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BITUMINOUS/ANTHRACITIC COAL OF KOTLI DISTRICT AZAD KASHMIR

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ABSTRACT:– Coal occurs at two horizons within Patala Formation in the Kotli anticiline (a continuation of Riasi anticline in Jammu). Most commonly the coal lies over the bauxite as in Sawar, Tattapani, Dandili and Karela. The second horizon occurs within the carbonaceous shales about 9 to 15m above bauxite bed as in Kamroti, Barmoach, Bangang and Nikial. The exposed thickness of individual seams ranges from 0.02 to 1.0m which in underground workings is from 1.0 to 2.2m in thickness.

Petrographic studies of coal show the presence of carbonaceous matter ($\bar{X}$ = 63), Clay ($\bar{X}$ = 30.14), quartz ($\bar{X}$ = 2.79) haematite/limonite ($\bar{X}$ = 0.87), pyrite ($\bar{X}$ = 2.53), carbonate ($\bar{X}$ = 0.12), and muscovite/sericite ($\bar{X}$ = 0.24). Carbonaceous shale has the same minerals as in coal but in quite different proportions.

Chemical studies of the coal indicate a wide range of variation. The coal samples can be classified as high fixed carbon (max. 86.75%) to low fixed carbon (35.31%), low volatile matter (7.25 to 13.56%) low ash (down to 3%) and high ash (26 to 49%) Coal.

Washibility study on coal samples shows that using sink/float, heavy media separation and flotation techniques on different size fractions such as 25X4 mm, 4X0.5 mm and less than 0.5 mm reduced ash from 34% to 21% and sulphur from 3.4% to 1.2%. This shows that coal is amenable to cleaning to a limited extent as ash forming mineral matter is uniformly and finely disseminated in the coal.

Some coal samples collected from Balmi, ohra Seri, Kamroti, Bangang and Kandel are low in ash (3.32% to 14.61%) and high in fixed carbon (51.56% to 86.75%). These coals can be blended with clean coal from other localities of Kotli to obtain a product containing 14 to 16% ash. Such a coal blend may be used for coking purposes.

The Kotli coal is of bituminous to anthracitic variety having decidedly better rank than any of the coal deposits found in Pakistan so far. The numerous coal exposures all along the strike on both limbs of eroded anticline are encouraging and are indications of the occurrence of large coal deposits.

INTRODUCTION

Bituminous to anthracitic coal occurs in the Palaeocene rock of the Kotli area. Kotli area in general is rugged and mountainous. The rocks exposed are of sedimentary origin from Precambrian to Late Pliestocene age (Precambrian Dogra Slates, Cambrian Sirban Formation, Post Mesozoic fireclay and bauxite, Paleocene Patala Formation containing coal, Eocene Margala Hill Limestone, Eocene basic intrusions, Miocene Murree Formation and Late Miocene to Pleistocene Siwalik Group (Wadia 1928, Ashraf et al. 1983).

Structurally the area lies to the south east of the great syntaxial bend. The most prominent structural features of the area are the two big inliers forming the central cores of the anticlinal folds with plunging ends. The main boundary fault passes through the centre of the area in NW-SE direction. The general direction of the inliers is also NW-SE but dip varies from place to place even over short distances.

For Kotli Coal ASTM & ASA Classification has been adopted in which high fixed carbon (FC=86 to 98%) and low volatile matter (VM=2 to 14%) coals are semianthracitic to Meta-anthracitic. Whereas if FC= 69 to 86% and VM= 14 to 31% these coals are low volatile bituminous to high bituminous. Our Coals according to the classification are therefore anthracitic to low ash to high ash bituminous.

GEOLOGY

Generally Coal in Kotli area occurs at two horizons within Patala Formation. Most commonly it lies just over the bauxite as in Sawar, Tattapani, Dandilli and Karela. The second seam occurs within the carbonaceous shale about 10 to 15 meters above the bauxite as in Kamroti, Barmoach, Bangang and Nikial. Because of structural disturbance coal is crushed, sheard and with obliterated bedding (E.C.L., 1978).

Coal is exposed at a number of places, the exposed thickness of individual seam ranges from 0.15 to 0.70 metres, however, in underground working it is generally found to be from 1 to 2.4 metres in thickness (Sawar and Tattapani mines).

PETROGRAPHY

1. Coal

TEXTURE AND STRUCTURE: It looks massive and poorly laminated, However, with increase in clayey content poor to moderate lamination may develop at places. The coal is fine grained and composed mainly of carbonaceous matter and clay. Heamatite/Limonite may form streaks and superficial coating. Tables – 1 and 2 may be seen for their constituents.

MINERAL COMPOSITION:

Carbonaceous Matter: It (X = 63.00, –= 14.71) is an important and very often predominant constituent of coal. It is often closely admixed with clay. It is generally fine grained.

Clay: It (X = 30.14, –= 15.01) occurs either very intimately admixed with carbonaceous matter or as small, irregular patches and laminae. It is very fine grained. It is difficult to study its optical properties.

Quartz: It (X = 2.79, – = 2.48) occurs as fine grains which are associated mostly with clay. The grains are subangular. It constitues only a small proportion of the rock.

Chalcedony: It (X = 0.33, – = .80) may occur occasionally as tiny aggregates. It shows usual lamellar to subradial or salt and pepper structure.

Pyrite: It (X = 2.53, – = 3.53) occurs commonly in coal. Its grain size is very variable. It is from fine to coarse grained. At places it occurs as elongate aggregates. In some samples its amount is very high (which is usually lost during thin section making). It may show alteration to haematite/limonite.

Haematite/Limonite: They (X = 0.87, – = 0.60) occur as streaks, stains and thin veinlets. They also occur with pyrite (as an alteration product).

Muscovite/Sericite: They (X = 0.24, – = 0.41) occur as fine flakes intimately associated with clay. Their distribution is quite haphazard. At places they may be stained with haematite/limonite.

Carbonaceous Shales:

The carbonaceous shales occur associated with coal. They occur either towards the top of the seams or bottom of the seams. At places, however, such shales may also occur as intercalations within the coal seams.

TEXTURE AND STRUCTURE: These shales are from moderately laminated to well laminated. They are fine grained and mostly microcrystalline. The carbonaceous matter occurs as streaks, films and very thin laminae.

