mylonites can be followed towards the northeast into Kohistan. The unit Consists of grainter mylonites, Cataclasites and Calcite mylonites. The granitic mylonites can be subdivided in two groups:

1) Mylonites with alternations of dark mica rich layers and quartz layers. The quartz layers consist of quartz ribbons with a crystallographic preferred orientation.

2) Mylonites with feldspar clasts (microcline, potassium, feldspar, plagioclase) in a quartz martrix. This matrix consists also of quartz ribbons, the quartz grains showing subgrain structures and recrystallised borders.

Both rock types show a well developed cleavage, steeply inclined towards the WSW, W and WNW. The quartz ribbons are parallel to the cleavage. The cleavage planes contain a flat lying stretching lineation, which in thin section is seen to be formed of elongated minerals. The cataclasites have the same mineralogical composition as the type 2 mylonites. However, they show only a brittle breaking up of the quartz and a weakly developed cleavage and stretching lineation. Shear bands with C-and S-planes (Berthe et al., 1979), as well as pressure shadows around the feldspar clasts, are characteristic features of those mylonites.

The sense of shear of the mylonites can be determined in thin sections perpedicular to the cleavage and parallel to the stretching lineation (XZ-sections). The criteria used are the crystallographically preferred orientation in the quartz ribbons, the asymmetry of the fragments in broken competent feldspar clasts (Fig. 11A) and the geometry of the shear bands (Fig. 11B). The shear sense is sinistral.

CONCLUSIONS

The observations on structures and stratigraphy as well as those on the pattern of the metamorphic isograds can be combined to propose a model of the formation of the Hazara syntaxis.

Figure 12A shows a possible pre-thrust configuration (of pre-Himalayan age) of the tectonic units discussed in this paper. The restoration is based on the observed geometry of the thrust sheets, i.e. the Salkhalas overlie the Panjal thrust sheets, which overlie the Murrees. The pre-thrust position of the Hazara formation is not clear, but it probably overlays the Precambrian metasedimentary and gneissic formations. The Salkhalas show in part Himalayan age amphibolite facies metamorphism, the three Panjal thrust sheets are of a greenschist facies, and the Murrees show a prehnite-pumpellyite facies metamorphism. The observation that the rock units of the highest metamorphic degree are today the tectonically highest in the chain, as well as the observation that the metamorphic isograds are cut by the actual Panjal- and Murree thrusts (although the surface traces of isograds and thrust planes are parallel), supports the idea that metamorphism preceded the Himalayan thrust tectonic events in the region. The onset of the earliest events was probably marked by the overthrust of the Salkhalas on the Panjal unit, followed by the formation of the Panjal thrust sheets, and then by an overthrust of all these units on the Murrees. This "piggy back" sequence of the overthrust history is proposed, because, apart from later complications in the west of the region, structures of

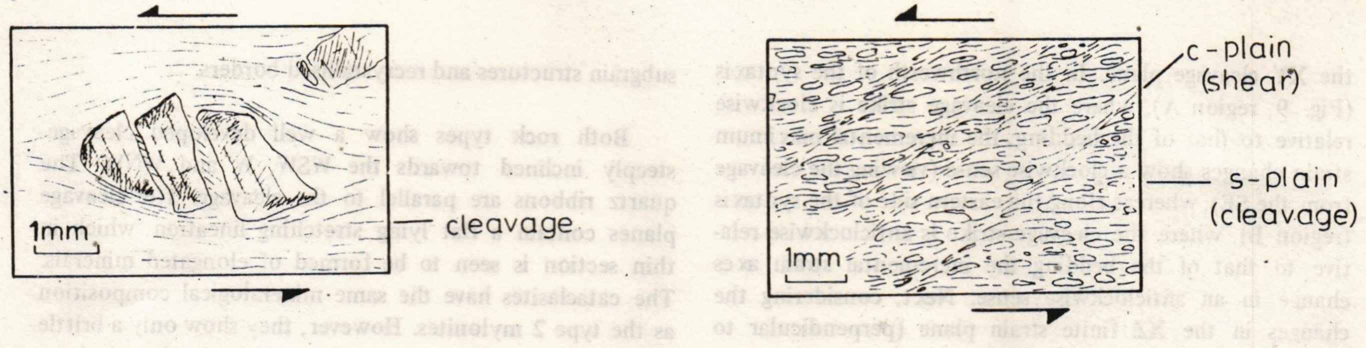


Fig: 11

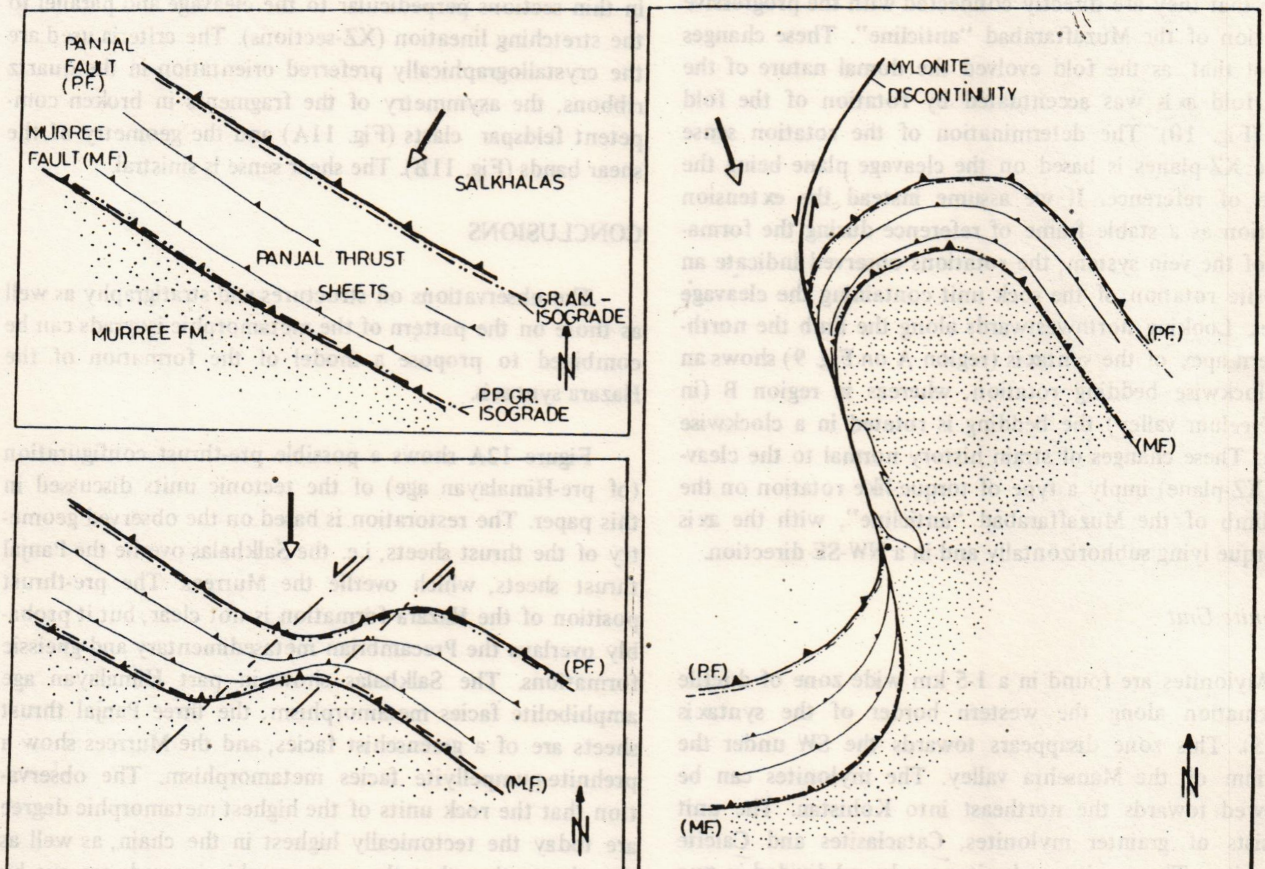


Fig: 12

BOSSARD et al., 1986

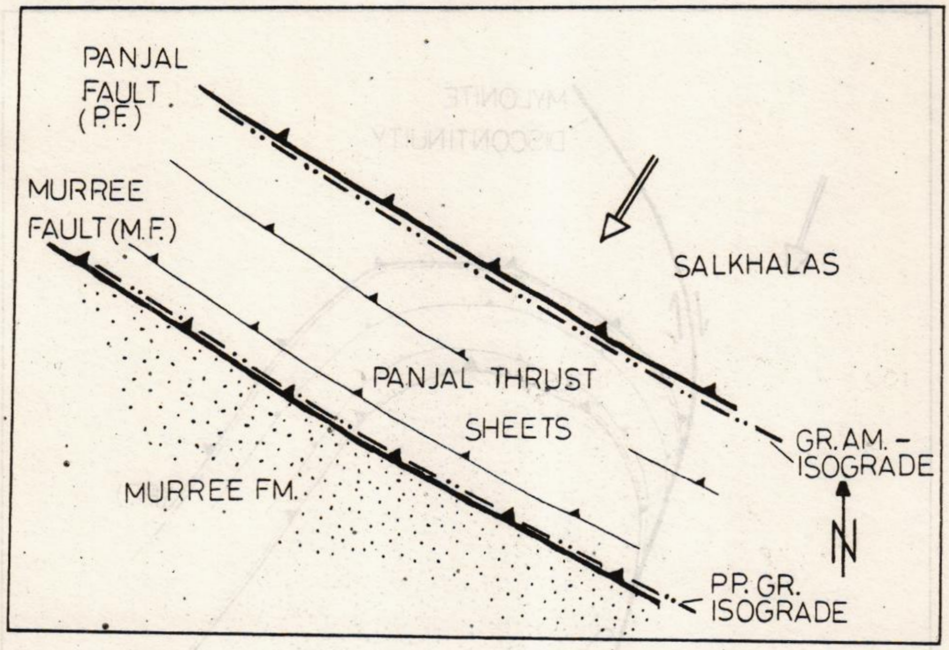


Fig: 12-A

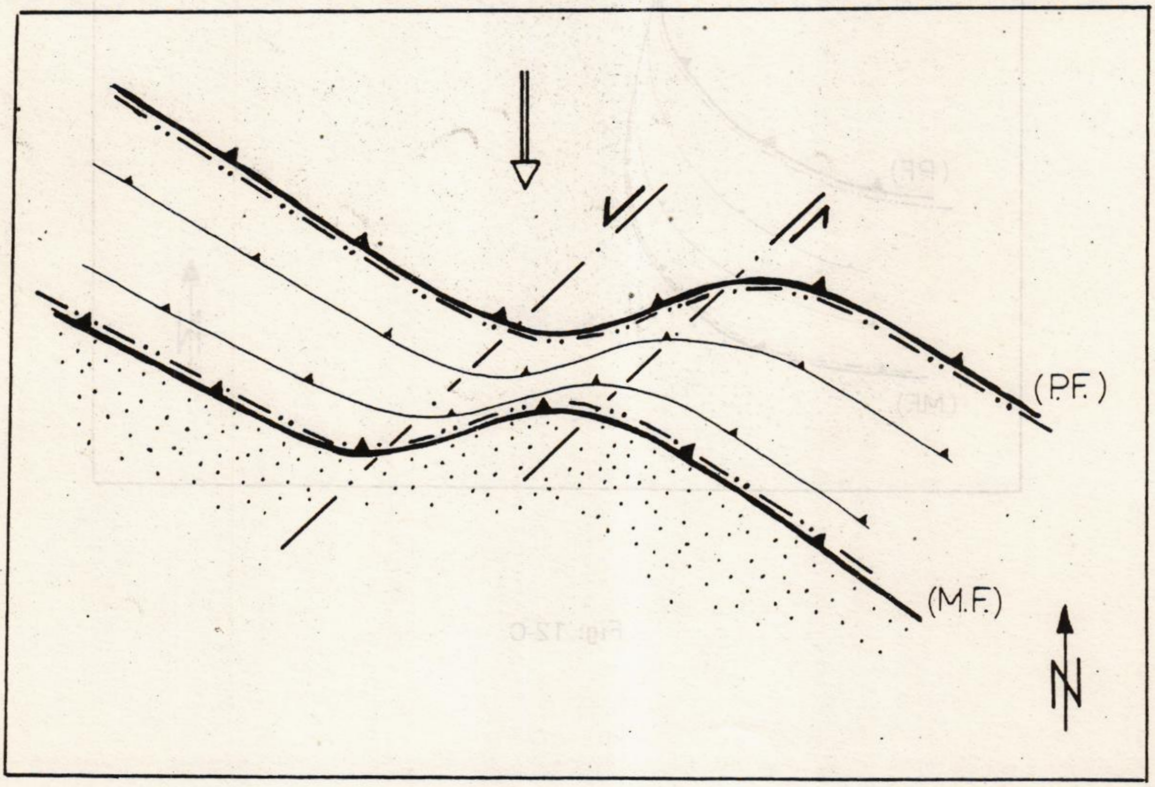


Fig: 12-B

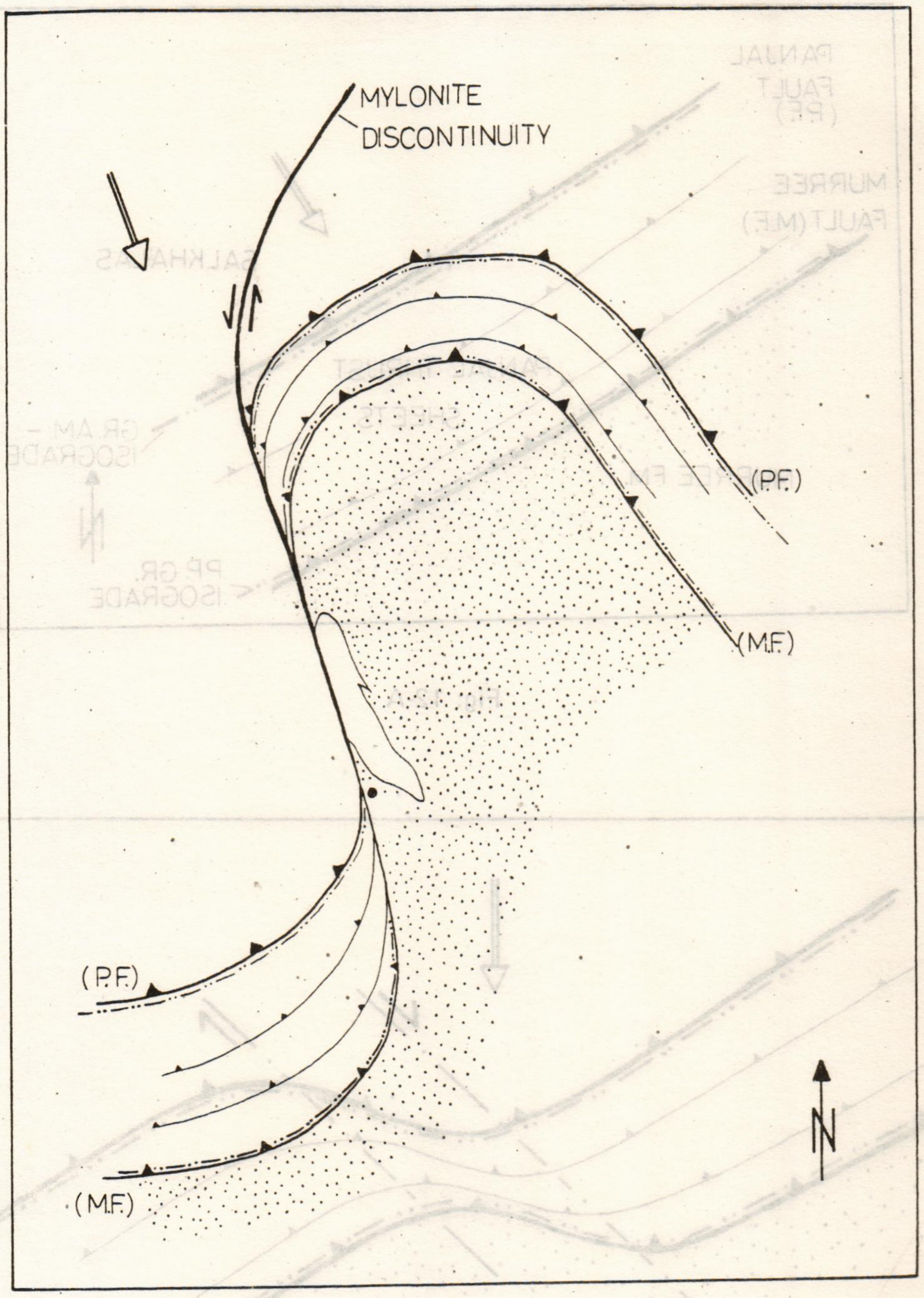


Fig: 12-C

underlying units are not cut by overlying thrust sheets. An overthrust direction from the northeast is suggested by the northeasterly plunging stretching lineation, as well as by the orientation of the branch line of the lowermost Panjal thrust sheet with the Murree thrust (Fig. 5). The two branch line points of these thrusts can be linked with a NW-SE line and the normal to this line represents an independent indication on the overthrust direction (Boyer & Elliott, 1982.

Figure 12B represents the next stage in the evolution of the syntaxial bend. A large sinistral shear zone was emplaced on the already formed part of the chain. Whilst the overthrust history led to a moderate to strong internal deformation of the thrust sheets, the shear zone related deformation is ductile and of extremely high strain (see discussion of the mylonites). This shear zone appears to be a feature of large tectonic scale, comparable to the size of the Main Central Thrust of the Himalayas, and to be induced by differential movements of low level crustal blocks. The shear zone boundary planes are very steep, and caused also a steepening of the previously developed thrust sheets along the already formed thrust zone.

An important consequence of these shear movements is an anticlockwise of the overthrust direction, leading to a final southeastwards thrust direction as represented in Fig. 11C.

Fig. 12C shows the geometry of the syntaxis as seen today. The thrusts between Abbottabad and Murree (Latif 1970) can be related to a final southeastwards overthrust direction. The late crenulation cleavage which can be found in most of the overthrust units as well as in the mylonites (Fig. 5, second cleavage), can also be related to a southeastwards thrust direction. A narrowing down of the shear zone during its development led to the mylonite discontinuity west of Balakot and to the very steep metamorphic gradient: in a distance of two kilometers the rocks showing prehnite-pumpellyite facies around Balakot pass westwards into rocks of upper amphibolite facies.

A major unresolved problem concerns the northward continuation of the mylonites, and the relationship of this zone of high deformation to the Main Mantle Thrust.

FIGURE CAPTIONS

Fig. 1 A geological map of the Hazara syntaxis, Pakistan.

Fig. 2 Stromatolites in the Abottabad formation, 2 km northeast from Muzaffarabad, on the road to Nausehre.

Fig. 3 The age of the rock types found in the melange zone in the apex of the syntaxis.

Fig. 4 A sedimentary cycle in the Murree formation.

Fig. 5 A structural map of the Hazara syntaxis. The stereograms are lower hemisphere equal area projections.

Fig. 6 Structural data from a synform in the Murrees of the Jhelum valley. Location of the fold in Fig. 5. Lower hemisphere equal area projection.

Fig. 7 The geometry of fibre growth in a typical vein from the Murree formation.

Fig. 8 Geometry of vein systems found in the apex of the syntaxis.

Fig. 9 The rotation sense of the veins as a function of the crosscutting relationship between the cleavage and the bedding. A: the situation in the Kaghan valley; B: the situation in the northeastern and eastern part of the syntaxis.

Fig. 10 The relationship of the vein rotations in the XY plane to the principal fold structure of the Hazara syntaxis. Discussion in the text.

Fig. 11 Microstructures used to determine shear sense.

Fig. 12 A model for the evolution of the Hazara syntaxis. A: Pre-thrust configuration (of pre-Himalayan age) The boundaries between the prehnite-pumpellyite/greenschist isogrades and the greenschist/amphibolite facies isogrades are indicated. The arrow, indicates the (future) overthrust direction. B: Shear zone emplacement. Note the rotation of the overthrust direction relative to Fig. 11 A. C: The present day geometry of the syntaxis.

REFERENCES

Berthe, D., Choukrone, P., Jegouzo, P., (1979). Orthogneiss, mylonite and non coaxial deformation of granites: the example of the South Armorican Shear Zone. *Jour. Struct. Geol.* Vol. I, p. 31-42.

Bion, H.S., Middlemiss, C.S. (1928). The fauna of the Agglomeratic Slate Series of Kashmir. *Mem. Geol. Surv.* of Indica New Series *Vol. 12.*

Boyer, S.E. & Elliott, D., (1982). Thrust systems. *Am. Ass. of Petroleum Geologists Bull.* v.66, no.9, p. 1196-1230.

Calkins, J.A., Offield, T.W., Abdullah, S.K.M., & Tayyab

Ali, S., (1975). Geology of Southern Himalaya in Hazara, Pakistan, and adjacent areas. *U.S. Geol. Survey professional paper* 716-C, 29 p.

Durney, D. & Ramsay, J.G., (1973). Incremental strains measured by syntectonic crystal growth. In: Gravity & Tectonics (edited by Dejong, K. & Scholten, R.) Wiley, New York, p. 67-96.

Gardezi, A., H. (1968). Note on the geology of the area around Nathiagali District, Hazara, West Pakistan. *Geol. Bull. Punjab Univ.* 7, p.71-78.

Latif, M.A. (1972). Lower Palaeozoic (Cambrian?) Hyolithids from the Hazara shale, Pakistan. *Nature,* 240, p. 92.

Latif, M.A. (1970). Explanatory notes on the geology of south-eastern Hazara, to accompany the revised geological map. *Jb. Geol. B.A., Sonderband* 15, p.5-20.

Le Fort, P., Debon, F., Sonet, J, (1979). The "Lesser Himalayan" Cordierite Granite Belt, Typology and Age of the Pluton of Manrhra (Pakistan). *Proc. of the Int.com. on geodynamics* group 6 Meeting at Peshawar, p.51-61.

Marks, P., Muhammad Ali, C, (1961). The geology of Abottabad area, with special reference to the Infra Trias. *Geol. Bull. Punjab Univ.* 1, p.47-55.

Middlemiss, C.S., (1910). Silurian-Trias Sequence in Kashmir. *Rec. Geol. Surv. of India,* Vol. 40, p. 206-265.

Muhammad Ali, C., (1962). The stratigraphy of the south west Tanol area, Hazara, West Pakistan. *Geol. Bull. Punjab Univ.* 2, p.31-38.

Tahirkheli Khan, (1982). Geology of the Himalaya, Karakoram and Hindukush in Pakistan. *Geol. Bull. Univ. Peshawar (spec. Issue)* Vol. 15.

Wadia, D.N. (1931). The syntaxis of the NW Himalaya. *Rec. Geol. Surv. of India,* Vol. 65, p. 189-223.

A PALAEOZOIC OPHIOLITE AND ISLAND ARC SEQUENCE OF HAZARA-KASHMIR SYNTAXIS, DISTRICT MANSEHRA

MUNIR GHAZANFAR AND M. NAWAZ CHAUDHRY
Institute of Geology, Punjab University, Lahore

ABSTRACT.– Detailed mapping and field relationships of the rocks in Paras-Jared-Sharan area in Kaghan Valley have revealed the presence of an ophiolite-arc derived metasedimentary suite of Palaeozoic age. The ophiolite-sequence is represented by basic lavas of Panjal Trap abundent between the villages of Malkandi and Shinu on the Kaghan valley roadside. North and east of the ophiolite sequence a sedimentary-volcanic sequence is represented by agglomeratic slates and arc derived metasediments. The likely age of this sequence of Hazara-Kashmir Syntaxis is between Devonian and Triassic. The sequence continues around the syntaxis, the eastern limb extending over the Kaghan ridge across Neelum Valley and beyond and the western limb turning south at Nadi Bungalow to Balakot and further south and southwest.

INTRODUCTION

A field account of Panjal Trap and associated Agglomeratic Slates and tuffs has been given by Wadia (1928) from Poonch district. These rocks were again mapped in Kaghan by Calkin et al. (1975). The petrology of Poonch Volcanics has been described in some detail by Chaudhry et al. (1980).

The Panjal Trap and associated rocks have been studied in greater detail in Kaghan by the present writers from petrotectonic angle. During their studies and detailed mapping of the area between Paras, Jared and Sharan better insight has been developed into the character of these rocks and their stratigraphic and petrotectonic relationships. The present paper is an interim report on this subject.

STRATIGRAPHIC SEQUENCE

The stratigraphic sequence in the area is as follows:

	Murree formation
Tertiary	Lockhart formation
	Hangu formation
Mesozoic	Samana Suk formation
	Panjal Series
Palaeozoic	Agglomeratic Slate Series
	Tanol formation
Pre-Cambrian	Salkhala formation

The main interest in the present paper is the nature of Agglomeratic Slates Series and the Panjal Series and the petrotectonic significance of these two rock units.

The Panjal Series

Within the area it mainly comprises a thick metamorphosed volcanic sedimentary sequence of greenstones. The rock is greenish to greenish grey with dark green porphyroblasts of chlorite and patches of epidote. At places it contains amygdules and vesicles filled with quartz and agate. The volcanic material at many places is preserved in the form of pillows. The basic flows are associated with contemporaneously deposited sediments. The greenstone is interbedded and folded with three major bands of fine grained crystalline limestone. The Ling band which outcrops at Ling village near Malkandi forest rest house,the Bhunja band, exposed near Bhunja bazaar four miles upstream of Paras and the Shinu band which outcrops where Shinu hatchery is locaated on the roadside. This Shinu band is smoewhat different and also contains a fair amount of psammatic material. It has been considered equivalent of Abbotabad Formation in the past.

The Panjal volcanics are predominently basic flows with tholeiitic affinities. The andesitic compositions are rare. The basic flows also appear to be associated with minor altered ultrabasics. The volcanic rocks as well as the limestones have undergone low grade metamorphism.

The Agglomeratic Slates

The Agglomeratic Slates represent a sedimentary volcanogenic arc derived metasedimentary sequence. Tuffaceous material has also been reported from comparable horizons. It is interbedded with arenaceous and argillaceous material. The top of the Agglomeratic Slate sequence (which stratigraphically appears to underlie the Panjal Trap sequence and the Shinu Limestone) contains interbedded graphitic schist, which acts as very good marker horizon for field mapping.

On the roadside the Sharan Fault has eliminated the major part of Agglomeratic Slate sequence underlying the graphitic part. The sequence is, however, well developed in the area between Badhawa and Jahra north of Paras and continues west. Here the Lower part of the Agglomeratic Slate sequence appears to be gradational with Tanol formation.

The Tanol Formation

A sequence of psammatic and pelitic schists and quartzites underlies the Agglomeratic Slates. On the roadside the contact is faulted out northwards between Jabra and Sharan it can be seen to be gradational. Here the rocks also show a characteristic development of chlorite porphyroblasts which could confuse their identification with Panjal Trap.

AGE RELATIONSHIPS

At the present we may only cite indirect evidence. The PanJal Trap and the Agglomeratic Slates lie between Samana Suk limestone (top) and the Tanol formation (bottom) the former contact being faulted and the later gradational.

The age of Tanols themselves is controversial. Apart from a Precambrian age assigned to them because they have been found to underlie Tanakki member of the Abbottabad Formation of Cambrian age (Latif, 1970, 1972, Rushton, 1973) there is also a large evidence for Silurian Devonian to Carboniferous (Martin et. al., 1962; Davies and Riaz Ahmad 1963; Stauffer, 1968; Tahirkheli, 1970; Tahirkheli et al., 1975, Gupta, 1975; Fuchs and Gupta, 1978). In the Kaghan Valley the Lower contact of Agglomeratic Slates appears gradational with Tanols. This gradation between Agglomeratic Slates and Tanols has also been observed in the past by Middlemiss (1911), Wadia (1931) and Coulson (1938). Further Wadia (1928) reported plant fossils represented by Gangemopteris, Alethopteris and Cordaites, etc. from the Agglomeratic Slates lying above Tanols at "Jured" and in the Chor-Panjal section.

The age of Panjal Volcanic series has been reported as Permian to Triassic from Kashmir.

Based on considerations cited above the maximum age limit on the ophiolite-flyschoid sedimentary volcanic sequence of Kaghan may be considered Silurian-Devonian to Triassic or more likely middle to upper Palaeozoic in age.

CONCLUSIONS

The presence of a Palaeozoic ophiolite-arc derived sequence indicates the presence of a Palaeozoic ocean basin between the main continental mass of India and the Precambrian continental rocks now occurring to the north of this sequence. It appears that Tanols were deposited in this basin prior to the start of northward directed subduction.

REFERENCES

Calkin, J.A.; Offield, T.W., Abdullah, S.K.M. and Ali, S. Tayyab, (1975). Geology of Southern Himalayas in Hazara, Pakistan and Adjacent Aeas. *U.S.G.S. Prof. Paper*, 716-C, pp. 1-29.

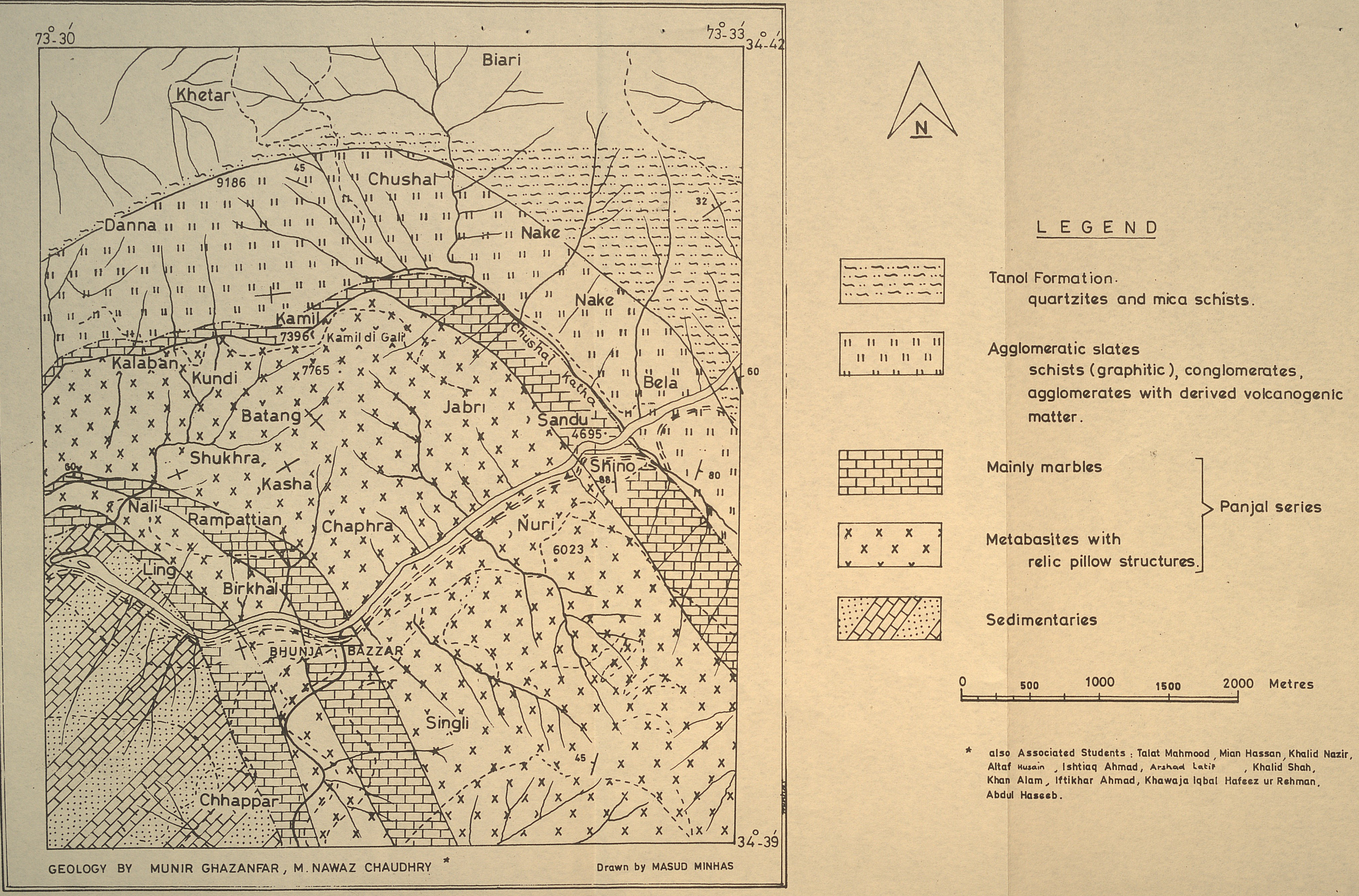
Chaudhry, M.N., and Ashraf, M., (1980). The Volcanic Rocks of Poonch District., Azad Kashmir. Proceed. International Committee on *Geodynamics Grp.* 6., pp. 121-128.

Wadia, D.N., (1928). The Geology of Poonch State (Kashmir) and Adjacent Portions of the Panjab, *G.S.I. Mem. No. 5* Vol. 51. Part II pp. 185-370.

Fuchs, G. and Gupta, V.J. (1978). Significance of Tanol Formation of the Western Himalaya. Contributions to *Himalayan Geology*, Vol. 1.

Latif, M.A., (1972). Lower Palaeozoic (? Cambrian) Hyolithids from the Hazira Shales, Pakistan.

Rushton, A.W.A., (1973). Cambrian fossils from Hazira Shales, Pakistan. *Nat. Phys Sci.*, 231, 76.



GEOLOGY BY MUNIR GHAZANFAR, M. NAWAZ CHAUDHRY *

Drawn by MASUD MINHAS

* also Associated Students : Talat Mahmood, Mian Hassan, Khalid Nazir, Altaf Husain, Ishtiaq Ahmad, Arshad Latif, Khalid Shah, Khan Alam, Iftikhar Ahmad, Khawaja Iqbal Hafeez ur Rehman, Abdul Haseeb.

GEOLOGICAL MAP of MALKANDI-SHINO AREA KAGHAN VALLEY

AGE OF THE SALT RANGE FORMATION IN THE LIGHT OF BROADER SETTING OF THE HIMALAYAN GEOLOGY

M. A. LATIF
Institute of Geology, Punjab University, Lahore

ABSTRACT.– Various facies of Eo-Cambrian rocks have been noticed from Salt Range to Hazara, underlying the Cambrian rocks with purple sandstone-dolomite association. The post Tanakki Abbottabad Group is correlated with post Blaini Krols on one hand and Jhelum Group, with Sirban & Tarnawai formations absent, on the other. Similarly pre Tanakki, Hazara Group followed by Tanol Formation is correlated with Simla Slate & Jaunsars on one hand and Salt Range Formation on the other.

INTRODUCTION

The Salt Range has long been known as one of the most interesting and important regions in Indo-Pakistan sub-continent for its geological interest, enhanced by its highly fossiliferous rocks and enormous economic potential.

The exposures of the Salt Range Formation extend between 71°.00' to 73°.30' East and 32°.10' to 32°55' North, dominantly exposed between the Indus River formerly known as Abasin (Father of Waters) and the Jhelum River fomerly known as Hydaspas. Information used in this article relates to areas situated between 71°.00' to 78°.00' East and 31.°00' to 35.00' North in general and Hazara in particular.

The rock salt of the Salt Range Formation has been used for domestic and industrial purposes and recorded since time immemorial. For the purpose of this study we shall try to sieve through some selected earlier works from 1808 to date.

During about 70 years from 1808 to 1878 some forty papers concerning the subject appeared. The earliest publication containing any mention of 'the Salt Range' is the "Elphinstone's Caubul" 1808-1815 in Wynne (1878) He speaks of a branch of the "Sufed Koh" which may be called" Salt Range" as projecting out from the Sufed Koh and extending in a south-easterly direction to "Calla baugh" (Kalabagh) where it crosses the Indus, stretches across part of the Punjab and ends at "Jellaulpoor" (Jalalpur). Elphinstone who travelled as a British Envoy to the court of Caubul (Kabul), noted hard, clear and almost pure rock salt in a narrow road cutting near Kalabagh and quarried salt piled at the entrance of the Lun Nala.

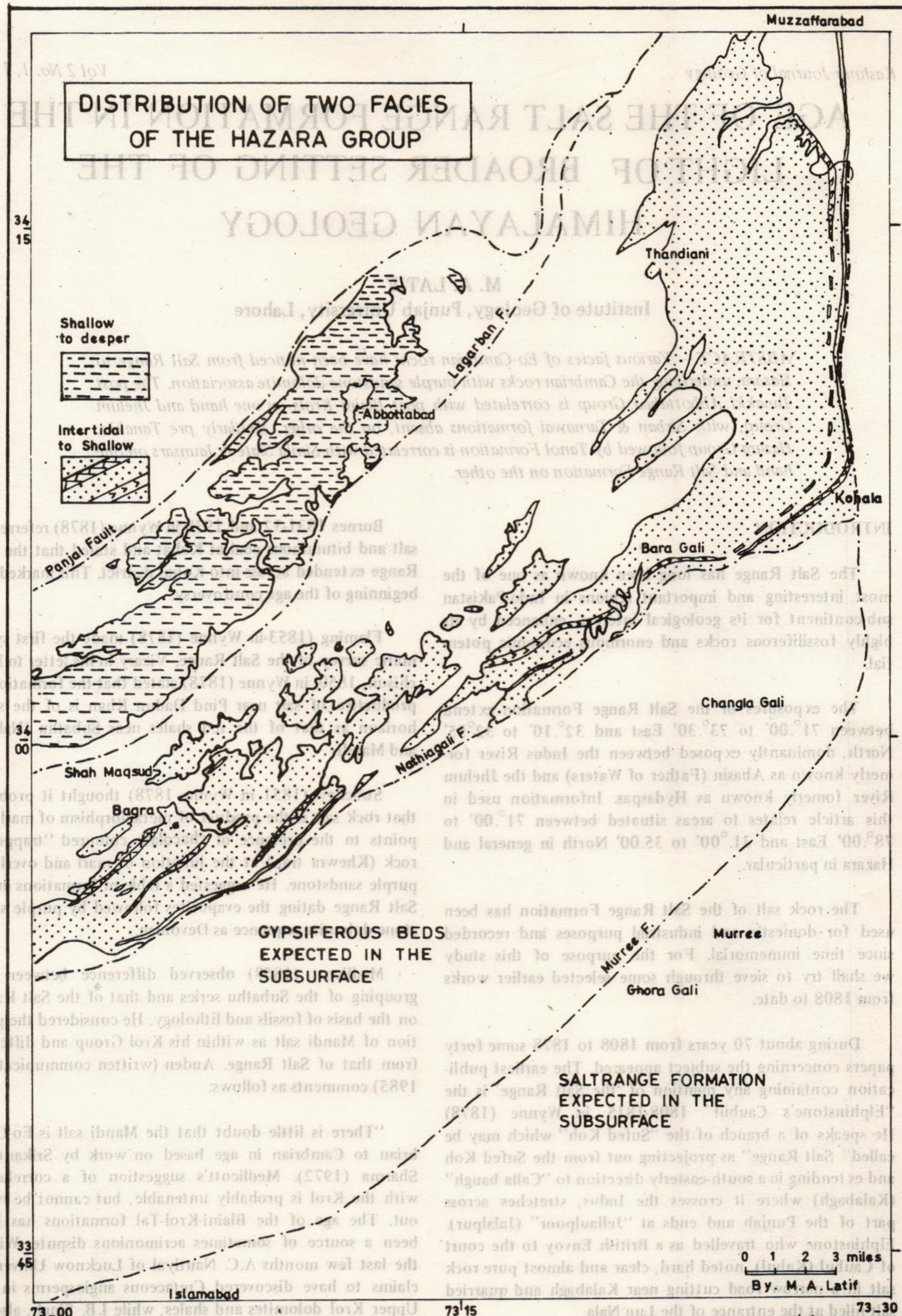
Burnes 1831-32 and 1938 in Wynne (1878) referred to salt and bituminous coal at Kohat and stated that the Salt Range extended across into Kohat district. This marked the beginning of the age controversy.