MINERAL COMPOSITION: The minerals in the coaly shales are the same as in the coal, though in quite different proportions. Clay is the predominant mineral and very fine grained. Quartz occurs as small subangular to subrounded grains. Carbonaceous matter is also fine grained and occurs as films, streaks and very thin laminae. Chalcedony may or may not occur. It is sublamellar to subradial. Salt and pepper structure may also be seen. Haematite/limonite occur as stains, streaks and veinlets. Pyrite occurs as small anhedra and their agrregates. The coaly shales

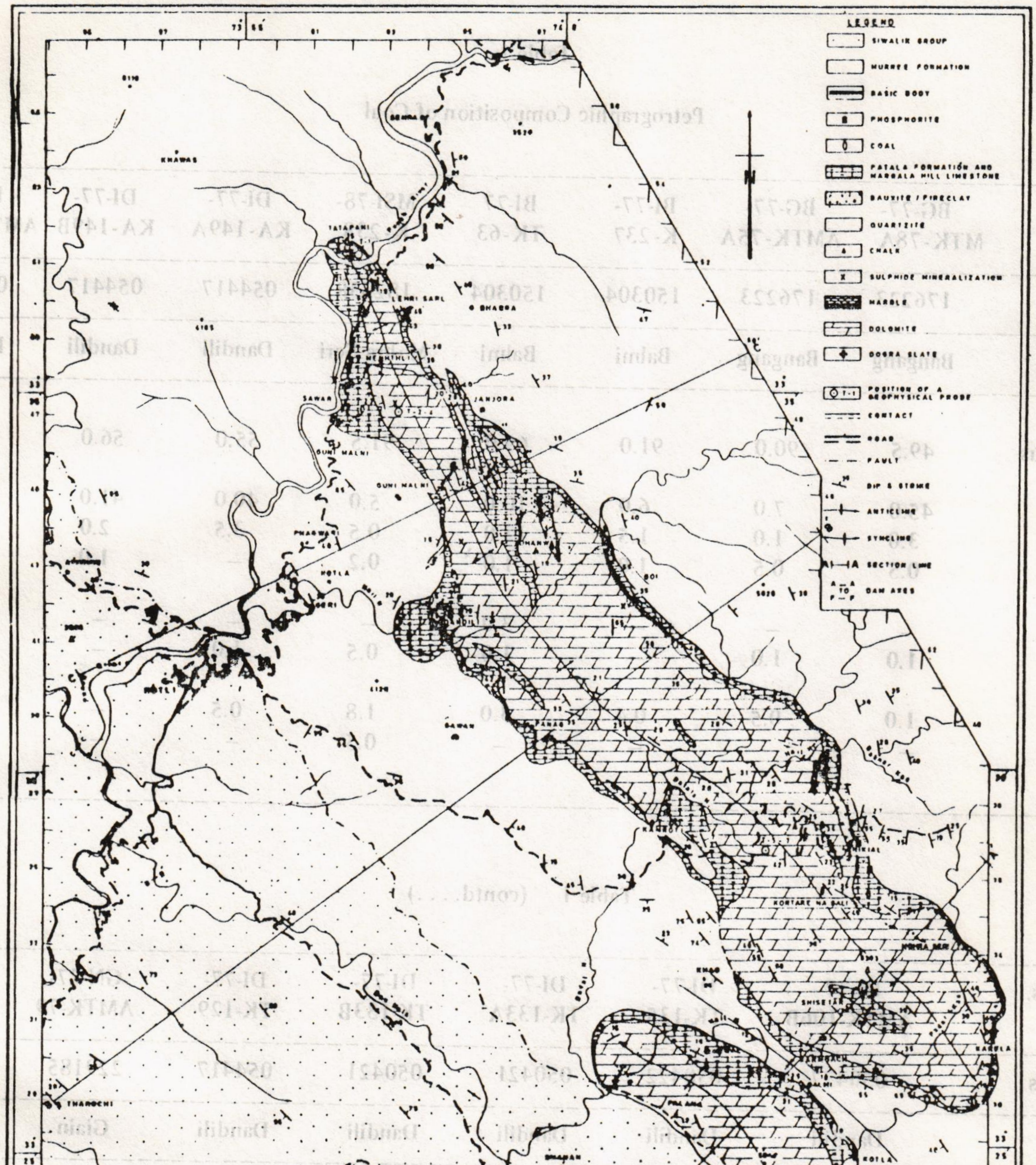

Fig. 1 GEOLOGICAL MAP OF KOTLI AREA SHOWING IMPORTANT MINERAL DEPOSITS

Table 1

Petrographic Composition of Coal

Sample No.	BG-77-MTK-78A	BG-77-AMTK-75A	BI-77-K-237	BI-77 TK-63	MSI-78-K-238	DI-77-KA-149A	DI-77-KA-149B	DI-77-AMTK-106A
Coordinates	176223	176223	150304	150304	182338	054417	054417	050427
Localities	Bangang	Bangang	Balmi	Balmi	Mohra Seri	Dandili	Dandili	Dandili
Carbonaceous Matter	49.5	90.0	91.0	69.0	91.5	55.0	56.0	46.0
Clay	45.0	7.0	6.0	10.0	5.0	40.0	41.0	50.0
Quartz	3.0	1.0	1.5	13.0	0.5	3.5	2.0	2.5
Haematite/ Limonite	0.5	0.5	1.0	1.0	0.2	–	1.0	0.5
Chalcedony	–	–	–	3.0	–	–	–	–
Muscovite/ Sericite	1.0	1.0	–	1.0	0.5	1.0	–	–
Pyrite	1.0	0.5	0.4	3.0	1.8	0.5	–	1.0
Carbonate	–	–	–	–	0.5	–	–	–

Table 1 (contd. . . .)

Sample Nos.	DI-77-AMTK-106B	DI-77-TK-135	DI-77-TK-133A	DI-77-TK-133B	DI-77-TK-129	GN-77-AMTK-79	SR-77-TK-140A
Coordinates	050427	050422	050421	050421	054417	229185	029476
Localities	Dandili	Dandili	Dandili	Dandili	Dandili	Giain	Sawar
Carbonaceous Matter	52.0	65.0	63.0	63.0	60.0	62.0	61.0
Clay	45.0	30.0	25.0	25.0	35.0	35.0	30.0
Quartz	1.5	2.0	3.0	3.0	2.0	2.0	2.0
Haematite Limonite	0.5	3.0	1.5	1.0	1.0	0.5	1.0
Chalcedony	–	–	–	–	1.0	–	2.0
Muscovite/ Sericite	–	–	–	–	–	–	–
Pyrite	1.0	–	8.0	7.0	1.0	0.5	3.0
Carbonate	–	–	–	–	–	–	1.0

Table 2

Petrographic Composition of Coal

Sample Nos.	SR-77-TK-140B	SR-77-AF-40	TP-77-KI-181A	TP-77-KI-181B	KA-78-KKI-225	KI-77-KI-218	X̄	S.D.
Coordinates	029476	029476	026520	026520	207333	118370		
Localities	Sawar	Sawar	Tattapani	Tattapani	Karela	Kamroti		
Carbonaceous Matter	62.0	60.0	52.0	51.0	40.0	84.0	63.00	14.71
Clay	30.0	34.0	30.0	45.0	54.0	10.0	30.14	15.01
Quartz	2.0	3.0	2.0	2.0	4.0	3.0	2.79	2.48
Haematite/ Limonite	1.0	0.5	1.0	0.5	1.0	1.0	0.87	0.60
Chalcedony	1.0	–	–	–	–	–	0.33	0.80
Muscovite/ Sericite	–	0.5	–	–	–	–	0.24	0.41
Pyrite	3.0	2.0	15.0	1.5	1.0	2.0	2.53	3.53
Carbonate	1.0	–	–	–	–	–	0.12	0.31

Table -3

Petrographic Composition of Carbonaceous Shales

Sample Nos.	DI-77-AMTK-105A	DI-77-AMTK-105B	BG-77-AMTK-78	DN-77-AKI-189	X̄	S.D.
Coordinates	050427	050427	176223	065464		
Localities	Dandili	Dandili	Bangang	Dhanwan		
Carbonaceous Matter	16.0	18.0	20.0	10.0	16.00	4.32
Clay	75.0	59.0	74.0	72.0	70.00	7.44
Quartz	4.0		5.0	7.0	4.0	2.94
Haematite/ Limonite	1.0	1.0	1.0	–	0.75	0.50
Pyrite	4.0	12.0	–		4.00	5.66
Carbonate	–	–	–	10.0	–	–
Tourmaline	–		–	1.0	–	–

grade into coal.