Fleming (1853-in Wynne (1878) made the first systematic survey of the Salt Range. Vicary in his letter to Murchison, 1850, in Wynne (1878) stated that the formation so productive of salt near Pind Dadun Khan is of the same horizon as that of the red shales near Subathu (Nahun) and Mandi.

Strachey (1851 in Wynne 1878) thought it probable that rock salt is the product of metamorphism of marl and points to the presence of chacolate coloured "trappean" rock (Khewra trap) at the junction of marl and overlying purple sandstone. He suggested a table of formations in the Salt Range dating the evaporites followed by purple sandstone-dolomite sequence as Devonian.

Medlicott (1859) observed difference between the grouping of the Subathu series and that of the Salt Range on the basis of fossils and lithology. He considered the position of Mandi salt as within his Krol Group and different from that of Salt Range. Auden (written communication, 1985) comments as follows:

"There is little doubt that the Mandi salt is Eo-Cambrian to Cambrian in age based on work by Srikanta & Sharma (1972). Medlicott's suggestion of a correlation with the Krol is probably untenable, but cannot be ruled out. The age of the Blaini-Krol-Tal formations has long been a source of sometimes acrimonious dispute. Within the last few months A.C. Nautiyal of Lucknow University claims to have discovered Cretaceous angiosperms in the Upper Krol dolomites and shales, while I.B. Singh, also of



DISTRIBUTION OF TWO FACIES OF THE HAZARA GROUP
Muzzaffarabad
34 15
Shallow to deeper
Intertidal to Shallow
Thandiani
Lagarban
Abbottabad
Panjal Fault
Kohala
Bara Gali
Changla Gali
34 00
Shah Maqsud
Bagra
Nathiagali F.
GYPSIFEROUS BEDS EXPECTED IN THE SUBSURFACE
Murree
Murree F.
Ghora Gali
SALTRANGE FORMATION EXPECTED IN THE SUBSURFACE
33 45
0 1 2 3 miles
By. M. A. Latif
Islamabad
73_00
73 15
73_30
minhas

Fig_1

Lucknow, has published a paper on the occurrence of trilobites in the Tal formation which overlies the Krol. If correct this would necessitate a thrust fault between overlying older Tals and underlying younger Krol. In 1935 I regarded the Tal-Krol contact as a sedimentary one without an intervening thrust plane. So varied have been the age determinations that one is led to suspect that some of the fossils collected were not actually found in the particular formations in which they have been stated to occur".

Wynne (1878) considered the age of Salt Marl as not newer than Silurian.

During the 1878-1947 period a large number of scientists directly or indirectly contributed their share, they include, Middlemiss 1891, Gee 1934, 1944 a & b, 1947, 1981, 1983, Sahni 1944, 1947, Lahiri 1944, Davies 1944, Pinfold 1944 & Davies 1944, Pinfold 1944 & Wadia 1944. The most significant contributions however were those made by Sahni 1944 based on the occurrence of plant microfossils in saline strata, oil shales and dolomites of the Salt Range Formation, favouring a post Cambrian age, in all probability Eocene, and those presented by Gee indicating their stratigraphic position below the Cambrian rocks based on field evidence. Whereas the views expressed by Sahni were corroborated by extensive laboratory studies those of Gee were further supported by field examination of critical sections at Khewra, Warchha and below Sakesar by a team of senior geologists from the Geological Survey of India and the Burmah, Attock and Anglo Iranian Oil Companies.

After 1947, no serious work, except an attempt by Schindewolf and Seilacher (1955) has been made towards the solution of this problem. Asrarullah (1962) named the Punjab Saline Series as Salt Range Formation. During the work in Hazara by Latif (1969, 1970, 1972a, 1972b 1973, 1974a and 1974b,) some indirect evidence has come to light. As the problem is both of economic as well as of academic interest, it is desirable to record it. An attempt is made to put together as far as possible, the related information and views that have been expressed from 1808 todate.

DIRECT EVIDENCES WITH COMMENTS

1. It has been suggested by some that the contact of the Salt Range Formation and the overlying formations is tectonic and by others normal. The evidence of the contact being disturbed is a negative evidence in solving the age problem. On the other hand that of a normal unconformable contact is a positive evidence. This critical evidence is provided by the conglomerates of the Tobra Formation (Permian) which overlie the Cambrian formations in the eastern part of the Salt Range, and transgress westwards on to the Salt Range Formation below Sakesar and in the western parts of the range. There, within the basal Tobra conglomerates, reworked pebbles of Salt Range Formation occur.

2. Whereas the presence of microfossils by Sahni, of a post Cambrian age has been recorded, a negative report has been made by Schindewolf and Seilacher who failed to trace any microfossil evidence from the fresh and systematically collected samples from the Salt Range Formation.

3. On the basis of the evaporitic nature of the rocks of the Salt Range Formation and Jatta Gypsum/Bahadur Khel Salt Formations some workers equate the Punjab and Kohat deposits. Whereas the Kohat deposits occur within the Eocene fossil bearing sequences those, in the Punjab stratigraphically underline the Khewra sandstone of Cambrian age (see Gee 1983).

4. Volcanic activity is present in the Punjab Salt Range rocks and absent in Kohat rocks.

5. Khewra trap (Khewrite) petrologically resembles rocks representing volcanic activity within Hormuz Formation (Cambrian) of Iran, than the Deccan trap, (Eocene) of India

6. Volcanic activity is considered not to be restricted to Eocene alone as it has been recorded at other horizons, including pre-Cambrian.

7. Among the pre Tertiary sequences, the Salt Range Formation of the Punjab has an enormous thickness, occasionally in thousands of metres with the base not exposed as against a restricted thickness of about 200 m. Kohat evaporites, including the Panoba Shales near Daud Khel.

Auden, written communication, comments as under:-

"The author suggests that the Saline Series may in places be thousands of feet in thickness. At Karampur, near Multan, the thickness of the series is 2900 ft. or 884 meters. Karampur is in a platform area which did not suffer orogenesis, and escaped plastic folding and diapiric injection. The 884 m. thickness is therefore likely to be undisturbed and true for that area.

The equivalent evaporite group of Iran, 70 km. northwest of Kerman, is stated to be 1,000 m. in thickness. Isotopic age 595to 760 m.y."

8. Evaporites of the Punjab are wide-spread and recorded as far south as Karampur and in the subsurface of Potwar, whereas the horizontal spread of Kohat evaporites is res-

tricted to a much smaller area, Latif in press.

Moreover the evaporites at Karampur occur between the Khewra Sandstone. (Cambrian) and Kirana Group (Pre-Cambrian) as against Kohat where the evaporites are within the Eocene.

9. Punjab evaporites and the overlying Cambrian sequence is comparable to Hormuz Formation and overlying Cambrian sequence of Iran and Oman.

10. Some observations, which are not considered as critical evidences, are as given below:

a) There is more of $K_2 SO_4$ and less of $Ca SO_4$ content in the Punjab rocks as compared to those of Kohat where the situation is just the reverse.

b) Gupsum of Punjab is generally pure and white to light grey as compared to that of Kohat which is impure greenish white to grey.

c) Deposits in Punjab contain quartz crystals (Mari Diamond) which are absent from Kohat rocks.

d) Punjab Salt is hard and that of Kohat brittle and soft.

e) Punjab deposits are overall pink in colour as compared to grey in Kohat.

INDIRECT EVIDENCES

During the work in Hazara initiated in 1959 by the author, the following fresh information has come to light which indirectly helps towards the solution of this problem.

In the explanatory notes on the Geological Map of South Eastern Hazara (Latif, 1970) doubted the Infra Triassic (Permo-Carboniferous) age of the Abbottabad Group which he considered as older. Later Latif, (1972) recorded Cambrian Hyolithids from Hazira Shale resting over the Sirban Formation of the Abbottabad Group. The Cambrian age was further confirmed by Fuchs and Mostler (1972) and Rushton (1973). The recorded fossils are the following:

Allonia tripodophora, Archiasterella pentactina, "Stauractinid" Archiaster, Lapworthella Spp., Rushtonia Spp., Circotheca, Line-vitus spiçules of Hateractinellid sponge chancelloria walcott.

Latif (1974) also recorded glacial striations on the boulders of Tanakki Member marking an unconformity at the base of Abbottabad Group. He (1974) considered the correlation of Tanakki glacial boulder bed, at the base of Abbottabad Group, with the Tobra Formation (Formerly Talchir Boulder Bed) of Salt Range and India as incorrect. On the basis of widespread occurrence of pre-Cambrian glacial beds in various parts of the world, Latif (1974) suggested a correlation between the Tanakki boulder bed of Hazara with the Blaini Boulder bed of Simla and correlated the pre Tanakki Hazara Group and Tanol Formation together with the Simla Slates and Jaunsars, and the post Tanakki, Abbottabad Group, of Hazara with the post Blaini, Krols of the Simla area of India, on the basis of striking lithological similarities. Rocks identical to those occurring in Hazara and Simla have also been noticed near Garhi Habibullah Khan (Hazara), Muzaffarabad and Kotli in Azad Kashmir (Ashraf et al., 1983). Tanol Formation occurs at places with a tectonic contact and at others with a normal sedimentary one with the underlying Hazara Group. In Katchi Section (Fuchs 1970, page 59) visited jointly by the author and Fuchs, in 1969, Abbottabad Group was found resting over Tanol Formation with an unconformity marked by the Tanakki Member consisting of boulders derived from Tanol Formation. The Tanakki conglomerate transgresses eastwards on the Hazara Group with the complete elimination of the Tanol Formation and now dominantly consisting of reworked boulders from Hazara Group. Apart from Katchi there are few other sections (Calkins 1975, plate 2) that show normal sedimentary contact between Hazara Group and Tanol Formation thus placing Tanol Formation of Southern Hazara above the Hazara Group and below the Abbottabad Group. As far the exposures in other areas, it is suggested that facies variations of Hazara Group and Tanol Formation and the effect of thrusts like Tarnawai Fault and Panjal Fault may be kept in mind while attempting correlations. Auden has following comments on this as per written communication (1985):-

"The Tanols or Tanawals appear to be grouped with the Hazara Slates. This is a curious formation, and according to Wadia presents many anomalous contacts in Kashmir with the underlying formations. Just south-east of the Tarbela dam the Tanols are cleanly thrust upon Abbottabad dolomites, but 2-25 km to the east Offield and Calkins of the USGS, and Afaq Ali of the G.S.P., mapped a folded succession of Hazara-Tanol-Abbottabad formations in normal succession.

Abbottabad Group

Tanawal Formation

Hazara Group

Where I have seen the Tanols in the Tarbela area and I was impressed by their resemblance to the Naghthat (or Jaunsar) Formation of the Garhwal area, which is pre-Blaini, and post-Chandpur.

The Lower Cambrian slates and phyllites of the Tragbal area greatly resemble the Chandpurs of Garhwal".

On the southern side of Hazara lithological identity between Cambrian rocks of Hazara and those of Salt Range have been noticed. There is a striking resemblence between the Sangargali sandstone and Khewra sandstone on the basis of physical criteria, as also observed by Waagen & Wynne (1872) in the following words.

"It rests with total unconformity upon the slates, the basal rock being, in places, a red argillaceous breccia full of large fragments from the underlying beds. The group presents two principal divisions, the lower one consisting chiefly of red sandstones, red shales, and red quartzitic dolomites (recognised as Kakul Formation by Latif (1970), the upper one composed of dolomites only, of lighter colour, often highly siliceous, and of very considerable thickness (recognised as Sirban Formation by Latif 1970). The red sandstones and shales have a very characteristic aspect, and remind the observer strongly of the dull red sandstones far below the carboniferous formation, and immediately overlying the bright scarlet saline marl of the Salt Range: there, however, the associated quartzose dolomites are absent, and the analogy ceases".

Hazara Group-Tanol Formation is followed by a conglomerate (Tanakki), derived from materials of either of the two or both. In Salt Range this is represented by transition between Salt Range Formation and Khewra Sandstone if not by the reworked Salt Range Formation boulders at the base of Tobra Formation near Sakesar and Kalabagh. The boulder horizon is followed in both areas by Shales and purple coloured sandstones. In upper horizones of both Khewra Sandstone and the Sangargali Member (Sandstone), the sandstone becomes lighter in colour to even white as also noticed in the upper parts of the Lalum Sandstone of Iran. In addition sequence in both areas shows the association of dolomite and glauconite. The Jhelum Group of Salt Range Lower Cambrian is considered equivalent to Kakul Formation (Cambrian) of Hazara. The siliceous dolomites containing phosphatic rock (Latif, 1972a) i.e. Sirban Formation, underlying the Lower to Middle Cambrian, (Rushton, 1973) Fossil bearing glauconitic Hazira Member may be younger and possibly absent in Salt Range due to unconformity above Baghanwalla Khisor formations. Similar suit of lithology i.e. purple sandstone, dolomite and glauconite is found in the Cambrian rocks of Iran underlain by Hormuz Formation, the evaporites.

The Hazara Group of rocks in south eastern regions are distinctly different both lithologically and in sedimentary structures from those in northwestern regions. The south eastern region is dominated by arenites, greywackes, intervened by algal limestones, Miranjani and Langrial, algal pisolites, calcareous slaty shales and gypsum, see map fig. 1. Sedimentary structures include cross bedding ripple marks, mudcracks see map fig. 1. The northwestern regions show considerable decrease in arenites subgreywackes and dominance of argilites. The algal limestones so frequent in the south eastern regions and gypsum have not been recorded. Sedimentary structures include flute casts and some graded bedding. The south eastern regions are considered to be intertidal and very shallow and north western regions shallow to slightly deeper. Though further work is required, the separating line between the two facies can tentatively be placed along a line joining the Lagarban Fault, Gardezi et al., 1965 (Kakul Fault Calkins et al., 1975, from Salhad Nala in the south of Abbottabad, merging in the north with Panjal Fault S.W. of Dabban. There are no expsoures of Hazara Group south of Nathiagali Fault while Salt Range Formation is reported in the subsurface immediately south of Murree Fault near Rawalpindi (verbal communication). A facies intermediary between the Salt Range Formation and South Eastern Hazara (intertidal) is expected in the subsurface between the regions bounding the Nathiagali and the Murree Faults. This would therefore place Hazara Group as facies equivalent of Salt Range Formation. On the basis of enormous thicknesses of Hazara Group, the Dogra Slate, the Simla Slate and the Salt Range Formation and their oldest position in the overall sequences Latif (1973) suggested their tentative correlation. The extension of evaporite facies towards north is further confirmed by their occurrence in a reduced thickness in the sub-surface of Potwar, further reduced to only 40 feet of Gypsum near Lassan, Nathiagali. The algal limestone and gypsum occur up to Muzaffarabad, Azad Kashmir, on the right bank of Jhelum in Eastern Hazara. The extension of Khewra Sandstone in northern Potwar is recorded South of Rawalpindi as per verbal communication.

The facts given above lead to the following conclusions

1. The Abbottabad Group, Cambrian of Hazara is tentatively of the same Horizon as the unfossiliferous Krols of Simla Himalayas, India, on one hand and Jhelum Group, Cambrian of Salt Range, the Sirban Formation of Abbottabad Group having been removed due to unconformity in the later.

2. The Hazara Group followed by Tanols, Eo-Cambrian, of Hazara are of the same horizon as the Simla Slate followed by Jaunsars of Simla and Dogra Slate, underlying the Cambrian beds, of Kashmir on one hand and evaporites near Mandi, India, and Salt Range Formation of Punjab Salt Range underlying the Jhelum Group on the other.

ACKNOWLEGEMENTS.

The author is grateful to Dr. E.R. Gee not only for his constructive suggestions on the article but also for taking pains to obtain views of Dr. J.B. Auden on the overall geology in general and Indian Himalayan Geology in particular. The views of Dr. Auden have been incorporated and gratefully acknowledged. The compilation of data in the form of present article would not have been possible without the persistant follow up by Syed Tayyab Ali whose efforts in this regard are gratefully acknowledged.

REFERENCES

Asrarullah 1962. Rock Salt resources of Pakistan. CENTO symposium on industrial rocks & minerals Lahore, 303-313.

Ashraf, M. Chaudhry, M.N. and Qureshi K.A. 1983. Stratigraphy of Kotli area of Azad Kashmir and its correlation with standard type areas of Pakistan. Kashmir Journ. Geol. Vol. I, pp. 19-30.

Auden, J.B. 1934. The geology of Krol Belt. Rec. Geol. Surv. Ind. Vol. 67, pt. 4, pp. 357-463.

Calkins J.A., Offield, T.W., Abdullah S.K.M. & Ali S. Tayyab (1975). Geology of Southern Himalaya in Hazara, Pakistan & adjacent areas. U.S.G.S. Prof. Paper No.

Davies, L.M. 1944. Origin of salt deposits of N.W. India. Proc. Nat. Acad. Sci. Ind. Vol. 14, Sec. B. pp. 225-232.

Fatmi A.N. 1973. Lithostratigraphic units of the Kohat Potward Provinces, Indus Basin Pakistan. Mem. Geol. Surv. Pak. Vol. 10, pp. 1-80.

Fuchs, G. & Frank, W. (1970). Geology of West Nepal between the rivers Kali Gandaki and Thulo Bheri. *J.B. Geol. B.A. Sond.* 18.

Fuchs, G. & Mostler, H., (1972). Der erste. Von fossilien (Kambrischan Alter) in der Hazira Formation, Hazara, Pakistan. *Inshruch Geol. Pal. Mott Bend* 2, pp. 1-12.

Gee, E.R. 1934. Saline Series of N.W. India Curr. Sci. Ind. t 69, pt. 1 pp. 64-72.

——— (1944 a) The age of Saline Series of the Punjab and of Kohat. Ind. Nat. *Acad. Sci. Sec. B. Proc.* Vol. 14, pt. 6, 269-310.

——— (1944 b). Comments on contributions to symposium. Proc. Nat. Acad. Sci. Ind. Vol. 14, Sec. B. pp. 327-328.

———(1947) Further note on the age of the Saline Series of the Punjab and of Kohat. *Ind. Nat. Acad. Sci. B. Proc.* Vol. 16, pt. 2-4, 95-153.

——— (1981). Pakistan Geological Salt Range Series Sheets 1 to 6, U.K. Overseas Survey.

———(1983). Tectonic problems of the sub-Himalayan Region of Pakistan. Kashmir Jour. Geology. Vol. 1, 11-18.

Gardezi, A.H. & Munir Ghazanfar 1965. A change of facies at the base of Jurassic in district Hazara, West Pakistan. Geol. Bull. Punj. Univ. No. 5, pp. 53-54.

Gardezi, A.H., (1968) Note on the Geology around Nathiagali district Hazara, West Pakistan. Geol. Bull. Punj. Univ. No. 7 p. 71-78.

Lahiri, A. (1944). Occurrence of bitumen in Punjab Sslt Range and Kohat areas and its bearing on the age of Saline Series. Proc. Nat. Acad. Sci. Ind. Vol. 14, Sec. B. pp. 329-334.

Latif, M.A. (1969). The stratigraphy of South Eastern Hazara and parts of Rawalpindi and Muzaffarabad districts of West Pakistan and Azad Kashmir. Ph. D. thesis London University, pt. I, pp 1-316, pt II Illustrations

———(1970). Explanatory notes on the Geology of South Eastern Hazara, to accompany the revised Geological Map. *Jb. Geol. B.A. Sond.* 15, S 5-20.

———(1972 a) An occurrence of Palaeozoic phosphate rock in Hazara, district West Pakistan. Inst. Min. Met. Trans. B. 81 50-53.

———(1972 b) Lower Paleozoic (Cambrian) Hyolithids from Hazira Shale Pakistan. *Nature. Phy. Sci. Vol. 240. No. 100 p. 92.*

———(1973) Partial extension of the evaporite facies of Salt Range to Hazara Pakistan. *Nature Phy. Sci.*, Vol. 244 No. 138, pp. 124-125.

——— (1974 a) A Cambrian age for Abbottabad Group of Hazara Pakistan. *Geol. Bull. Punj. Univ.* No. 10, pp 1-20

———(1974 b) A new evidence to solve the controversy of Paleoglaciation in Indo-Pakistan. Geol. Bull. Punj. Univ. No. 11, pp. 1-5.

Medlicott, H.B. (1859). On the Vindhyan rocks and their associates in Bundelcund-Mem. Geol. Surv. Ind. t. 2 pt I. pp. 1-95.

Middlemiss, C.S. (1891). Notes on the geology of Salt Range of the Punjab with a reconsidered theory of origin and age of Salt Marl. Rec. Geol. Surv. Ind. t. 24, pt. I, pp. 19-42.

——— (1896). Geology of Hazara & Black Mountain. *Mem. Geol. Surv.* Ind. 26, pt. 1.pp. 1-302.

Pinfold, E.S. (1944). Age of Saline Series of Punjab Salt Range. Proc. Nat. Acad. Sci. Ind. Vol. 14, Sec.B. pp. 239-243.

Rushton, A.W.A. (1973). Cambrian fossils from the Hazira shale, Pakistan, *Nature. Phys. Sci.* Vol. 243 No. 130, pp. 142.

Sahni, B., (1944). Microfossils and problems of Salt Range Geology. *Ind. Nat. Acad. of Sci.* Proc. Sec. B. Vol. 14, Pt. 6 pp XXXII.

——— 1947. Microfossils and the Salt Range Thrust. *Ind. Nat. Acad. Sci. Proc.* Sec. B. Vol. 16 pt. 2-4, pp. 1-44.

Schindewolf O.H., and Seilacher, A. (1955). Beitragezur Kentisdes Kambrium in der Salt Range (Pakistan) - *Akad. Viss. Lit. Mainz Abb. Math-Natl.* No. 10, p. 446.

Shah, S.M.I. (1977). Stratigraphy of Pakistan. *Mem Geol. Surv. Pak.* Vol. 12, pp. 1-138.

Wadia, D.N., (1929). Age of gypsum and origin of gypsum associated with Salt deposit of Kohat. Trans. Min. *Geol Inst. Ind.* Vol. 24, pp. 202-222.

-------- 1944. A note on the repeated overthrusts of Cambrian rocks on the Eocene in North Eastern part of Salt Range. *Proc. Nat. Acad. Sci. Ind.* . Vol. 14, Sec. B. pp. 214-221.

Waagen, W. & Wynne, A.B., (1972). The geology of mount sirban in Upper Punjab. *Ind. Geol. Surv. Mem.* Vol. IX, 331-350.

Wynne, A.B. (1878). On the Geology of Salt Range in the Punjab. *Ind. Geol. Surv. Mem.* Vol. 14, pp 1-313.

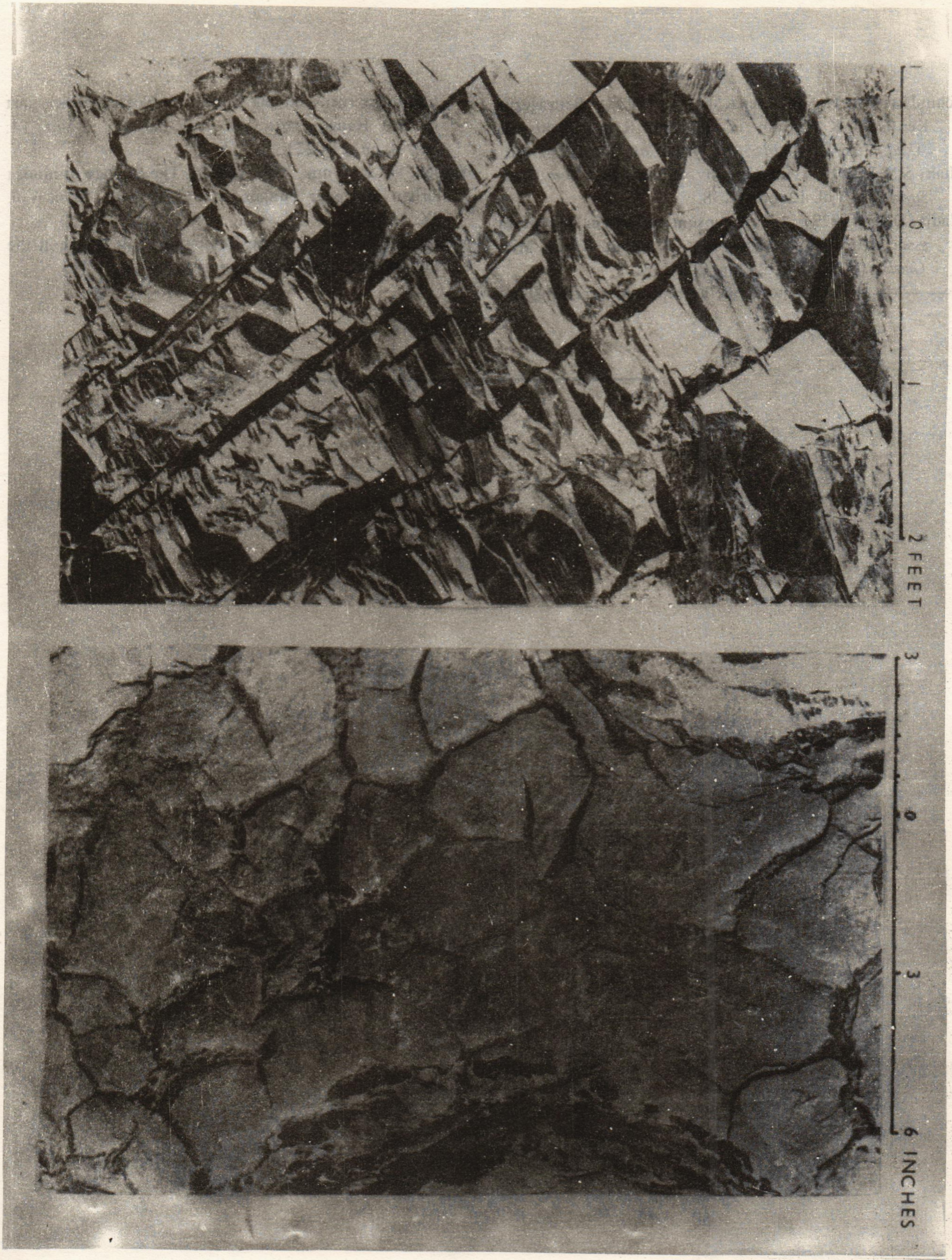


Plate - 1

Top uniform massive bedded Hazara Group dominantly arenaceous near Bagra on Maqsud-Langrial road <u>Bottom</u> Mud cracks in Hazara Group near Bagra.

Plate - 2 Top. Pisolites in calcite matrix often replaced by calcite in Hazara Group which is fairly arenaceous at Lassan near Nathiagali

<u>Bottom</u>

Mud Cracks appearing to be replaced by algal growth at Lassan near Nathia-gali.

X 1

X 4

Plate - 3 Stromatolites in Miranjani Limestone, lacking algal structures but with well preserved laminations, suggesting the original presence of blue green algal and deposition in intertidal environments at Government House, Nathiagali.

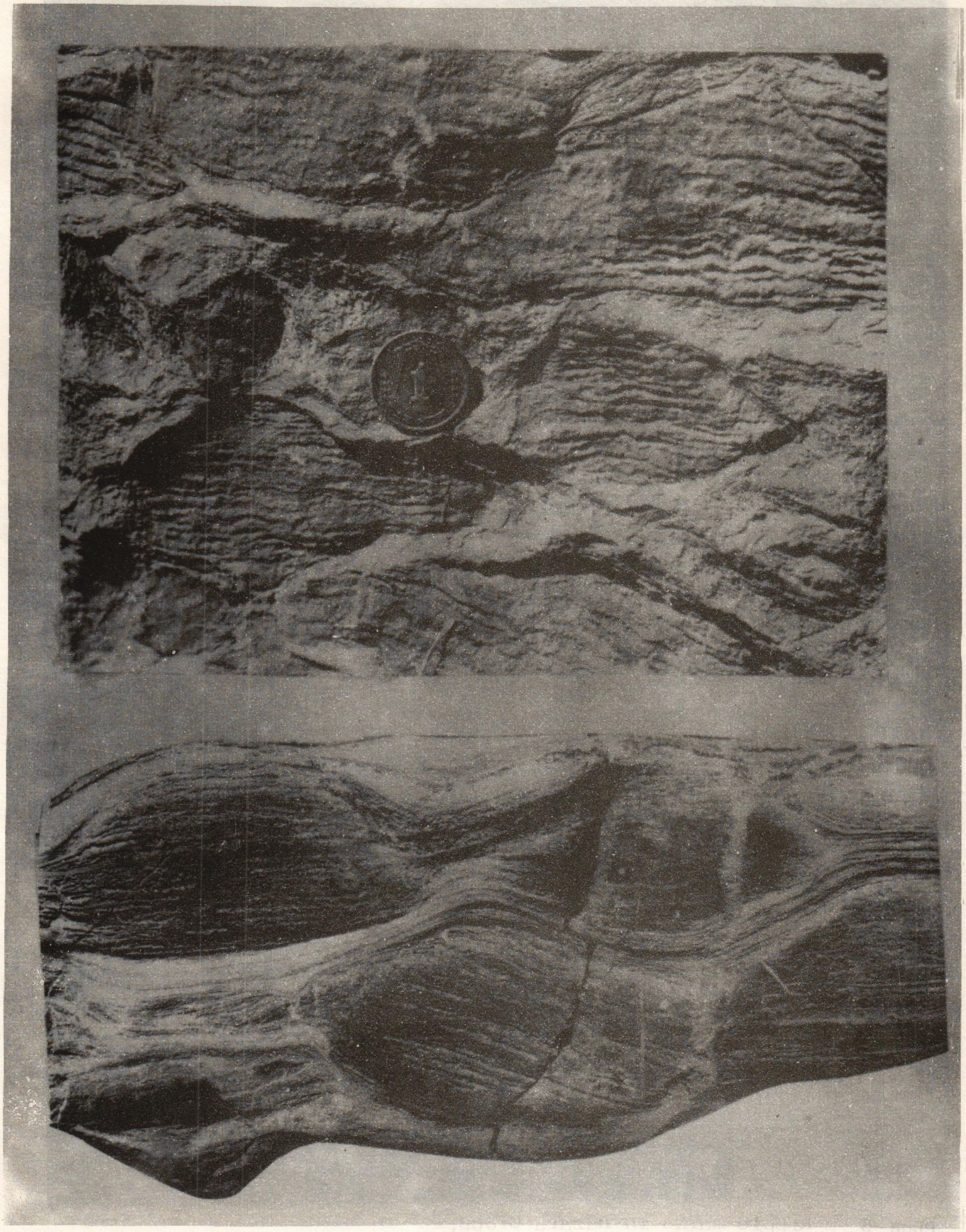


Plate - 4 Nearly nodular algal Langrial Limestone near Langrial.

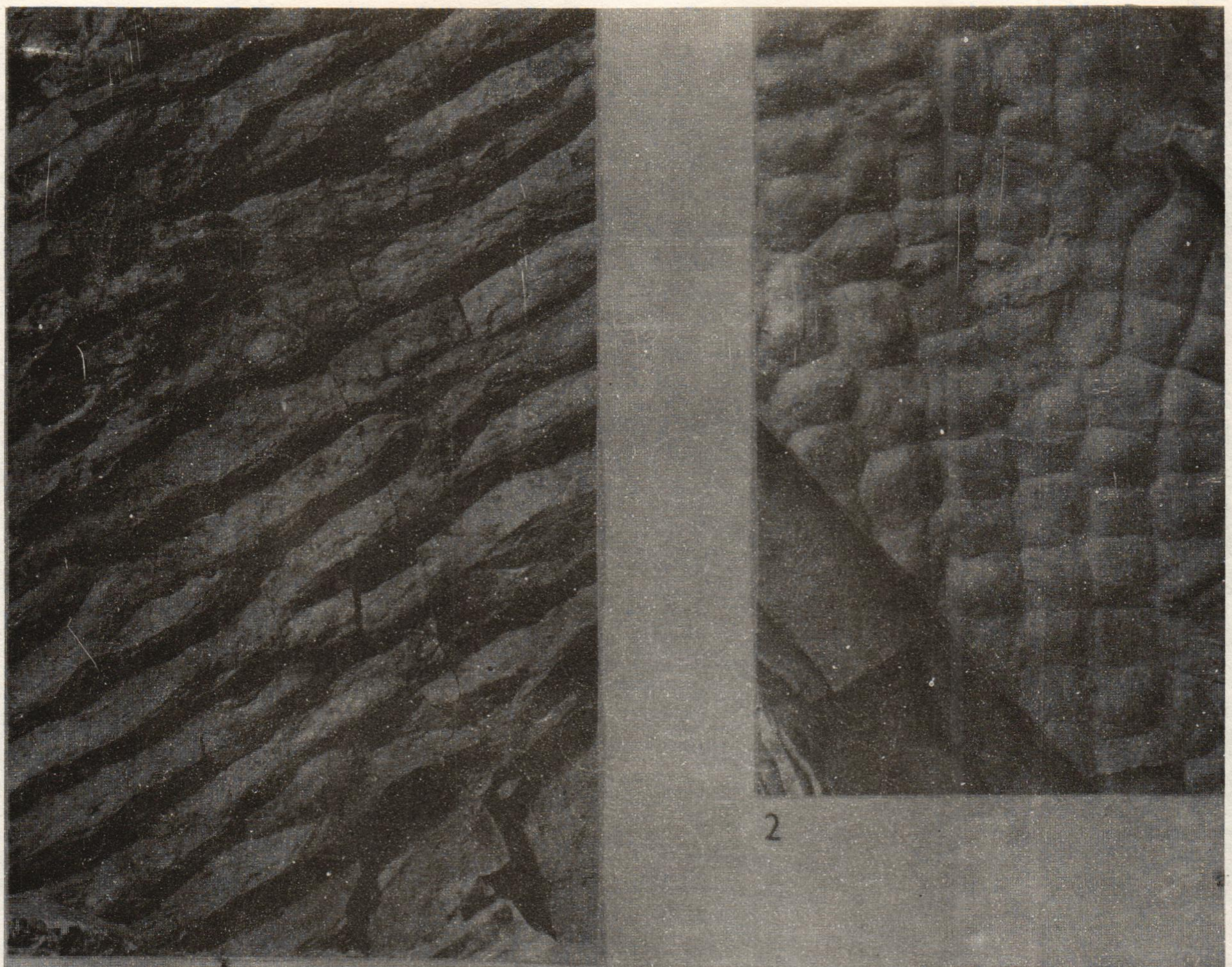


Plate - 5 Ripple marks in Hazara Group.

1. Symmetrical branching at Bagra near Havelian.
2. Interference at Boragali.
3. Symmetrical regular at Bagra near Havelian.

Plate - 6. Flute casts in Hazara Group near Tarnawai.

Kashmir Journal of Geology *Vol 2 No. 1, 1984*

GEOLOGY OF THE SHEWA-DIR-YASIN AREA AND ITS PLATE TECTONIC INTERPRETATION

M. NAWAZ CHAUDHRY AND MUNIR GHAZANFAR
Institute of Geology, University of the Punjab,
New Campus, Lahore.
MUHAMMAD ASHRAF
Institute of Applied Geology, University of Azad Jammu & Kashmir, Muzaffarabad.
S. SHAHID HUSSAIN
Gemstones Corporation of Pakistan,
Peshawar, N.W.F. Province.

ABSTRACT.– Regional Geology of a large area between Shewa, Malakand, Warsak in the south and Hunza, Yasin, Chitral in the north through the valleys of Dir and Swat has been broadly described Petrography and Model compositions of the principal petrologic units are presented. Chemistry of some of these rocks has also been discussed. Petrotectonic significance of the principal rock units in the area is assessed. A number of linear petrotectonic belts have been established running approximately east-west between Shewa in the south and Yasin in the north. It is suggested that the mass of rocks enclosed in the Kohistan area between the India and Asian plates is not a single island arc sequence but comprises on the other hand at least two and possibly three island arcs and associated trenches. The extensive amphibolite, and complex is separate and does not represent the lower part of a single Kohistan island arc sequence as suggested in the past but comprises at least three distinctive belts two belts of obducted melanges with a central belt consisting of a possibly trapped portion of the Tethy's oceanic crust. Finally a southward subduction of the Tethyan lithosphere is postulated under the Indo-Pak plate in contrast to north directed subduction of the Indian plate as suggested in the past. A sequence of different subduction zones is suggested.

INTRODUCTION

Voluminous geological data accumulated over the past three decades has been interpreted in terms of plate-tectonics for the central and eastern Himalayas have been regarded, as a whole, to be a belt of collisional mountains representing typical continent to continent collision. Variant details of this theme have been presented by a number of authors such as Dewey and Bird (1970), Nowroozi (1972), Powell and Conaghan (1973), Stonley (1975) and Sillitoe (1975).

Tahirkheli, Mattauer, Proust and Tapponnier (1979) after careful analysis of the geolgical data collected from northwest Himalayas presented a new model for this region. These writers postulated on initial phase of ocean-ocean collision and formation of an island arc to the north of the Indo-Pak plate. This arc was later sutured to the Asian continent to the north along MKT and to the south with the Into-Pak plate along MMT. The sandwitched arc was named by them as the Kohistan Island Arc. This appreciation of certain petrotectonic assemblages and deciphering the two sutures MKT and MMT and the discovery of an arc was indeed a landmark.

The present paper which puts forward a different model is based mainly on the work carried out by Chaudhry, Jaffery and Saleemi (1974), Chaudhry, Shafiq and Mahmood (1974), Chaudhry M. N. and Chaudhry A. G. (1974), Chaudhry, Kausar and Lodhi (1974), Chaudhry M. N., Mahmood and Chaudhry A. G. (1974), Chaudhry, Ashraf and Hussain (1976), Chaudhry, Ashraf and Hussain (1980), Chaudhry , Ashraf and Hussain (1980, 1981), Chaudhry and Shams (1983), Chaudhry, Ashraf and Hussain (1983). The comprehensive model was partially developed in Butt, Chaudhry and Ashraf (1980) and Chaudhry, Ghazanfar and Ashraf (1983). These papers deal with Dir and Malakand. Information collected from Swat, Indus valley and northern areas now has also been for the first time included in the present paper for an interpretation of a wider region of northwest Himalayas.

The main approach continues to be petrotectonic in the present paper since detailed geophysical and structural information is lacking. Petrotectonic assemblages have been defined by Dickenson (1971) as rock assemblages that characterise plate boundaries or specific plate interior settings.

This approach is particularly suited to northwest Himalayas where extensive thrusting and transport of rock masses over large areas has caused considerable obliteration of the regional relations destroying or modifying some critical evidence. Juxtaposition through thrusting and mass transport of unrelated rock units can be unravelled to a large degree through a petrotectonic approach since petrological studies on such blocks help in establishing their natural positions on plate margins or plate interiors.

GENERAL GEOLOGY

Now a generalised sequence from the Indo-Pak plate marginal zone in the south to the Eurasian plate marginal zone in the north as based on the study in the Northern areas is as follows: –

1. Indo-Pak plate marginal zone.

   a) Zone of tension, the alkaline province

   b) Zone of compression, the regionally metamorphosed sequence with Tertiary magmatism, contact metamorphism and regional mobilization.

   c) Zone of minor shears and overthrusts and small scale tectonic slicing.

2. Southern island arc, the southern sedimentary volcanic zone (remnants).

3. Southern obducted melange with products of partial melting.

   a) Southern trench zone with high pressure, low temperature assemblages.

   b) Southern main melange zone with amphibolites slices of ultrabasics and eclogites and remnants of metamorphosed sea-floor sediments. Also fusion products of amphibolites like pyroxene meladiorites, meladiorites and diorites with minor tonalites and porphyries.

4. Tethys crust.

   a) Remnants of Tethys sediments
   b) Remnants of pillow lavas
   c) Sheeted dyke complex
   d) Extensive central plutonic basic and ultrabasic complex.

5. Northern melange, sedimentary volcanic and trench zones. In the Dir to Yasin-Gupis section there is some evidence suggesting a double arc sequence which from south to north comprises amphibolites sedimentary volcanics with intrustive product of partial melting of amphibolites like numerous pyroxene diorites, meladiorites and their more acidic derivatives and differentiates followed by a second belt of greenstones (also intended by granite, granodiorite, tonalite, diorite suite) and a second belt of sedimentary-volcanics (second arc). This in turn is followed by some ultrabasics.

6. Eurasian plate marginal zone.

   a) Zone of minor shears and overthrusts.

   b) Zone of compression. Regionally metamorphosed rocks with Tertiary magmatism, contact metamorphism and possible regional mobilizates.

   c) Zone of tension. Possible alkaline province.

INDO-PAK PLATE MARGINAL ZONE

The Indo-Pak Plate marginal zone is composed of precombrian to Palaeozoic metasediments, older and younger granites, basic sills, dykes and minor bodies, rocks of the alkaline province and marginal minor tectonic slices. The various zones from south to north are discussed in the following: –

(a) Zone of Tension, the Alkaline Province:

A zone of tension exists on the Indo-Pak plate. This zone is complimentary to the zone of compression lying to its north. This alkaline province of northwest Pakistan extends from Loe Shalman in the west to Tarbela in the east for a known distance of about 170 km. This zone of tension containing en-echelon planes of weakness is estimated by the writers to be spread over about 50 km. width.

The rocks of the alkaline province were discovered for the first time by the staff of the Institute of Geology, Punjab University (Shakoor: A verbal communication, 1965, and Siddiqui, 1965). Genetic relations between Shewa porphyries and Chamla alkaline complex were clearly recognized by Siddiqui, Chaudhry and Shakoor (1968). The alkaline province was recognised by Jan and Kempe (1970). The Malakand carbonatite was recognised by Ashraf and Chaudhry (1977).

The Province is composed of feldspathoidal syenites syenites and nordmarkites, fenites – carbonatites, soda granites and soda porphyries. The members from west to east are as follows: –

i) *Loe Shalman (Khyber) foliated nepheline syenite, carbo-natite and fenites: –*

valley of Loe Shalman in the northeastern part of Khyber Agency (Ahmad and Ali, 1977). These rocks occur within slate, phyllite – and argillite which comprise the Landi Kotal Formation. The intrusions are of foliated nepheline syenites, fenites and sill like masses of carbonatite.

ii) Warsak Alkaline Rocks:- The Warsak alkaline granites and associated lamprophyres occur near Warsak at a distance of about 24 km. northwest of Peshawar. The alkali granites and lamprophyres intrude the low grade metasediments like slate, phyllite, quartzite and marble. The rocks are of very low grade and are either pre-Cambrian or Upper Palaeozoic. The granites are the foundation rock for the Warsak Dam (Ahmad et al. 1969). Six samples of the foliated alkali granites studied by Chaudhry gave on the average 45% quartz, 28% microcline, 17% soda pyriboles, 5% albite, 1.5% ilmenite and 0.5% each of zircon, sphene and apatite (unpublished data).

Associated lamprophyres (gneissic) studied by Chaudhry gave riebeckite 28–50%, biotite 28–58%, calcite 1–5%, sphene 5–15%, ilmenite 1–5% and apatite 1–6% (Unpublished date).

The Malakand carbonatites were first reported by Ashraf and Chaudhry (1977). These carbonatite bodies occur in metamorphosed pelitic rocks which form a part of pelitic-psammatic and calcareous sequence of probable pre-Cambrian age.

Samples studied petrographically are porphyritic to sub-porphyritic and coarse grained and show that the rocks are composed of carbonates (50–90%) arfvedsonite (2–25%), ilmenite traces, titanomagnetite (2–5%) vermiculite (2–18%), apatite (2–12%), chlorite (traces) and feldspar (0–5%).

One sample analysed for rare earths gave Nb 100 to 300 ppm, Y 100 to 200 ppm, La 400 ppm.

iii) *Shewa Prophyrites:–* The 85 Km^2 metasediments-porphyry complex constitutes a roughly triangular outcrop, surrounded by alluvium and limited by the villages of Shahbazgarhi, Shewa and Machai at the three corners. They have been mapped and described in detail by Chaudhry and Shams (1983). Genetic affinities of these porphyries with the alkaline rocks of Warsak area have been suggested

The country rocks are composed essentially of mica-schists and metaconglomerates with rare thin bands of schistose quartzite. The porphyries occur as dykes, sills, plugs and irregular bodies. Field relations, supplemented with laboratory studies show following sequence of rock emplacements.

Acid black porphyries
Riebeckite porphyries
Acid grey prophyries
Riebeckite gneisses.

The riebeckite gneisses are composed of (five samples studied) albite/oligoclase 22.3 to 32.1%, K-feldspar 19.8 to 23.9%, quartz 22.1 to 28.5%, biotite 4.8 to 7.6%, riebeckite/arfvedsonite 6.4 to 15.6%, magnetite 1.3 to 3.5%, apatite 0.8 to 2.2%, sphene 0.5 to 5.6% and zircon nil to 0.6%, and muscovite 0.6 to 3.5%.

The riebeckite porphyries are composed of albite/oligoclase 34.2 to 40.4%, K-feldspar 25.1 to 35.0%, quartz 17.1 to 22.1%, riebeckite 8.0% to 12.5%, magnetite 1.0 to 1.6%, sphene 0.5 to 1.0%, apatite 0.4 to 0.8% and zircon 0.2 to 0.4%.

The acid grey and acid black porphyries are similar to the riebeckite gneiss and riebeckite porphyries except the absence of soda pyriboles and ziron.

iv) *The Koga Alkaline Complex.* The rocks of the Koga alkaline complex are located on the border between the districts of Swat and Mardan. But the main mass is situated within Swat. These rocks are emplaced within Swabi-Cambla metasedimentary group. This group has been placed in Mid-Palaeozoic by Davies and Ahmad (1963).

The igneous complex has been divided into three types by Siddiqui, Chaudhry and Shakoor (1968). The alkaline rocks of the complex have been studied in great detail by Chaudhry, Ashraf and Hussain (1983). A brief description of the complex and associated rocks follows:–

i) Chingalai Granodiorite Gneiss. It is a granodiorite granite gneiss which is typically paraluminous and hypidiomorph porphyritic and is rich in biotite and K-feldspar. It is poorly to moderately foliated.

ii) Babaji syenites and granites. This association is composed of alkali granites, quartz-soda pyribole nordmarkites, soda pyribole syenites and aplites. These granitoid rocks are definitely peralkaline.

iii) Koga feldspathoidal syenites. These rocks are distinctly undersaturated and occur mainly as dykes (Chaudhry et al. 1983). It is not a single horse-shoe type intrusion as described earlier by Siddiqui et al. (1968).

The main rock types in the complex are pluskites and nepheline syenites and dykes of nepheline syenite, foyaites, sodalite nepheline syenite litchfieldite and nepheline syenite pegmatites. Their genetic affinity with other types of alkaline rocks of the alkaline complex has been discussed by Chaudhry et al. (1983) and Siddiqui et al. (1968).

Average petrographic and chemical composition of these rocks is given in table 1 and 2.

v) *Tarbela Alkaline Rocks:* – These rocks are composed of soda pyribole bearing porphyritic microgranites. These rocks along with associated gabbroic sills occur within the Salkhala Series. One of these bodies studied by Kempe and Jan (1970) is a differentiated sill of gabbroic base which passes upwards into a diorite and oligoclase carbonate rock at top. The carbonate bearing part contains 120 ppm Nb and 1300 ppm Zr.

(b) Zone of Compression:

This zone is a zone of high pressure and heat flow. This zone has undergone regional high pressure-temperature metamorphism. The rocks involved are mainly Precambrian Salkhalas, Tanols and Attock Slates. Some Lower to Middle Palaeozoic rocks may also be effected in Swat and Malakand (Swat-Buner Schistose group and Abbottabad Formation).

The grade of metamorphism increases from south to north from phyllite, chlorite to kyanite grade and then falls again to biotite grade as we approach MMT along Indus from Attock to Besham or Allai Valley. The grade is even lower in Allai. Elsewhere due to extensive faulting and thrusting and mass transport the situation is even more complicated.

These metasediments contain older remobilized granites and their thermal aureoles. The gneissic and foliated masses of granite such as Malakand granite gneiss, Mansehra granite, Susalgali granite gneiss, Kel gneiss and Nanga Parbat gneiss are Cambrian or even Precambrian. However, the emplacement of these bodies as energised mobilizates and development of thermal aureoles is much younger and is related to the subduction of the Tethys under the Indo-Pak plate during Jurassic, Cretaceous and later Time.

Then there are the younger granites such as Malakand granite, Chail Sar microgranite, Karka granite etc. (and many more such bodies are sure to be discovered). These granites may be directly related to the development of the magmatic arc and are generally Tertiary intrusions.

Also present are a large number of sills and dykes and minor bodies of dolerites cutting the metasediments. Some of these are metamorphosed while others are rather fresh. They represent passages of ascending melts, for details of this zone in the Mansehra area consult Ashraf (1974, 1983), Shams and Rehman (1966), Shams (1969) and Shams and Ahmad (1968).

(c) Zone of Minor Shear and Overthrusts.

This zone has been studied by Chaudhry, Ashraf and Hussain (1980). They have defined various types of these bodies. The following study is a continuation by Chaudhry of the earlier work.

This zone is located near the volcanic arc. A number of ultrabasic rock slices/intrusions occur within Cretaceous/ Tertiary as well as older (Palaeozoic and Precambrian) metasediments. Marginal parts of the southern amphibolite belt also contain these slices. These rocks are serpentinised, serpentinites, talc-carbonate rocks, olivine - pyroxene-amphibole, serpentinites and garnetiferous serpentinites (altered ecologites).

Thirty five samples of talc-carbonate rocks from Shangla and Jabba areas were studied petrographically. On the average they are composed of talc/pyrophyllite 46.2%, carbonate (magnesite) 28.5%, antigorite 8.6%, quartz 7.9%, magnetite/chromite 4.1%, haematite/limonite 3.7%, sulphides (millerite, pentalandite, polydymite, pyrite) 0.5% and chlorite 0.5%.

Fifteen rock samples from the same area gave the following average chemical composition:

SiO_2 38.75%, Al_2O_3 4.18%, Fe_2O_3 8.9%, MnO 0.10%, Mgo 30.03%, CaO 1.68%, N : O 0.36% and I/L 17.0%.

Thirty eight samples of serpentinites from the same areas are composed, on the average, of antigorite/chrysotile 80.9%, talc 1.8%, carbonate (magnesite) 5.1%, haematite/ limonite 0.4%, pyroxene 5.5%, picotite 0.3%, olivine 3.7%, garneirite 0.2%, sulphides (millerite, polydymite, pentalandite and pyrite) 0.6%.

Twenty analysed samples of these rocks gave the following average chemical composition SiO_2 40.85%, Al_2O_3 1.69%, FeO_3 8.62%, MgO 37.30%, CaO 0.54%, NiO 0.46% and I/L 11.21%.

In addition there are some serpentinised periodotites, talc-amphibole, olivine-pyroxene-amphibole, talc-amphibole serpentinites, margarite-antigorite-serpentinite, olivine-amphibole-pyroxene and garnetiferous serpentinites (ecologite) rocks.

Table - 1

Mineral Composition of Nepheline Syenites of Koga, Swat

No. of samples	35	8	10	14	11	15
	Nepheline Syenite	Foyaites	Nepheline Syenite Dykes	Sodalite Nepheline Syenite	Litch-fieldites	Nepheline Syenite Pegmatites
Nepheline	20.5	53.1	26.1	15.8	20.0	5.2
Microcline	48.8	16.8	50.7	54.4	15.3	49.4
Albite	17.0	17.0	8.4	6.5	50.8	33.7
Sodalite	0.1	–	0.3	14.3	0.1	–
Cancrinite	0.8	5.6	2.8	2.1	3.0	–
Aegirine	4.2	0.7	0.3	–	0.9	2.5
Arfvedspnite	1.8	–	3.5	0.7	1.5	1.0
Biotite	1.9	5.3	3.6	3.9	2.7	2.4
Muscovite	1.0	–	0.4	0.8	0.8	2.3
Calcite	1.3	–	–	–	–	–
Apatite	0.1	–	0.3	–	0.2	–
Zircon	0.3	0.4	0.6	–	0.2	–
Sphene	0.6	0.5	0.9	0.1	0.7	0.6
Ilmenite	0.7	0.6	0.6	0.4	1.4	1.1
Garnet	0.3	–	1.3	–	1.5	0.4
Haematite	0.2	–	–	0.2	0.6	0.3
Magnetite	0.1	–	–	–	–	0.4
Pyrite	0.1	–	–	0.6	0.3	0.5
Epidote	0.2	–	0.2	0.2	–	0.2

Table - 2

Chemical Composition of Nepheline Syenites of Koga, Swat.

No. of Samples	Nepheline Syenite	Foyaites Dykes	Nepheline Syenite Dykes	Sodalite Nepheline Syenite	Litch-fieldites	Nepheline Syenite Pegmatites
	32	5	12	5	7	5
SiO_2	57.31	55.65	58.50	55.92	58.90	61.65
TiO_2	0.23	–	–	0.13	0.01	0.14
Al_2O_3	20.75	22.72	20.08	23.46	21.84	21.01
Fe_2O_3	3.19	2.46	2.15	2.32	1.70	2.88
MnO	0.02	–	–	–	0.01	0.01
MgO	0.78	1.40	0.83	0.16	0.25	0.40
CaO	1.96	1.39	2.27	1.27	1.99	0.55
Na_2O	7.80	9.91	8.13	10.68	9.56	6.12
K_2O	6.23	5.34	6.77	4.97	4.70	6.97
P_2O_5	0.18	–	0.26	0.04	0.15	0.01
I/L	1.41	1.37	1.39	1.11	1.10	0.57
Total	99.86	100.24	100.38	100.06	100.21	100.37

THE SOUTHERN SEDIMENTARY-VOLCANIC ZONE.

This zone is present as slices south of the Main Mantle Thrust (MMT). No single continuous belt could be traced. The zone is present, in the form of slices, near Shangla, north of Kabal and Southern Dir. The volcanics are mainly acid to intermediate. Rhyolites, dacites, andesites and their tuffs and breccias are present interbedded with low grade Tertiary metasediments. This zone is closely associated with older metasediments of the Indo-Pak Plate. At places faulted slices of pillow lavas and oceanic basalts are tectonically juxtaposed.

THE SOUTHERN OBDUCTED MELANGE WITH PRODUCTS OF PARTIAL MELTING.

This zone from south to north is subdivided into the southern trench zone and the southern main melange zone. A somewhat detailed description of these follows below:

THE SOUTHERN TRENCH ZONE

This is a zone of low temperature and high pressure. Blue schists are found in this zone near Shangla (Shams 1979, Shams, Jones and Kempe 1980 and Shams and Desio 1980). The blue schist at Shangla is a faulted slice. A full survey of high pressure and low temperature assemblages has not yet been carried out. So precise characterisation of assemblages is not possible at this stage. Metabasite assemblages in this zone near Shangla are (1) Glaucophane-actinolite-quartz ± sphene, (2) Glaucophane-chlorite-clinozoisite ± quartz ± sphene, (3) Actinolite-clinozoisite-quartz ± sphene. The presence of glaucophane is sufficient to place these rocks in the blue-schist facies.

THE SOUTHERN MAIN MELANGE ZONE.

In this zone are found obducted tectonic slices of amphibolites, ophiolites, eclogites and talc-carbonates. The amphibolite represent a transformed variable admixture of submarine volcanics and sediments.

On the southern side close to the MMT these are cut by acid porphyries and probable volcanics near Bandagai, Ziarat, Talash and Shahai in Dir (Gansser, 1974), for a different interpretation of these rocks see Jan (1980), Jan (1980 a). Further north they are cut by a belt of diorites.

The exact areal extent of the amphibolite belt is not defined as yet. However, the best studied part of amphibolite belt is exposed in Panjkora river valley. The belt shows an apparent tendency to pinch in the southwest while along the strike towards north northeast the belt shows relatively broader exposed area.

This zone consists essentially of amphibolites containing exotic pieces of eclogites, serpentinites, dunites and periodotites. In addition to the exotic blocks the amphibole belt also hosts a varied intrusive sequence ranging in composition from diorites to noritic gabbros with minor granites and tonalite.

Chaudhry et al. (1974) have defined two categories of amphibolites from this belt. A classification of these rocks based largely on petrographic, chemical and field criteria is as follows: –

1) Southern Amphibolites. These rocks have a fine to medium grained, hypidiomorphic and granular texture, allotriomorphic and idiomorphic textures are also seen.

Amphibole, plagioclase, quartz and orthoclase are the main constituents while garnet, epidote, chlorite, sphene, calcite and biotite are the accessories. The southern Dir amphibolites are much more uniform in texture and rarely show banding which is characteristic of northern Dir Amphibolites.

2) Hornblendites. Blocks of hornblendites, patches, dykes and sills are present both in the southern and northern amphibolites of Dir area. These rocks usually grade into more typical amphibolites. A general hypidiomorphic granular texture is characteristic of these rocks. They are composed chiefly of hornblende with minor cummingtonite and plagioclase.

At places gradational contacts between hornblendite and periodite/dunite have been observed. The cores of hornblendite bodies contain fresh periodite or dunite.

3) Eclogites. These rocks occur as exotic screens within the amphibolites. There is apparently no relationship of these rocks with the surrounding amphibolites. Such ecologites form under exceptionally anhydrous conditions (Fry and Fyfe, 1969).

These rocks contain quartz and have clinopyroxene-garnet-quartz assemblage characteristic of ecologite facies.

4) Southern Diorites. A diorite belt runs along the central intrusive complex. This belt is composed of amphibolitic-quartz-diorites, The belt is younger than the southern amphibolite belt while it is older than the central intrusive complex of norites, noritic gabbros and gabbros with dunites, pyroxenites and peridotites.

This belt has been studied in Dir by Chaudhry et al. (1974). The average composition of the belt from Dir and adjoining Swat areas shows these rocks to be fairly basic. They are composed (n = 120) on the average of plagioclase (An 48) 38%, amphibole 48%, quartz 5%, epidote 3%, magnetite 3%, orthoclase 1%, biotite 1%, sphene 1%, apatite traces and mucovite traces.

Within the diorite bodies hornblendites and scylites are also present.

THE TETHYS CRUST

The various layers of the Tethys crust are all present along a very long belt which crosses into Afghanistan. However, only the plutonic basic and ultrabasic rocks are persistently present. The upper layers comprising the sediments, the pillow lavas and the sheeted dykes are only present at few places as fault slices. Below a brief description of these different layers of the Tethys crust found at different places follows:

1) Remnants of Tethyan sediments. These are found near Dir and close to and south of MMT in survived obducted blocks. These contain Palaeocene and Eocene fossils mainly Assilina spp and Nummulites spp found from Kabal by Hussain and from Dir by Chaudhry and students.

2) Pallow lava remnants are present at Shangla Par and Mohmand and have associated manganese mineralisation. Remnants are also present near Chalt in Hunza.

3) Sheeted dyke complex remnants are found in Yasin valley. These are now metamorphosed in green schist facies.

4) The central layered intrustions are the lower plutonic layer which is composed of norites and noritic gabbros and with pyroxenites, dunites and peridotites.

Bojites and meladiorites are associated at places. The rocks may be massive or layered. Cryptic as well as mineral layering is well shown by these bodies.

A total of 130 samples analysed from Dir show that they contain on the average, plagioclase (An 58) 55%, orthopyroxene 20%, clinopyroxene 14%, hornblende 3%, biotite 2%, quartz 4% and magnetite 2%. Trace amounts of sphene and apatite are common.

The pyroxenite bodies (n = 30) in this complex contain on average clinopyroxene 48%, orthopyroxene 45%, amphibole 4% and ore 1%.

There are also bodies composed predominantly of orthopyroxene (local cumulate layers) and bodies composed principally of clinopyroxene.

5) Also present are dunites and peridotites at many places. The fragments of ultrabasics are the mantle remnants.

THE NORTHERN MELANGE, SEDIMENTARY, VOLCANIC AND TRENCH ZONES.

In the Dir to Yasin – Gupis section there is some evidence suggesting a double arc sequence which from south to north comprises amphibolites, sedimentary volcanics with intrusive products of partial melting of amphibolites like numerous pyroxene diorites, metadiorites and their more acidic derivatives and differentiates followed by a second belt of greenstones (also intruded by granite, granodiorite, tonalite, diorite suite) and a second belt of sedimentary-volcanic (second arc). This in turn is followed by some ultrabasics.

The Northern Dir Amphibolites are medium to coarse grained rocks with a dominantly xenoblastic texture. Other textural variations are also observed. The variability in the amount of hornblende and felsic minerals is obvious from thin section studies. The rocks with higher colour index contain hornblende and epidote as their major constituents with accessory amounts of chlorite, sphene, quartz, plagioclase and magnetite. Lighter coloured varieties not only have lesser hornblende but their felsic mineralogy is also very different. In these rocks quartz and plagioclase take over as major minerals whereas chlorite, garnet, epidote, muscovite, orthoclase, sphene, calcite and apatite represent accessories.

At least two sedimentary-volcanic zones are found in the north. The more northern of these the Yasin zone is the better developed one. In Dir it is represented by a thick sequence of quartzite with substantial volcanic element and marl, shale and limestone with interbedded volcanics. This sedimentary volcanic sequence extends into Swat-Kohistan and beyond. The volcanics belong to the andesite-dacite-rhyolite sequence. A part of the volcanic activity was subaerial. A few ash flow and ash fall horizones have been encountered. The sedimentary volcanic sequence has undergone greenschist facies metamorphism. The deposits. cut by a number of acid plutons. The environment throughout its extent is suitable for porphyry deposits all along and close to this sequence. The area is also suitable for stratiform stratabound ore Deposits.

As far as the trench zones are concerned the evidence of one developed between Dir amphibolites and Dir sedimentary volcanic zone is only rudimentary in the form of talc-carbonates andultrabasics in this position. However, the trench zone in the Yasin valley is much better developed consisting of talc carbonates, widespread ultrabasic slices etc. It appears that this is older of the two trench zones if indeed there is a double arc, as the northern greenstones are extensively cut by later granites and are rich in potash metasomatism while the younger sediments met within Dir are not yet reported from here.

THE ASIAN PLATE MARGINAL ZONE

It is composed of metasediments of Palaeozoic and older ages. These are cut by a large number of acid to intermediate plutons. These plutons must fall in two age groups i.e. Palaeogene, Neogene and Mesozoic, Palaeozoic and older. The younger intrusions are related to subduction of the Tethys under the Asian mass and the older represent the Asian continental mass.

The grade of regional metamorphism in Hunza increases from chlorite grade at Chalt to staurolite and kyanite grades towards Karimabad. Beyond the Karakoram axial batholith the grade of metamorphism decreases against a very low?

INTERPRETATION

The Indo-Pak and the Asian Marginal Zones. – The Indian marginal zone is composed of Palaeozoic and older sediments except for the overlying exogeosynclinal sediments or isolated patches of sediments containing Tertiary fossils like *Assilina* and Disocyclina present close to the trench. These latter may throw light on the age of the sedimentary volcanic arc.

The generally Precambrian metasediments of the Indo-Pak marginal zone are cuty by two categories of granite. One category is Palaeozoic and older and is represented by Mansehra granite, Lahor granite and Kel granite. The other category which is much younger and mostly Tertiary with some possibly Mesozoic is represented by the Malakand granite, Chail Sar granite, Hakle tourmaline granite and Neelum granite. Also present are a large number of dykes (Shams and Ahmad, 1968) representing passages from basic to intermedite volcanic eruptions. All this activity seems to be connected with post-Cretaceous subduction south of MMT.

In the Mansehra-Allai Section the grade of metamorphism from south to north first increases to kyanite grade but then decreases again further north and the metamorphism is of greenschist facies close to the trench except where high metamorphic blocks are tectonically juxtaposed close to the trench.

The Asian plate marginal zone has some similarities of geological history to its counterpart the Indo-Pak plate in the south. One similarity relates to the two age groups of acid to intermediate plutons; and the second similarity relates to the grade of metamorphism which in this case increases from chlorite grade at Chalt in Hunza valley to staurolite and kyanite grade towards Karimabad in the north. Beyond the Karakoram axial batholith the grade of metamorphism decreases again to very low grade.

The Alkaline Zone.— The alkaline province trends WSW-WNW and runs from Tarbela to Loe Shalman over a distance of some 200 km and finally extends into Afghanistan on the west. This belt of alkaline intrusives and hypabyssal rocks consists of several independent centres of alkaline magmatism including carbonate plugs. These rocks have not been radiometrically dated, but from the geological criteria most of the rocks are very young. A possible Tertiary age has been indicated from one syenite sample in Koga (Siddiqui et al. 1968). Warsak alkaline granite has been interpretted to be Lower Tertiary by Ahmad et al. (1969).

Most strongly alkaline rocks are generally known to be associated with the first systems i.e., zones of tension within the continental crust. Many of these rocks contain $Na_2O + K_2O$ more than 10%. Chemical data on Koga alkaline complex shows that the $Na_2O + K_2O$ in the rocks average more than 15% (Siddiqui et al. 1968, Ashraf et al. 1979). Similarly in Warsak alkaline granite $Na_2O + K_2O$ averages upto 10% of the rock, Ahmad et al. (1969).

South of the MMT we can expect a zone of intense compression resulting in pressure metamorphism. Further south, however, the zone of compression would be followed by a complementary zone of tension. It is here that the alkaline zone has developed.

Chaudhry and Shams (1983) have shown that the intrusive rocks along this zone developed from melts generated at variable depths and emplaced along weak planes of a zone which suffered intermittent and alternate periods of variable tension and compression. The alkaline rocks of this zone developed during periods of tension while the normal acidic rocks emplaced along this zone were formed during periods of compression.

The Trench Zones.— The southern trench zone is not a continuous zone and is represented by ophiolite masses at Jijal and Jalalabad as well as by blue schists at Shangla Par (Swat). Blue schists were first reported from Shangla Par by Arif (1972). These rocks here are exposed only as thin slices apparently underlying the ophiolites and melanage. The blue schists are indicative of high pressure low temperature metamorphism which results when the sediments as well as volcanics are trapped in a trench environment, generally down to some 25 km. This metamorphosed complex is then obducted. One problem of the southern trench zone is the absence of blue schists along most of the MMT. This, however, must be explained tectonically although depending upon the composition of the original material high pressure mineral suites other than the blue amphibole, glaucophane, may form and may be discovered in time.

The northern trench zone is more complicated and possibly there are two of these. The one which is met within northern Dir consists of ultrabasic bodies while the more northern of these two trenches is met within Yasin and Hunza Valleys where fairly extensive slices of ultrabasics and talc-carbonates are found.

Sedimentary-Volcanic Zones.— Chaudhry et al. (1983) have described two main island arc sequences between the Indo-Pak and the Asian plates, the southern and the northern island arcs. however, appear to be a double one of which there is one in northern Dir and one in Yasin valley. From whatever geological evidence is available the sequence of events appears to be as follows:—

(i) Southward subduction of the Tethys under the Indo Pak plate and the formation of the southern sedimentary volcanic zone found in southern Dir and near Shangla Par in Swat.

(ii) Northward subduction of Tethys floor under the Asian plate and formation of the sedimentary volcanic zone now seen in Yasin.

(iii) Jamming of the Yasin subduction and initiation of subduction in northern Dir leading to the development of island arc now seen in northern Dir and at Kalam in Swat.

Here a comment on the position of the MMT (Main Karakoram Thrust) may not be out of place. Tahirkheli has shown it to be passing north of the northernmost sedimentary volcanics (herein called the Yasin Island Arc). If the MKT is to represent a north directed subduction of the Tethys ocean floor the island arc cannot be present to the south of the trench zone. The position of the MKT must, therefore be placed at least to the south of the northern Dir Island Arc sequence.

The South and North Melange Zones:– The southern amphibolites have been interpreted by Chaudhry et al, (1974) as orthoamphibolites while the northern amphibolites have been interpreted as para-amphibolites. The two amphibolite bodies of the south and north are, however, probably different from each other only in the relative proportion of the relic sedimentary material present.

The southern amphibolites are basically igneous but contain relic chunks of carbonates and impure carbonates.

The northern Dir amphibolite and melange zone on the other hand contain impure quartzites, recrystallized chert and marble along with transformed oceanic basalts. The proportion of the relic sediments in the northern amphibolites increases as we move from south to north towards the arc and represent an increasing incorporation of the arc derived sediments.

There are two amphibolite zones in the north. The Northern Dir Amphibolites and the Yasin Valley Amphibolites. The latter have been called greenstones in the past but their mineralogy shows these to be amphibolites which are extensively cut by later acid to intermediate bodies. Some of these bodies represent products of a possible second subduction in Dir while some very young acidic bodies occuring both in the greenstones as well as elsewhere are related to the remobilization of the Nanga Parbat massif.

The Tethys Crust:– There has been a controversy regarding the nature of those basic and ultrabasic rocks. These were classified in the past as granulites by Jan et al. (1980). and as lower part of an overturned island arc sequence by Tahirkheli et al. (1979).

But, Chaudhry and Ashraf (1979) described this sequence as ranging in composition from norites to noritic gabbros and minor diorites. Such rocks when plotted on FMA diagram show a calc-alkaline trend typical for an oceanic suite (Thayer 1969). The ultramafic fractions include harzburgite and dunite with minor plagioclase bearing Iherzolites. At places the gabbroic and ultramafic rocks show a cumulative texture and banding (Chaudhry and Chaudhry 1979) indicating their development in shallow magma chambers feeding the basalts now represented by amphibolites. In short the petrography, chemistry and texture of these rocks leaves no doubt about the igneous nature of the these rocks and the tholeiitic type of magma from which they formed, for the sediments and pillow lavas of this oceanic crust (see the description of the Tethys crust given in the previous pages).

The central basic mass represents oceanic lithosphere as against the idea that it forms lower part of an island arc sequence. The huge succession that was called by Tahirkheli et al. (1979) as the Kohistan Island Arc actually comprises a number of distinct petrotectonic provinces consisting of more than one melange sequence, more than one island arc and more than one trench.

REFERENCES

Ahmed, R., and Ali, S. Tayyab, (1977). Occurrence of phosphate in Loe Shalman carbonatite. Geol. Survey Pak. Inf. Releae No. 101, 19p.

Ashraf, M., and Chaudhry, M. N., (1977). A note on the discovery of carbonatite from Malakand District. *Geol. Bull. Punjab Univ. No.* 14, pp.91–94.

Ashraf, M., Hussain, S. S. and Chaudhry, M. N. 1980. Magnetite deposits of Lower Kohistan District, Hazara Division. Pak. Metallurgist.

Ashraf, M., (1974). Geochemistry and petrogenesis of acid minor bodies of Mansehra and Batgram area, Hazara. Unpublished Ph. D. thesis submitted to the University of the Punjab, Lahore.

Ashraf, M., (1983). Geochemistry of acid minor bodies associated with the Hazara Granitic complex, Hazara Himalayas, Northern Pakistan. In: Granites of Himalayas, Karakorum and Hindukush Ed. F.A.Shams. *Inst. Geol. Punjab Univ.* Lahore, pp 123-141.

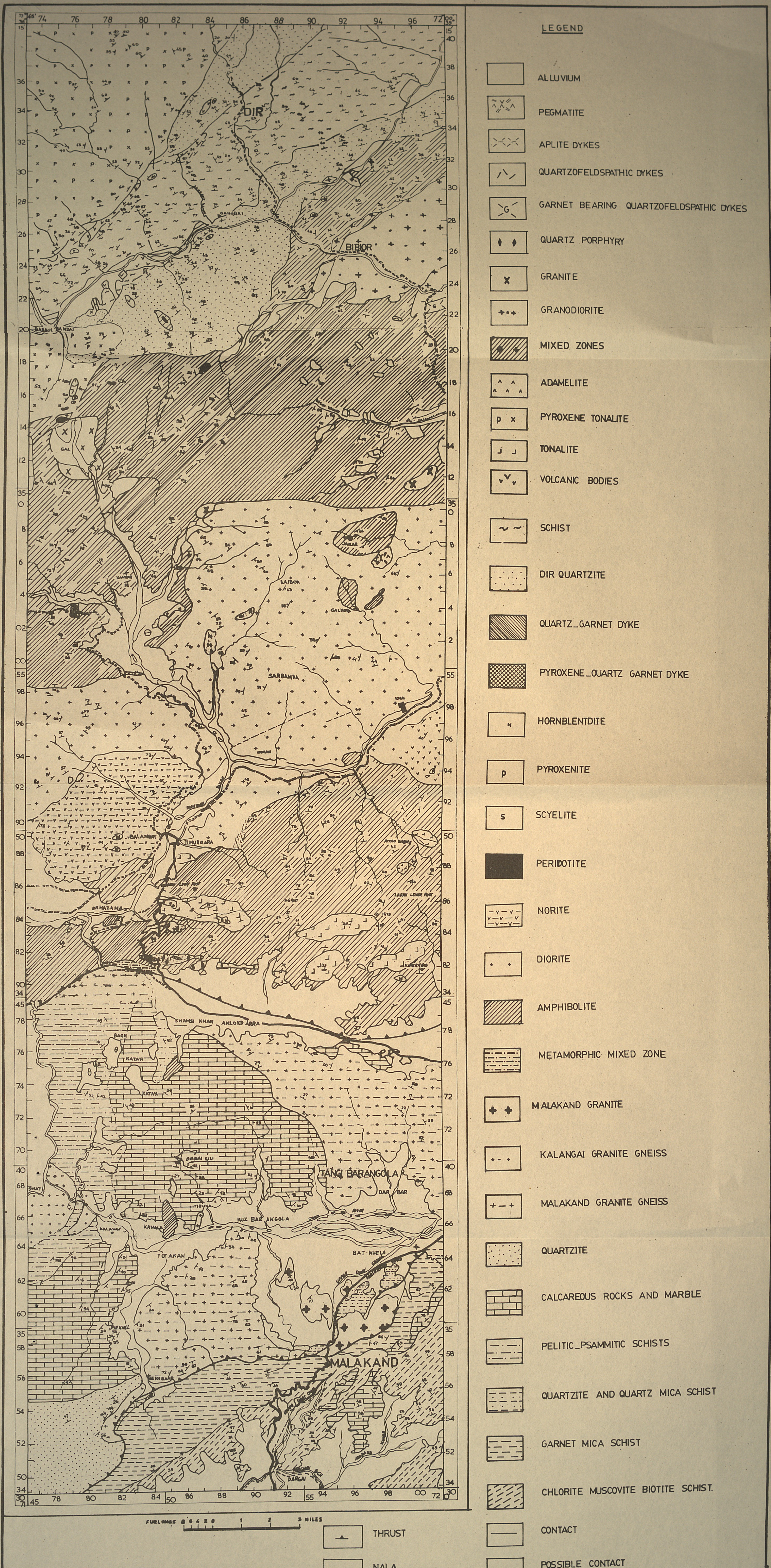
Ashraf, M., Chaudhry, M.N. and Hussain, S.S., (1980a). General geology and economic significance of the Lahore granite and rocks of southern ophiolite belt in Allai Kohistan area. *Proc. Intern. Comm. Geodyn. Gp. 6.Mtq., Peshawar. Spec. issue Geol. Bull. Pesh. Univ.* Vol. 13, pp. 207-213.

Butt, K.A., Chaudhry, M.N., and Ashraf, M., (1980). An interpretation of petrotectonic assemblage west of western Himalayan syntaxis in Dir District and adjoining areas in Northern Pakistan. *Proc. Intern. Comm. Geodyne. Gp. 6, Mtg., Peshawar. Spec. Issue Geol. Bull. Univ. Peshawar,* Vol. 13, pp. 79–86.

Chaudhry, M. N., and Chaudhry, A. G., (1974). Geology of Khagram area, Dir District. *Geol. Bull Punjab Univ.* No. 10.

Chaudhry, M. N., Kausar, A. B., and Lodhi, S. A. K., (1974). Geology of Timurgaral-Lal Qila area, Dir District N.W.F.P. *Geol. Bull. Punjab Univ.* No. 11, pp. 53–74.

Chaudhry, M.N., Mahmood, A., and Chaudhry, A. G., (1974 a). The orthoamphibolites and the paraamphi-



GEOLOGICAL MAP OF MALAKAND-DIR AREA.

FIG. 1

GEOLOGY BY:- Chaudry, Ashraf et al.

REVISED GEOLOGICAL MAP OF THE CHITRAL DISTRICT.

LEGEND

- HOLOCENE PLEISTOCENENE UNDIFFERENTIATED
- REDDISH SANDSTONES "RESHUN RED FORMATION"
- LIMESTONES, PARTLY REDDISH, DOLOSTONES CALCAREOUS SLATES.
- SANDSTONES AND CONGLOMERATE, PARTLY REDDISH "RESHUN CONGLOMERATE"
- LIMESTONES PARTLY ORBITOLINA_BEARING.
- SLATES AND SCHISTS PARTLY INTERBEDDED WITH META_VOLCANICS.
- DARK GREY SLATES SILTITES SCHISTS
- SANDSTONES PARTLY QUARTZITES OFTEN REDDISH.
- CHITRAL SLATE DARK GREY SLATES SILTITES PARTLY CALCAREOUS.
- MONOTONOUS DARK GREY SLATES SILTITES AND QUARTZITES
- LIMESTONES PARTLY CRYSTALLINE
- LIMESTONES PARTLY CRYSTALLINE

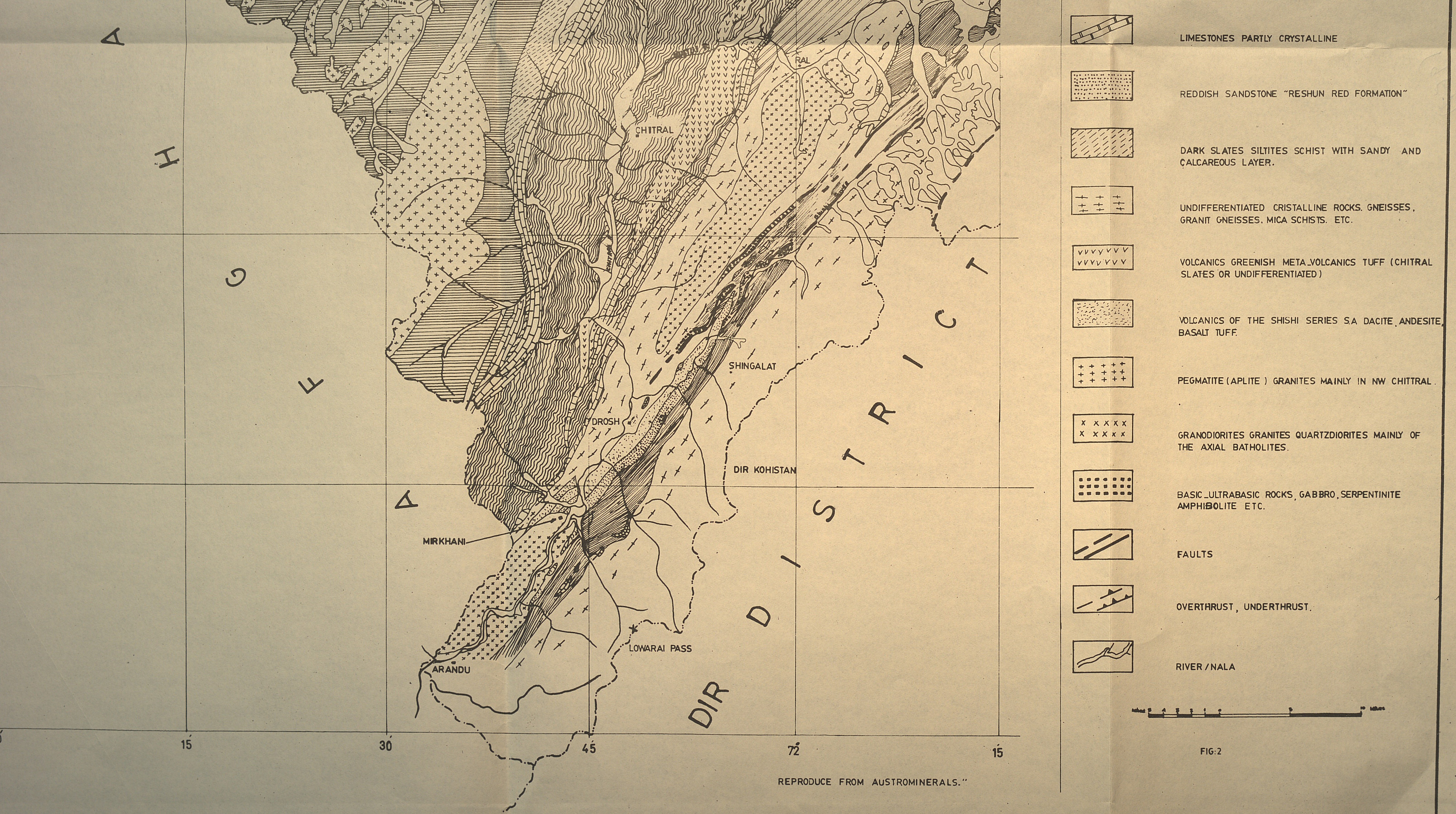


FIG:2

REPRODUCE FROM AUSTROMINERALS."