CHEMISTRY

Five exposures of coal from the Bangang area were studied. One sample each of the three exposures and two samples each of the two exposures were taken. The results of the chemical analyses are given in Tables 4 to 6.

One sample (BG-77-MTK-70) from coal seam A was chemically analysed. Its fixed carbon is 83.54% whereas volatile matter is 8.27%. The other constituents are sulphur 3.67%, ash 7.74%, moisture, 0.45% and I/L 92.26%.

Two samples (BG-77-AMTK-74, and BG-77-AMTK-75) collected from seam B, from Bangang area were chemically analysed. Sample BG-77-AMTK-74 is taken from the associated carbonaceous shales. The constituents of carbonaceous shales and the coal seam, are, fixed carbon 13.45% and 45.54%, volatile matter 8.01% and 9.30%, sulphur 0.74% and 2.30%, ash 77.98% and 44.58%, moisture 0.56% and 0.58% whereas I/L is 22.02% and 55.42%.

Two samples (BG-77-AMTK-76A, and BG-77-AMTK-76B) from seam C were chemically analysed. Sample 76A represents the coaly portion of the seam while 76B is from the associated carbonaceous shales.

Percentage of the various constituents are as follows. Fixed carbon content 46.49% and 25.47%, volatile matter 10.03% and 11.12%, sulphur 2.24% and 4.83%, ash 43.35% and 63.36%, moisture 0.13% and 0.05 whereas I/L is 56.65% and 36.64%.

One sample (BG-77-AMTK-77) from coal seam D was collected. Its fixed carbon content is 39.83% whereas volatile matter is 11.44%. The other constituents are sulphur 15.04%, and ash 48.15%, moisture 0.585 and the I/L 51.85%.

The percentages of various constituents of sample (BG-77-AMTK-78) are, fixed carbon 35.31%, volatile matter 11.19%, sulphur 3.83%, ash 52.76%, moisture 0.74% and I/L 47.24%.

One sample (GN-77-AMTK-79) was collected from Giain coal seam outcrop. Its chemical analysis shows the presence of fixed carbon 45.21%, volatile matter 14.77%, sulphur 1.14%, ash 35.47%, moisture content 4.55%, and I/L 64.53%.

One sample (KA-77-FT-32) of carbonaceous shales is collected from Karela. The various constituents of shales are fixed carbon 11.61%, volatile matter 12.43%, ash 74.60%, and moisture 1.36%.

Two samples (DI-77-ATK-106 and DI-77-AMTK-105B) of Dandili coal from two different exposures of seam A were collected. The constituents of these sample occur as fixed carbon 35.42% and 56.93%, volatile matter 8.89% and 8.15%, sulphur 3.93% and 3.48%, ash 54.21% and 34.34%, moisture 0.48% and 0.58% and I/L 65.66%.

One sample (DI-77-AMTK-105A) of carbonaceous shales was collected from Dandili area. The percentage of the various constituents of these shales are, fixed carbon 6.42, volatile matter 12.09, sulphur 5.23, ash 79.95, moisture 1.54 and I/L 20.05.

Two sample (DI-77-KA-149 and DI-77-TK-129) were collected from seam B in Dandili area. The percentage of the various constituents is fixed carbon 36.32 and 44.52, volatile matter 12.99 and 13.56, sulphur 1.118 and 1.23, ash 49.11 and 40.30 moisture 1.58 and 1.64 whereas I/L is 59.70.

One sample (DI-77-TK-133) was collected from Dandili seam. The percentage of the various constituents of this seam is fixed carbon 52.19, volatile matter 10.39, sulphur 4.31, ash 36.50 and moisture 0.92.

One sample (DI-77-TK-135) of coal from Dandili area was collected. The chemistry of this coal shows the constituents as fixed carbon 44.93%, volatile matter 13.47%, sulphur 1.49%, ash 39.64%, moisture 1.92% and I/L 60.32%.

One sample (NL-77-M-31) from carbonaceous shales was chemically analysed. The constituents of shales are fixed carbon 6.10%, volatile matter 10.14%, ash 81.80% and mosture 1.96%.

One sample of carbonaceous shales (KA-77-TK-1) from Kortara area was chemically analysed. The constituents of these shales show fixed carbon 5.70%, volatile matter 13.52%, ash 74.72%, and moisture 6.06%.

Two samples(KD-77-KT-2A and KD-77-KT-2B) of coal from Kandel coal seam A were chemically analysed. The various constituents are fixed carbon 61.08% and 59.84%, volatile matter 10.49% and 22.23%, sulphur 5.02% and 1.49%, ash 26.84% and 9.16%, moisture content 1.59% and 8.77% and I/L 73.16%.

Two samples (SR-77-K-167 and SR-77-TK-140) of coal were collected from the Sawar seam. The constituents of these samples are fixed carbon 51.36% and 53.60%, volatile matter 9.83% and 7.25%, sulphur 2.24% and 3.86%, ash 38.16% and 38.43%, moisture 0.65% and

Table-4

Evaluation of Coal/Carbonaceous Shales

Sample Nos./ Seam Nos.	BG-77-MTK-70/A	BG-77-AMTK-74/B	BG-77-AMTK-75/B	BG-77-AMTK 76A/C	BG-77 AMTK-76B/C	BG-77-AMTK-77/D	BG-77-AMTK-78/E	GN-77-AMTK-79	KAMN-77-T-26	KA-77-FT-32
Coordinates	183225	176223	176223	176223	176223	176223	176223	229185	207333	207324
Localities	Bangang	Bangang	Bangang	Bangang	Bangang	Bangang	Bangang	Giain	Karela Kajhan	Kerela
Rock Type	Coal	Carbonaceous	Coal	Coal	Carbonaceous	Coal	Coal	Coal	Coal	Carbonaceous shales
Volatile Matter	8.27	8.01	9.30	10.03	11.12	11.44	11.19	14.77	11.42	12.43
Ash	7.64	77.98	44.58	43.35	63.36	48.15	52.76	35.47	48.73	74.60
Moisture	0.45	0.56	0.58	0.13	0.05	0.58	0.74	4.55	2.18	1.36
Fixed Carbon	83.54	13.45	45;54	46;49	25.47	39.83	35.31	45.21	37.67	11.61
Sulphur	3.67	0.74	2.30	2.24	4.83	15.04	3.83	1.14	–	–
Graphitic Carbon	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
I/L	92.26	22.02	55.42	56.65	36.64	51.85	47.24	64.53	N.D.	N.D.