M.A.Kiani Illustrator Geology

bolites of Dir District. *Geol. Bull. Punjab Univ.* No. 11, pp. 81–96.

Chaudhry, M. N., Mahmood, A., and Shafiq, M., (1974 b). Geology of Sahibabad-Bibior area Dir District N.W.F.P. *Geol. Bull. Punjab Univ.* No. 10, pp. 73–90.

Chaudhry, M.N., Saleemi, B.A., and Jafferi, S.A., (1974). Geology and Petrology of the Malakand granite and it's environs. *Geol. Bull. Punjab Univ.* No. 10.

Chaudhry, M.N., Ashraf, M., and Hussain, S.S., (1983). Lead/zinc mineralization of Lower Kohistan District, Hazara Division, N.W.F.P., Pakistan. *Kashmir Jour. Geol.*, Vol. 1, No. 1, pp. 31–42.

Chaudhry, M.N., Ghazanfar, M. and Ashraf, M., (1983). A plate tectonic model for Northwest Himalayas. *Kashmir Jour. Geol.* Vol. 1, No. 1. pp. 109–112.

Chaudhry, M. N., and Shams, F. A., (1983). Petrology of Shewa Porphyries District Mardan, N. W. F. P. In: Granite Volume, *Instt. Geol. Bull. Punjab Univ.*

Coulson, A. L., (1936). A soda granite suite in N.W.F.P. *Proc. Nat. Inst. Sc. Ind.* 2, No. 3, pp. 103–111.

Davies, R. G., and Ahmed, R., (1963). The orthocanic nautiloid of the Kala limestone and the probable age of Swabi Formation. *Geol. Bull. Punjab Univ.* No. 3, pp. 1–6.

Dewey, J.F., and Bird, J.M., (1970). Mountain belts and the new global tectonics. *Jour. Geophys. Res.* Vol.75, pp. 2625–2647.

Dickinson, W. R., (1971). Plate tectonics in geologic history. *Science* 174, pp. 107–113.

Fry, N., and Fyfle, W. S., (1969). Eclogites and water pressure problem. Gon Tethyan examples. *Eclogae. Geol. Helvetia,* 67, pp. 497–507.

Gansser, A, (1974). The Ophiolite melange, a world wide problem on Tethyan examples. *Eclogae, Geol. Helvita,* 67, pp. 479–507.

Jan, M. Q., (1980). Chemical changes accompanying the granulite to amphibolite transition in Swat, N. W. Pakistan, In: *contemporary Geoscientific Researches in Himalaya, India.*

Jan, M. Q., (1980). Petrology of the obducted mafic ultramafic metamorphites from the southern part of the Kohistan island sequence, *Proc. Intern Commit, Geodynamics, Group, 6 Spec. Issue, Geol Bull. Univ. Peshawar,* Vol. 13, pp. 95–108.

Kempe, D. R.C., and Jan, M. Q., (1970). An alkaline igneous province in the N.W.F.P.W. Pak. *Geol. Mag.* 107, pp. 395–398.

Nowroozi. A., (1971). Seismo tectonics of the Persian plateau, Eastern Turkey, Caucaus, and Hindu Kush regions. *Seismol, Soc. America Bull.* 61, pp. 317–341.

Powell, C. McA and Conagham, P. T., (1973). *Plate tectonics and the Himalaya.* Earth. Planet. Sci. letters, 20, pp. 1-12.

Shams, F.A., (1961), A preliminary account of the geology of the Mansehra area, Hazara District, West Pakistan. *Geol. Bull. Punjab Univ.* No. 1, pp. 57–67.

Shams, F. A., (1969). The geology of Mansehra-Amb state area, N. W.F.P., Pakistan. *Geol. Bull. Punjab Univ.*, No. 8, pp. 1–31.

Shams, F.A., (1979). Origin of Shangla blueschist and its petrotectonic implications, *Proc. Int. Comm. Geodyn. Peshawar.*

Shams, F. A., and Ahmad, Z., (1968). Petrology of the basic minor intrusives of the Mansehra-Amb State area, N. W. Pakistan – Part I, The dolerites. *Geol. Bull Punjab Univ.*, No. 7, pp. 43–48.

Shams, F.A., and Desio, A., (1980). The age of blueschists and the Indus Kohistan Suture line, N. W. Pakistan, *Proc. Italian Acad. Sci.,* Milan, Italy. Vol. 68, pp. 74–79.

Shams, F. A., Jones, G. C., and Kempe, D. R.C., (1980). Blueschists from Topsin, Swat District, N.W. Pakistan. *Min. Mag.*, Vol. 43, pp. 941–942.

Shams, F.A., and Rehman, F., (1966). The petrochemistry of the granitic complex of the Mansehra-Amb State area, N. W. Pakistan. *Geol. Bull. Punjab Univ.* Vol. 1, No. 2, pp. 47–55.

Siddiqui, S.F.A., (1965). Alkaline rocks in Swat-Chamla area. *Geol. Bull. Punjab Univ.* No. 5, p. 52.

Siddiqui, S.F.A., Chaudhry, M.N., Shakoor, A. (1968). Geology and Petrology of the feldspathoidal syenites and associated rocks of Koga area, Chamla Valley, Swat, West Pakistan. *Geol. Bull. Punjab Univ.* No. 7.

Sillitoe, R.H., (1975). Metallogenic evolution of a collisional mountain belt in Pakistan. *Rec. Geol. Surv. Pak.* Vol. 34, 16 p.

Stonley, T.P., (1975). On the oppiolite complexes in the southern Tethys region. *Tectonophysics. Vol.* 25. pp. 303–322.

Tahirkheli, R. A. K., (1982). Geology of Himalayas, Karakorum and Hindus Kush in Pakistan. Spec. Issue *Cent. Excell. Geol. Peshawar Univ.* Pakistan.

Tahirkheli, R.A.K., Mattauer M., Proust, F and Tapponnier, P., (1979). The India-Eurasia Suture Zone in Northern Pakistan : Synthesis and interpretation of data at plate scale, *Geodyn. Pak. Geol. Surv. Pak.* pp.125–130.

BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE LOWER FARS FORMATION (L.M. MIOCENE) FROM A BORE HOLE IN SOUTHERN IRAQ

RIAZ AHMED

Hydrocarbon Development Institute of Pakistan, Islamabad, Pakistan

ABSTRACT.– A large number of microfossils belonging mainly to benthonic formainifera have been identified and illustrated from the cutting samples obtained from the Lower Fars Formation (L.M Miocene) of INOC Abo Amood-1, southern Iraq (Fig.1). Ten species and subspecies of Rotalia, nine species of Eliphidium, two species each of Triloculina and Quinqueloculina and one species each of Florilus, Archias, Pyrgo, and Sigmoilina are the significant components of the identified fauna. Many of the species are reported for the first time from southern Iraq. A few biozones have also been proposed to faunistically divide the unit. The Paleoecological study indicates that the formation was deposited under shallow marine lagoonal conditions with cyclic evaporitic phases represented by repeated beds of anhydrite (Fig. 2).

INTRODUCTION

The study was carried out in 1982 at Geology Department of Iraq National Oil Company, Basrah, with a view to illustrate the diagnostic fauna of the Miocene section in sourthern Iraq, and to reconstruct the past environments of deposition. Camera lucida drawings of the important fauna drawn during the study were arranged on plates in the order of occurrence to portray a true picture of the sequence.

The purpose of publishing results of the study in the form of present paper is to provide a base for biostratigraphic study in Makran coastal area, where the author has recorded similar fauna from the Miocene sediments (report under preparation).

FIG. 1–Location Map of Abo Amood–1

BIOSTRATIGRAPHY AND PALEOECOLOGY

The formation is overlain by continental/subcontinental Upper Fars formation and underlain by continental/subcontinental Ghar formation. It was encountered at the depth interval 800-1189 m. The lithology of the formation (in drilling direction) is described below:

(i) From 800-850 m: Light brown clay with subordinate anhydrite and buff finely crystalline limestone.

(ii) From 850-1189 m: Alternations of anhydrite, marl and limestone with rare claystone and dolomite. The limestone is frequently anhydritic.

Fauna:– The fauna includes mainly euryhaline foraminifera and ostracods with rare mollusca, chara and scolecodents. The following fossils have been identified from the interval:

Rotalia baccarii sobrina Shupack, R. becc. honyaensis Asano, R. becc. amoriensis Asano, R. becc. globula Colom, Rotalia nipponica Asano, R. papillosa compressiuscula Brady, R. umbonata Leroy, R. ikebei Inoue and Nakaseki, Elphidium advenum (Cushman), E. hyalocostatum Todd, E. hokkaidoense Asano, E. indicum Cushman, E. crispum (Dinne), E. rota Ellis, E. poeyanum (d, orbigny), E. vulgarae Volshinova, E. sp; Florilus scaphus (Fichtel and Moll), Archias angulatus (Fichtel and Moll), Sigmoilina sp. 1, Pyrgo subsphaerica d, Orbigny, Quinqueloculoculina daintitensis Asano, Q. laevigata d, Orbigny, Quinqueloculina daintitensis Asane, Q. laevigata d, Orbigny, Triloculin inornata d, Orbigny, T. intermedia Karrer, Chara, Mollusca, Ostracods, and Spine elements.

Age:– Already established L – M. Miocoene age is supported by the fauna.

Zonation:– The following three biozones in descending order are proposed:

(i) Rotalia beccar ii sobrina (R. becc. parkinsoniane),
(ii) ·Elphidium rota – Rotalia Nipponica and
(iii) Archias angulatus.

FIG. 2

Distribution of fauna in the Lower Fars formation of Abo Ahmood-1.

Paleoecology:– Using fauna and lithology the environments of deposition have been reconstructed and summarised below in figure 3. These are further highlighed in the following discussion:

FIG. 3

Paleoecology of Lower Fars formation.

A number of small cycles of deposition can be recognized in the section. Each anhydrite bed alternates with argillaceous carbonate bed. The repitition of the cycle was probably caused by tectonic or eustatic processes active in the region.

Underlying gypsum from the anhydrite sequence is missing. The deposition of calcium sulphate as gypsum or anhydrite depends on temperature and salinity of the water body. Anhydrite is precipitated if the temperature is above 42°C and the conditions hot and arid or the gypsum was converted into anhydrite after burial because of increasing pressure and temperature in the subsurface. Another possible mechanism accounting for the lack of gypsum from anhydrite can be the coastal tilting which could have removed the concentrated brine from one sub-basin of gypsum deposition and filled it into another one resulting in the depostion of anhydrite there. Absence of planktonic foraminifera, poor diversity of the benthonic foraminifera and occurrence of typical lagonnal fauna (e.g. R. beccarii, aomoriensis, R. beccarii hatatatensis and various species of Elphidium etc), indicate shallow water depth, restricted circulation and increasing salinity. The site could be a lagoon of fluctuating water depth. The bathymetric estimates based on fauna put these fluctuations in the order of 10 of meters.

From the regional picture it seems that the marginal aea of the Lower Fars basin which includes the study area was divided into a number of small partly isolated subbasins separated by weak barriers.

Finally, it is inferred from the presence of continuing overlying land deposits and the shallowing nature of the formation. The upper part of the formation contains Chara sp which indicates limited fresh to brackish water influence that the unit was laid down during a major regression in a mainly restricted marine basin by evaporitic, organic and mechanical processes.

ACKNOWLEDGEMENTS

The writer is indebted to the Manager and staff of the Geology Department of INOC, Basrah, for the provision of facilities and administrative help during the study.

REFERENCES

Ahmed, R., (1979). *Micropaleontology* of Nasirlya well No. 1, INOC. Internal report.

——— (1980) Biostratigraphy and paleoecology of the Cretaceous and Tertiary of Eastern Abo Ahmood Well No. 1, INOC. Internal report.

Bandy, O.L., (1961). Distribution of foraminifera, radiolaria and diatoms in sediments of the Gulf of California. *Micropaleontology*, Vol. 7, No. 1, pp. 1-26, pls. 1 - 5.

Bateman, A.M., (1950). Economic Mineral deposits. pp. .186-188.

Brooks, W.W., (1973). Distribution of Recent foramainifera from the southern coast of Puerto Rico. *Micropaleontology*, Vol. 19, No. 4, pp. 385-416, pl. 2, figs. 13-16.

Ellis, B., and Messina, A., (1940). Catalogue of foraminifera. *U.S. Mus. Nat. Hist.*

Hung, T., (1964). "Rotalia" group from the upper Cenozoic of Taiwan. *Micropaleontology*, vol. 10 no. 1, pp. 49-62, pls. 1-3.

Levin, H.L., (1957). Micropaleontology of the Oldsmar limestone (Eocene) of florida.

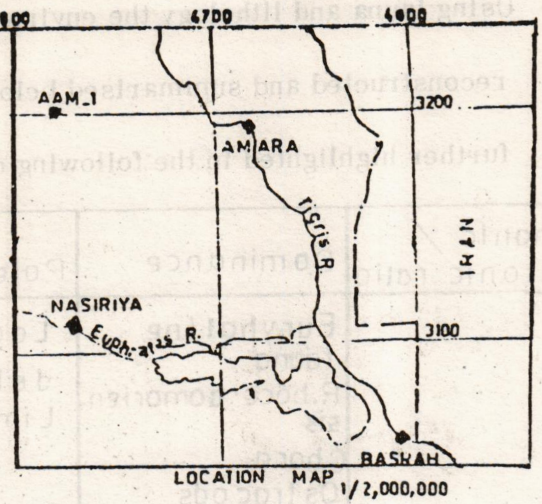
Lucchi, F.R., and Val, G.B., (1977). Algal crusts, autochthonous and clastic gypsum in a cannibalistic evoporite basin: a case history from the Messinian of Northern Appennines. *Sedimentology*. Vol. 21, No. 2, pp. 211-21.

Poag, C.W., (1966). Paynes Hammock (Lower Miocene?) foraminifera of Albama an Mississipi. *Micropaleontology*, Vol. 12, No. 4, pp. 393-440, pl. 6, figs 17-19 pl. 7 gigs. 7-8.

Sengupta, B.K., and Schafer, C.T., (1973). Holocene benthonic foraminifera in leeward bays of st. Lucida, West Indies. *Micropaleontology*, Vol. 19, No. 2, pp. 341-365, pl. 2, fig. 2.

Souaya, F.J., (1966). Miocene foraminifera from the Gulf of Suez region, U.A.R. *Micropaleontology*, Vol. 12, No. 2, pp. 183-202.

Vilks, G., (1969). Recent foraminifera in the Canadian Arctic. *Micropaleontology*, Vol. 15, No. 1, pl. 12, figs. 7-8.



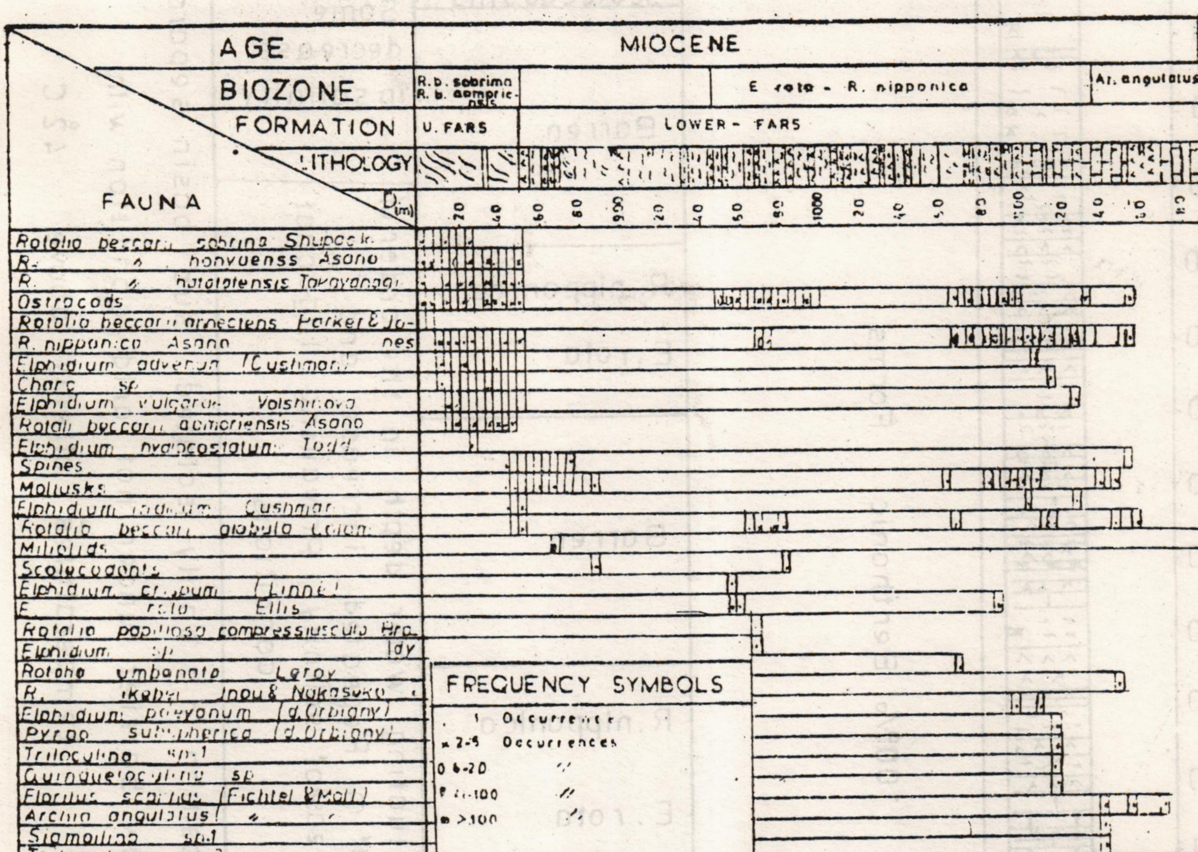


FIG. 2 Distribution of fauna in the Lower Fars formation of Abo Amood-1 .

Paleoecology :- Using fauna and lithology the environments of deposition have been reconstructed and summarised below in figure 3. These are further highlighted in the following discussion :

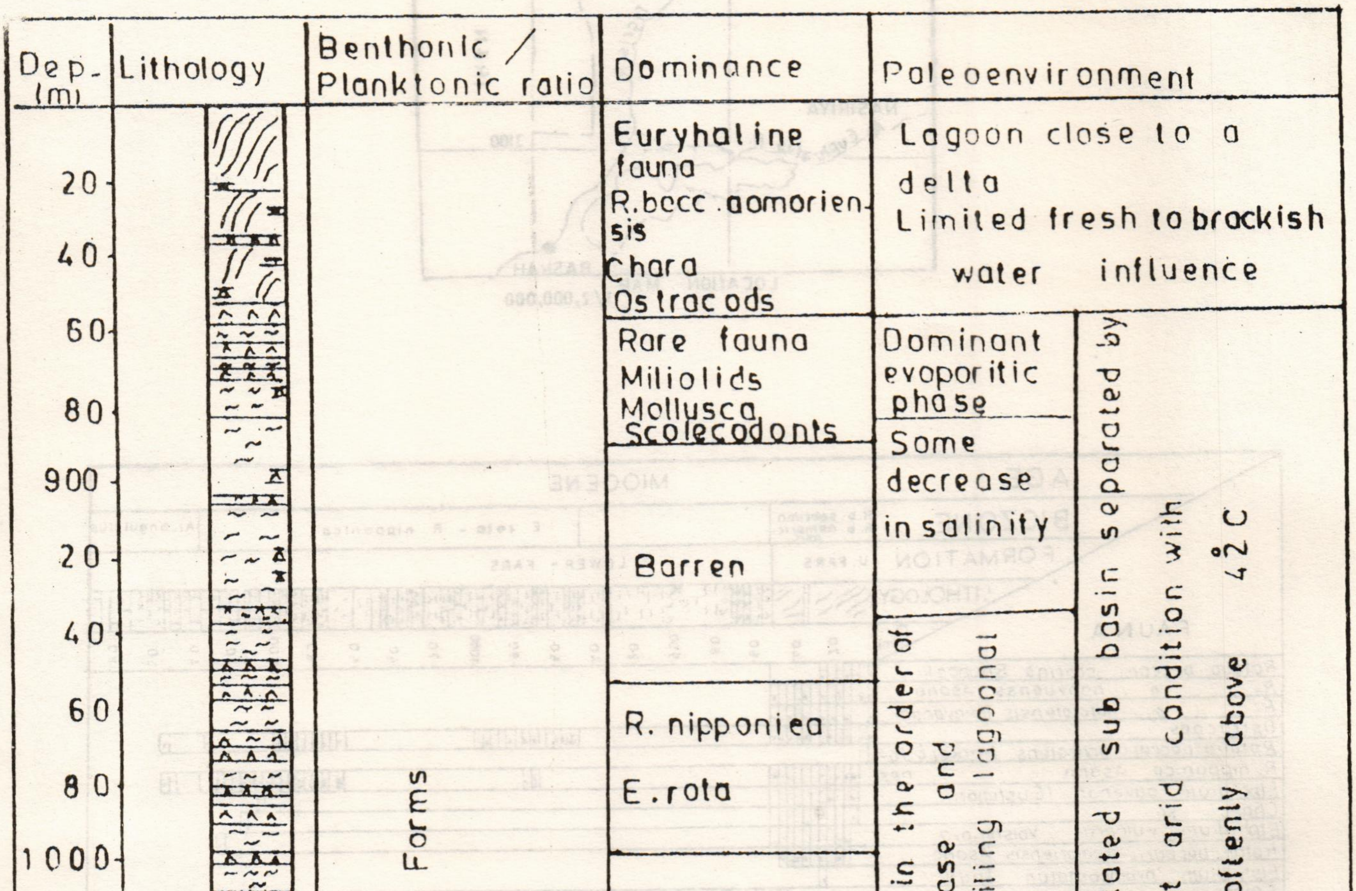


FIG. 3 - Paleoecology of Lower Fars formation .

PLATE 1

All figures X 62 unless otherwise stated

1-3 Rotalia beccarii sobrina Shupack

1, dorsal view
2, ventra

PLATE 1

All figures X 62 unless otherwise stated

1-3 Rotalia beccarii sobrina Shupack

1, dorsal view
2, ventral view
3, edge view

Cutting 800m, L. Fars, Miocene.

4-5 Rotalia beccarii annectens? Parker and Jones

4, dorsal view
5, edge view

Cutting 808m, L. Fars, Miocene.

6-8 Rotalia beccarii somoriensis Asano

6, dorsal view
7, ventral view
8, edge view

Cutting 820m, L. Fars, Miocene.

9-17 Rotalia beccarii hatatatensis Takayanagi

13, dorsal view
9, 11, 14 and 16, ventral view
10, 12, 15 and 17, edge view
9-10, cutting 820m; 11-12, cutting 836m; 13-15 cutting 840m; 16-17, cutting 852m, L. Fars, Miocene.

18-32 Rotalia nipponica Asano

18, 21, 24, 27 and 28, dorsal view
19, 22, 25, 28 and 31, ventral view
20, 23, 26, 29 and 32, edge view
18-20, cutting 820m; 21-23, cutting 852m; 24-29, cutting 1068m; 30-32, cutting 1116m, L. Fars, Miocene.

33-38 Retalia beccarii honyaensis Asano

33 and 36, dorsal view
34 and 36, ventral view
35 and 38, edge view
33-35, cutting 828m; 36-38, cutting 848m, L.Fars, Miocene.

39-46 Rotalia beccarii globula Colom

39, 42 and 44, dorsal view
40, 43 and 45, ventral view
41 and 46, edge view
39-41, cutting 852m; 42-43, cutting 920m; 44-46, cutting 968m, L. Fars, Miocene.

PLATE 2

All figures X62 unless otherwise stated

1-3 Rotalia papillosa compressiula Brady

1, dorsal view
2, ventral view
3, edge view

Cutting 968m, L. Fars, Miocene

4-6 Rotalia umbonata Leroy

4, dorsal view
5, ventral view
6, edge view

Cutting 1068m; L.Fars, Miocene

7-9 Rotalia ikebei Inoue and Nakaseko

7, dorsal view
8, ventral view
9, edge view

Cutting 1112m, L. Fars, Miocene

10-11 Elphidium hyalocostatum Todd

10, side view
11, edge view

Cutting 828m, L. Fars, Miocene

12-27 Elphidium hokkaidoenso Asano

12, 14, 16, 18, 20, 22, 24 and 26, side view
13, 15, 17, 19, 21, 23, 25 and 27, edge view
12-13, cutting 844m; 14-15, cutting 936m; 16-17, cutting 960m; 18-19, Cutting 1076m; 20-21,

cutting 1088m; 22-23, cutting 1116m; 2-25, cutting 1088; 26-27, cutting 1152m, L. Fars, Miocene.

28-33 Elphidium indicum Cushman

28, 20 and 32, side view
29, 31 and 33, edge view
28-29, cutting 844m; 30-31, cutting 852m; 32-33, cutting 1128m, L. Fars, Miocene.

34-35 Elphidium sp. 1

34, side view
35, edge view

Cutting 852m, L. Fars, Miocene.

36-37 Elphidium crispum (dinne)

36, side view
37, edge view

Cutting 956m, L. Fars, Miocene

38-39 Elphidium rota Ellis

38, side view
39, edge view

Cutting 956m, L. Fars, Miocene

PLATE 3

All figures X62 unless otherwise stated

1-2 Elphidium rota Ellis

1, side view
2, edge view

Cutting 960m, L. Fars, Miocene.

3-4 Elphidium sp. 2

3, side view
4, edge view

Cutting 968m, L. Fars, Miocene.

5-6 Elphidium sp. 3

5, side view
6, edge view

Cutting 1076m, L. Fars, Miocene.

7-8 Elphidium sp. 3

7, side view
8, edge view

Cutting 1108m, L. Fars, Miocene

9-12 Elphidum advenum (Cushman)

9 and 11, side view
10 and 12, edge view

13-16 Elphidium vulgarae Volshinova

13 and 15, side view
14 and 16, edge view
13-14, cutting 1116m; 15-16, cutting

17. Archias angulatus (Fichtel and MOΠ)

Side view, cutting 1140m, L. Fars, Miocene

18-20 Quinqueloculina daintitiensis Asan

18 and 19, opposite side views
20 apertural view.

Cutting 1116m, L. Fars, Miocene.

21-22 Quinqueloculina laevigata d'Orbigny?

Opposite side views, cutting 1180m,

23-25 Triloculina inornata d' Orbigny?

23 and 24, opposite side views
25, apertural view

Cutting 1116m, L. Fars, Miocene.

26-28 Triloculina inornata d' Orbigny

26 and 27, opposite side views
28, apertural view
Cutting 1140m, L. Fars, Miocene.

29-31 Triloculina intermedia Karrer

29 and 30, opposite side views
31, apertural view
Cutting 1140, L. Fars, Miocene.

32-33 Pyrgo sub sphaerica d' Orbigny

32, front view
33, edge view
Cutting 1116m, L. Fars, Miocene.

34-35 Sigmoilina sp. 1

38 Chara sp.

Cutting 836m, L. Fars, Miocene

39-42 Triloculina austriaca d' Orbigny

39-40, opposite side views
41, front view
42, apertural view
Cutting 1268m, contamination from L. Fars, Ciocene

43-46 Triloculina trigonula Lamarck

43-44, opposite side views
45, front view.
46, apertural view
Cutting 1268m, contamination from L. Fars, Miocene

47-49 Quinqueloculina akneriana d' Orbigny

47 and 48, opposite side views
49, apertural view
Cutting 1268m, contamination from L. Fars, Miocene.

PLATE 1

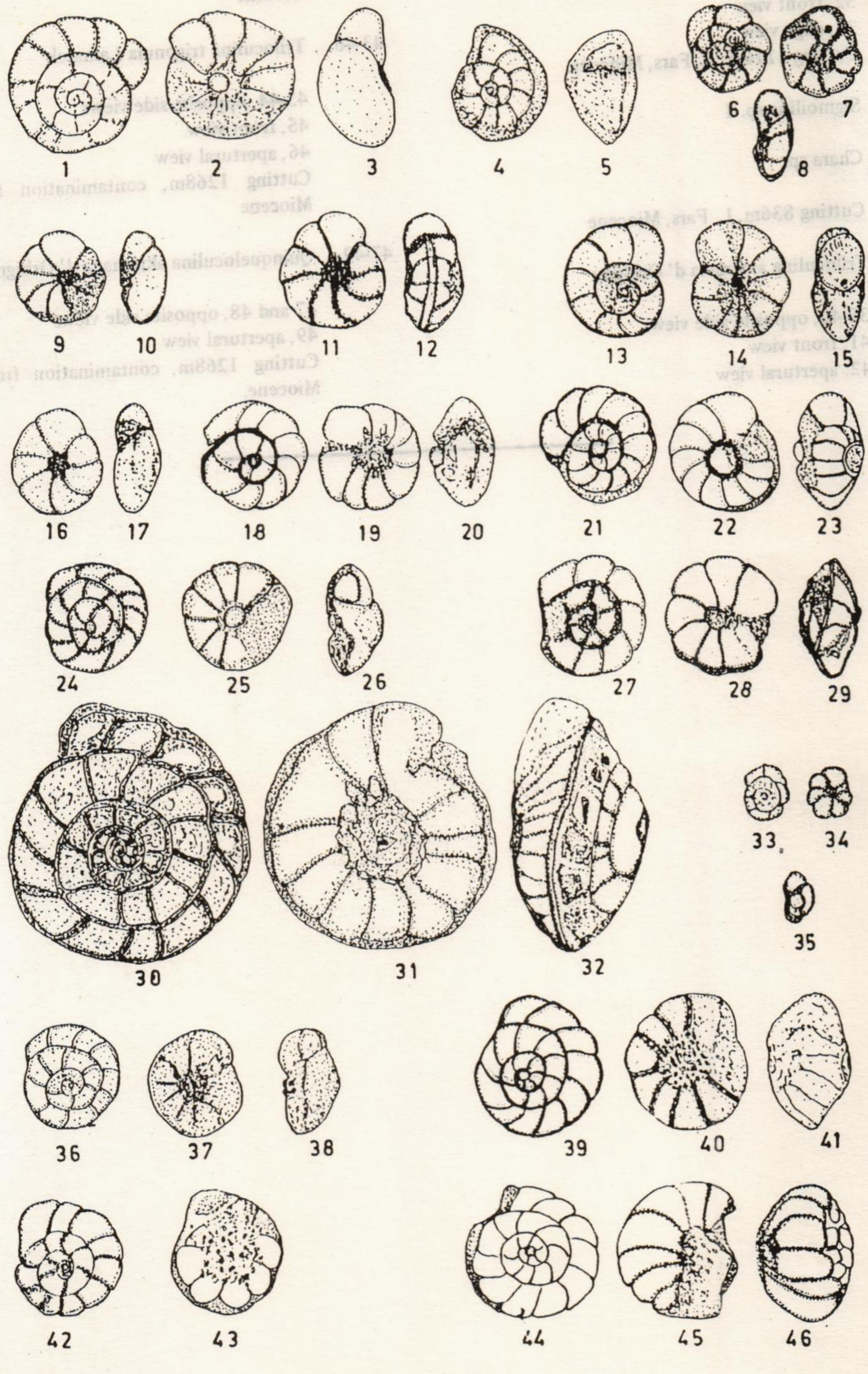

1 2 3 4 5 6 7 8
9 10 11 12 13 14 15
16 17 18 19 20 21 22 23
24 25 26 27 28 29
30 31 32 33 34 35
36 37 38 39 40 41
42 43 44 45 46

PLATE 2

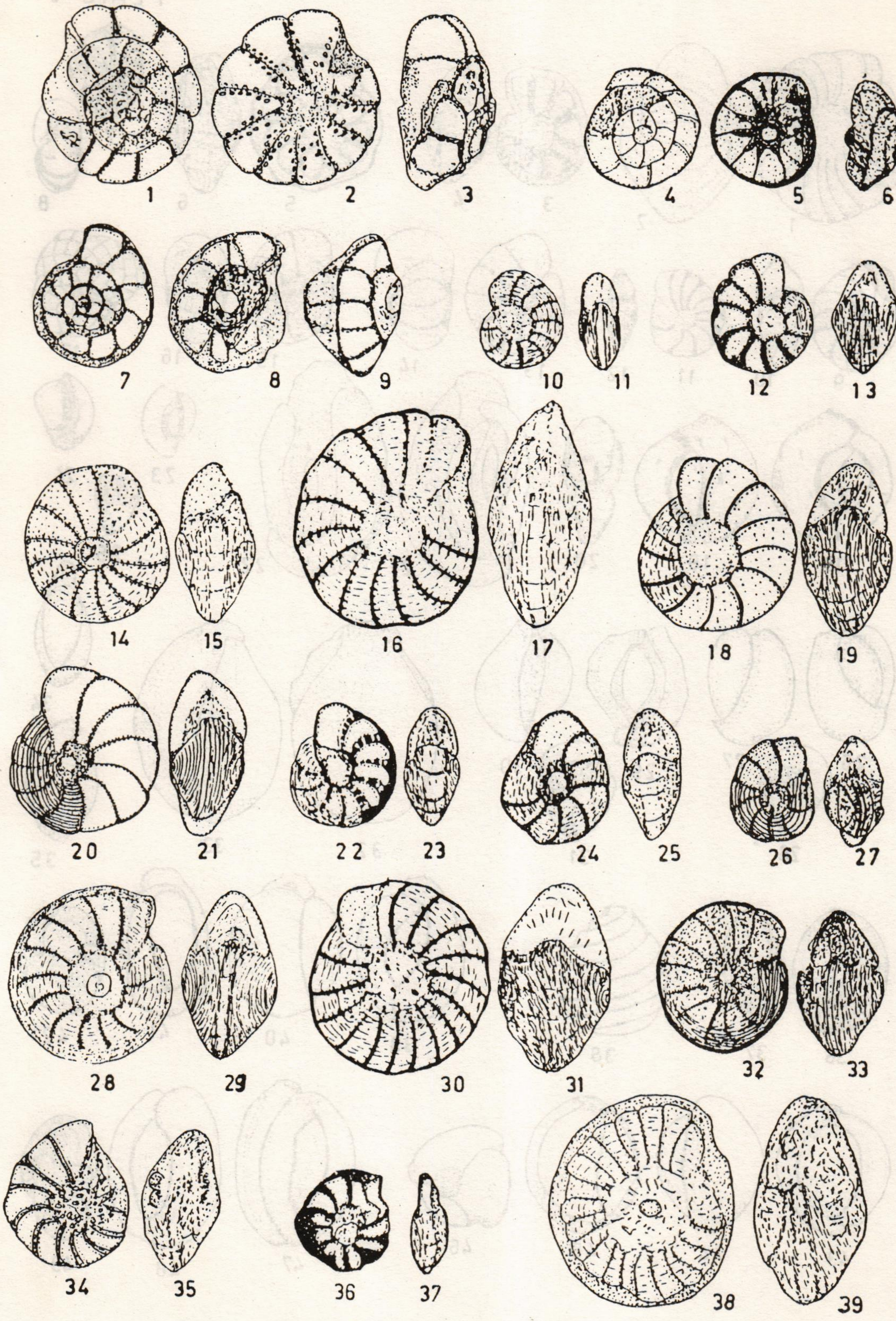
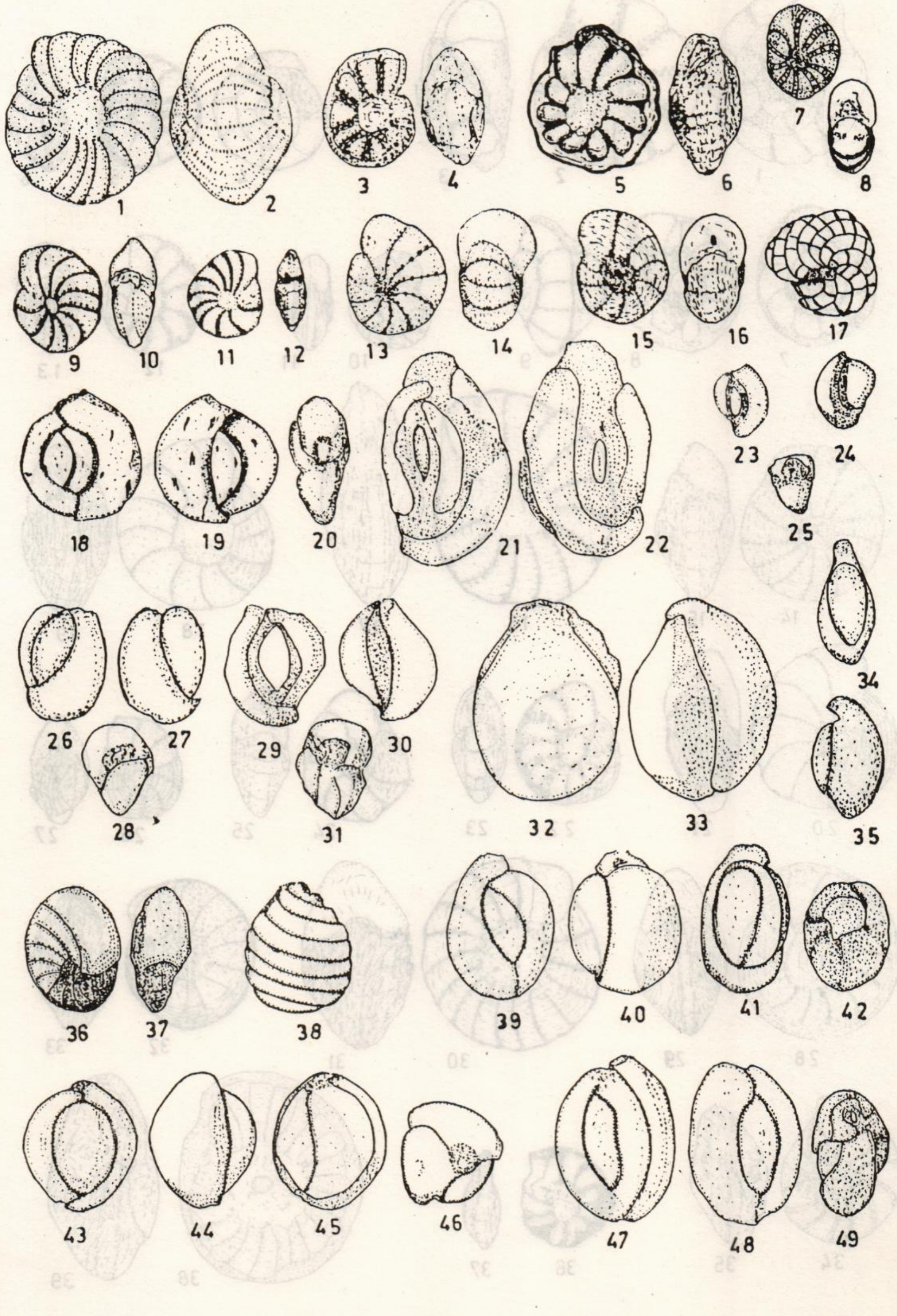


PLATE 3


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

Kashmir Journal of Geology Vol 2 No. 1, 1984

THE CORRELATION OF KHEWRA SANDSTONE (SALT RANGE) WITH A CAMBRLAN SANDSTONE, EXPOSED NEAR ABBOTTABAD, HAZARA DIVISION, NORTH WEST FRONTIER PROVINCE, PAKISTAN.