Analyses at: P.C.S.I.R. Laboratories, Lahore.
Engineers Combine Limited, Lahore.

Table-5

Evaluation of Coal/Carbonaceous Shales

Sample Nos./ Seam Nos.	NL-77-ML-31	DI-77-ATK-106/A	DI-77-AMT-105-B/A	DI-77-KA-149/B	DI-77-TK-129/B	DI-77-TK-135	DI-77-TK-133	DI-77-AMTK-105/A	KA-77-TK-1	KD-77-KT-2A/A	KD-77-KT-2B/A
Coordinates	164369	050427	050427	054417	054417	050422	050421	050427	158354	170352	170352
Localities	Nikial	Dandili	Dandili	Dandili	Dandili	Dandili	Dandili	Dandili	Kortara	Kandel	Kandel
Rock Type	Carbonaceous shales	Coal	Coal	Coal	Coal	Coal	Coal	Carbonaceous shales	Carbonaceous shales	Coal	Coal
Volatile Matter	10.14	8.89	8.15	12.99	13.56	13.47	10.39	12.09	13.52	10.49	22.23
Ash	81.80	54.21	34.34	49.11	40.30	39.64	36.50	79.95	74.72	26.84	9.16
Moisture	1.96	0.48	0.58	1.58	1.64	1.92	0.92	1.54	6.06	1.59	8.77
Fixed Carbon	6.10	35.42	56.93	36.32	44.52	44.93	52.19	6.42	5.70	61.08	59.84
Sulphur	–	3.93	3.48	1.118	1.23	1.49	4.31	5.23	–	5.02	1.49
Graphitic Carbon	–	0.34	–	0.50	–	–	0.66	–	–	–	–
I/L	–	–	65.66	–	59.70	60.32	–	20.05	–	73.16	–

Analysis at: P.C.S.I.R. Laboratories, Lahore.
* P.C.S.I.R. Laboratories, Peshawar.
** Engineers Combine Limited, Lahore.

Table 6

Evaluation of Coal Carbonaceous Shales

Sample Nos./ Seam No.	Sr-77- K-167/A	SR-77- TK-140/A	TP-77- K-181	BI-77- KKI-214/A	BI-77- K-237/A	MSI-78- K-216/A	MSI-77 K-238/A	KI-77- TK-8C/A	KI-77- KI-218/B	PG-77- TK-11
Coordinates	029476	029476	026520	150304	150304	182338	182338	118370	118370	397072
Localities	Sawar	Sawar	Tattapani	Balmi	Balmi	Mohra Seri	Mohra Seri	Kamroti	Kamroti	Panag
Rock Types	Coal	Coal	Coal	Coal	Coal	Coal	Coal	Coal	Coal	Carbona-ceous shaies
Volatile Matter	9.83	7.25	11.25	16.35	15.40	9.35	8.00	28.42	10.49	9.65
Ash	38.16	38.43	52.48	7.68	14.61	3.32	5.85	7.54	26.84	78.09
Moistere	0.65	0.72	0.97	5.69	3.99	0.58	1.58	11.48	1.59	1.08
Fixed Carbon	51.36	53.60	35.30	70.28	66.00	86.75	84.57	51.36	61.08	11.18
Sulphur	2.24	3.86	12.32	1.29	1.16	2.57	3.30	1.26	5.02	1.96
Graphitic Carbon	Nil	1.78	Nil	Nil	–	Nil	–	–	Nil	–
I/L	61.84	–	47.52	92.02	–	96.70	–	–	73.16	–

Analysis at: P.C.S.I.R. Laboratories, Lahore.
* P.C.S.I.R. Laboratories, Peshwar.

0.72% and I/L 61.84%.

One sample (TP-77-K-181) of coal from Tattapani coal seam was collected. The various constituents of this seam are, fixed carbon 35.30%, volatile matter 11.25%, sulphur 12.32%, ash 52.48%, moisture 0.97 and I/L 47.52%.

Two samples (BI-78-KKI-214 and BI-78-K-237) of coal from Balmi coal seam were collected. The various constituents of this seam are fixed carbon 70.28% and 66.0%, volatile matter 16.35% and 15.40%, sulphur 1.29% and 1.16%, ash 7.68% and 14.61%, moisture 5.69% and 3.99% and I/L 92.32%.

Two samples (MSI-78-K-216 an MSI-78-K-238) of coal from Mohra Seri seam were collected. The constituents of this seam are fixed carbon 86.75% and 84.57%, volatile matter 9.35% and 8%, sulphur 2.57% and 3.30%, ash 3.32% and 5.85% moisture 0.58% and 1.58% and I/L 96.70%.

One sample (KI-77-TK-8C) of coal from the Kamroti seam was chemically analysed. Its constituents are fixed carbon 51.036%, volatile matter 28.42% sulphur 1.26% ash 7.54%, moisture 11.48%.

One sample (PG-77-TK-11) of carbonaceous shales from Panag was collected. The constituents of these shales are, fixed carbon 11.18%, volatile matter 9.65%, sulphur 1.96%, ash 78.09% and moisture 1.08%.

It is clear from the above that the variation in the composition of coal from Kotli is large. Most of the sulphur occurs as pyrite and can be separated easily. Moisture is low and volatile matter is also low. The ash content is very variable. Since after benefication most of pyrite and ash may be separated, the coal may be usefully employed as anthracitic to bituminous coal.

WASHABILITY STUDIES OF KOTLI COAL

The chemical composition of the bulk coal samples follow the general pattern of small samples. The sample No. 237 and 238 are low ash high fixed carbon coals, whereas No. 105, 167 and 181 coals are high ash varieties. The coal sample No. 181 also contained exceptionally high sulphur.

There is, however, one thing common in all the coal samples that is, they are low in volatile matter content. From the proximate analysis of the coals it may be said that their composition confirms to that of ANTHRACITE coal.

1. SIZE ANALYSIS OF BULK COAL SAMPLES:

The bulk samples selected for detailed test work were subjected to screen analysis. The results are presented in Table – 7.

Table – 7

Screen Analysis of Bulk Raw Coal

Size (mm)	DI-77-K-105	BI-78-K-237	SR-77-K-167
	Cummulative % passing		
+ 25.0	97.0	97.8	92.2
+ 12.5	83.8	92.48	70.2
+ 8.0	77.0	89.97	65.4
+ 4.0	53.1	–	52.4
+ 2.84	45.5	84.76	45.4
+ 2.41	37.6	77.24	39.6
+ 1.40	28.8	68.21	30.6
+ 1.00	18.1	60.19	26.2
+ 0.70	13.7	53.47	22.6
+ 0.35	10.5	43.84	19.0
+ 0.252	8.0	35.02	15.4
+ 0.177	5.8	26.70	13.0
– 0.152	–	–	–

The main size ranges generally used in the industry for washing the coal are 25 x 4 mm, 4 mm x 0.50 mm and 0.5 x 0 mm Each size range has its own washing characteristics so that different methods are applied to each fraction.

The washing method to be applied on 25 x 4 mm is jigging and heavy media separation. The method applied to 4 x 0.5 mm size is heavy media cyclones. Flotation process is used to treat the coal finer than 0.5 mm size.

The coal samples accordingly were classified in the size ranges mentioned above and their respective ash contents were determined. The results are shown in Table – 8.

Table – 8

Weight Proportion and Ash Content of Various Size Fraction of Raw Coal (Bulk).

Size (mm)	No. 105		No. 237		No. 167	
	Wt %	ash%	Wt %	ash %	Wt %	ash %
25 x 4	44.0	37.0	10.0	92.2	40.0	44.7
4 x 0.5	42.0	33.1	39.8	13.7	32.0	35.9
0.5 x 0	11.0	29.9	48.0	12.4	20.2	32.1

It is apparent from tabulated data that gangue is gradually liberated from coal on increasing the fineness, although the extent of impurities are intimately associated with the coal to some extent.

2. *WASHING STUDIES:* The bulk coal samples selected for washing studies were 105 and 167. Sample No. 181 has high ash and sulphur whereas samples No. 237 and 238 conformed to standard, therefore, not considered for the study in detial.

Sample No. 105 was sieved into 3 fractions as mentioned in the last section. Two heavy medium circuits were utilized to wash + 0.5 mm coals. The heavy media was constituted of aqueous solution of zinc chloride.

(i) *Washing of 25 x 4 mm size Caol:* The first set of vessles washed 25 x 4.0 mm coal in 1.40 – 1.70 sp.gr. liquids. The 1.70 float material was crushed to 4.0 x 0.5 mm and mixed with the similar size fraction from the raw coal and washed separately. High speed centrifuge was used to hasten the settling. The results are shown in Table – 9.

Table - 9

Sink/Float Tests on 25 x 4 mm Coal No. 105

Sp. Gr.		Direct Recovery %		Cumulative Recovery %	
Sink	Float	Wt.	Ash	Wt.	Ash
_	1.40	0.2	12.3	0.2	12.3
1.40	1.45	2.7	13.0	2.9	13.0
1.45	1.50	5.2	13.5	8.1	13.3
1.50	1.55	7.9	18.2	16.0	15.7
1.55	1.60	9.7	20.7	25.7	17.6
1.60	165	16.9	27.3	42.6	21.4
1.65	1.70	10.6	32.2	53.2	23.6
1.70	–	46.8	44.0	100.0	34.4

It will be seen from Table – 9 that about 25 percent of the clean coal can be recovered from 25 x 4 mm size upto 1.6 sp.gr. The cumulative ash in the washed coal was just 50% of the raw coal for the size fraction mentioned. It was thought necessary to reduce the size of the coal to 12.5 x 4 mm and repeat the exercise so as to determine the effect to size reduction of the coal on its washability. Table-10 summarizes the results of the sink float test.

Table - 10

Sink/Float Test on 12.5 x 4 mm Size Coal No. 105

S.p. Gr.		Direct Recovery %		Cumulative Recovery %	
Sink	Float	Wt.	Ash.	Wt.	Ash
	1.40	0.6	9.6	0.6	9.6
1.40	1.45	2.6	10.8	3.2	10.6
1.45	1.50	6.2	13.7	9.4	12.7
1.50	1.55	66.9	18.1	16.3	15.0
1.55	1.60	12.6	21.5	18.9	17.8
1.60	1.65	22.0	27.1	50.9	22.9
1.65	1.70	13.6	32.5	64.5	24.1
1.70	–	35.5	51.1	100.0	34.4

It will be appreciated after reviewing Table – 6. That size reduction had significantly improved the comulative weight recovery to about 29 percent at about the same ash content, at 1.6 sp.gr. At sp. gr. 1.65, however, cumulative weight recovery upto about 50 percent can be achieved, although cumulative ash content also increased to about 22 percent. The above procedure was repeated on coal sample No. 167. The results are given in Table-11.

Table-11

Sink/Float Test on 12.5 x 4 mm Size Coal No. 167

Sp. Gr.		Direct Recovery %		Cumulative Recovery %	
Sink	Float	Wt.	Ash	Wt.	Ash
–	1.40	0.3	6.3	0.3	6.3
1.40	1.45	1.5	9.4	1.8	8.9
1.45	1.50	1.1	12.1	2.9	10.1
1.50	1.55	4.4	15.1	7.3	13.1
1.55	1.60	4.6	21.1	11.9	16.1
1.60	1.65	10.1	17.1	22.0	21.1
1.65	1.70	16.9	32.0	38.9	25.8
1.70	–	61.1	50.4	100.0	–

The sample 167 did not respond particularly well to the washing test. It may be seen from Table 11 that as

12% weight recovery could be obtained at 1.60 sp.gr. the No. 167 washed coal had ash in about the same range as washed coal No. 105. The subsequent washing study was restricted to coal No. 105 only.

The product coal may be suitably marketed as steam coal for locomotives and power houses.

ii) *Washing of 4 x 0.5 mm Size Coal:* In the raw sample No. 105 size fraction 4 x 0.5 mm constitutes about 42 percent by weight. Washing of this fraction was carried out separately using heavy media maintained at 1.60 and 1.70 sp.gr. The results are shown in Table – 12.

Table-12

Heavy Media Separation of 4 x 0.5 mm Size Coal No. 105

Sp.Gr.		Direct Recovery %		Cumulative Recovery %	
Sink	Float	Wt.	Ash	Wt.	Ash.
–	1.60	7.2	15.4	7.2	15.4
1.60	1.70	60.6	24.00	67.8	23.1
1.70	–	32.2	53.9	100.00	33.1

It will be observed that only 7.2 weight percent material could be obtained at 1.60 sp. gr. However, at 1.65 sp. gr. more than 50 percent material can be recovered although at 20 percent ash content.

A close examination of the washability of 25.x 4 mm and 4 x 0.5 mm size fraction would show that at about 50 percent weight recovery, the ash content in the washed coal was about 20 percent.

A heavy media test was repeated on raw head coal No. 105, reduced to 4 mm size. The fraction finer than 0.5 mm was removed from the coal. The coal fraction 4 x 0.5 mm was found to be about 76 percent by weight whereas about 24 percent of the coal passed 0.5 mm screen. The results of heavy media separation are shown in Table-13.