S. R. H. BAQRI

Pakistan Museum of Natural History, Pakistan Science Foundation
Islamabad

ABSTRACT:– The detailed lithological units of the Khewra Sandstone (Salt Range) and Tanakki-Sanghargali members have been compared for their probable correlation. The probable correlation of the Khewra Sandstone with the Tanakki-Sangharghali members indicates that the Khewra Sandstone extends as north as Riwat Rawalpindi in the subsurface. It is also inferred that the Khewra Sandstone is not locallized in Salt Range only but extends regionally towards Abbottabad.

INTRODUCTION

The rocks of Cambrian age have been exposed in Salt Range and Hazara areas. Many investigators inferred that these rocks are similar in several aspects but no systematic efforts were made to correlate these rocks. The present paper gives a detailed description of the lower units of Cambrian age and provides correlated sections of similar lithological units. The correlation between the Cambrian rocks exposed in Salt Range and Abbottabad areas is not only a useful academic exercise but it may serve as a significant advancement for the exploration of the economic mineral resources of the region. The correlation between Khewra Sandstone and Tanakki-Sangarali members of Kakul Formation may provide an initial base for further detailed correlations as they lie over the rocks of Pre-Cambrian age.

The Cambrian rocks of the Salt Range area are well known and do not need any further investigations, but it would be appropriate to give a brief summary of the Cambrian rocks exposed near Abbottabad and surrounding areas as their stratigraphical position has been placed in various ages by different workers. Waagan and Wynne (1872) for the first time mapped Mount Sirban and Middlemiss (1896) collected all the information on the geology of Abbottabad area in an orderly form. He called the rocks to be of Triassic and Jurassic age. Many other workers carried out geological investigations in Abbottabad area but no one presented a systematic description of the area. Wadia (1929) observed glacial striations on the Tanakki boulders and concluded an Upper Carboniferous age. Marks and Mohammad Ali (1962) differed with Middlemiss and stated that the rocks around Abbottabad belong to the Jurassic age and are not of Triassic. Latif (1969) carried out detailed field work in the area and discovered Cambrian fossils in Hazira Shales near Salhad (2 miles south of Abbottabad). Latif (1974) described the geology of Abbottabad and surrounding areas in detail and calssified the lithological units of Cambrian age. He named the lowest unit of the Cambrian age as Tanakki Member of his Kakul Formation which consists of conglomerate and marks a local unconformity. The Tanakki Member is overlain conformably by the Sangargali Member of the Kakul Formation. In the present work, efforts have been made to correlate the Khewra Sandstone (Salt Range area) and Tanakki-Sangargali members (Abbottabad area) described by Latif (1974).

1. KHEWRA SANDSTONE

The Khewra Sandstone includes mainly purple to dark brown sandstone and dark brown shales. The sandstones are medium to fine grained, well sorted and display primary sedimentary structures. The shales are thinly bedded, laminated and occur towards the base. The Khewra Sandstone may be divided into three sub units on the basis of shale contents, bedding characters and grain size.

The lower unit conformably overlies the Salt Range Formation and consists of purple to dark brown shales intercalating thin siltstones and sandstones. The shales are calcareous, medium hard, thinly bedded and fractured. The fractures are occasionally filled with gypsum and other calcareous minerals. The frequency of the siltstones and sandstones increases towards the top of the unit. The siltstones and sandstones are fine grained, cross bedded, ripple marked and occasionally display chemical weathering.

The middle unit of the Khewra Sandstone includes sandstones of this unit are fine grained towards the base and gradually get medium grained towards the top. They are cross bedded, ripple marked, fractured, micaceous, moderately sorted and occasionally display cavities due to chemical weathering. The sandstones are medium to thick bedded.

The upper unit of the Khewra Sandstone consists of massive to thick bedded yellowish white to light brown sandstones . The sandstones are comparatively of dark colour (light brown) towards the base and gradually attain a lighter colour (yellowish white) towards top. The grain size increases from medium to coarse grained from base to top respectively. They are medium hard (base) to friable (top) cross bedded, quartzose and moderately porous. The upper unit of the Khewra Sandstone is disconformably overlain by Kussak Formation. A bed of conglomerate marks the disconformity.

The conglomeratic bed consists mainly of gravels and pebbles of quartz with occasional clay fragments. The Khewra Sandstone has been assigned a lower Cambrian age (Fatmi, 1973).

2. KAKUL FORMATION

a) *Tanakki Conglomeratic Member:* The Tanakki conglomerate includes mainly subangular to angular pebbles and gravels of mainly Hazara Shales/Slates with subordinate pebbles and gravels of quartzites derived from other older formations (probably Tanawal Formation). The angular to subangular detritus appears to be locally eroded and lie in a gray shaly/slaty matrix of Hazara like sates. The colour of the detritus remains generally gray (occasional brown) but the matrix varies from gray to reddish brown. The Tanakki conglomerate often includes loose detritus and matrix but some times it gets hard and compact due to strong metamorphic effects. The conglomerate indicates a local unconformity.

b) *Sanghargali Member* The Sanghargali Member consists of thinly laminated purple to dark brown shales, medium to fine grained, dark brown and purple sandstones and medium grained light brown to white brown sandstones with quartzites and lenticular dolomites. The Sanghargali Member may be further sub divided into three units.

The Lower Unit includes purple dark brown shales which generally weather to the same colour, but occasionally display weathering to purple gray colour. The shales are thinly bedded, laminated, medium hard, calcareous to slightly calcareous, occasionally micaceous and gradually get silty towards the top. The thin bands of siltstones and fine sandstones gradually increase in frequency towards the top. The silty bands display ripple marks and cross bedding. The shales do not display severe metamorphic effects near Mian-Di-Dairy, but gets reasonably metamorphosed near Nilepair area. The shales of the lower unit occasionally show a core of greenish gray colour surrounded by the purple red colour. It is likely that the shaly unit was deposited in shallow marine conditions.

The Middle Unit (Unit - B) includes mainly fine to medium grained sandstones. The sandstones are medium to thick bedded cross bedded, ripple marked, fractured, non-calcareous (base) to clacareous (towards top) and gradually change in colour from purple red (towards base) to light brown/whitish brown (towards top). The grain size of the sands gradually increases towards the top. The thickness of the individual beds also increases towards the top of the unit the sandstones display varied effects of low grade metamorphism. They are friable at places but often get quartaitic compact and hard due to metarnorphic effects. The sand stones of the middle unit are ridge forming and show lusticular development of dolomits toward the top.

The Upper Unit of the Sanghargali member consists of thick to massive bedded sandstones with intercalations of lenticular dolomite. The colour of the sands gradually changes from whitish brown (base) to yellowish white/dirty white. The grain size also increases towards the top of the unit. This unit displays massive quartzites which are hard and highly fractured. The lenticular dolomites are hard, fractured, concretionary, thick bedded and increase in frequency towards the top of the unit.

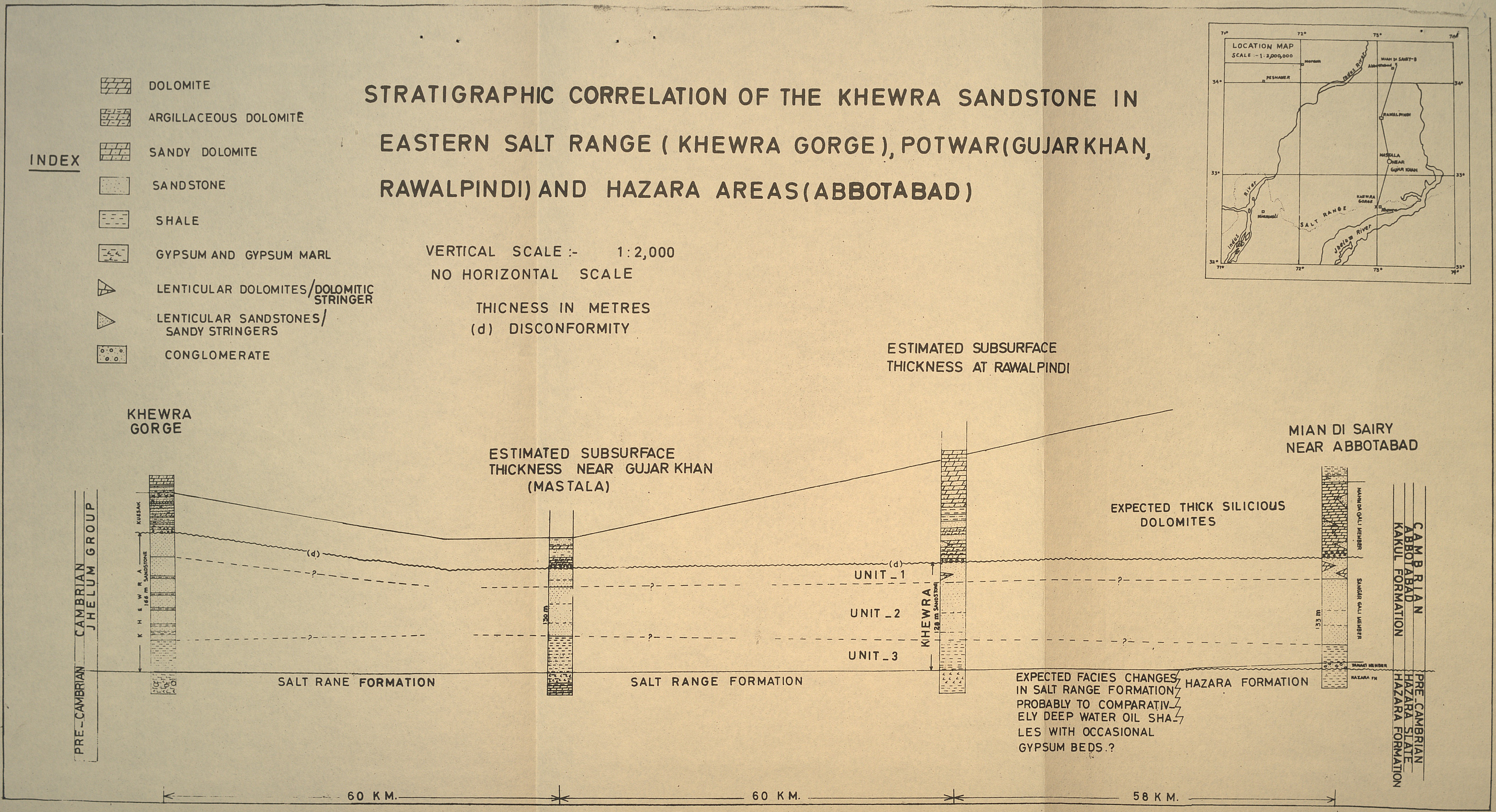
The upper unit of the Sanghargali member is disconformably overlain by a conglomeratic bed. The conglomeratic bed is about 2m to 3m thick and consists of mainly gravels and pebbles of quartz lying in a silty, sandy and dolomitic matrix. The gravels and pebbles are of mainly quartz but occasional dolomitic gravels/ pebbles may be observed. The coarse detritus often display lenticular bedding. A Cambrian age has been assigned to the Sanghargali Member (Latif, 1969).

CORRELATION

a) Common characters between Sanghargali Member and Khewra Sandstone.

1. Both sandstones display a presistant purplish colour. The colour gradually changes from purple maroon to brownish white towards their top.
2. Both the sandstones show similar cross bedding and lithology.
3. Both the sandstones may be divided into three similar units with more or less similar thickness

STRATIGRAPHIC CORRELATION OF THE KHEWRA SANDSTONE IN EASTERN SALT RANGE (KHEWRA GORGE), POTWAR (GUJAR KHAN, RAWALPINDI) AND HAZARA AREAS (ABBOTABAD)



Insertion, VIII.

(figure - 1). The bedding character in their sub-units are also similar.

4. The grain size in both the sandstones increases from base to their tops.
5. Both the sandstones are disconformably overlain by a conglomeratic bed of dominantly quartz gravels.
6. Both the sandstones (Sanghargali and Tanakki) overlie the formations of Pre-Cambrian age.

b) Characters not common between Sanghargali Member and Khewra sandstone.

1. The upper unit of the Sanghargali Member displays lenticular dolomitic development, which is not observed in Khewra sandstone.
2. The Sanghargali Member unconformably overlies the Pre-Cambrian shales/slates (Hazara Formation) with the development of a local conglomerate (Tanakki Member) at its base. The Khewra Sandstone conformably overlies the Salt Range Formation of Pre-Cambrian age.
3. The upper part of the Sanghargali Member also displays the development of quartzites which are not observed in Khewra Sandstone.
4. Khewra Sandstone did not suffer as high temperatures as Sanghargali Member.

DISCUSSION

The Khewra Sandstone conformably overlies the Salt Range Formation of Pre-Cambrian and probably Early Cambrian age. But the Tanakki Member, between Sanghargali Member and Hazara Shales/Slates, indicates on unconformity. The detritus of the Tanakki Member is dominantly of angular/subangular nature and indicates the local nature of the conglomerate. It is probable that the Tanakki Member represents a facies change from South to North. The presence of dolomite in the upper part of the Sanghargali Member could be due to more favourable conditions for dolomitization towards north during the Early Cambrian times. These conditions were later on extended towards south. The Khewra Sandstone is known to extend as far north as Riwat/Rawalpindi and probably it extends further north towards Abbottabad. Figure - 1. gives a simplified correlation section of the Khewra Sandstone exposed at Khewra and expected in the subsurface. the expected stratigraphic throw by the Hazara fault has been omitted as it requires further seismic/geological/structural work in the area. Latif (1973) proposed the extension of the Salt Range evaporitic facies to Hazara.

ACKNOWLEDGEMENTS:

I am thankful to Dr. Syed Riaz Ali Shah for his encouragement to write this work. I am grateful to Professor Dr. M. A. Latif, who is the pioneer investigator in defining the stratigraphy and geology of Abbottabad area and who has very kindly criticised the manuscript of this paper.

REFERENCES:

Fatmi, A.N., (1973). Lithostratigraphic units of the Kohat Potwar Province, Indus Basin, Pakistan. *Mem. Geol. Survey of Pakistan*, V. 10.

Latif, M.A., (1969). The Stratigraphy of South East Hazara and parts of Rawalpindi and Muzaffarabad districts of West Pakistan and Kashmir, Ph. D. thesis, Lond. Univ. London.

Latif, M.A., (1973). Partial extension of the evaporite facies of the Salt Range to Hazara; Pakistan. *Phys. Sci.*, V. 244, No. 138, pp. 124-125.

Latif, M.A., (1974). A Cambrian age for the Abbottabad group of Hazara Pakistan. *Geol. Bull. Punjab Univ.*, V. 10, p. 1–20.

Marks, P., and Ali, C.M., (1962). The Abbottabad Formation. A new name of Middlemiss Infra Trias. *Geol. Bull. Punjab Univ.* No. p. 2, 56.

Middlemiss, F.S., (1896). The Geology of Hazara. *Mem. Geol. Surv Ind.*, V. XXII.

Waagen, W., Wynne, A.B., (1872). The Geology of Mount Sirban in the Upper Punjab *Mem. Geol. Surv. India*, V. 9, pp 331–350.

Wadia, D.N., (1953). Geology of India, MacMillan and Co., London.

PLEISTOCENE ICE AGE CYCLE IN THE HIMALAYAS

ALI H. KAZMI

Geological Survey Of Pakistan, Lahore Regional Office.

ABSTRACT.– Extensive and repeated glaciation of the northwestern part of the Himalayas occurred during the Pleistocen. Godwin Austen (1859) was probably the first to record evidence of Pleistocene glaciation in the Himalayas. Further studies have revealed well preserved outcrops of terminal morains, ground morains and associated fluvio-glacial cutwash and boulder and gravel deposits in the Jhelum Valley in Kashmir, in the Pir Panjal Range and in the Poonch area which indicate that these localities have witnessed a series of four glacial and three interglacial epochs during the Pleistocene. Whereas the glacial morains and related boulder gravels provide evidence for repeated glaciation, the interglacial periods were characterised by deep erosion and valley down-cutting as indicated by benches and rock terraces in the valley profiles.

Evidence for a Pleistocence Himalayan Ice Age cycle was probably first recorded by Godwin Austen (1859, 1861, 1862) and Lydekker (1878, 1879, 1883). Further studies by Drew (1875), Theolbald (1880), Oestreich (1906). Middlemiss (1910), Grinlinton (1928), and Dainelli (1922, 1935) led to the recognition of four main periods of glaciation in the Himalayas. De Terra and Patterson (1939) carried out elaborate studies on the Pleistocene deposits in the Kashmir Himalayas, the Pir Panjal Range and the Potwar region. They have been able to compile a correlation chart and draw a comprehensive regional chronology of events during the Pleistocene.

The Sind and Liddar valleys, draining the southern slopes of the Central Himalayan Range north of the Kashmir valley, contain the best known evidence of the Himalayan Ice Age cycle and are the classic locations for the study of the Pleistocene glaciation of the Himalayas. Here well preserved outcrops of the terminal moraines, ground moraines and associated fluvio-glacial outwash and boulder and gravel deposits, provide convincing evidence of a series of four glacial and three interglacial epochs. From the oldest to the youngest, these glacial advances have been referred by earlier authors as the First, Second, Third and Fourth Glacial Periods. The intervening periods have been referred to as the First, Second and Third Interglacial Periods.

Deposits of the Second, Third and Fourth Glacials each from two or more groups of moraines and related boulder gravels. This suggests that there were significant authors as the Fifth Glaciation of the Himalayas.

In the Sind and Liddar valleys, the moraines of the First Glacial are found at an elevation of 5,500 feet, and those of the Second Glacial at 6,600 feet to 7,100 feet. However, it may be noted that since the First Glacial this region has been considerably uplifted. Thus at the time of the First and Second Glaciations, the elevation of the moraines must have been considerably lower. The Second Glaciation was probably more vigorous than the First and endured for a longer period. The intensity and duration of the subsequent glaciations became successively less as indicated by the smaller extent of their debris and other glacial features.

In the Himalayas the Interglacial periods were marked by deep erosion and valley down-cutting, as indicated by the numerous benches and rock terraces in the valley profiles. During these periods, the debris removed from the upper part of the hill ranges was deposited along the foot-hills or carried farther away to be laid down in larger valleys or basins such as the Kashmir Valley or the Indus Plain Basin.

South of the Central Himalayan Range of Kashmir and parallel to it is the smaller and less lofty Pir Panjal Range. This range forms the northern boundary of the Upper Indus plain. It, therefore, has a considerable bearing on the Quaternary Geology of the Indus Plain and it is significant to examine briefly the Quaternary Ice age record from this range.

Towards the close of the Pliocene and at the time of the First Himalayan Glaciation, the Pir Panjal probably formed a low hill range with considerably lower relief and a much less dissected or rugged surface than at present. Owing to its lower (than present) elevation, the

range probably did not form an effective barrier to the moisture laden winds, and this must have resulted in less precipitation on the Pir Panjal and must have produced the maximum precipitation on the Central Himalayan Range. It is, therefore, not surprising that the First Glaciation of the Pir Panjal was a very weak one. This inference is supported by the fact that only poorly preserved, scattered traces of ground moraines, largely composed of boulder clay with frosted and shattered boulders of limestone and slate, are found in the Pir Panjal Range at elevations of 12,000 to 12,500 feet. Invariably in all localities they rest on old plateau remnants or on inter-stream divides. If one accepts Penok and Bruckner's (1909) conclusion that the variation of the snow line bears a linear relation to glacier extension, it may be argued that the snowline on the Pir Panjal at the time of the First Glaciation may have been within 1,000 feet of the snow line in the Central Himalayas. In other words the glacial debris of First Glacial which is at present seen at elevations of about 12,000 feet in the Pir Panjal, would have been initially within 1,000 feet elevation of the First Glacial moraines of the Central Himalayan Range, which are at present seen at an elevation of 5,500 feet. Allowing for the uplift of about 5000 feet, more or less, is indicated for the Pir Panjal since the First Glacial.

According to De Terra and Patterson (1939), there are thick deposits of boulder conglomerate near the northern foot-hill slopes of the Pir Panjal (underlying the Lower Karewas) and these are believed to be First Glacial deposits. Along the southern foot-hill slopes, similar conglomerate sandstone and clay of the Tatrot Formation are found. These have been correlated with the First Glacial of the Kashmir valley.

It was probably during the Early First Interglacial, (Post Tatrot?) that the main uplift of the Pir Panjal occured. Thereafter owing to its enhanced elevation, precipitation on the range increased. Consequently the processes of weathering and erosion also intensified. The subdued topography of the pre-glacial relief was gradually transformed into a youthful landscape. Steep and narrow valleys and defiles were curved out on the flanks of the range. In some parts of the range, this vertical downcutting was in excess of 500 feet. The debris thus produced was carried down to the foot-hill region. In the Kashmir valley it was deposited as the Lower Karewa Beds and along the foot-hill region to the south it was deposited as the Pinjor. Formation in small structural trough. Both of these formations have a thickness of about 2,000 feet.

The Second Glaciation of the Pir Panjal was much more vigorous than the First. Most valleys were occupied by valley glaciers. Practically all the area above the present 7,000 feet contour was covered by ice. On the southern slopes in the Poonch basin, the glaciers may have descended to the 5000 feet level. Abundant evidence of the extent of the ice is provided by striated bed rock, moraines, erratics and glacio-fluvial outwash. During this period the glaciers deepend and widened their valleys, and the former interstreams divides were eroded and worn down,. Most of the debris was carried and dropped in the foothill region as glacial outwash. Thick and extensive deposits of this outwash, largely in the form of extensive alluvial fans, composed of boulder conglomerate, were formed all along the foot-hill region. In the Jhelum valley near Naushera and in the Udhampur basin on the southern slopes of the Pir Panjal, this Boulder Conglomerate has been traced upstream to the Second Glacial moraines. There is therefore reasonable evidence that the Boulder Conglomerate is of the Second Glacial age.

The deposition of the Boulder Conglomerate was followed by more vigorous earth movement, which resulted in the folding and faulting of the Boulder Conglomerate as well as the earlier rock formations.

During the Second Interglacial, the southern slopes of the Pir Panjal were deeply gallied and eroded, probably owing to the rejuvenation caused by the uplife and also due to the increased run-off produced by the melting ice of the re-treating glaciers. The steams cut back deeper into the divides and in their upper parts degraded their profiles by as much as 2,000 feet. In the lower reaches this down-cutting ranged from about 300 to 500 feet. Along the foothill region there is much evidence of profound drainage changes during this period. According to De Terra and Patterson (1939) it was during this period that the ancestral Jhelum changed its course owing to the uplift of an anticlinal hill northwest of Panjar, near Kahuta. It now ceased to flow across the Potwar and was replaced by a misfit stream, the present Soan River. Since then the Jhelum has been flowing across the Indus Plain as seen today.

In the valleys along the foothills, there is no trace of any sedimentary deposits belonging to the Second Interglacial period. Only thin depoits of loessic silt or alluvium are found on scattered terraces. Thus it may be inferred that the large volume of debris removed as a result of the massive erosion that occurred during this period must have been swept down farther away and deposited on the Indus Plain.

The Third Glaciation was not as strong as the Second, yet the deepened and rejuvenated vallyes of the Second Interglacial provided considerable momentum to the glaciers which now occupied them, and these glaciers

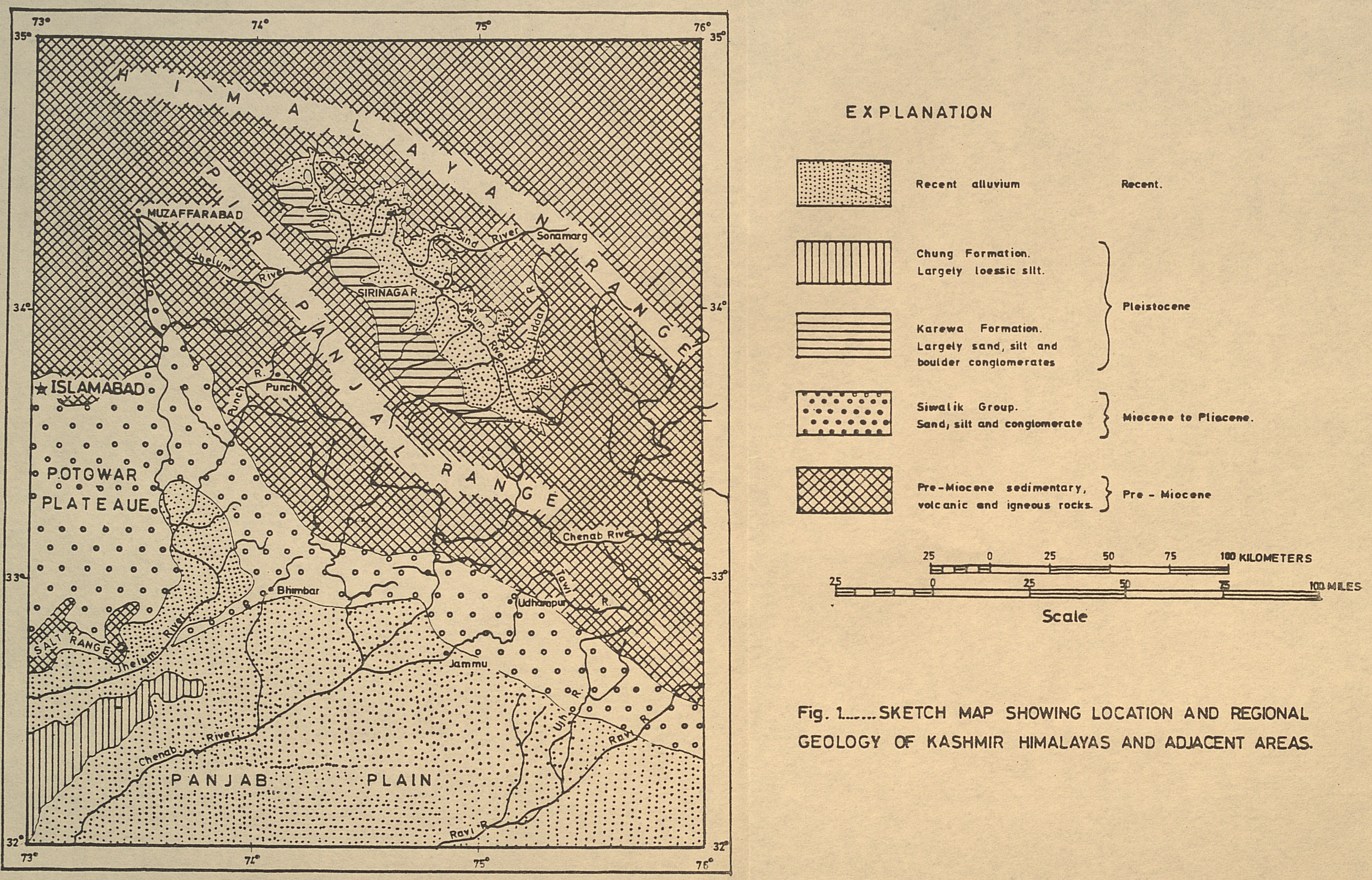


Fig. 1......SKETCH MAP SHOWING LOCATION AND REGIONAL GEOLOGY OF KASHMIR HIMALAYAS AND ADJACENT AREAS.

descended almost to the same elevation as during the previous glaciation. In the Poonch valley, on the southern, slopes of the Pir Panjal Range, four terminal moraines are seen at an elevations of 45000, 4900, 5000 and 6000 feet above sea level. In the lower part of most valleys, fluvioglacial boulder gravels are found resting on the slopes excavated during the earlier interglacial. These gravels are frequently capped by loessic silt depoist, commonly referred to as the Potwar Loess. The age of these gravels has been reasonably well established in some tributary valleys of Kashmir basin and in the Poonch valley where they have been found in association with moraines of the Third Glaciation. The Potwar Loess is believed to be Late Third Glacial in age and some evidence for its age is provided by the Levallois type stone implements found in it. The loess and the gravels or the T-2 terrace of De-Terra and Patterson.

The Third Interglacial produced renewed erosion and degradation and formation of terraces. Slight uplift probably occurred as indicated by the tilting and warping of the earlier terraces. Most valleys were degraded by about 100 to 400 feet. According to De Terra and Patterson (1939), the T-3 terrance was formed during this period. They have traced this terrace over a wide area in the Kashmir valley, in the Jammu, Poonch and Bhimber valleys and in the Potwar. According to them, this period began with degradation and down-cutting, which formed the slope of the T-2 terraces. This downcutting, in most areas, is in excess of 100 feet. They visualize that it was followed by a period of quiescené or plantation, when the streams aggraded their valleys and formed wide planed surfaces. Towards the latter part there was a further down-cutting (in most valleys 100 feet) and this resulted in the formation of T-3 terrace. On page 142 they write: –

"The Regional occurrence and uniform characteristics of T-3 . . . . indicate that the river was graded in these areas. What happened in the intermediate region, where the stream broke through the range, is difficult to tell owing to lack of observation. We presume that it had reached gradient sufficiently small to prevent vertical erosion in the lower tractor. In other words, the formation of this terrace required relatively stable conditions, such as might have resulted from crustal quiescene and from the weakness of inter-glacial stream action. These considerations argue in favour of the contention, mentioned above, that it was stability of gradient rather than the nature of the valley fill which led to lateral erosion and terrace formations".

On page 192 they write, "No exact proof can be offered for this contention unless T-2 and T-4 are actually traced to heir respective glacial deposits. However, this has been done on the Kashmir flank of the Pir Panjal and in the Poonch River Tract".

A critical review of the data presented by them suggests that ther is reasonable evidence to show that T-2 is of Third Glacial age. However, there is no satisfactory evidence regarding the age of T-3 terrace. It appears that there has been some confusion in identifying the various terraces and this is supported by the fact that Patterson while describing the terrace sequence in the Poonch valley near Sehr (page 204) refers to the T-3 gravels as probably of Fourth Glacial age."

All evidence in the Himalayas and the Pir Panjal suggests that erosion anddown-cutting has coincided with interglacial periods and there are unmistakable sings of valleys aggradation in the mountains during the Glacial periods. Along the foot-hill region of the Salt Range, the Suleiman Range, and the Kirthar Range, the author has found the same five-fold sequence of terraces and in these regions, each terrace clearly depicts a period of extensive fan development and valley aggradation, followed by degradation. Thus, in the southern regions, the T-3 surface probably represents a colder and wetter climatic period. In any case the correlation of the terrace sequence over such a large area is a difficult problem, particularly in view of the fact that both climatic changes as well as uplift or movement along major faults can produce terrace features.

The fourth and fifth Himalayan ice advances have been less dramatic and are characterised by several retreat stages.

In the Central Himalayas, moraines of four retreat stages of the Fourth Glaciation are found near Sonamarg, at about 8500 feet. Higher up in this valley there are two more moraine remnants which have been referred to as Fifth Glacial. These could also belong to the final retreat stage of the Fourth Himalayan glaciation. In the Pir Panjal, moraines of the Fourth Glaciation are found at elevations of 11,000 to 11,500 feet. Cirque remnants and terminal moraines of the last and final phase of glaciation are found above those of the Fourth Glaciation.

Our knowledge of the Quaternary in the Himalayas, particularly the foothill region, is still sketchy and generalised. The stratigraphy and chronology both in Kashmir valley and along the southward slopes of Pir Panial and the Potwar Conglomerate. Thereafter the interpretation and correlation, particularly as proposed by De Terra and Patterson, becomes less certain. Already Gill (1952) has cast doubts at some of their conclusions.

The paper by Morris (1938) has revealed the presence of 7000 to 10,000 feet thick deposits of sand and grit which can only be referred to the Early Pleistocene and which until then were believed to be largely Nagri or Early Siwalik. The Pliocene and Pleistocene geology of the foothill region, therefore, may have to be revised considerably in course of time.

REFERENCES

Austen, H.H. Godwin-1859. On the lacustrine or Karewa deposits of Kashmere. Geol. Soc. London, Quart. Jour., vol. 15, pt. 1, pp. 221-229.

—— 1981. Notes on the vallye of Kashmir. Roy. Geogr. Soc. Jour., m. vol. 32, pp. 30-37.

——1962. On the glacier phenomena of the valley of the Upper Indus. Br. Assoc. Rept., vol. 32, p. 67.

Dainelli, I.I.-1922. Studi sul glaciale: Sped. ital-de Fillippi. Rec. Sci., vol-3.

——1935. II/Sollevamento dell' Himalaya: Mem. geol. e/ geog. vol. 4, pp. 205-300.

De Terra, H., and Patterson, T.T.-1939. Studies of the ice age in India and associated human cultures. Carnegie Inst. Washington Publ.

Drew, F.-1975. The Jammu and Kashmir Territories. London.

Gill, W.D.- 1952. The Stratigraphy of the Siwalik Seres in the northern Potwar, Panjab, Pakistan. Geol. Soc. London. Quart. Jour., vol. 107, pt. 4, no. 428, pp. 375-394.

Gill, W.D.-1952. The tectonics of the Sub-Himalayan fault zone in the Kangara district of the Punjab. Geol. Soc. London, Quart. Jour., vol. 107, pt. 4, no. 428, pp. 394-421.

Grinlinton, J.L.-128. The former glaciation of the east Liddar valley, Kashmir. Mem. Geol. Surv. Ind., vol 49, pt. 2, pp. 289-388.

Lydekker, R.-1878. Notes on the geology of Kashmir, Kistwar and Panji. Geol. Surv. Ind., Rec. vol. 2, pp. 30—60.

——1883. The geology of the Kashmir and Chamba Territories and the British district of Khagan. Geol. Surv. Ind., Mem. vol. 22, pp. 1-344.

Middlemiss, C.S.-1910. Sections in the Pir Panjal Range and Sind valley, Kashmir. Geol. Surv. Ind., Rec. Vol. 41, pp. 115-144.

Morris, T.O.-1938. The Bain boulder bed; a glacial episode in the Siwalik series of the Marwat Kundi Range and Sheikh Bedin, NWFP, India. Geol. Soc. London. Quart. Jor., no. 375, vol. 94, pp. 385-421.

Oestreich, K.-1906. Die Taler des nordwest Pichen Himalaya Petermanns Milt., Erg bed. 33, 155, pp. 1-106.

Theobald, W.- 1880. On some Pleistocene deposits of the northern Pajab and the evidence they afford of an extreme climate during a portion of that period. Geol. Surv. Ind., Rec. vol. 13, pt-4, pp-221-243.

Kashmir Journal of Geology Vol 2 No. 1, 1984

A MODEL TO PREDICT COMPOSITION OF ROCKS FROM VELOCITY INVERSION

MUBARIK ALI
Department of Earth Sciences, Quaid-e-Azam University,
Islamabad, Pakistan.

ABSTRACT:– A statistical model designed from known mineralogical composition and velocities of the basement crystalline rocks, predicts very interesting patterns of mineral distribution in the Lewisian Metamorphic complex of NW Britain. The modelling suggests that the shear wave velocities can be of great significance in improving conventional Vp-based seismic interpretations.

INTRODUCTION:

A rock is defined as an assemblage of minerals, and these minerals occupy the rock in different proportions. Seismic Velocities also vary in different rock types. This implies that the mineral distribution is very relevant to the velocity changes in rocks. Statistically, it could be stated that the seismic wave velocity in rocks is a multivariate function in which mineral proportions play a very important role. In designing the prediction model this fact is taken into consideration and an attempt is made to break down the multivariate function into a single-mineral variable. For this purpose the composition and velocity data are taken from the Lewisian Metamorphic complex of NW Britain. The pre-Cambrian basement crystalline rocks of the complex are divided into three main belts (Peach etal 1907); the southern and northern belts which are mainly composed of quartz-feldspathic gneisses (Laxford assemblage) are separated by the central belt of pyroxene-granultities (Scourie assemblage) and its retrogressed equivalents. The contact know as the Ben Stack Line (Holland & Lambert 1973) is interpreted as a major crustal lineament. On the southern end of the northern belt there is a concentration of granites and pegmatities (Bewes 1978).

The P-and S-wave velocity information of different rock units of the complex has been obtained from the interpretation (by ray-tracing technique, Cerveny et al 1974) of a 40 km refraction line (LUST - Lewisian Units Seismic Traverse, Hall 1978) across the outcrop of the central and northern belts (Fig. 1). The composition and velocity data are provided in Table-1.

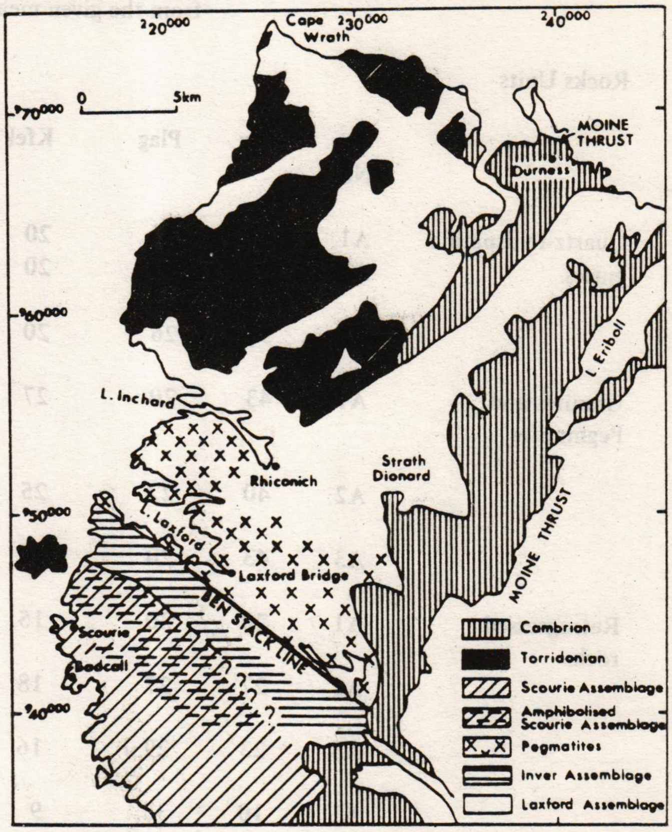


Fig. 1
Lithological units of the Lewisian complex Northern Belt, Laxford assemblage, Central Belt = Scourie assemblage + amphilbolised Scourie assemblage + Inver assemblage.

TABLE – 1

The composition and velocities (Vp, Vs) of different rock units.

Rock Unit	Composition Volume percentage)						Vp (km/s)	Vs (km/s)
	Qtz	Plag.	Kfel	Amph	Pyr	Minor		
Quartz–feldspathic gneisses	33	25	20	15	2	5	6.10	3.59
Granites & Pegmatites	43	20	27	5	–	5	5.95	3.55
Retrogressed rocks	20	30	15	20	10	5	6.17	3.61
Pyroxene Granulites	10	35	9	5	36	5	6.50	3.65

TABLE – 2

Predicted composition by Vp-based (A2) and Vs-based (A3) models, and their variance (var) from the given mean composition (A1).