Table-13

Heavy Media Test on 4 x 0.5 mm Raw Head Coal No. 105

Sp. Gr.		Direct Recovery %			Cumulative Recovery %		
Sink	Float	Wt.	Ash	S	Wt	Ash	S
–	1.60	27.4	14.1	1.26	27.4	14.1	1.26
1.60	1.70	41.3	25.4	1.14	68.7	20.9	1.19
1.70	–	31.3	68.3	8.51	100.0	35.7	3.48

It will be seen that at 1.70 sp.gr. a product containing 20.9 percent ash and 1.19 percent sulphur could be obtained. The over all recovery based on feed coal was about 52 percent. The remaining 24 percent fine coal can be washed using flotation method so as to obtain maximum weight recovery. The washed coal has reasonable amount of sulphur, although the ash content is slightly high.

The Washing excercise was repeated on coal No. 237 using 40.5 mm size fraction. The results of the test are given in Table-14.

Table-14

Sink/Float on 4 x 0.5 mm Raw Coal No. 237

Sp. Gr.		Direct Recovery %			Cumulative Recovery %		
Sink	Float	Wt	Ash	S	Wt	Ash	S
–	1.6	60.1	77.3	0.54	60.1	7.3	0.54
1.6	1.7	23.1	15.1	0.62	83.2	9.5	0.55
1.7	–	16.8	40.0	4.17	100.0	14.6	1.16

The washing behaviour of No. 237 coal is similar to those of other coals. It may be seen that the coal can be upgraded to a product containing 9.5 percent ash and 0.55 percent sulphur at about 83 percent weight recovery.

iii) *Flotation of Fine Coal:* Flotation of fine coal has been considered unfeasible in some plants. This is due to the fact that the process is mis-applied. When fine coal is coated with slime, surface properties of various phases are equalized, making it impossible to separate than by flotation. The high surface area of slimes required excessive reagent and causes considerable difficulty in handling the froth product. Success in flotation of coal in this case depends on proper desliming of coal.

The size fraction 0.5 mm was made into 10 percent slurry and transferred into a Denver D 12 flotatation cell. Several reagents were tested to float the coal including kerosene oil, cresot and methyl isobutyl carbinol (MIBC). Also sodium silicate and D-67 were used to depress the siliceous shale.

The raw coal of size fraction 0.5 x 0. mm was floated in a single step. The flotation was conducted for about 5 minitues after allowing 5-10 minutes conditioning time. The flotation products were collected after every minute separately to determine the gradual change in the grade and recovery of the washed cpa;/ Table 15 shows the results of flotation of No. 105 raw coal, using kerosene at about netural pH.

Table - 15

Flotation of 0.5 x 0 mm Raw Coal
No. 105 using Kerocene.

Kerosene 1.0 kg/tonne pH 6.5

Product	Recovery %		Cumulative Recovery %	
	Wt	Ash	Wt	Ash
Conc 1st minute	26.8	21.4	26.8	21.4
2nd "	14.0	23.8	40.8	22.2
3rd "	5.2	24.8	46.0	22.5
Tails	54.0	36.4	100.0	30.0

The coal flotation is a fast process, it was observed that maximum weight was recovered in about 3 minutes. At 46 percent weight recovery the cumulative ash content was found to be 22.5 percent, flotation beyond 3 minutes did not yield any concentrate unless further addition of kerosene was made. The quality of concentrate even then was poor.

In another series tests, cresol was substituted for kerocene. Besides, sodium silicate was used to depress the silicate gangue. The results of the tests are summarized in Table 16.

Table-16

Flotation of 0.5 x 0 mm Raw Coal
No. 105 Using Cresol

Cresol 0.5 kg/ton pH 6.5

Product	Recovery %		Cumulative Recovery %	
	Wt	Ash	Wt	Ash
Conc Ist minute	24.7	20.8	24.7	20.8
2nd "	23.1	22.5	47.8	21.7
3rd "	21.4	24.6	69.2	22.6
Tails	30.8	48.0	100.0	30.0

An examination of the results given in Table-16 would reveal that much better recovery and slightly improved grade could be obtained using cresol. The reagent consumption per ton of clean coal was also low in comparison to kerosene.

Another reagent used as frother for coal flotation was methyl isobutyl carbinol (MIBC). The results of flotation are shown in Table – 17.

Table-17

Flotation of 0.5 x 0 mm size Raw Coal
No. 105 Using MIBC

MIBC 0.45 Kg/ton pH 6.6

Product	Recovery %		Cumulative Recovery %	
	Wt	Ash	Wt	Ash
Conc 1st minute	17.2	21.9	17.2	21.9
2nd "	20.5	22.6	37.5	22.4
3rd "	17.2	24.8	54.7	23.1
Tailings	45.3	38.5	100.00	30.0

It will be observed from Table 17 that the grade and recovery of clean coal using MIBC is intermediate between those for kerosene and cresol. The reagent comsumption per ton of the clean coal,however, was comparatively lowest.

The flotation exercised on the fine coal has shown that at 60-70 percent weight recovery, a product containing about 22 percent ash could be obtained.

A flotation test was performed on raw head coal sample crushed and pulverized to pass 0.152 mm, using cresol. The results are given in Table-18.

Table-18

Flotation Test on Raw Head Coal No. 105 reduced to 0.152 mm size

Cresol 0.5 kg/ton pH 6.5

	Recovery %			Cumulative Recovery %		
	Wt	Ash	S	Wt	Ash	S
Conc 1st minute	23.4	20.9	1.4	23.4	20.9	1.4
2nd "	20.8	22.6	1.1	44.2	21.7	1.2
3rd "	18.2	26.5	1.2	62.4	23.0	1.3
Tailings	37.6	53.4	7.2	100.0	34.4	3.48

It will be noticed that even on fine grinding the ash forming impurities in the coal do not get completely liberated, so that, the flotation concentrate at 62 percent weight recovery contained as much as 23 percent ash. One of the reason for high ash in the concentrate may be due to co-flotation of slimes which may have to be incompletely removed. In order to obtain better grade and recovery, it is proposed to wash various size fraction of the coal separately and blend the concentrates into one or two washed coal products. The sulphur content, however, got considerably reduced to about 37 percent of the original value. This level of sulphur in the washed coal in industrially acceptable.

The washed coal having ash contents between 9-12 percent, sulphur 1.5 percent and volatile in the range of 18-22 percent may be used for cooking purpose. The coal No. 237, 238 after blended with washed coal No. 105 type may confirm to the specification of cooking coal.

CONCLUSION AND RECOMMENDATIONS

1 Coal samples from Kotli Azad Kashmir contain generally high fixed-carbon, low voltile matter and somewhat high sulphur.

2. The coal samples are of two types: (i) high ash coal containing 26 to 54 percent ash, and (ii) low ash coal containing 3 to 15 percent ash.

3. Washability studies on different size fractions 25 x 4, 4 x 0.5 x 0 mm using sink/float, heavy media separation and flotation techniques have shown that in each case washed coal containing about 21 percent ash and 1.2 percent sulphur can be obtained from raw coal containing 34 percent ash and 3.4 percent sulphur. This shows that the coal is amenable to cleaning.

4. The ash forming mineral matter is uniformly and finely disseminated in the coal, so that only limited amount of upgradation viz-a-viz ash content could be achieved.