Rocks Units	Gr No.	Composition						Variance
		Qtz	Plag	Kfel	Amph	Pyr	Minor	
Quartz-feldspathic gneiss.	A1	33	25	20	15	2	5	66
	A2	31	26	20	10	8	5	66
	A3	31	26	20	13	5	5	19
Granites and Pegmatites	A1	43	20	27	5	–	5	–
	A2	40	22	25	9	–	4	34
	A3	43	20	26	5	–	6	2
Retrogressed rocks	A1	20	30	15	20	10	5	–
	A2	27	27	18	10	13	5	176
	A3	23	29	16	18	9	5	16
	A1	10	35	9	5	36	5	–
Pyroxene-granulites.	A2	8	36	8	7	36	5	10
	A3	9	35	9	5	37	5	2

MODELLING

It should be noted from the composition of the rocks (Table-1) that the mineral components (in volume percentage) have some inter-relationship. For example, with the increase of quartz content the contents of plagioclase and pyroxenes are decreased, and k-feldspar is increased. The 'minor' component, which is a group of accessory minerals, is almost constant throughout. Contrarily the content of amphiboles is uncorrelated with quartz variation. But combination of amphiboles with pyroxenes into a 'mafic couplet' gives a related variation. It is also obvious from the Table that seismic velocities (Vp, Vs) decrease with the increase of quartz content in rocks. These relationships which describe a critical role of quartz in rocks, are determined by regression analyses as follows:

Letting, Qtz = Quartz, Plag = Plagioclase, Kfel = Kfeldspar Amph = Amphibole, Pyre = Pyroxene, and r = correlation coefficient.

Qtz	=	1226.00 – 333.33 Vs r = 0.985	(1a)
Qtz	=	390.50 – 85.90 Vp R = 0.945	(1b)
Plag.	=	39.30 – 0.445 Qtz r = 0.999	(2)
Kfel	=	3.87 + 0.524 Qtz r = 0.994	(3)
Mafics	=	51.84 – 1.079 Qtz r = 0.999	(4)

For the isolation of the amphibole component from the mafic couplet, bivariate analysis performed on Vp, quartz, and amphibole contents gives following equation.

Amph = 111.11 (6.69 – Vp – 0.016 Qtz) r = p.985 (5a)

If the value of quartz in terms of Vs, given in eq. 1a, is substituted the equation 5a is modified as follows: –

Amph = 111.11 (6.59-Vp) - 5.33 (3.678 - Vs) (5b)

Pyr = Mafic - Amph

Minor = 100 - (Qtz + Plag + Kfel + Amph + Pyr.)

This sequence of equations, sensitive to quartz component, suggesta a single mineral solution of the problem. In other words, this set of equations constitutes a prediction model which allows translation of velocity information of the basement crystalline rocks into their mineral composition. It can be noticed that the equations constitute two models; Vp-based and Vs-based. If relations 1a and 5a are ignored the model is purely Vp-based; If 1b and 5b are neglected the model becomes Vs-based. For comparison both models are applied to source velocity data and predictions are compared with the given composition of rocks to calculate respective variances. The results are shown in Table - 2. It is to be noted that the variance in case of Vs-based predictions is substantially lower than that of Vp-based prediction, i.e., the performance of the Vs-based model is much better. This is a very significant result and suggests that the consideration of shear wave velocities along with P-wave velocities is a rewarding exercise in improving seismic interpretations.

The application of the model on LUST line data, using velocities from 2km depth at a horizontal interval of 2km, displays significant variational trends in mineral components (Fig.2, Table - 3). It is to be observed (Fig. 2) that amphiole, k-feldspar and quartz, gradually replace pyroxene and plagioclase from pyroxene-granulites (Scourie assemblage) in the first 6 km range, and this process of replacement is more rapid in retrogressed rocks (from 6km to 10km). Corresponding to that mineralogical change, Vp and Vs in the central belt are both reduced Vp more than Vs) gradually towards the Ben Stack Line. Velocity minima over granites and pegmatites is due to a high concentration of quartz and k-feldspar. In quartz-feldspathic gneisses (Laxford assemblage) of the northern belt, the amphibole and plagioclase contents increase progressively northwards against the decreasing contents of quartz and k-feldspar. From the 18km range onwards the situation is reversed. This characterises an amphibole-rich intermediate composition at 18 km range in quartz-feldspathic gneisses, and beyond that pegmatitic materials in gneisses are increased towards Durness. (cf. Bowes 1978). The amphibole-rich composition could be a concealed amphibolite correlating approximately with a zone of exposed amphibolite basic intrusions in amphibolite facies (Bowes 1978). This is the source of the Vp-spike detected by Hall (1978) in low velocity acidic environments, and not the pyroxene-granulite masses (Ali 1983). These predictions plausibly explain the lateral compositional changes in the source rocks. Similar performance of the model can be expected in unknown areas provided the basement rocks have significantly correlated physical and compositional characteristics.

It is to be emphasised that the influence of cracks and pores on the model has been neglected. It has been assumed that the seismic velocities from 3km depth one minimally affected by cracks. However the model may not be as reliable in situations where this assumption is no longer guaranteed.

CONCLUSIONS

1) The prediction model describes appreciably the lateral mineralogical change in the basement crystalline rocks of the central and northern belts of the Lewisian complex.

2) The Vs-based model is more effective than the model based on Vp, and it can be inferred that the use of shear wave velocities in seismic interpretations can enhance the reliability of results.

3) The omission of the influence of pores and cracks below 3km depth from the model acts as a limitation or its range of applicability.

Table — 3

Predicted distribution of rock-forming minerals on different ranges.

Range (km)	Velocity Vp(km/s)	Vs(km/s)	Composition Qtz	Plag	Kfel	Amph	Pyr	Minor
5	6.50	3.65	9	35	9		37	5
6	6.30	3.63	16	32	12	15	20	5
8	5.99	3.57	36	23	23	13	–	5
10	5.95	3.55	43	20	26	4	–	6
12	6.00	3.56	36	23	23	10	3	5
14	6.06	3.59	29	26	19	18	3	5
16	6.10	3.61	23	29	16	25	2	5
18	6.18	3.65	9	35	9	40	2	5
20	6.16	3.63	16	32	12	30	5	5
22	6.15	3.63	16	32	12	31	4	5
24	6.15	3.63	16	32	12	31	4	5
26	6.14	3.62	19	31	14	27	4	5
28	6.11	3.61	23	29	16	24	3	5
30	6.10	3.61	23	29	16	25	2	5
32	6.09	3.60	26	28	17	20	4	5
34	6.08	3.60	26	28	17	21	3	5
36	6.07	3.59	29	26	19	17	4	5
38	6.07	3.59	29	26	19	17	4	5
40	6.06	3.58	33	25	21	12	4	5

ACKNOWLEDGEMENTS:

The author is grateful to Dr. J. Hall (Glasgow University U.K.) for his invaluable suggestions, Dr. Altan Necioglu (Department of Earth Sciences) Z.U. Mian for critical review, and M. Nazir for giving typing help.

REFERENCES

Ali, M. (1983). Shear wave velocities in the Lewisian Metamorphic Complex of NW Scotland. *Uni. of Glasgow Ph. D. Thesis (unpubl.).*

Beach, A. (1974). Amphibolitisation of Scourie granulites. *Scott. J. Geol. 10, 35-44.*

Beach, A., Corward, M.P., and Graham, R.H. (1973) An interpretation of the structural evolution of the Laxford Front. *Scott. J. Geol.* 9, 297-308.

Birch, F. (1960). The velocity of compressional waves in rocks to 10 kbar, part I. *J. Geophysics Res. 65,* 1083-1102.

——————(1961). The velocity of shear waves in rocks to 10 kbar, part II. *J. Geophysics Res. 66,* 2199-2224.

Bowes, D.R. (1978). Shield formation in early precambrian times: The Lewisian complex. *In* Bowes, D.R. & Leake, B.E. (eds), *Crustal evolution in north Western Britain and ajacent regions. Geol. J.Sp. Issue 10,* 39–80.

Cerveny, V., Langer, J. & Psencik, I (1974). Computation of geometric spreading of seismic body waves in laterally inhomogeneous media with curved interfaces. *Geophysics. J.R. Astr. Soc. 38,* 9-20.

Hall, J. (1978). LUST - a seismic refraction survey of the Lewisian basement complex in NW Scotland. *J. Geol. Soc. Lond. 135,* 555-563.

Holland, J.G. & Lambert, R. St. J. (1973). Comparative major elements geochemistry of the Lewisian of the mainland of Scotland. *In* Park, R.G. & Tarney, J. 9ed). *The early Precambrian of Scotland and related rocks of Greenland,* 51-62. Univ. Keele.

Peach, B.N., Horne, J., Green, W., Clough, C.T., Hinxman, L.W. & Teall, J.J. (1970). The Geological Structure of the North West Highlands of Scotland. *Mem. Geol. Surv. U.K.,* 668.

Toksoz, M.N., Cheng, C.M., & Timur, A. (1976). Velocities of Seismic waves in porous rocks. *Geophysics 41, 621-645.*

Walsh, J.

Walsh, J.B. (1965). The effect of cracks on the compressibility of rocks. *J. Geophysics. Res. 70,* 381 – 389.

Kashmir Journal of Geology Vol 2 No. 1, 1984

BITUMEN LUMINESCENCE ANALYSIS OF LAKHRA FORMATION (PALEOCENE) ENCOUNTERED IN BOREHOLE NEAR LAKHRA DISTRICT DADU, SIND PAKISTAN.

MUHAMMAD ALI BARYAR, A.R. ABRO,
AND SAEED AHMED SOOMRO
Department of Geology, University of Sind, Jamshoro.

ABSTRACT.– The interpretation of the results based on Bitumen Luminescence analysis of the samples from Lakhra PMI well was carried out. The total bitumen content in the various core samples is found to be below average. The total content of the bitumen is insignificant for aSource or Reservior rock.

INTRODUCTION

A bitumen is a natural organic substance soluable in neutral organic liquids under normal conditions of temperature and pressure. Bitumens are composed chiefly of organic compounds of low molecular weight, oxidised to a slight degree and having a low content of polar groups.

The investigation made on samples pertain to syngenetic dispersed oil bitumen which have been transformed from dispersed organic matter. In this regard about twelve samples were analysed from PMDC Lakhra PMI well taken from different petrographic horizons, and the samples with different results of bituminosity are recorded in the given table I. The selected Paleocene rock samples analysed were obtained from P.M.D.C. borehole PMI core, drilled for the evaluation of the coal reserves in the area (lat. 25° 40' 15" N, Long. 68° 8' 30" E), 40 miles north west of Hyderabad (Fig I).

STRATIGRAPHY

Classic sections of Paleocene in the Lower Indus Basin are exposed at many localities such as Bara Nala, Ranikot Fort, Gaj River section and Lakhra area in Dadu District.

The stratigraphic succession of Paleocene in the southern part of the Lakhra area is as follows:

Eocene . . . Disconformity represented by Laterites ————
Lakhra Formation Marine Shale, Sandstone, and Limestone.

Paleocene. . .Bara Formation Fluviatile Shale, Sandstone and Clay with Lignitic Coal Seams.

Khadro Formation Marine Shale, Limestone, Sandstones and Marl.

Disconformity

Khadro Formation: These are the basal rocks of Paleocene in Sind, containing characteristic Danian fauna. Nagapa (1960), Haque (1964), Blanford (1876) considered it as representing the top most part of the Late Cretaceous. Douville (1928) and Cox (1934) on the basis of mega fauna regarded it as Danian.

Bara Formation: It is exposed at several localities such as Bara-Nala, Jhakmari and Lakhra. It is generally composed of sandstone, shale, and clay often richly coloured. Sandstone and shale are highly carbonaceous, occasionally pyritous and contain four to six coal seams.

Lakhra Formation: It is exposed in the core of symmetrical Lakhra Anticline. It is mainly composed of dark brown foraminiferal limestone interstratified with yellwish brown sandstone, shale and clay which are frequently gypseous or ferruginous. Limestone grades into calcareous sandstone.

PURPOSE OF STUDY

The present investigation was carried out with a view to determine the total contents of the bitumen in the core samples of Lakhra Formation, with the help of quantitative fractional analysis by paper strip chromatographic method. Besides, fractional composition of the bitumen, nature and distribution is also determined.

METHOD AND LABORATORY TECHNIQUE:

Shlezinger (1939), Florovskaya and Kleinman (1941) were first to apply the bitumen luminescence method in route surveys and to study the nature of bitumen cores from exploratory wells and also in the logging of drilling muds and cuttings.

The basis of this method is to luminescence bitumens under ultraviolet light. The technique of luminescence used here is photoluminescence (levshin) which may be defined as radiation of light that is excited by absorption of light and which also ceases immediately upon cessation of excitation i.e. ultraviolet light. The brightness (intensity) of the luminescence depends on the luminescence yield. The yield of a solution depends in turn on the concentration of luminescent substance in the solution. There are two indices of luminescence analysis.

Quantitative index: It records the brightness of luminescence.
Qualitative index: this depends on the luminescence spectrum.

Since luminescence is the property of compounds containing aromatic rings, so nearly all the bitumens luminesce. The luminescence of coals is entirely determined by their content of bitumens. As a rule, heavier the fraction the greater the wavelength of its luminescence spectrum. The luminescence spectrum of the bitumen is composed of luminescence spectrum of its individual fraotions (Florovskaya and Melkov, 1946).

Although some inorganic minerals, like urenyl minerals, scheelite, many calcites and flourite also luminesce, but unlike bitumens they are insoluble in organic liquids.

Calculation of determined qualities are made by primary standards of various concentrations, by selective solubility and absorption on silica gel by chromatograph method. These standards are made from gravimetric weights of total bitumen and its constituents and the results are normalized to 100%. Pure components of the bitumen are obtained by separating the oil on silica gel. The quantity of reduced bitumen is an index of presence of oil in the particular sample.

CONCLUSIONS

The total bitumen content in all the samples is below average. This has been established by tests on numerous samples. Such a poor content of bitumen cannot yield significant quantities of oil as source rock in shale and clay. Like-wise the content of bitumen in sandstone is also too small for the reservior of epigenitic oil.

The predominent oily portion of bitumen in these core samples indicates that favourable conditions prevailed for the transformation of organic matter into oil. But the total bituminosity is insignificant for a source or reservior rock. During the generation of oil from organic matter, oxygen from the source material played secondary role in hydrocarbon formation, since tars and asphatenes are not prominent which are spot-lighted in coals even of anthracite quality.

ACKNOWLEDGEMENTS

We are highly indebted to M.K.I. Qureshi, Deputy Chief (Chemist) of Oil and Gas Development Corporation for labs. help in carrying out investigations and reviewing the script.

Thanks are also due to Pakistan Minerals Development Corporation authorities who donated the core material of lakhra area for detailed investigations.

REFERENCES:

Florovskaya, V.N. (1941), Luminescence method of detecting bituminosity in rocks. *Doklady Akad. Nauk. SSSR* 31 No. 4.

Florovskaya and Melkov, V.G. (1946): Introduction to. luminescence bituminology. *Gosgeolozdt.*

Ibrahim Shah, S.M. (1977). Stratigraphy of Pakistan. *Memoirs Geol. Survey of Pakistan* Vol. 12.

Kleminman, M. Kh. (1941) Application of Luminescence analysis. *Razvedka Nedr., No. 6.*

Levshin, V.L. (1951). Photoluminescence of luquid and solid substances. *Gostekhizdat.*

Shlezinger, N.A. and Novozhenova, L. (1941). Fluorescence method of discovering petroleum in geological prospecting work. *Byull. Vses. Khim.* O-va. No. 4.

Table - 1

RESULTS OF BITUMEN LUMINESCENCE ANALYSIS OF CORE SAMPLES EX-LAKHRA PM-I.

No.	Analy-sis No	Sample No.:Pm-1 Well Sample No.(Core)	Age	Depth	Lithol-ogy	Forma-tion	Nature of Capillery		Bitumen Content	Quantitative Fractional Analysis — Paper Strip Chrometographic Method			
							Colour	Width (mm)		Oil	Benzene Tar%	Alchol-Benzene Tars%	Asphalt-enes%
1.	387	2	Pale-ocene	107 feet	Sandstone, Siltstone, Clevstone Shele and Cley	Upper to Mid Rani-Kot	Brownish Yellow	5	0.04	96.97	1.52	0.76	0.75
2.	388	3	,,	112		,,	Yellow	3	0.02	96.97	1.52	0.76	0.75
3.	389	8	,,	126		,,	Brownish Yellow	7	0.08	98.46	0.77	0.39	0.38
4.	390	9	,,	150		,,	Yellow	5	0.04	96.97	1.52	0.76	0.75
5.	391	12	,,	190		,,	Orange Yellow	6	0.04	96.77	1.52	0.76	0.75

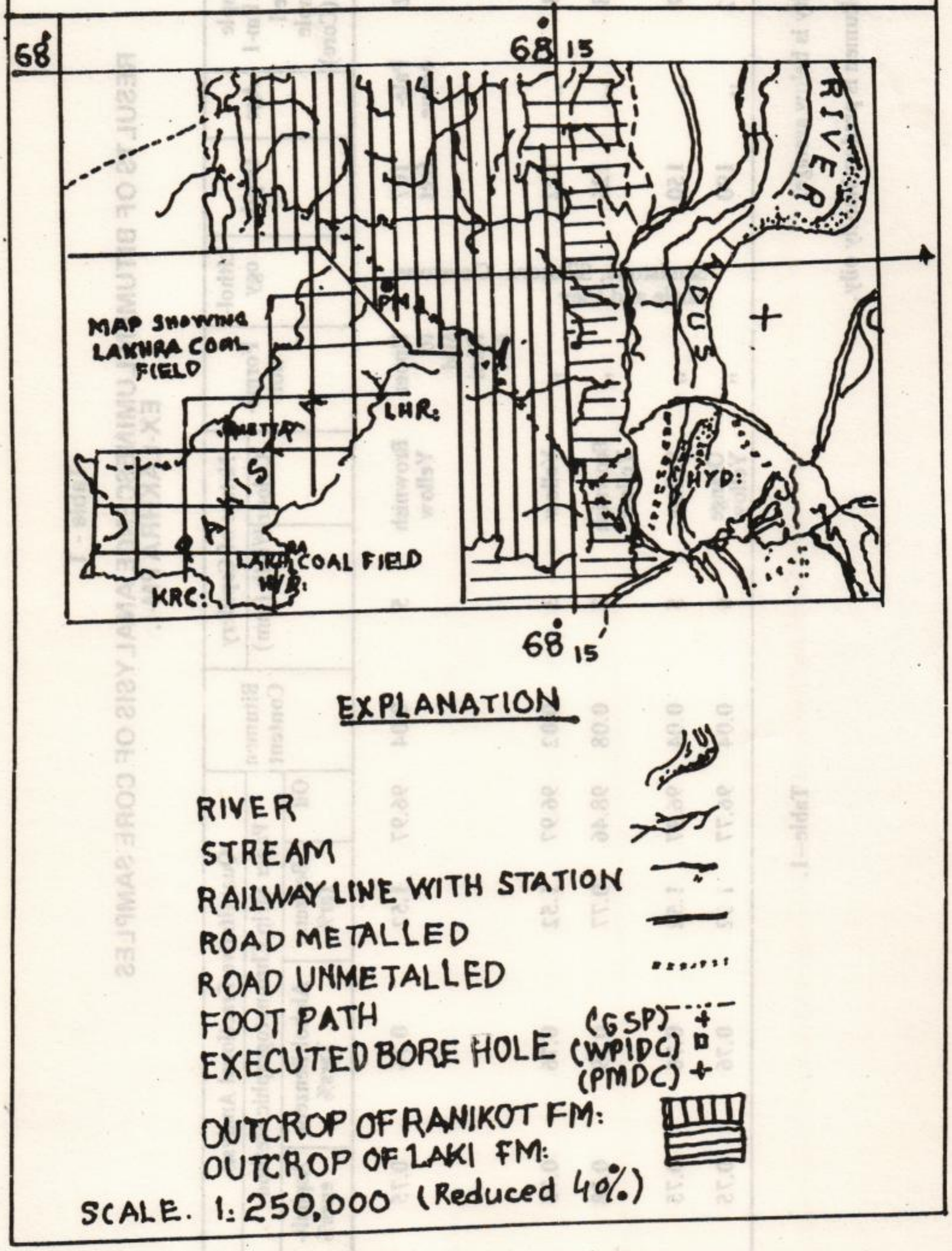
The bituminosity is below average.

Table–1.

However, the bitumen is predominantly oily.

Geological & Location Map of Lakhra area Sind

Fig – 1



PETROLOGY OF SIWALIK ROCKS OF CHAKRI—CHAUNTRA AREA, ATTOCK AND RAWALPINDI DISTRICTS, PUNJAB, PAKISTAN

M. SALEEM BAJWA
Geological Survey of Pakistan, Lahore.

ABSTRACT:– A sequence nearly 3000 meters thick of the Siwalik Group of Late Cenozoic age is exposed in the Chauntra quadrangle, in Attock and Rawalpindi Districts. For the purpose of petrological studies, the sequence has been differentiated in to Lower, Middle and Upper Siwaliks. The sandstones and clays of these sub groups have been studied lithologically, petrographically and chemically. The petrographically evidences suggest that sediments of the Siwalik Group were derived from igneous, metamorphic and sedimentary rocks of the adjacent Himalayan region and were deposited in a shallow fast sinking basin, after their short and rapid transportation.

INTRODUCTION

This work is based on the data collected by the author from Chauntra and adjoining areas, during 1982-83, field season, as a part of research work for Ph.D. thesis.

The area is bounded by latitudes 33∴ 15' and 33^{0} 30' N; longitudes 72^{0} 45' and 73^{0} 00' E (Survey of Pakistan-toposheet 43 C/15) and is a part of Attock and Rawalpindi districts of Punjab Province.

Almost thirty specimens of the sandstone sequence were subjected to grain size analysis and studied under reflected light. Detailed petrological analysis of the selected samples were also undertaken (Table 4; Figs 3 to 6).

PREVIOUS WORK

This paper is the first petrological study of its kind on the Siwalik Rocks of Chauntra area. However, Cotter (1933) prepared the first geological map of Kala Chitta and the adjoining areas on 1:250,000 scale. Wynne (1877) and Pilgrim (1912–13), Anderson (1927), made contributions in the field of general geology and stratigraphy. Tectonics of the Potwar region were described by Martin (1960) and physiography of the region was presented by Elahi and Martin (1961) Hussain, Bhatti and Sethi (1964–65) mapped 43 C quadrangle on 1:250,000 scale. The Stratigraphic Committee of Pakistan (Shah, S.M.I. editor, 1977) finalized the stratigraphic nomenclature of the Potwar region. Naeem and Bajwa (1978) prepared a geological map of Chakri - Chauntra area on 1:50,000 scale.

GEOLOGICAL SETTING

The Siwalik rocks are found in the central and southern parts of the investigated area. Siwaliks are well exposed at the southern limb of the faulted Gali Jagir anticline and towards the south and south-eastern side of the papin village, whereas near Chakri and Chauntra villages, they have been covered by the thick mantle of alluvium (Fig.1) On the basis of lithology, the Siwaliks of the area can be divided into six lithostratigraphic units, viz., Kamlial, Chinji (Lower Siwaliks); Nagri, Dhok Pathan (Middle Siwaliks); Soan and Boulder Conglomerates (Upper Siwaliks), and attain an average thickness of 3000 meters (Tab.1).

The Siwaliks of the area are composed of sandstones, clays, mudstones and conglomerates. The sandstones are calcareous, but at some places argillaceous, medium to coarse grained, moderately sorted and formed of rock fragments, quartz, calcite, dolomite, feldspars, muscovite, sericite, magnetite, hematite, garnet, tourmaline, epidote, and hornblende. They are grey to greenish grey in colour, medium to thick bedded, massive at places. Inter bedded clays are reddish brown to orange brown. Generally the sandstones are tough to moderately compacted rocks, forming strike ridges, whereas the clays are relatively loose and soft, resulting in strike valleys. Cross bedding is frequently found in the sandstones.

Generally the sandstone beds are 5 to 20 meters thick, some beds are even 30 meters thick, and at some places contain concretions and coarse pebbles. They are predominently lithic greywackes and lithic subgreywackes.

Table–1

STRATIGRAPHIC SEQUENCE OF AREA

	Alluvium	Recent
....	Unconformity.	....
&	Loessic clays &	Sand Sub Recent
....	Unconformity	....
Upper Siwaliks	Soan Formation	Early Pleistocene
	Dhok Pathan Formation	Middle Pliocene
Middle Siwaliks	Nagri Formation	Early Pliocene
	Chinji Formation	Late Miocene
Lower Siwaliks	Kamlial Formation	Middle to Late Miocene
	Murree Formation	Early to Middle Miocene
	Kuldana Formation	Middle Eocene
Chharat Group	Chorgali Formation	Early Eocene
	Margala Hill Limestone	Early Eocene
	(Base not Exposed)	

PETROGRAPHY OF THE SIWALIK SANDSTONES

Texture

Texture and Structure

The sandstones of the Siwalik Group in the investigated area are medium to coarse grained, moderately sorted, with subrounded to subangular grains. The grains are mostly of quartz, rock fragments, chert, feldspars, micas, garnet, epidote and tourmaline. The matrix is composed of very small grains of the above minerals, and of clay,sericite and calcite.

Calcite/Dolomite are very important constituents of cement. They occur mostly as precipitated matter, but clastic carbonate grains are also present.

Muscovite/Biotite/Sericite occur as fine to very fine anhedral grains, mostly in the cement Muscovite and biotite occur as small flakes and long laths, but also occur as coarse flakes. Biotite flakes show moderate pleochroism from light brown to yellow brown. Sericite may be closely associated with clay and as an alteration product of feldspar. Clay occurs predominantly in the matrix. It is extremely fine grained.

Chlorite occurs as small individual flakes, some small aggregates are also seen. It is green, poorly pleochroic and shows anomalous interference colours.

Epidote occurs as anhedral to subhedral grains, light green showing anomalous colours. Volcanic rock fragments may also contain epidote grains, which are generally medium to fine grained.

TABLE–2
THICKNESSES OF ROCK UNITS MEASURED IN VARIOUS STRATIGRAPHIC SECTIONS OF THE INVESTIGATED AREA ADN ADJOINING AREAS:

Sec-tion No.	Location of Stratigraphic Sections	THICKNESS IN METERS					
				SIWALIKS		MIDDLE SIWALIKS	LATE SIWALIKS
		MURREE FORMATION	LOWERY KAMLIAL FORMATION	CHINJI FORMATION	NAGRI FORMATION	DHOK-PATHAN FORMATION	SOAN FOR-MATION
1.	S.E. of Papin Village (Inve-stigated Area)	1000 b	600 (Measured at S of Ranial)	650 b	1050	850	500 b
2.	S. W. of Riwat Village	110 b	695	728	325	430 b	490 b
3.	S.E. of Sukho Village.			40 b	586	325	300 b
4.	N. of Sohawa	385	138	435	545	960	170

TABLE – 3
CHEMICAL COMPOSITION OF SIWALIK SANDSTONES AND CLAYS

Sample No.	PCL-14	PCL-14	PCL-1a	PCL-12
Localities.	S. of Khairi Murat Range	–do–	–do–	–do–
Rock Type	Sandstone	Sandstone	Shale/Clay	Shale/Clay
SiO_2	48.58%	74.21%	57.44%	54.02%
Fe_2O_3	07.18%	04.38%	07.97%	06.78%
Al_2O_3	10.72%	08.02%	14.63%	10.87%
TiO_2	00.50%	00.40%	00.60%	00.75%
CaO	10.09%	00.56%	00.56%	05.60%
MgO	03.62%	02.82%	03.62%	06.45%
Na_2O	00.28%	01.31%	00.13%	00.06%
K_2O	02.33%	01.53%	04.14%	02.23%

(Samples analysed by Mr. Azhar Khan at the Labs Quetta)

Tourmaline occurs as green fine grained, subangular grains, which are randomly distributed and show moderate pleochroism from brownish green to dark greenish brown.

Amphibole occurs as fine, subhedral grains with moderate pleochroism and at places altered to chlorite.

Garnet is colourless to lightpink, fine to medium grained, subangular to subrounded grains. It is also seen in the matrix, some grains contain tiny quartz inclusions.

The Siwalik clays are unlaminated to poorly laminated, uncompacted and fine-grained. Detailed petrographic work on the clays is yet not done, however they include, clay, quartz, calcite/dolomite, hematite/limonite, muscovite/sericite, chalcedony and carbonaceous matter.

CHEMISTRY

Siwalik Sandstones:- Two samples of sandstones from the Lower Siwaliks were chemically analysed. Sample No. PCL-14 contains 48.58% SiO_2; 7.18% Fe_2O3; 10.72% Al_2O_3 and 10.09% CaO and sample No. PCL-1 contains 74.21% SiO_2: 4.38% Fe_2O_3; 8.02% Al_2 O_3 & 00.56% CaO. The percentages of other elements are given in table-3. The above results show that the first sample is calcareous sandstone with about 48% quartz and the second sample have very high percentage of quartz.

Siwalik Clays/Shales:- Two samples of Lower Siwalik clays were chemically analysed (results given in Table 3). Sample No. PCL-1A contains 57.44% SiO_2; 07.97% Fe_2O_3; 14.63 Al_2 O_3 and 00.56% CaO and sample No.PCL-12 contains 54.02% SiO_2; 06.78% Fe_2 O3; 10.87% Al_2 O_3 and 05.60 CaO. The second sample is slightly calcareous.

PROVENANCE AND ENVIRONMENTS OF DEPOSITION

Rock fragments of the Middle Siwaliks, represent greater variety of parent rocks, and constitute a little higher percentage of model composition. Percentage of polycrystalline quartz, mica and mechanical matrix is also increased.

The features which have direct bearing on the provenanance and environmental conditions of the deposition of the upper Siwaliks are frequency and dominance of conglomerates, presence of trap in the rock fragments and an increase in number and variety of minor mineral contents.

After the removal of the sedimentary veneer and low and medium grade metamorphics of the adjoining Himalayan region, deeper seated medium and high grade metamorphics and plutonics, representing various types of schists and gneisses were exposed to denudation and supplied a major part of the sediments for the formation of the Middle and Upper Siwaliks. During the sedimentation of the Upper Siwaliks, traps also emerged as the source rocks. The development of huge deposits of conglomerates in the Upper Siwaliks may be due to upheaval in the catchment areas and consequent increase of rainfall (Pasco, 1964; Raiverman, 1968).

High proportion of undecomposed rock fragments, general angularity of the detritus and presence of fossil vertebrate matter (Dayal and Chaudhri, 1967) suggest convincingly the closeness of source rocks and basin of deposition. Frequency of occurrence of shallow water features, such as current bedding, ripple marks, association of larger fragments with the finer ones and poor sorting are indications of the shallow nature of basin. Development of reaction rims at the contact of quartz and carbonate is indicative of rapid burial (Siever, 1959; Walker, 1962). Huge thickness of Siwaliks with shallow water conditions and evidence of rapid burial indicate a shallow fast sinking basin.

The author supports the view that the sediments of the Siwaliks were derived from igneous, metamorphic and sedimentary rcoks of the adjacent Himalayan region. They were deposited in freshwater conditions, in a shallow fast sinking basin, under conditions of rapid erosion, short transportation and rapid deposition.

TABLE – 4
PETROGRAPHIC COMPOSITION OF SIWALIK SANDSTONES

Locality:- SE of Papin village (Lat. 33° 15' 30" N long. 72° 55' 28" E)

Samples No.s –	32/60-SB	32/80-SB	32/100-SB	32/150-SB	32/200-SB	32/200-SB
1. Quartz	32%	40%	44%	42%	42%	42%
2. Feldspar	05%	06%	05%	04%	06%	08%
3. Rock-fragments	18%	12%	08%	03%	01%	01%
4. Calcite	24%	20%	20%	23%	26%	24%
5. Tourmaline	03%	06%	05%	01%	02%	03%
6. Garnet	01%	01%	01%	02%	01%	02%
7. Epidote	03%	02%	01%	02%	01%	02%
8. Rutile	–	01%	01%	02%	02%	03%
9. Hornblende	02%	01%	01%	04%	03%	02%
10. Chlorite	03%	02%	03%	02%	01%	01%
11. Muscovite/ Sericite	04%	02%	02%	02%	02%	02%
12. Biotite	05%	04%	04%	04%	05%	04%
13. Ilmenite	–	02%	02%	04%	03%	03%
14. Magnetite	–	–	03%	04%	05%	03%
15. Hematite	–	01%	–	02%	–	–

Analysis at G.S.P. Labs by M.S. Bajwa.

ACKNOWLEDGEMENTS

The author is indebted to Prof. F.A. Shams and Dr. M. N. Chaudhry for their guidance in the petrological studies.

Thanks are due to Dr. N.A. Bhatti, Director, Geological Survery of Pakistan, for going through the manuscript.

Cooperation of A. H. Kazmi, Dr. A. N. Fatmi, M.W.A. Iqbal, M. Akhtar and Mahmood-ul-Hasan, for the finalization of this paper, is also acknowledged.

REFERENCES

Bhatti, N.A. (1966) Limestone investigation of margala Hills G.S.P., I.R. 39.

——————— (1981) Depositional envir-onment of phosphate deposits of Hazara, District published or unpublished.

Booy, T.D. (1965) Petrology of detritus in sediments, a valuable tool *Kon. Ned. Akad. Van. Wet.* Amsterdam. S.B., 69, No. 2, PP. 277-282.

Chaudhry, M.N., . and Ashraf. M. (1981) Petrology of Middle Siwalik Rocks, of Kotli area, Azad Kashmir. *Geol. Bull. Univ. Peshawar,* Vol. 14, pp. 183-191.

Chaudhri, R.S. (1970) Petrology of Siwalik Formations of north western Himalayas. *Bull. Ind. Geol. Assoc.,* Vol. 3, No. 1 & 2, pp. 19-25.

Chaudhry, R.S. (1971) Petrogenesis of Cenozoic sediments of north-western Himalayas. *Geol. Mag.* 108 (1), pp. 43-48.

Fatmi, A.N. (1973) Lithostratigraphic Units of Kohat-Potwar Province, Indus Basin, Pakistan. *GSP. Mem.,* Vol. 10.

Gill, W.D. (1951) The stratigraphy of Siwalik Series in the northern Potwar Punjab, Pakistan. *Geol., Soc., London. Quar. Jour.,* Vol. 10, pt. 4, pp. 375-394.

Krav Tchenko, K.N. (1964) Soan Formation, Upper Unit of Siwalik Group in Potwar. Sc. & Ind. Vol. 2, No. 3, pp. 230-233.

Krishan, M.S. (1960) Geology of India and Burma. Higginbothom (private) Ltd., Madras. pp. 604, illus., Incle. Geol. Maps.

Krumbein, W.C. and Sedimentary petrography. pp. 43-51. Pettijohn, F.J.

Malik, I.A. (1983) Grey wacke in Middle Siwaliks. Geol. Gaz Vol. 6, No. 1, pp. 11-13.

Martin, N.R. (1962) Tectonic style in Potwar. Geol Bull. P.U., No. 2. pp. 40-49, Incl. Illust. and Maps.

Potter, P.E., (1980) Sedimentology of shale. pp. 3-7 Potter, P.E Maynard, J.B and Praor, W.A. (1980) 46-72, 258-269, incl. Illust.

Shah, S.M.I. (1977) Stratigraphy of Pakistan, *G.S.P Mem., Vol. 12.*

Tickell, F.G. The examination of fragmental rocks pp. 3-15, 50-62, incl. illust.

Wadia, D.N. (1957) Geology of India. London Mac-Millan & Co. Ltd. Illust., Incl. Geol. Map 3rd Ed.

Yeats, R.S., Khan, S. H. and Akhtar, M. (1984) Late Quaternary deformation of Salt Range of Pakistan. *Geol. Soc of America Bull,* V. 95, P. 958-966, inc Illust.

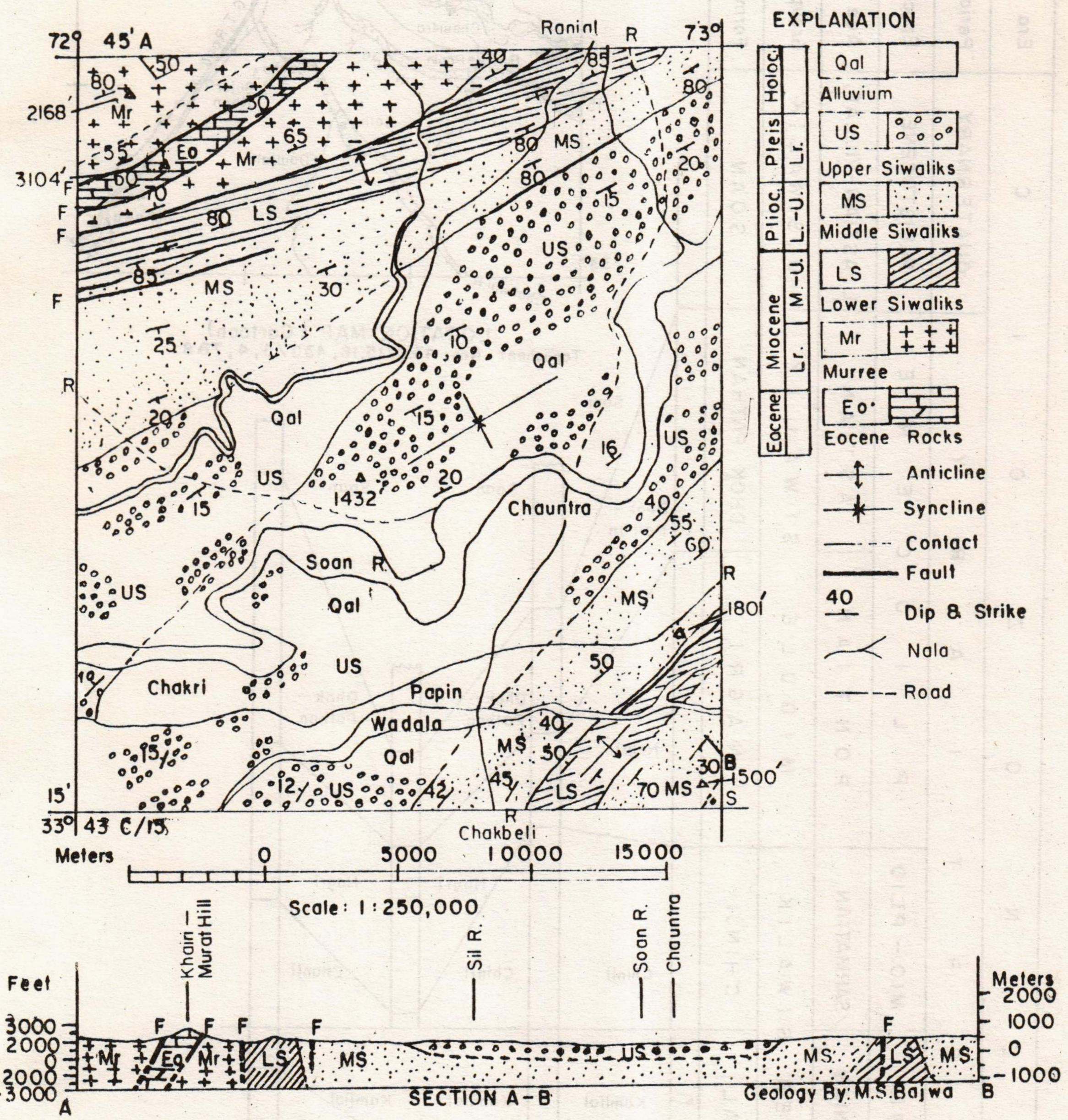


FIG. I GEOLOGICAL MAP OF CHAKRI - CHAUNTRA AREA.

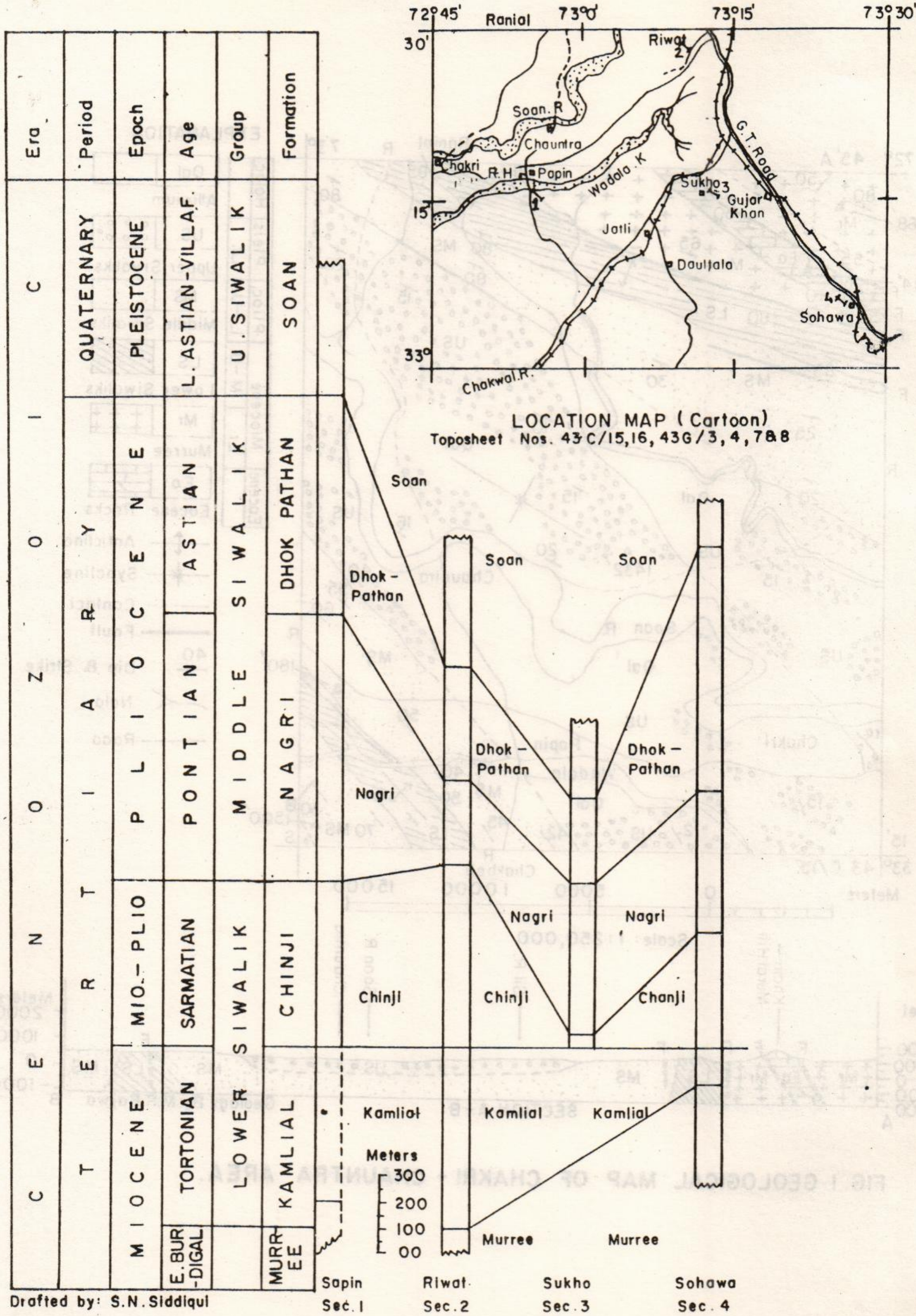


FIG. 2 CORRELATION OF MEASURED STRATIGRAPHIC SECTION OF INVESTIGATED AREA AND ADJOINING AREAS OF ATTOCK, RAWALPINDI AND JHELUM DISTRICTS, PUNJAB.

Prepared by: M.S. Bajwa

Sample No. 28 - SB

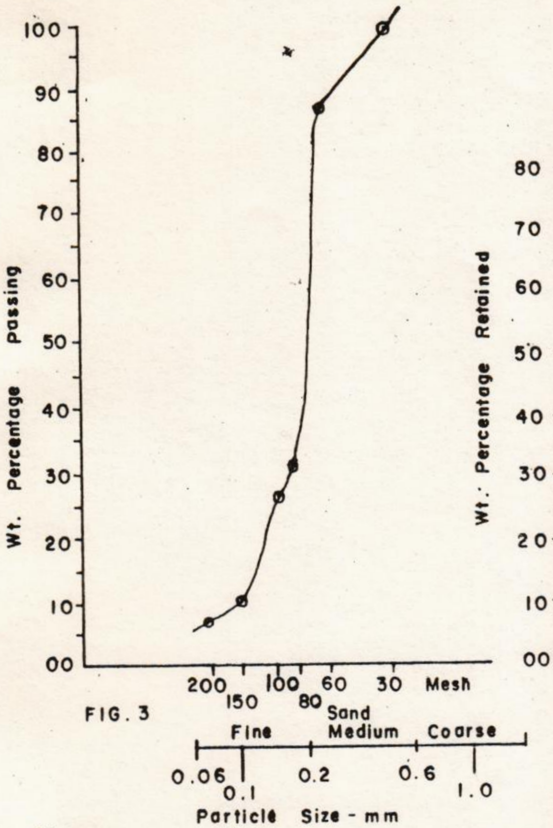


FIG. 3

Sample No. 28 - SB

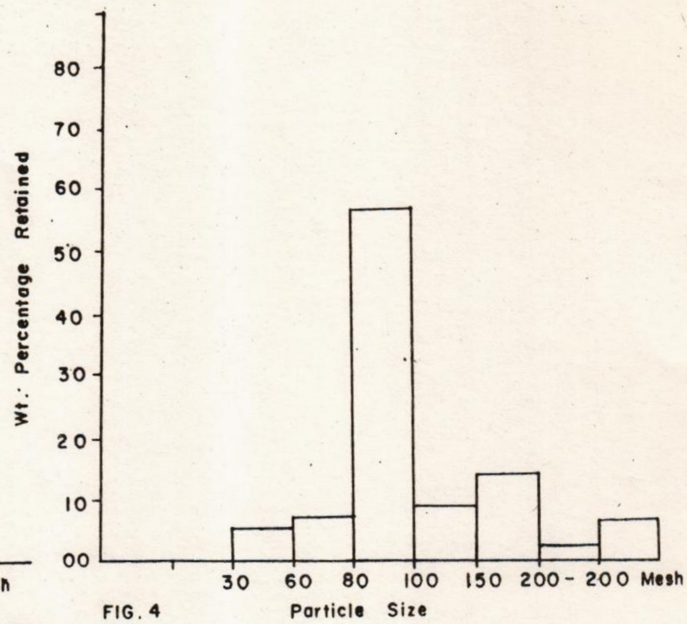


FIG. 4

GRAIN- SIZE CURVE AND HISTOGRAM OF SAND SPECIMEN OF MIDDLE SIWALIKS (MID. PART)

Sample No. 37

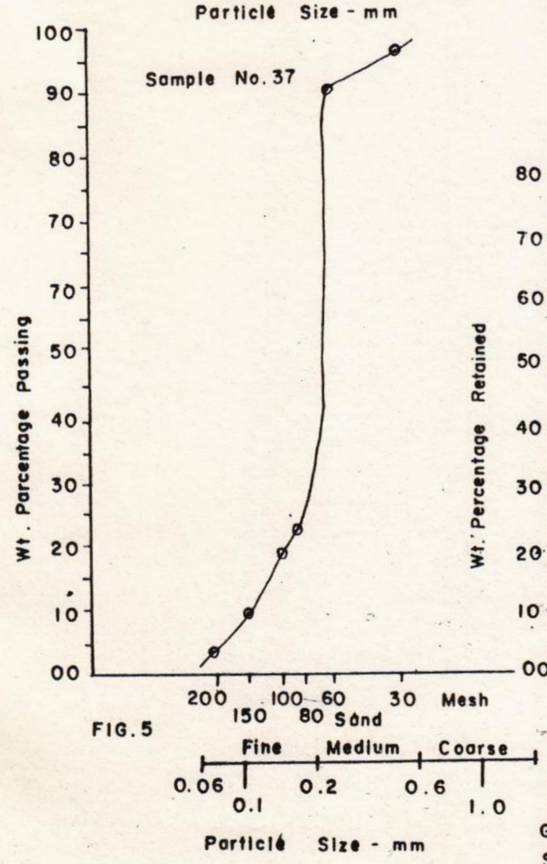


FIG. 5

Sample No. 37 - SB

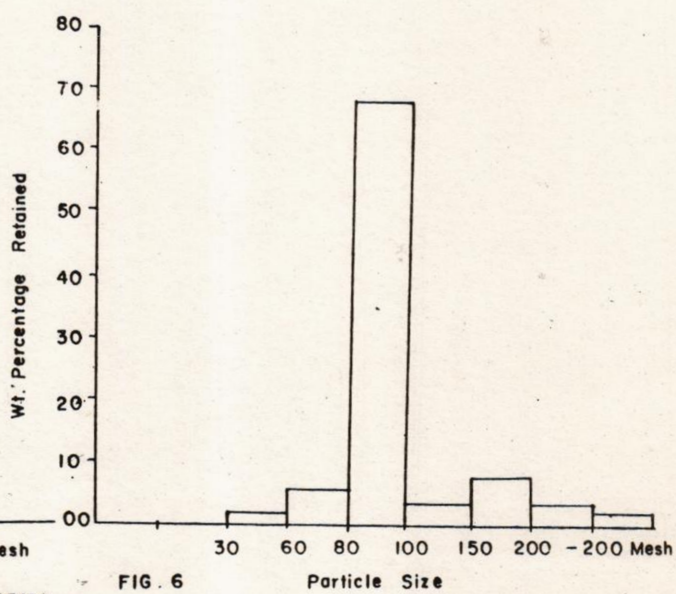


FIG. 6

GRAIN- SIZE CURVE AND HISTOGRAM OF SAND SPECIMEN OF MIDDLE SIWALIKS (L.R. PART)

Prepared by: M.S. Bajwa

EVALUATION OF OPTICAL QUALITY HAZARA SAND NORTH WEST FROTIER PROVINCE

MUHAMMAD RAFIQUE AND F. A. FAROOQI.
Pakistan Council of Scientific and Industrial Research, Lahore

ABSTRACT.– A representative sample of glass sand from Hazara District was procured for investigation for optical glass making point of view. It was found that after water washing and grading, the reduction of iron content ($Fe^2 03$) was so significant that this sand was quite suitable for the manufacture of optical glass.

INTRODUCTION

The presence of colour, in quality container glass and other finer grades of glass including optical glass (Din et al. 1963), is not acceptable. This is particularly true of optical glass, in which even traces of colour make it unsuitable for practical application, because of its enhanced absorption and reduced transmission. Corrosion of refractories in the furnace and the impurities of colouring oxides like (Fe_20_3. TiO_2 etc.) present in the raw materials are mainly responsible for imparting colour to glass. The first source of colour can be eliminated to a large extent by the use of better quality refractories. A good number of studies have been made to evaluate the raw materials found in Pakistan. Soda ash of desired quality and high purity limestone are available. The silica sand (major component of raw material) has posed a great problem.

Much work has been reported on evaluation of various indigenous silica sand (Din et al. 1963, Faruqi et al. 1966 and Rasul et al 1962). It is concluded from these studies, that these sands after proper beneficiation, can be used for the manufacture of container and sheet glass. However, they are unsuitable as a raw material for optical and other superior quality glasses, as they even after their beneficiation impart tangible colour to glass.

The present work is a repotrt on the suitability of a sand found at Manda Kacha (Majeed, 1958) 75 kilometers North of Abbottabad in Mansehra District (Fig 1). This sand forms a substantial part of the total deposits of sand of varying quality, estimated as 250 million metric tons. The preliminary examination of this sand showed the absence of colouring oxides. A rather detailed study was therefore, undertaken to evaluate it completely.

EXPERIMENTAL

a) *Grading:* After sampling of the raw sand by the usual method of coning and quartering (B.S.S. 1952) 100 grams of the original and water washed samples were subjected to sieve analysis by using B.S.I.S. test Sieves Nos. 18, 36, 44, 52, 60, 72, 100 and 120. Mechanical shaking machine was employed to facilitate the sieving process. The materials retained on each sieve and that passing through 120 mesh, were weighed and are tabulated in Table Nos Ia and Table-Ib.

b) *Water Washing:* About 500 grams of the raw sand was stirred with 1 litre of water in a two litre beaker and allowed to settle for 30-40 seconds. The supernant liquid was decanted off and the washing was continued till the supernatant layer showed no turbidity on stirring. The washed sand was dried at 110 + 5°C. The loss on washing was found 2.51%.

c) *Chemical Analysis.* Ten grams of each of the raw sand, water washed and different graded fractions were ground to a fine powder and analysed (B.SS. 1958) for SiO_2, TiO_2, $A1_2O_3$, Fe_2O_3 (Vogel, 1959) MgO, CaO, Na_2O, K_2O and L.O.I. The results are tabulated in Table Nos. 2a and 2b.

d) *Microscopic Examination:* Under a petrological microscope it was identified that the sand mainly consists of loose, colourless, sub-angular to sub-rounded quartz grains with a definite size with a diameter ranger of 0.1 to 1.00 mm. one to two percent of the total grains have yellowish coating of limonite and reddish coating of hematite. Some colourless clayey particles are seen on the microscope slide.

Results & Discussions

The examination of the sand under a microscope showed no visible impurities except a lot of clayey matter. Thus it was expected that washing of sand to remove clayey matter, would result in considerable improvement in quality. Accordingly chemical analyses were done not only for the raw sand and its fractions but also for washed sand, raw graded – 18, + 120 and washed graded sand.

It can be seen from Table No. 2a that the raw sand contains considerable amounts of impurities like Al_2O_3, Fe_2O_3 and CaO most probably originating from clay. However, after screening, if + 18 and –120 mesh fraction were rejected, the rest i.e. –18 + 120 fraction had 96.91 SiO_2, 1.30% Al_2O_3, 0.04% Fe_2O_3, 0.87% CaO as compared to 94.14% SiO_2, 2.18% Al_2O_3, 0.06% Fe_2O_3 and 1.47% CaO of raw sand. It showed that the major amounts of the impurities are present in + 18 and –120 fractions. Thus even by simple screening considerable improvement in the quality of the sand is obtained. The beneficiated sand i.e. –18, +120 mesh forms about 67% of the total. According to B.S.I.S. No. 10, this amount should not be less than 94%. However, if the beneficiation is done at the spot, the extra cost involved in transporting the un-desirable fractions can be avoided. Further, if the purity of the –18, + 120 mesh fraction matches the specifications laid down by B.S.I.S. No. 410, this sand can be used as a raw material for colourless glasses, till the discovery of any better sand. On water washing, the fraction, –18, + 120 mesh had about 98.73% SiO_2, 0.58% Al_2O_3 and 0.008% Fe_2O_3 and 0.08% CaO.

The making of colourless glass demands the use of sands of good quality both as regards chemical composition and uniformity of grain size. An even higher degree of purity is required in sands suitable for making optical glass and the finest grades of colourless artistic wares, than is necessary in sands used in the production of colourless bottles and general colourless glass.

According to the British Standard Institution Specifications No. 410, it has been recommended:–

i. Sand for Colourless Glass:

Grading:

Remaining on Mesh No. 18	Nil
Remaining on Mesh No. 25	Not more than 1%
Remaining on Mesh No. 36	Not more than 5%
Passing through Mesh No. 120	Not more than 5%

Chemical Composition:

SiO_2 on dry basis	Not less than 94.4%
Fe_2O_3	Not more than 0.02%

ii. Sand for Colourless Bottle and General Glass:

Remaining on Mesh No. 18	Nil
Remaining on Mesh No. 25	Not more than 5%
Remaining on Mesh No. 36	Not more than 5%
Passing through Mesh No. 120	Not more than 5%

Chemical Composition:

SiO_2 on dry basis	Not less than 98.5%
Fe_2O_3	Not more than 0.04%

In chemical composition the –18, + 120 mesh fraction of raw sand is comparable in its silica content 96.91% compared to 98.5% recommended by B.S.I.S., for general colour glass. The Fe_2O_3 content of raw graded sand under study is just according to the B.S.I.S. i.e. 0.04%. The washed and graded sand (–18, + 120 mesh) has a silica content 98.73% silightly lower than that given by B.S.I.S.(99.4%) but in respect of Fe_2O_3 content i.e. (0.008), it is much better than that given in the specifications i.e. (Fe_2O_3) content not to exceed 0.02%. The lower silica content is because of higher content of Al_2O_3 which does not have any colour imparting properties.

As regards the grain size of –18, + 120 mesh fraction of the sand, the retension on mesh No. 36 is about 16% which is higher than its counterpart value of 10% specified by B.S.I.S.

CONCLUSSIONS:

None of the sands available in Pakistan, even after various physical treatments could be used as a raw material for optical glass. The sand under study, inspite of its short comings stated above, if properly screened and water washed, can be suitably used for the production of optical glass.

ACKNOWLEDGEMENT

The authors are thankful to Mr. Muhammad Yunis, Junior Technical Officer for his useful help in carrying out these studies.

REFERENCES

Ali, S. Tayyab, Calkins, J. A. and Official, T.W. (1964) Mineral Resonrces of S. Hazara, N.W.F. Province, Pakistan. *Rec. G.S.P.*, Vol. 13 a.

Din, A., Sindu, S.A., and Faruqi, F.A., (1963), Purification of Dera Pezu Sand for making Colourless and Optical Glass. *Pak. J. Sci. Ind. Res.* Vol. 15, No.4, pp.20–25.

Din, A., Rasul, G., and Rana, M.A., (1963), Purification of Commercially Exploited Glass Sands of West Pakistan. *Pak J. Sci. Ind. Res.* Vol.15, No. 1, pp. 157–163.

Faruqi, F.A., Ayub, M., Aslam, M., (1966). An investigation on the Beneficiation of Glass Sands from Hazara and Sylhet Districts., *Science & Industry*, Vol.4, No.3, pp. 217–224.

Rasul, G., Faruqi, F.A., (1962). Characteristics of Some Glass Making Sands of Pakistan. Vol.14, No.2, pp. 63–80.

Majeed, A., Khan., (1958). Glass Sands of Pakistan. Unpublished Report, *Geological Survey of Pakistan.*

Methods for the use of British Standard Test Sieves, (1952). B.S.I.S. No. 1796.

Sand for making Colourless Glasses, (1958). B.S.I.S. No. 2975.

Vogel, I., (1959). A Test Book on Quantitative Inorganic Analysis (Longmans Green & Co., London) Second Edition, pp. 598–646.

TABLE–1a

Sieve Analysis of Original Sand

Sieve No.	Mesh Size in microns.	%age Retention	%age Comulative
18	835	5.73	5.73
36	422	15.70	21.43
44	355	7.31	28.74
52	295	5.19	33.93
60	250	9.59	43.52
72	212	6.00	49.52
100	152	19.88	69.40
120	124	1.41	70.81
–120	–	28.58	99.49

TABLE–2a

Chemical Analysis

Sample	%age SiO_2	%age TiO_2	%age Al_2O_3	%age Fe_2O_3	%age MgO	%age CaO	%age Na_2O	%age K_2O	%age L.O.I.
1. Raw Sand	94.16	0.00	2.17	0.06	0.02	1.47	0.05	0.02	2.05
2. Ungraded, water washed.	94.64	0.00	2.00	0.05	0.02	1.40	0.04	0.02	1.84
3. Raw graded –18 + 120	96.91	0.00	1.30	0.04	0.02	0.87	0.04	0.02	0.86
4. Grade –18 + 120 water washed.	98.73	0.00	0.58	0.008	traces	0.08	0.03	0.01	0.57

TABLE–1b

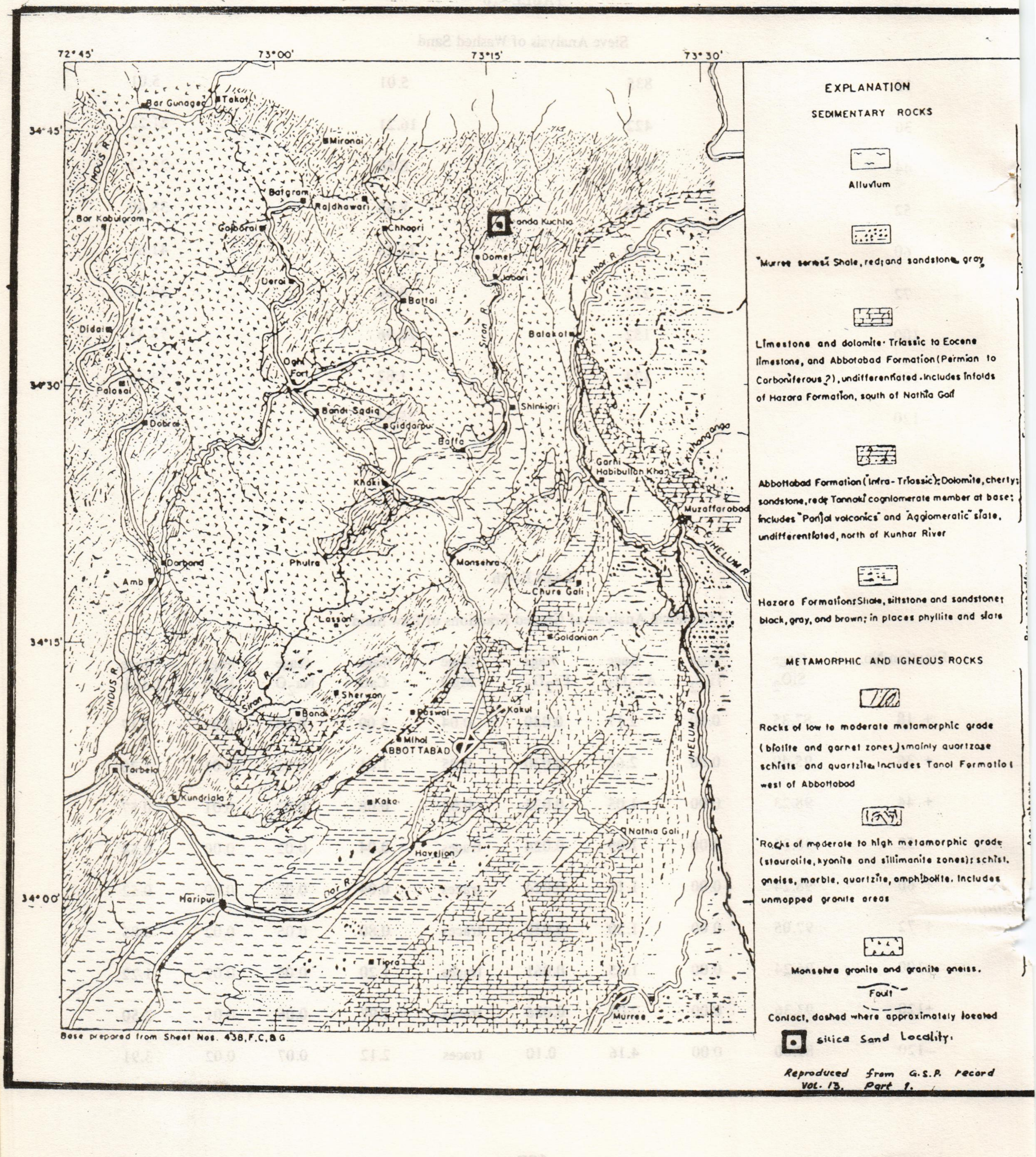
Sieve Analysis of Washed Sand

18	835	5.01	5.01
36	422	16.21	21.22
44	355	8.50	29.72
52	295	8.68	38.40
60	250	13.25	41.65
72	212	8.80	50.45
100	152	22.96	73.41
120	124	1.82	74.23
–120	–	25.34	99.57

TABLE–2b

Chemical Analysis of Graded Fractions of Raw Sand

Fraction No.	%age SiO_2	%age TiO_2	%age Al_2O_3	%age Fe_2O_3	%age MgO	%age CaO	%age Na_2O	%age K_2O	%age L.O.I.
+ 18	87.35	0.00	2.17	0.030	0.04	5.09	0.08	0.02	5.17
+ 36	95.40	0.00	2.67	0.030	0.05	1.61	0.03	0.01	1.20
+ 44	98.23	0.00	1.05	0.025	0.02	0.08	0.02	0.01	0.57
+ 52	98.34	0.00	1.05	0.024	traces	0.04	0.02	0.00	0.54
+ 60	98.24	0.00	1.15	0.024	traces	0.04	0.02	0.00	0.52
+ 72	97.05	0.00	1.20	0.030	traces	0.80	0.05	0.02	0.85
+100	96.24	0.00	1.25	0.061	traces	1.20	0.05	0.02	1.22
+120	93.36	0.00	2.03	0.086	traces	1.97	0.06	0.01	2.50
–120	89.60	0.00	4.16	0.10	traces	2.12	0.07	0.02	3.91


72°45'
73°00'
73°15'
73°30'
34°45'
34°30'
34°15'
34°00'
EXPLANATION
SEDIMENTARY ROCKS
Alluvium
"Murree series": Shale, red; and sandstone, gray
Limestone and dolomite: Triassic to Eocene limestone, and Abbotabad Formation (Permian to Carboniferous ?), undifferentiated. Includes infolds of Hazara Formation, south of Nathia Gali
Abbottabad Formation (Infra-Triassic): Dolomite, cherty; sandstone, red; Tannaki conglomerate member at base; includes "Panjal volcanics" and "Agglomeratic" slate, undifferentiated, north of Kunhar River
Hazara Formation: Shale, siltstone and sandstone; black, gray, and brown; in places phyllite and slate
METAMORPHIC AND IGNEOUS ROCKS
Rocks of low to moderate metamorphic grade (biotite and garnet zones); mainly quartzose schists and quartzite. Includes Tanol Formation west of Abbottabad
Rocks of moderate to high metamorphic grade (staurolite, kyanite and sillimanite zones); schist, gneiss, marble, quartzite, amphibolite. Includes unmapped granite areas
Mansehra granite and granite gneiss.
Fault
Contact, dashed where approximately located
Silica Sand Locality.
Reproduced from G.S.P. record Vol. 13, Part 1.
Base prepared from Sheet Nos. 43B, F, C, & G
Bar Gunagee
Takot
INDUS R.
Mironai
Batgram
Rajdhawari
Bar Kabulgram
Gojborai
Chhopri
Konda Kuchha
Domel
Jabori
Kunhar R.
Derai
Battal
Didai
Siran R.
Balakot
Oghi Fort
Palosai
Bandi Sadiq
Shinkiari
Dobrai
Giddarbu
Baffa
Kishanganga
Garhi Habibullah Khan
Khaki
Muzaffarabad
JHELUM R.
Darband
Phulra
Mansehra
Amb
Chure Gali
Lassan
Goldonian
Sherwan
Siran R.
Bandi
Paswal
Kakul
Mirhal
ABBOTTABAD
Torbela
Kundriala
Kakot
Nathia Gali
Havelian
Dor R.
JHELUM R.
Haripur
Tiora
Murree

EVALUTION OF THE SIWALIK BUNODONT AND BUNOLOPHODONT PROBOSCIDEA

MOHAMMAD SARWAR AND GUL NAFEES

Department of Zoology, University of the Punjab, Lahore, Pakistan.

ABSTRACT: – A comparative study of the bunodont and bunolophodont Siwalik mastodonts indicates that Hemimastodon crepusculi (Pilgrim, 1908) was related to Palaeomastodon (Phiomia) and was a member of the relict proboscidean fauna that continued on surviving in the Sub-Continent. Genera Synconophus and Stegolophodon, which are the product of local evolution, have been regarded as descendant of the genus Gomphotherium.

INTRODUCTION

Siwalik mastodonts were studied on scientific basis for the first time by Falconer & Cautley and the observations were published in 1846 in the form of a voluminous report, entitled "Fauna Antiqua Sivalensis". This is the first account giving some basic idea of the probable relationship of the Siwalik mastodonts. Few years later, Lydekker started his studies and tried to interpret the interrealationships of various types of Gomphotheres (Lydekker, 1880) and anancoides (Lydekker, 1884). In early years of the 20th century, Pilgrim made an attempt to work out the inter-relationship of the Siwalik mastodonts. He also believed in the presence of *Palaeomastodon* (as *Hemimastodon crepusculi* Pilgrim) in South Asia. Osborn (1936) was the first to work out the phylogeny of the Siwalik mastodonts in detail. He was able to publish a number of papers on the Siwalik forms dealing with their migration, adaptability and extinction. His most notable work dealing with these forms is in the form of research papers/monographs published in 1929, 1932, 1934 and 1936. After Osborn, Chakravarti (1957) and Tobien (1973, 1976) attempted to know the phylogenetic relationship of the Siwalik mastodonts. The work of Tobien is based upon a large scientific data and is really a good phylogenetic analysis. He not only correlated the Siwalik forms with the alike forms of the world but also tried to know the direction of flow of different mastodont populations. In the recent years, the present author has studied the Siwalik mastodont genera, *Gomphotherium, Synconolophus, Tetralophodon, Anancus, Stegolophodon* and *Stegotetrabelodon*. A detailed account on the morphology and distribution of the genera has been given in the monograph." Taxonomy and Distribution of the Siwalik Proboscidea", published in 1977. Besides this monograph, comments on the smaller groups have also been given in different research papers published by the senior author in 1978, 1979 & 1980.

DISCUSSION

Bugti beds of Baluchistan which are of Lower Miocene age (Eames, 1950), have yielded two primitive species, *Hemimastodon crepusculi* and *Gomphotherium cooperi*. The type tooth (Ind. Mus. A446) of *Hemimastodon crepusculi*, as figured by Pilgrim (1912), is very large bunolophodont with thick enamel layer. The tooth contours are perfectly proboscidean. The median sulcus is running throughout the molar length as is expected in the early proboscideans. When compared with the type and referred material of *Palaeomastodon (Phiomia)* on the one hand and with the type and referred material of primitive gomphotheres of the Sub-Continent on the other hand, it appears that the tooth Ind. Mus. A-446 is certainly related to *Palaeomastodon (Phiomia)*. Like the zygodonts (Sarwar, 1977, Sarwar & Abubakr, 1980), it is also a member of the relict mammalian fossil fauna of the Siwaliks that continued on living in this part of South Asia. Keeping in view the above cited facts, the assumption of Osborn (1932) that Hemimastodon crepusculi was some suoid, does not appear to be justified. The proboscidean affinities of Hemimastodon crepusculi have also been proposed by Cooper (1922) and Tobien (1973).

The other species, *Gomphotherium cooperi* (described as *Trilophodon cooperi* by Osborn, 1932) is geologically one of the oldest and is closely related with *Gomphotherium angustidens* of Europe. Its molars have the same dimensions and the same morphological features as those of *G. angustidens* and is hence inseparable from the latter. Genus *Gomphotherium* probably immigrated from Europe somewhere in Lower Miocene as has also been suggested by Tobien (1973, 1976). The presence of *G. angustidens* in Miocene of distant areas like Africa (Fourtau, 1920 and Savage, 1971), Europe (reported by many workers such as Osborn, 1929; Bergounioux and Grouzel, 1960; Ginsburg

and Antunes, 1966; Tassy, 1977 and Tassy and others, 1977), North Asia (Osborn, 1924, 1932; Hopwood, 1935; Bohlin, 1946) and Baluchistan (Osborn, 1932), demonstrates that the members of the species were well adapted for rapid migrations.

Murrees Formation which is older than the Kamlial beds but younger than the Bugti beds of Baluchistan (Wadia, 1953), have not yielded more than a few teeth of *Deinotherium* and a damaged left upper molar of *Gomphotherium* (Sarwar, 1974). The latter was collected from the Upper Murrees, exposed near Kotli Sittian, Punjab, Pakistan. It is smaller than that of *Gomphotherium angustidens* in anteroposterior length but is similar in the number of ridge-plates. The anterior two ridge-plates are fairly oblique while the posterior two are almost transverse. The conelets are very low, much blunt, rounded and smooth. Median conule was most probably very small and present in the anterior two valleys. In view of these characters, it is probably referable to the genus *Anancus* and being the earliest record may be regarded ancestral to the anancoids. However, the assumption remains doubtful because the record is just a single poorly preserved tooth and is not accompanied by an intermediate molar. In case it is not an anancoid then in all probability, Europe should be considered as the place of origin for anancoids. The latter assumption would thus support Tobien's opinion (1973), according to which tetralophodonts did not make their appearance before upper Miocene.

Murrees are overlain by the Kamlial beds. The two series show a little lithological distinction (Gansser, 1961; Elahi and Martin, 1961). Kamlial is also poorly fossiliferous but has yielded comparatively much more specimens than the Murrees. From the base of Kamlial zone, an M^3 has been described as *Gomphotherium chabbariensis* by Sarwar (1977). The tooth is somewhat advanced as compared to *G. angustidens* in having rudimentary double external trefoil. The type tooth of G. chabbariensis has the same number of ridge-plates as that of *G. angustidens.* It appears that the former is a direct descendant of the latter. From G. chabbariensis, three lines of evolution can be traced. In the first line, the trend was an increase in the number of ridge-plates and the prominence of conelets. These features progressively developed through *G. intermedius* and *G. chinjiensis* to *G. macrognathus.* The last lower molar in *G. chabbariensis* is small and 4½ ridge-plated (Sarwar, 1977) but large with 5½ ridge-plates in *G. macrognathus* (Pilgrim, 1913; Osborn, 1936). The second line of evolution, which is represented by *G. brovni* shows a trend towards the reduction of median conule and its alignment with the outermost conelet of the pretrite. The third line is represented by *G. palaeindicus.* In this species, the molar ridge-plates (particularly the posterior ones) tended to become arched. Also the median conules became larger and rounded. The species ranged from Kamlial to Chinji stage of the lower Siwaliks (Sarwar, 1979). Apart from the above mentioned species, another species, *G. dialensis* occurs in the Lower Chinji. This species is extremely specialised in both mandibular as well as in dental characters. The evolutionary trends shown by this species are: (1) reduction in vertical depth and the transverse width of the mandibular rami leading to extreme slenderness and (2) addition of accessory conelets in the transverse valleys of teeth. Such trends have not been reported so far in any gomphothere None of the known Siwalik gomphotheres has been reported from the Dhok Pathan beds except for the species, *G. dhokpathanensis.* It was reported by Sarwar (1978) from Dhok Pathan type locality. *G. dhokpathanensis* shares some molar characters with *G. dialensis* i.e. the arcuate forwardly inclined ridge-plates in lower last molar. However, the two species differ in the shape of trfoil spur. It is strongly arcuate in *G. dhokpathanensis* but linear in *G. dialensis.* Comparison of the molar features shows that the *G. dhokpathanensis is* the derivative of *G. dialensis.* The two species are so different (in spur formation) from the other Siwalik gomphotheres that they appear to be the direct descendant of *G. angustidens.*

Manchhars of Sind are equivalent to Kamlial zone of the Siwaliks (Osborn, 1936). These beds have yielded a species, *Mastodon (Trilophodon) pandionis* (as named by Falconer in 1857). This species has now been transferred to the genus *Synconolophus* (Sarwar, 1977). *Synconolophus pandionis* appears to be relatively advanced over the species, *S. ptychodus.* The conelets of the ridge-plates are more dislocated in *S. pandionis* than in *S. ptychodus. Synconolophus ptychodus* is also more primitive than the European forms and is also found in the relatively older geological strata. *Synconolophus ptychodus* appears to be ancestral to all the known synconolophines including European species. From *S. ptychodus,* four lines of evolution may be derived. These are: (1) *S. pandionis* ,(2) *S. corrugatus, S. propathanensis, S. dhokpathanensis and S. osborni* ;(3) *S. hasnoti* and (4) European species. The species of the second line although occur in the same geological horizon (Dhok Pathan zone), yet they differ structurally. They exhibit specializations in different directions e.g. S. corrugatus shows well developed corrugations in the enamel layer, S. propathanensis shows a trend towards heightening of the crown, *S. dhokpathanensis* shows a trend towards extreme choerodonty while *S. osborni* shows choerodonty alongwith enamel corrugations. The structural diversification and their occurrence in the same geological horizon clearly show that none could be ancestral to the other. They might have descended from the common ancestor, *Synconolophus ptychodus.* Teeth of all these four species can be derived from the relatively simple and unspecialized teeth of *S. ptychodus,* through dislocation of the conelets, enamel corrugation or the crown heightening of the ridge-plates. The third line which is represented by *S. hasnoti,* reattained rounded and smoothly enamelled conelets characteristics of the ancestral gomphotheres. The fourth line of evolution is represented by European synconolophines. Among the European species, *S. serridentinoides* seems to be the most primitive. Regarding structure of ridge-plates, this European species appears to be advanced over *S. ptychodus* of the Siwaliks and hence Siwaliks appear to be the centre of radiation for the genus.

The Siwalik species of the genus *Anancus* can be placed in three groups. These are: (1) *Anancus properimensis* and *A. perimensis* ,(2) *A. sivalensis* and (3) *A. osborni.* Species of the first group differ in number and the prominence of conelets (Sarwar, 1977). Based upon molar morphology, *A. perimensis* can be derived from the species, *A. properimensis. Anancus sivalensis* resembles *A. properimensis* and *A. perimensis* except that it shows pentalophodont tendancy in intermediate molars. It might have descended from *A. properimensis.* The species of the third group has adapted some sort of choerodonty and hence differs from the species of the other two groups. Nothing could be said about its origin.

As explained by Sarwar (1977), the earliest geological record of the genus *Tetralophodon* is from the Miocene of Europe, Asia and America. Of these, the Asian material which is represented by *T. sinensis,* morphologically appears to be the most primitive. This species, according to Osborn (1936), is of Upper Miocene age. Since, the Siwalik species, *T. falconeri, T. punjabiensis* and *T. buzdarensis* are known from much younger horizon (Dhok Pathan zone) than *T. sinensis* and all the three are entirely divergent forms (Sarwar, 1977), nothing could be stated with certainty about their ancestry. They probably descended from some European stock and entered the Southern Asia somewhere in Lower/Middle Pliocene.

The primitive features of the genus *Stegolophodon* i.e. (1) Upper tusks with enamel band, (2) presence of lower tusks, (3) Accessory tubercles in the transverse valley of the molars, (4) Median cleft at least in the anterior part of the teeth, (5) rounded and blunt conelets and, (6) somewhat irregular arrangement of the conelets of the molars, strongly suggest a gomphothere origin of this group and not of zygodont as suggested by Maglio (1973). The latter group also cannot be considered as the probable ancestor because of its well defined transversely linear ridge-plates. Since, *Stegolophodon* is essentially an Asiatic group (Maglio, 1973; Tobien, 1975; Sarwar, 1977), its ancestors may be found in this region. Stegolophodont stock might have got separated from its ancestral gomphothere stock somewhere in Upper Miocene, retaining at first almost all the primitive features except the addition of ridge-plates in the intermediate molars. Among the known stegolophodonts, *Stegolophodon cautleyi* is the most primitive and is ancestral to the other species of the genus. From *S. cautleyi,* three lines of evolution can be derived, one leading to *S. daratensis,* the other to *S. latidens* and the still other to *S. lehriensis.* The descendant of the first lines lacked accessory tubercles while those of the other two retained it though in reduced condition. *S. daratensis* probably gave rise to *S. stegodontoides* through the addition of ridge-plates, disappearance of median sulcus and general increase in size. In some of the dental features e.g. large size of the tooth and the more number of ridge-plates, *S. lehriensis* is more advanced than the species *S. latidens* (Sarwar, 1980). In others e.g. the presence of median sulcus, the tooth of *S. lehriensis* is comparatively primitive than that of the *S. latidens.* Keeping in view this comparison and the fact that both are known from the Dhok Pathan formation, none could be ancestral to each other. Probably both descended from the species *S. cautleyi* independently of each other.