5. Samples No. 237, 238, 214 and 216 are particularly low ash coals, these coals can be blended with clean coal from other places to obtain a product containing 14-16 percent ash. Such a. coal blend may be used for coking purpose.

The Kotli coal is of anthracite variety having decidedly better rank than any of the coal deposit found in Pakistan so far. It is recommended that further exploratory work may be carried out to determine the reserves of coal and, if possible, such coal seams wherein the ash forming mineral matter is least disseminated. It is also recommended that detailed work on petrology, washibility and coking behaviour may be carried out on the coal.

ORIGIN

The origin of the coal is definitely, known to be result of plant decay, either in situ or transported from place of growth to the place of deposition.

In the Kotli area the Cretaceous regression has resulted in the removal of rock formations down to Cambrian, Sirban dolomite and the unconformity is represented by bauxite/fireclay. This was followed by the earliest Paleocene transgression. This transgression is related to faster rate of spreading. This brief phase of transgression was followed by continental conditions which resulted in the growth of vegetable matter and the formation of coal. This peroid was again followed by rapid rate of spreading and a period of transgression in which shale and limestone shelf facies were deposited. Then started another peroid of regression in which marshy hot and humid conditions were restored and luxuriant vegetable growth took place and a recent coal horizen was formed. Again rapid rate of spreading started and rest of Paleocene and Eocene represent marine facies.

It is, therefore, concluded that the rate of spreading in Paleocene was variable and cyclic resulting into at least two transgressions and regressions phases.

Other agents, which influence the formation of coal are heat and pressure. The pressure was exerted by vertical weight of the overlying strata and also by the poweful lateral compression resulting in folding of rock formations. The chemical action eliminated the water and oxides of carbon thus reducing the volume of material, such as , volatile vapours gases and making the coal bituminous to anthracitic.

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PETROLOGY OF ULTRAMAFICS FROM SHANGLA-ALPURI-MALAM JABBA AREA, SWAT

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ABSTRACT: Chromite and chrome spinel bearing metamorphosed ultramafites occur south of the MMT within a eugeosynclinal assemblage composed of green schist, slices of blue schist and mafic lavas. The rocks originally peridotites are now composed of serpentinites, serpentinised peridotites and a varied assemblage of talc-carbonates. The mineral assemblages show that the main metamorphic phase took place between 325° and 500 C°. That would correspond to low to very low grades of metamorphism. This paper presents petrography, chemistry and metamorphism of these rocks.

INTRODUCTION

The ultrabasic bodies occurring along and close to the Main Mentle Thrust (MMT) zone have been described and discussed briefly by Chaudhry, Ashraf and Hussain (1980), Butt (1983) and Ashraf & Chaudhry (1986). The petrotectonic significance of these bodies has been discussed by Butt, Chaudhry and Ashraf (1979) and Chaudhry, Ghazanfar and Ashraf (1983, 1984).

Chaudhry, Ashraf & Hussain (1980) distinguished the "Alpine type ultrabasics from the complex ultrabasic bodies and related the later to the Tethyan domain. They suggested that most of the ultrabasic bodies south of the MMT are Alpine type i.e belong to the mantle while those north and away from MMT are mainly complex and related to Tethyan domain. The bodies south of MMT fall in the zone of minor shear and overthrusting i.e.. melange. The bodies north of MMT are generally located in the thick main melange zone (Chaudhry et-al 1984).

In this paper petrography, chemistry and metamorphism of "Alpine type" bodies from Malam-Jabba-Shangla-Alpuri Area, Swat is discussed.

GEOLOGY AND OCCURRENCE OF ULTRABASIC ROCKS.

A large number of ultrabasic bodies occur close to and along the MMT zone in Swat (Fig. 1 & 2). Important occurrences which have been studied are as follows.

Shangla Alpuri : Shangla (longitude 72° 36'E, latitude 34°, 52.5'N) is about 51 Km northeast of Mingora. The ultrabasic rocks intrude green schist, blue schist and metamorphosed volcano sedimentary pile. The main ultrabasic body of Shangla area from Bar Kotkai to Lilauni (Alpuri) is 8 x 2.7 Km.

The main mass of the body is often well jointed and sheared serpentinite. It is light green, green and greenish gray in colour. Yellowish green colours develop in highly jointed and strongly sheared zones.

Serpentine is the main mineral, but relics of pyroxene, olivine and grains of chromite, magnetite and nickel sulphides can also be seen. Near Kuz Kotkai, Kandogai, Barmachar and Zaregai chromite concentrations are also present.

Minor associates of this serpentinite are talc-carbonate and carbonate-talc rich bodies. The biggest exposure of these rocks is 600 x 240 x 75 m near Bar Kotkai. This body contains relics of serpentinite.

Malam Jabba Area : This area is situated close to the Shangla area. The ultrabasic body here is a serpentinite 1500 m x 300 m, its northern part 150 m x 90 m is converted to a talc-carbonate rich rock. The serpentine is highly sheared and fractured. It is greenish gray in colour.