The inclusion of *Stegolophodon* in the family Elephantidae by Simpson (1945) has been questioned by Maglio (1973). According to the latter author, these genera are an offshoot from the family Mammutidae. In my opinion, stegolophodonts should not be regarded the descendants of zygodonts because the former genus is the product of local evolution and moreover the zygodonts are extremely rare in South Asia. The only 3 zygodonts recorded from South Asia (Osborn, 1929; Sarwar, 1974, Sarwar and Abu Bakr, 1980) are probably the immigrants from north.

According to Tobien (1973), *Stegotetrabelodon* descended from *Tetralophodon grandincisivus* group and immigrated Africa as well as Asia. It has been recorded from Africa by Petrocchi (1941) and from Asia by Sarwar (1974) & Chow & Chang (1983). Another Asian record is by Hussain and others (1979) from the Chinji beds of the Lower Siwaliks. They have labelled it as gomphothere but it is certainly a stegotetrabelodont specimen, not so dissimilar to the Middle Siwalik *Stegotetrabelodon maluvalensis* described by Sarwar (1977). The genus has been regarded as ancestral to the elephants by Maglio (1970, 1970a, 1973) and Maglio and Ricca (1978). The present author differs from Maglio's view of stegotetrabelodont ancestry of the Asiatic elephants and had regarded the genus *Stegotetrabelodon* a specialized group having no bearing on the evolution of elephants (Sarwar, 1978a).

EXTINCTION

Siwalik gomphotheres range from Kamlial to Dhok Pathan zone of the Middle Siwaliks. It flourished at the

Kamlial/Chinji transition and is relatively abundantly found in the late Kamlial and early Chinji beds of the Lower Siwaliks. The genus started declining towards the end of Chinji times and its presence in the Dhok Pathan zone is indicated by only one species, *Gomphotherium dhokpathanensis described by* Sarwar (1978). Its extinction in the Dhok Pathan times can be attributed to the presence of stegodonts, advanced trilophodont such as *Synconolophus and advanced tetralophodonts* such as *Tetralophodon, Anancus* and *Stegolophodon.* Members of these three groups were relatively more efficient browsers as compared to those of the genus *Gomphotherium.* In group I, the molar efficiency was due to the numerous ridge-plates armoured with the abundance of cement. In group II, it was due to the choerodonty and the abundance of cement. In group III, it was due to the more ridgeplates. *Gomphotherium* spp. which were provided with relatively few and simple ridge-plates most probably could not survive in competition with the above mentioned groups and thus became extinct before Middle Pliocene.

Likewise members of the genera *Synconolophus, Tetralophodon, Anancus* and *Stegolophodon* could not survive in competition with those of the genus *Stegodon* which were far better adapted to browsing due to their large molars armoured with thick cement layer. Their populations went on decreasing and ultimately became extinct one after the other. Extinction of the former genera can also be accounted for the great Himalayan uplift which brought about drastic climatic as well as topographic changes. During Pleistocene, stegodonts flourished and were the successful browsers. Ultimately, they had to compete with the members of the genus *Elephas* which became most successful proboscideans on account of their hypsodont molars. Elephant molars were far better grinders than those of their stegodont ancestors (Sarwar, 1978a) not only in hypsodonty but also in the development of cement and enamel corrugacy.

REFERENCES

Bergounioux, F.M. & Crouzel, F., (1960). Mastodontes du Miocene du Bassin d'Aquitaine. *Bull. Soc. hist. natur. Toulouse.* 95, 232-286.

Bohlin, B. (1946). The fossil mammals from the Tertiary deposits of Tabenbuluk, Western Kansu. Part II: Simplicidentata, Carnivora, Artiodactyla, Perissodactyla, and Primates. *Rep. Scient. Exped.* N.W. Prov. China Sect. 6 Vert. Pal. 4, 1-259.

Chakravarti, D.K., (1957). A geological, palaeontological and phylogenetic study of the Elephantoidea of India, Pakistan and Burma: Part I. Gomphotheriidae. *J. Pal. Soc. India.* 2, 83–94.

Chow, M. & Chang, Yu-Ping., (1983). Occurrence of the proboscidean genus Stegotetrabelodon in China. *Vert. Pal.* 21 (1): 52–58.

Cooper, C.F., (1922). Miocene proboscidea from Baluchistan. *Proc. Zool. Soc. London.* 609–626.

Eames, F.E., (1950). On the age of the fauna of the Bugti Bone beds, Baluchistan. *Geol. Mag.* 87, 53–56.

Elahi, M.K. & Martin, (1961). The physiography of the Potwar, West Pakistan. *Geol. Bull. Univ. Punjab. 1, 5–14.*

Falconer, H., (1857). On the species of Mastodon and elephant occurring in the fossil state in Great Britain. *Quart. Journ. Geol. Soc. London.* 13, 307–360.

Falconer, H. & Cautley, P.T., (1846). *Fauna Antiqua Sivalensis, being the fossil zoology of the Siwalik Hills in the North of India.*

Fourtau, R., (1920). *Contribution a l'etude des Vertebres miocenes de l'Egypte.* Survey Dept. Govt. Press, Cairo, 2e ed., 122.

Gansser, E., (1961). *The Geology of Himalayas.* 1–482.

Ginsburg, L. & Antunes, M. T. (1966). Considerations sur les mastodontes du Burdigalien de Lisbonne et des sables de l'Orleanais (France). *Revta. Fac. Cienc. Univ. Lisb. Cienc nat. 14, 135–150.*

Hopwood, A.T., (1935). Fossil proboscidea from China. *Palaeont. sinica.* 9. 1–1–108.

Hussain, S.T., Munthe, J., Shah, S.M.I., West, R.M. & Lukacs, J.R., (1979). Neogene stratigraphy and fossil vertebrates of the *Daud Khel area, Mianwali district, Pakistan. Mem. Geol. Surv. Pakistan.* 13, 1–27, pls. 1–7.

Lydekker, R. (1880). Siwalik and Narbada proboscidea. *Mem. Geol. Surv. India, Palaeont. Indica.* 10, 182–300

———, (1884). Mastodon teeth from Perim Island. *Mem. Geol. Surv. India, Palaeont. Indica.* 10, 149–154, pls. 16, 17.

Maglio, V.J., (1970). Early Elephantidae of Africa and a tentative correlation of African Plio-Pleistocene deposits. *Nature, London.* 225 (5230), 328–332.

———(1970a). Four new species of Elephantidae from the Plio-Pleistocene of North-Western Kenya. *Breviora* 341, 1–43.

———, (1973). Evolution of mastication in the Elephantidae. *Evolution.* 26, 638–658.

Maglio, V.J. & Ricca, A.B., (1978). Dental and skeletal morphology of the earliest elephants. *Ver. Konin. Nederl. Akad. Wetens.* 29, 1–51.

Osborn, H.F., (1924). Additional generic and specific stages in the evolution of the proboscidea. *Amer. Mus. Novitates.* 154, 1–5.

——— (1929). New Eurasiatic and American proboscideans. *Amer. Mus. Novitates.* 393, 1–23.

———, (1932). *Trilophodon cooperi* sp. n. of Dera Bugti, Baluchistan. *Amer. Mus. Novitates.* 585, 1–6.

———, (1934). The thirty nine distinct lines of proboscidean descent, and their migration into all parts of the world except Australia. *Proc. Amer. Phil. Soc.* 74, 273–285.

—————— (1946) Proboscidea. New York, *The American Museum of Natural History Press.* 1, 1–802.

Petrocchi, C. (1941). I giacimento fossilifero di Sahabi. *Bull. Soc. Geol. Italiana.* 60, 107–114.

Pilgrim, G. E. (1908). The Tertiary and Post-Tertiary deposits of Baluchistan and Sind, with notices of new vertebrates. *Rec. Geol. Surv. India.* 37, 139–168.

——————(1912) The vertebrate fauna of the Gaj Series in the Bugti Hills and the Punjab. *Pal. Indica, N.S.* 4, 1–83.

——————(1913) Correlation of the Siwaliks with Mammal Horizones of Europe. *Rec. Geol. Surv. India.* 43, 264–326.

Sarwar, M. (1974). *Studies on the Siwalik proboscidea.* Ph. D. Thesis, University of the Punjab. 1–347.

——————(1977). Taxonomy and distribution of the Siwalik proboscidea. *Bull. Dept. Zool. Univ. Punjab (N.S.) 10, 1–172.*

——————(1978) A new spur bearing bunodont gomphothere recorded from the Dhok Pathan beds of Pakistan. *Pakistan J. Zool.* 10, 225–259.

—————— (1978a) On the stegodont ancestry of the elephants. Geol. Bull. Univ. Punjab, Pakistan. *15, 62–68.*

——————(1979). Origin, vertical distribution and the dental morphology of *Gomphotherium palaeindicus* (Proboscidea: Mammalia). *Pakistan J. Zool. 11,* 143–148.

—————— (1980) A new species of the genus *Stegolophodon* from Lehri, district Jhelum, Punjab, Pakistan. Pakistan J. Zool. 12 (1) : 33–38.

Sarwar, M. & Abubakr, (1980). Record of a deciduous premolar of the genus *Zygolophodon* Vacek from the Bhandar bone beds of the Pakistan Siwaliks. Contr. Geol. of Pakistan. 1: 109–112.

Savage, R.J.G. (1971). Review of the fossil mammals of Libya. In symposium on the Geology of Libya. Fac. Sci. Univ. Libya. 215–225.

Simpson, G.G. (1945). The principles of classification and a classification of mammals. *Bull. Amer. Mus. Nat. Hist.* 85, 1–350.

Tassy, P. (1977). Le plus ancien squelette de gomphothere (proboscidea mammalia) dans la formation Burdigalienne des sables de L'Orleanais France. *Memores du Museum National d'Historie Naturelle, serie* C. 37, 1–51, pls. 1–3.

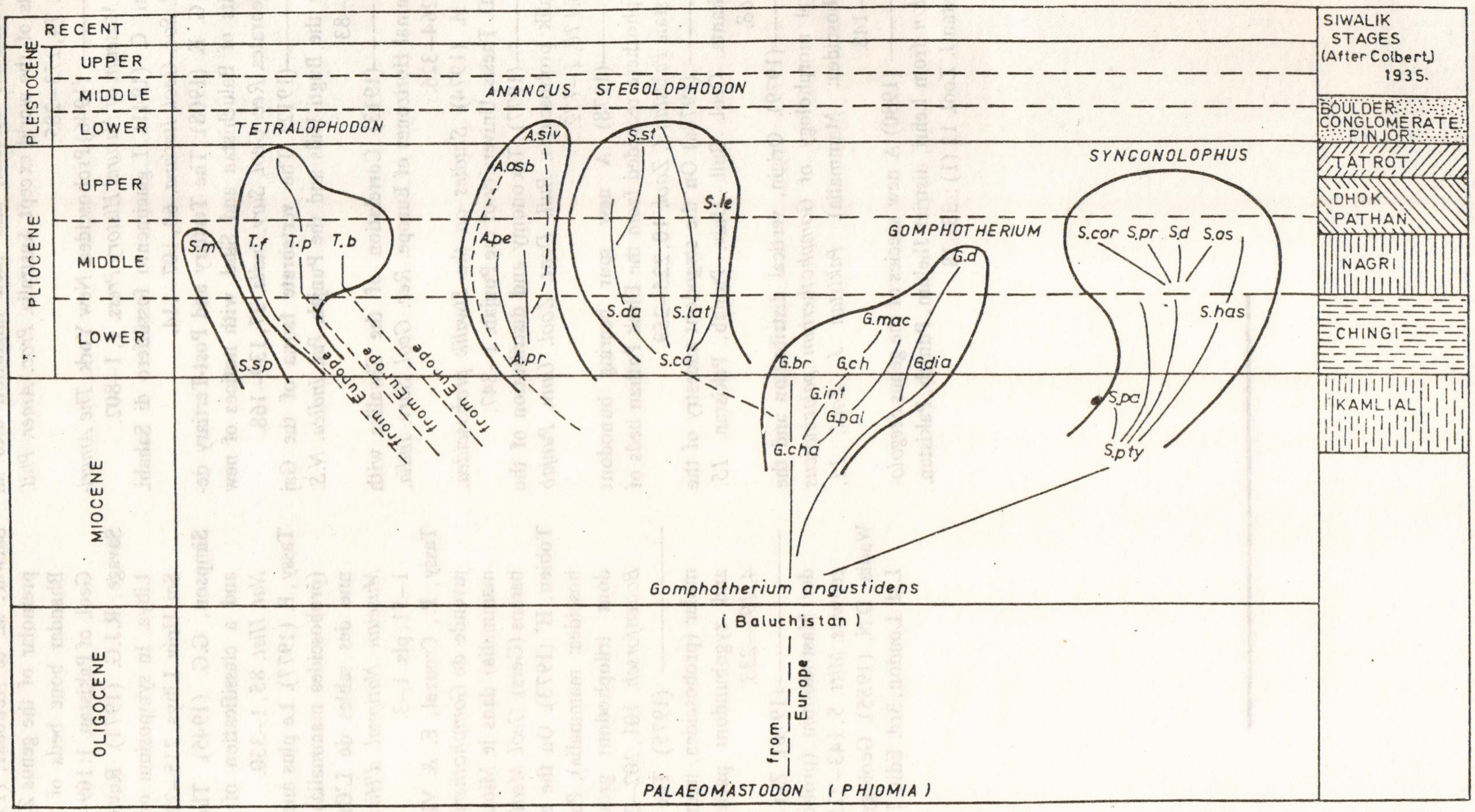
Tassy, P., Crouzel, F. & Vidalenc, D. (1977). Un crane juvenile de *Gomphotherium angustidens* (proboscidea, mammalia) dans le Miocene moyen de Castelnau Barbarens (Gers). *Geol. Mediterraneenne.* 4, 211–220.

Tobien, H' (1973). On the evolution of mastodonts (proboscidea: mammalia), Par I: The bunodont trilophodont trilophodont groups. *Notizbl. hess. L.-Amt. Bodenforsch.* 101, 202–276.

—————— (1975) The structue of the mastodont molar (proboscidea, mammalia) part 2: The zygodont and zygobundont pattersn. *Mainzer geowiss. Mitt. 4, 195–233.*

——————(1976). Zur palaontologischen Geschichte der Mastodonten (proboscidea, mammalia). *Mainzer geowiss. Mitt.* 5, 143–225.

Wadia, D.N. (1955). Geology of India. Macmillan and Co. Ltd. London, 3rd. Edit. 1–531.



ANANCUS

A.osb: A.osborni
A.pe : A.perimensis
A.pr : A.properimensis
A.siv : A.sivalensis

STEGOTETRABELODON

S.m: S.maluvalensis
S.sp: S.sp.

GOMPHOTHERIUM

G.br : G.browni
G.ch : G.chinjiensis
G.cha: G.chabbariensis
G.d : G.dhokpathanensis
G.dia : G.dialensis
G.int : G.intermedius
G.mac: G.macrognathus
G.pal : G.palaeindicus

STEGODON

S.bom: S.bombifrons
S.dh : S.dhokawanensis
S.g : S.ganesa
S.in : S.insignis
S.pin : S.pinjorensis
S.sar : S.sardhokensis

STEGOLOPHODON

S.ca : S.cautleyi
S.st : S.stegodontoides
S.da : S.daratensis
S.lat : S.latidens
S.le : S.lehriensis

SYNCONOLPHUS

S.cor: S.corrugatus
S.d : S.dhokpathanensis
S.has: S.hasnotensis
S.os : S.osborni
S.pa : S.pandionis
S.pr : S.propathanensis
S.pty : S.ptychodus

TETRALOPHODON

T.b : T.buzdarensis
T.f : T.falconeri
T.p : T. punjabiensis

SHORT COMMUNICATIONS ABSTRACTS AND REVIEWS

GEOLOGY OF TARLI DOMEL-SHONTHAR AREA, NEELUM VALLEY, AZAD KASHMIR

MUHAMMAD IQBAL SIDDIQI

Institute of Geology, Azad Jammu and
Kashmir University, Muzaffarabad, Azad Kashmir.

ABSTRACT.– The area studied is about 80 sq. Km. It lies NNE of Muzaffarabad at a distance of 173 km. The mapped area lies between 74e 24' 50" - 74° 31' 50" longitudes and 34° 54' 40" - 35° latitudes it covers parts of Survey of Pakistan topographic sheets No. 43 J/5 & 43 J/9.

The rocks of the area are of Salkhala Formation. The Salkhala Formation is a metamorphic complex of variegated lithology comprising of schists (chlorite-garnet grade), amphibolites, quartzite and marble. Granite gneiss is emplaced in Salkhala Formation and is inturn introuded by pegmatites and quartz veins. Regional metamorphism and accompany penetrative deformation, post-date the granite intrusion, because the granite itself is involved in the deformation. Field evidences and Laboratory studies favour magmatic origin for granite bodies.

The area is tectonically disturbed being involved in Himalayan orogeny. The major faults are the Shonthar Nar fault and Daliwala fault. The Shonthar Nar fault trends NE-SW. Shonthar Nar Valley runs more or less along the trace of this fault. Daliwala fault may be considered a dip-slip-strike fault along the eastern margin of Ulti Domel granite body.

Retional Metamorphism and tectonic effect has imparted well developed secondary foliations and gneissosity in the rocks of the area. Minor folds are numerous. These are close and tight folds and reflect the intensity of forces involved in their formation. Jointing is abundant in the rocks. Tension and shear joints are encountered in granite gneiss, marble and schists.

The mineral occurrences in the area under review include Graphite, marble, gemstone (Ruby, Topaz, Aquamarine Quartz etc) and mica etc.

GEOLOGY OF LAHUR VALLEY HAZARA DIVISION NORTH WEST FRONTIER PROVINCE PAKISTAN. WITH SPECIAL EMPH. STRATIGRAPHY AND MICRO PALEONTOLOGY.

MUNIR-UL-HASSAN MUNIR
M. ANWER QURESHI
Institute of Applied Geology
University of Azad Jammu & Kashmir.

ABSTRACT.– The project area lies between long. 73°24' 40" to 73°30" and lat. 34° 1 to 34° 3' 30" N and grids 46-55 E and 98-03 N. The field work was carried on 1: 10,000 scale after enlargement of parts of 1:50,000 survey of Pakistan toposheet No. 43 F/8.

The area is rugged with extreme relief and is for the most part covered with thick vegetation. The degree of exposures is low and therefore difficult for geological mapping.

The rocks exposed in the area range from Jurassic to Miocene in age. Generally, the formation are well recognizable due to their distinguishing lithological characters. However, repetitions of bands of shales and lime-stone of Paleocene and Eocene ages, offer some difficulty at least where exposures are secondary. There are three breaks in stratigraphic record in the project area. 1st after Samana Suk Formation of Jurassic age; 2nd after Kawagarh Formation of Cretaceous age and the 3rd after Kuldana Formation of Eocene age.

The area remained under the sea for considerable period hence most of the formations are of marine origin except Murree Formation, Which was deposited during the period of transgression of the "Tethy's Sea".

A study of the area shows that it has suffered strong tectonic disturbance. A number of isoclinal folds with almost parallel axes are exposed in the area. These are longitudinal and transverse faults. The fault planes have been covered due to lateral tilting. The general strike of the strata is N-E, S-W. The faults are generally thrust faults.

The sedimentary structures such as cross-bedding nodularity. Colites, Worm trails and pisolites etc. are common.

A systematic and detailed sampling of the rock units was done to investigate foraminiferal assemblages of different stratigraphic units.

GEOLOGY AND PETROLOGY OF JURA–BANDI, AREA NEELUM VALLEY MUZAFFARABAD, AZAD KASHJRM

MUHAMMAD KHURSHID KHAN RAJA
Institute of Applied Ceology, University of Azad Jammu & Kashmir Muzaffarabad

ABSTRACT.– Jura-Bandi an inganous and Metamorphic complex, near Syntaxial influence (i-e involvment of Himalayan orogeny) on Toposheet No-43/14, 43 F/15 of Survey of Pakistan. The Metamorphic rocks are the oldest working of Salkhala series (Wadia et. al) which includes Granitic rocks Quartze-feldspathic usive along with prominent fobated structure with development of Augen-Gneisses at places.

The oldest metamorphic rock present is Petitic-Psammatic (Chlorite-Quartz mica schist-Grannet Birtete mica schist. The highest grade observed in the area is garnet, some-how, some evidence of retrograde metamorphic is also observed.

Among Quartz-e-feldspathic rocks, two granites granete-gneiss-poryphyritic grenite, lie side by side extending NE and NW direction. Mineralogically both the Intrusive bodies are rich in Potash-feldspar. Pegmatites and Aplites dykes are common.

The basic rocks among the minor bodies are dykes of Diorite, and Diabase. The report submits a detail map on scale. 1"-789 miles of about 27 sq. miles along with details on 1:50,000 with three times enlargement with field and laboratory investigation. The petrogensis of the both the granites body is derived on Strekieson's traingle method.

LETTER TO THE EDITOR

COMMENTS ON M. A. LATIF'S PAPER ON THE AGE OF THE SALT-RANGE FORMATION

There is little doubt that the Mandi salt is Eo-Cambrian to Cambrian in age based on work by Srikanta & Sharma, Himalayan Geology Vol 2, pp 222-238, 1972, published by the Wadia Institute of Himalayan Geology (then based on Delhi: now headquarters in Dehra Dun) Medlicott's suggestion of a correlation with the Krol is probably untenable, but cannot be ruled out. The age of the Blaini-Krol-Tal formations has long been a source of sometimes acrimonious dispute. Within the last few months A.C. Nautiyal of Lucknow University claims to have discovered Cretaceous angiosperms in the Upper Krol dolomites and shales, while I.B. Singh, also of Lucknow, has published a paper on the occurrence of trilobites in the Tal formation which overlies the Krol. If correct this would necessitate a thrust fault between overlying older Tals and underlying younger Krol. In 1935, I regarded the Tal-Krol contact as a sedimentary one without an intervening thrust plane. So varied have been the age determinations that one is led to suspect that some of the fossils collected were not actually found in the particular formation in which they have been stated to occur.

The Tanols or Tanawals appear to be grouped with the Hazara Slates. This is a curious formation, and according to Wadia presents many anomalous contacts in Kashmir with the underlying formations. Just south-east of the Tarbela dam the Tanols are cleanly thrust upon Abbottabad dolomites, but 20-25 km to the east Offield and Calkins of the USGS, and Afaq Ali of the G.S.P., mapped a folded sucession of Hazara-Tanol-Abbottabad formations in normal succession

Abbottabad
Tanawal
Hazara

Where I have seen the Tanols in the Tarbela area I was impressed by their resemblance to the Nagthat (or Jaunsar) formation of the Garhwal area, which is pre-Blaini, and postChandpur.

The Lower Cambrian slates and phyllites of the Tragbal area greatly resemble the Chandpurs of Garhwal.

The author suggests that the Saline Series may in places be thousands of metres in thickness. At Karampur (Nr. Multan) the thickness of the series is 2900 ft. or 884 m., Karampur is in a platform area which did not suffer orogenesis, and escaped plastic folding and diapiric injection. The 884 m. thickness is therefore likely to be undisturbed and true for that area.

The equivivalent evaporite group of Iran, 70 km north-west of Kerman, is stated to be 1,000 m. in thickness. Isotopic age 595 to 760 m.y.

There does not appear to be much discussion of the map Fig. 1. Is the boundary between Shallow-Deeper and Intertidal to Shallow gradual or sharp, and what is the structural relationship between the two facies?

J.B. Auden

24.2.85 London.

My dear Tayyab Ali

Thank you very much indeed for your letter enclosing copy of your journal departmental journal vol. 1, No. 1 which Prof. Ramsay forwarded on to me.

Please accept my congratulations on its excellence, and variety of its contents.

Yours sincerely
Sd/- Rowland Gee
(E.R.GEE)

Dear Prof. Tayyab Ali,

Thank you for your kindness in sending me the first issue of the Kashmir Journak journal of Geology. Several papers in it are of value in my work.

Please keep up the standard of the journal.

Yours sincerely
Sd/- S. M. Mathur
Professor Emeritus
C-6, Madir Part, Mahanagar
Extension Lucknow, 226016, India.

My dear Tayyab Ali,

Many thanks for your for your letter of 20th March and the first issue of the Kashmir Journal of Geology. Very well printed and produced.

Yours sincerely,
Sd/- John B. Auden

Dear Sir,

I am in receipt of your kind letter and excellent, journal published under your supervision titled 'The Kashmir Journal of Geology'.

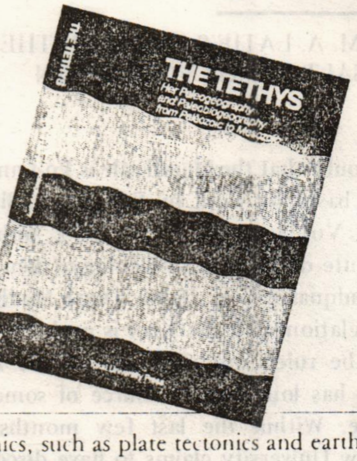
Sd/- Tajammal Hussain
Deputy Chief (Mineral Planning
Division Govt of Pakistan.

BOOK REVIEW

The Tethys

Her Paleogeography and Paleobiofacies from Paleozoic to Mesozoic.

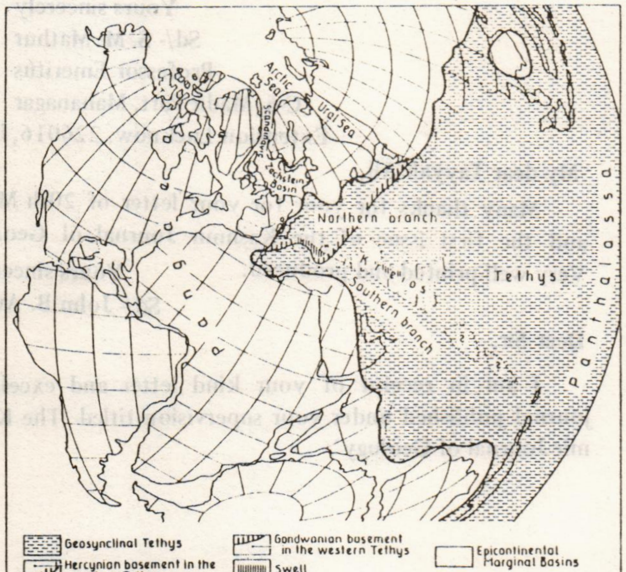
Edited by Keiji NAKAZAWA (Emeritus Prof. Kyoto University) and
J.M. DICKINS (Bureau of Mineral Resources, Geology and Geophysics, Australia)
Hard Cover, 7[1]/2 × 10[1]/2in. 332p.
US$70.00, May 1985

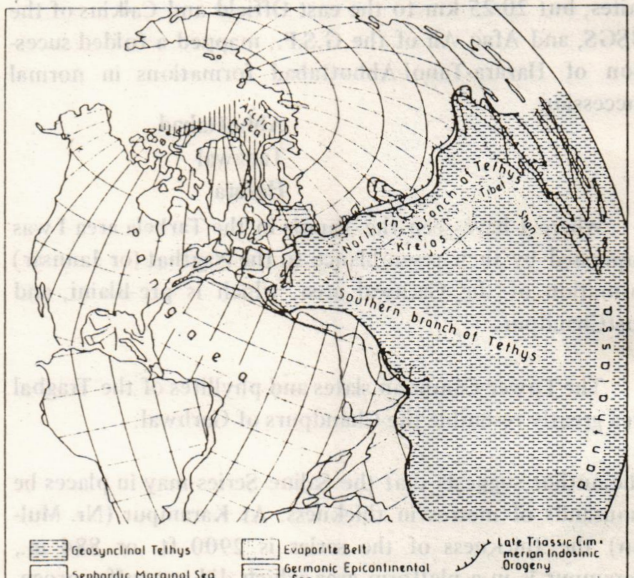


The durations as well as special distribution of Tethys has been variously interpreted by many authors after SUESS introduced the term as early as the ninetieth century. It was originally defined as continuing from Permian to Mesozoic, and is here considered to have existed as a broad ocean between Gondwanaland to the south and Laurasia to the north.

The Japanese scientists have studied serial surveys on the Permian-Triassic sequences in various parts of the Tethyan realm in cooperation with staff of the geological surveys or institutions of respective countries. In the present volume, the Permian and Triassic paleogeography and paleobiogeography are discussed by the project members and several other scientists in the lingth of new global tectonics, such as plate tectonics and earth expansion theory.

This book consists of three parts. Part I contains five paper concerning the regional aspects of the European, Himalayan and Chinese Tethys and the general aspects of Gondwanaland and Tethys. Part II includes six papers treating with the paleobiogeography and/or paleobiofacies of respective taxa, namely, smaller foraminifers, fusulinids, conodonts, bryozoans, brachiopods, and land plants. Part III is a detailed report of the Permian-Lower Triassic stratigraphy, biostratigraphy, and sedimentary environment of the Salt Range region in Pakistan by the Pakistani-Japanese joint research group.





Permian Western Tethys — Paleogeography — Triassic Western Tethys

Education · Routine · Research

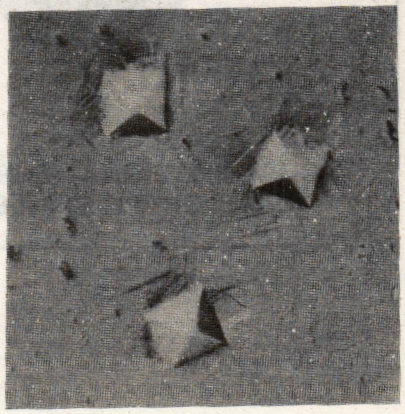
Zeiss has the complete microscope program

Zeiss – the Pioneer in Scientific Optics

ZEISS

West Germany

- upright and inverted micoscopes
- microscopes for routine and research work
- microscopes for reflected and transmitted light
- equipment for photomicrography and TV
- image analysis instruments
- photometry equipment



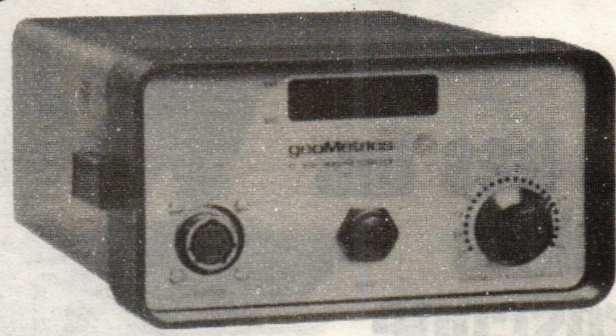
A-45
BLOCK 2
GULSHANE IQBAL
KARACHI-47
Grams : SIEMSSENIO
Tele : (021) 468780

SCIENTIFIC EQUIPMENT SUPPLY COMPANY

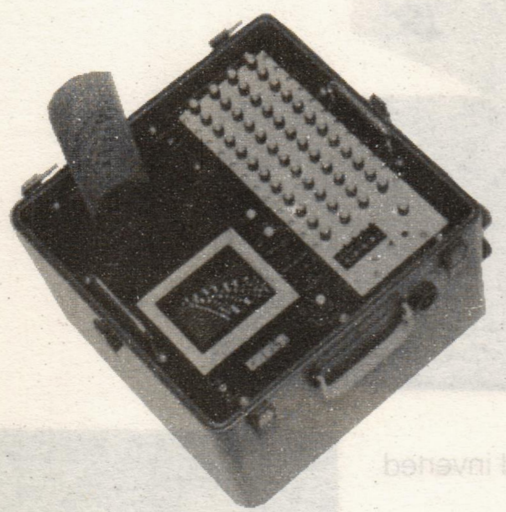
HEAD OFFICE : 66-A, MOZANG ROAD,
LAHORE-4
PHONES : (042) 30 12 36, 304236
GRAMS : SESCOM

EG&G Geometrics is one of the world's leading suppliers of geophysical instruments. These products are used for exploration for natural resources, especially minerals and petroleum, and for geologic mapping and engineering studies.

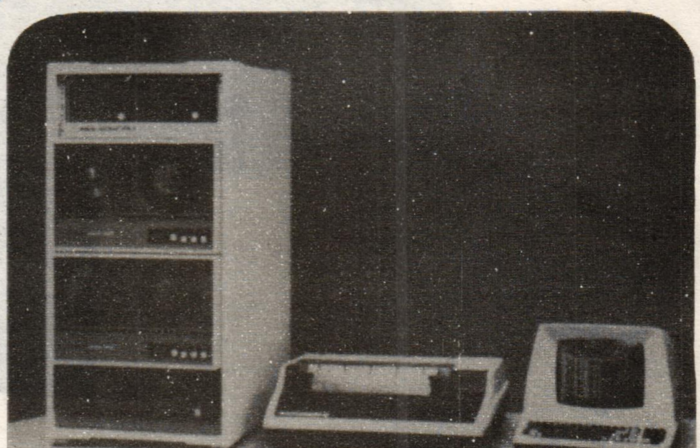
PORTABLE GAMMA RAY SPECTROMETER Model GR-310



PORTABLE PROTON MAGNETOMETER Model G-816/826



12-CHANNEL SIGNAL ENHANCEMENT SEISMOGRAPH Model ES-1210F



GEOPHYSICAL SURVEY DATA PROCESSOR Model G-725

EG&G GEOMETRICS

395 JAVA DRIVE, P.O. BOX 497
SUNNYVALE, CALIFORNIA 94086 U.S.A.

LETZ WETZLAR
Inseral-Nr. 1901-93-512/01.78

THE NEW DIALUX 20 - TODAY'S MICROSCOPE FOR TOMORROW'S DEVELOPMENTS

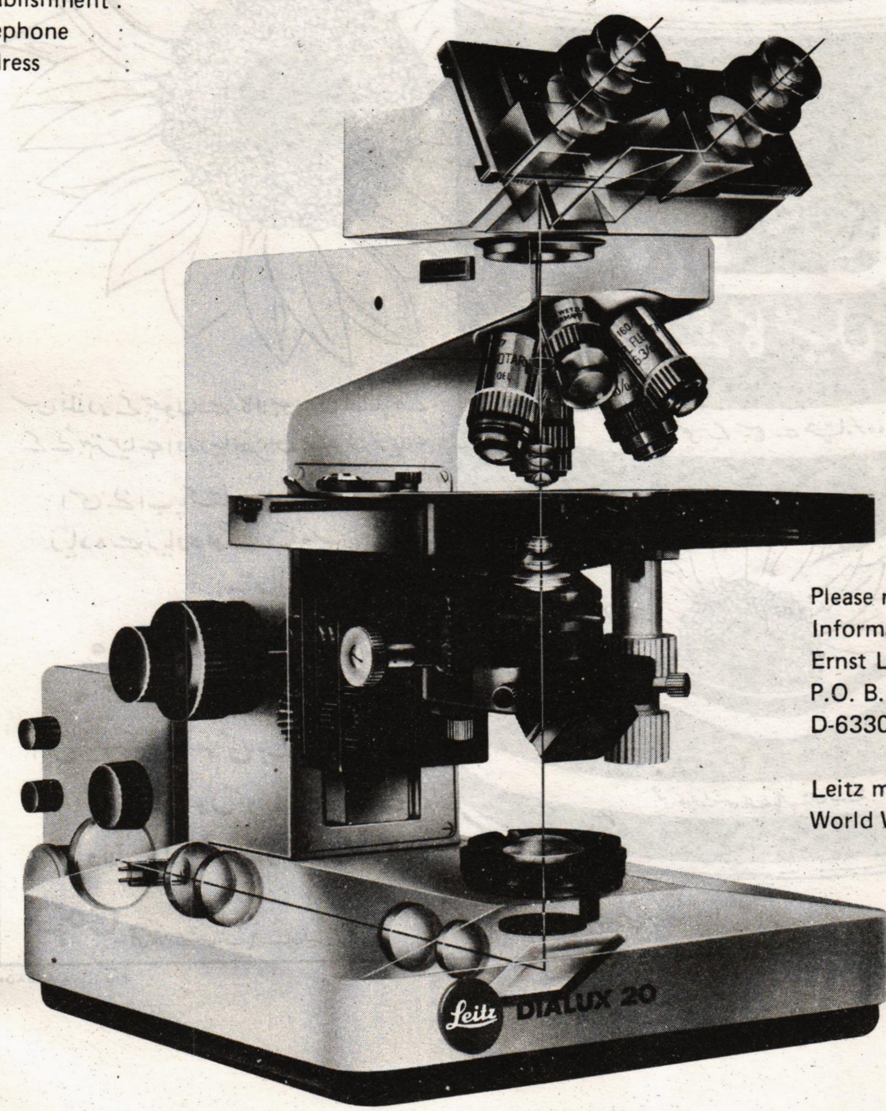
The new LETZ DIALUX 20 has been designed with an eye to the future development of microscopy: the established LEITZ modular principle has been extended as a result of current experience: it is now even more practical, and offers optimum operating covenience with maximum functional reliability.

A considerably improved arrangement of the optical illuminating system makes the LEITZ DIALUX 20 even more efficient for all optical examinations of transparent specimens. It has been possible to enlarge the microscope field of view even further through the use of the excellently corrected series of LEITZ NPL FLUOTAR objectives. Amounting to more than 23% when compared with that of conventional microscopes - with critical definition across the entire image, this ensures that the new LEITZ DIALUX 20 is not only a reliable tool for diagnostic microscopy, but also a basic instrument that has the necessary reserves for biological research. We should like to convince you of the extremely favourable relationship between performance and price.

☐ I should like to know more about the LEITZ DIALUX 20 and would be pleased to receive full details.

☐ I should to arrange a date for the Leitz consultant to visit me.

Name / Department:
Establishment :
Telephone :
Address :



Please return the coupon or write to:-
Information Service,
Ernst Leitz Wetzlar Gmbll,
P.O. B. 20 20
D-6330 Wetzlar

Leitz means Precision
World Wide

PRESTIGE G.C.P 867.2.84

PID (ISLAMABAD)

INSTRUCTIONS TO THE AUTHORS

The Kashmir Journal of Geology is devoted to the publication of original research in the field of geology including geophysics, geochemistry, geomorphology and paleontology. Review articles, short papers and abstracts are welcomed The articles should deal with somc aspects of the geology of Pakistan or should pertain to significant advancement of geological knowledge of international importance.

The authors are solely responsible for the facts and opinions stated in their papers and the correctness of the rcferences.

The articles should be written in English accompanied with adequate abstract, type written (double space) on one of the foolscap paper, with wide margin and should be submitted in duplicate. The illustrations (figures, diagrams, and maps) should be drawn in black ink on tracing paper with allowance for reduction in final print. Lettering should be preferably done with stencil. Colour photo prints can be arranged on payment. All tables, illustrations maps and photographs should be self - explanatory. International symbols should be used on maps as for as possible. In all maps and illustrations linear scale should be used. The Maximum length of the articles generally should be around 20 foolscap pages including diagrams. One copy of the book for publishing reviews on it in the Kashmir Journal of Geology, should be sent for consultation.

References should be arranged as follows :

Latif, M.A., (1976). Stratigraphy and micropaleontology of the Gali's Group of Hazara, Pakistan. *Geol. Bull. Punjab Univ.*, No. 13, p. 1-65.

Calkins, J. A., Offield, T.W., Abdullah, S.K.M., & Tayyab Ali, S., (1975). Geology of Southern Himalayas in Hazara, Pakistan and adjacent areas. *U.S. Geol. Survey, Professional Paper*, 716-C, 29 P.

25 Reprints of each article will be provided to the author free of charge. Additional copies should be ordered at the time of submitting articles.

The Journal is edited by an Editorial Board. It is published by the Institute of Applied Geology, University of Azad Jammu and Kashmir, Muzaffarabad, Azad Kashmir (Pakistan).

RIVER JHELUM MEANDER NEAR MUZAFFARABAD