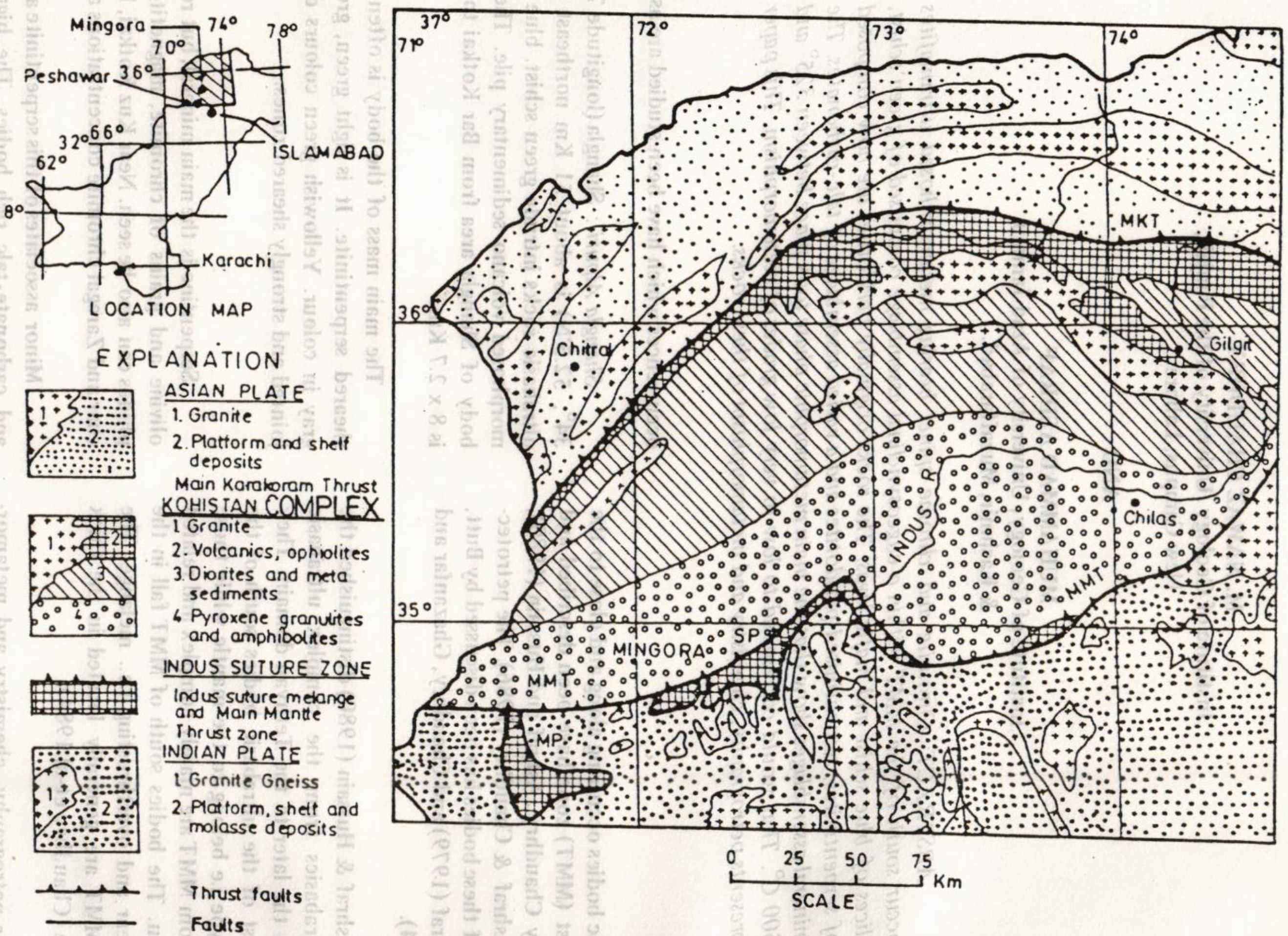

Fig. 1. Geological sketch map of Indus suture zone in northern Pakistan. (After A.H. Kazmi, 1984).

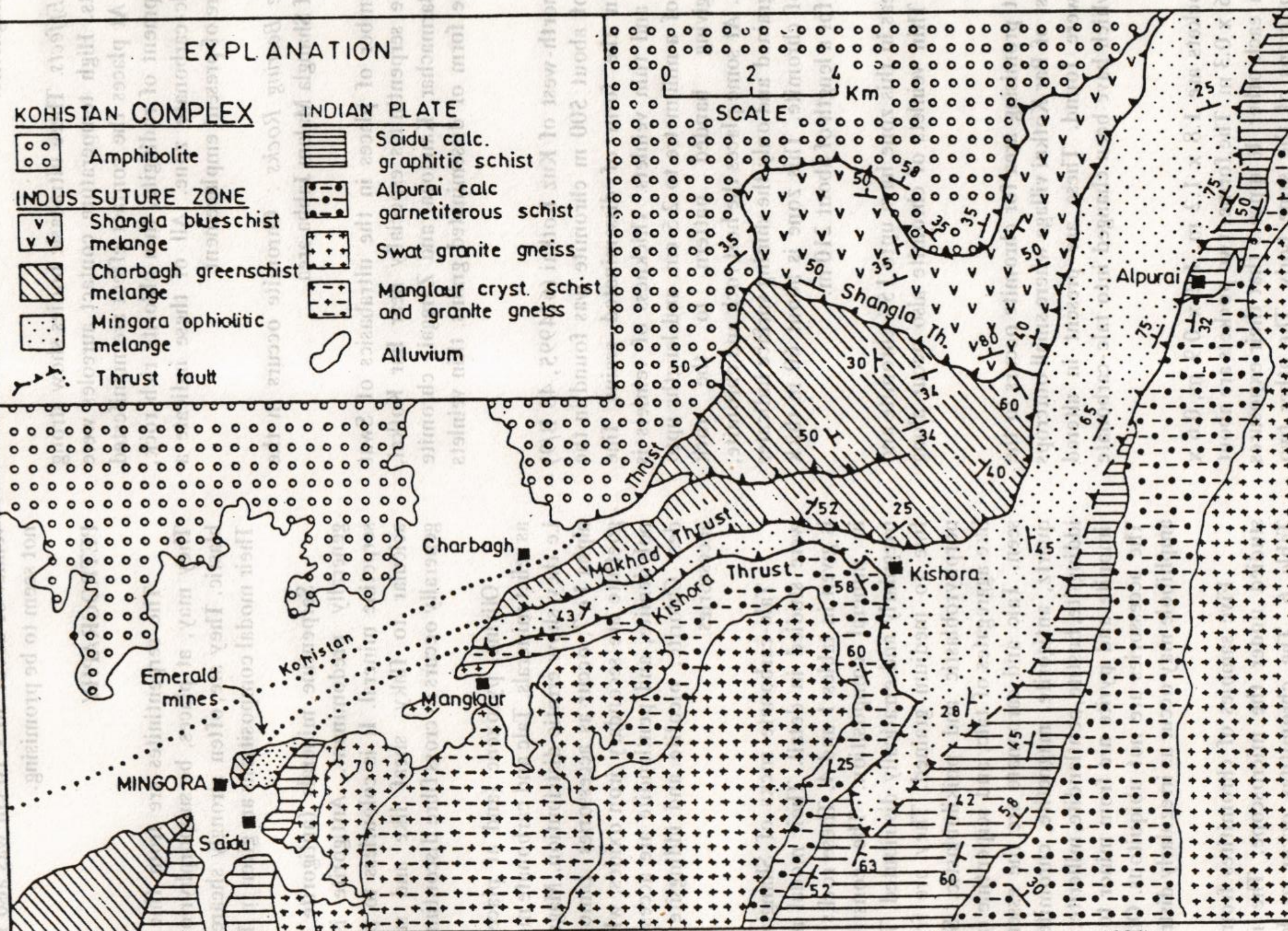

Fig. 2. Geological map of the Mingora-Alpurai area (After A.H. Kazmi, 1984).

Smaller talc-carbonate patches occur erratically in this body. The serpentinite is composed mainly of serpentine with relics of olivine and pyroxene and disseminated grains of chromite, magnetite and nickel sulphides. The talc-carbonate rocks also contain grains of nickel sulphides, chromite and magnetite.

Contact Effects. These ultrabasic bodies show strong shearing effects. High temperature contact aureoles were not observed. At places the contact effect are manifested by the development of rodingite, thin chlorite rich rock, steatite or talc-carbonate zone. All of these indicate a low temperature of present emplacement.

Chromite Bearing Rocks : Chromite occurs in the serpentinites of Shangla Malam Jabba area.

At a number of places in the ultrabasics of Swat District, in the serpentinites especially near Bar Kotkai, Kuz Kotkai, Barmachar, Kandogai and Zaregai,, chromite is present inthe form of disseminated grains, thin veinlets and pods.

To the north-west of Kuz Kotkai (614995, 43 B/9) at a distance of about 500 m chromite was found in the serpentinites in the form of disseminated grains, fine impregnations and thin veinlets. Thickness of veinlets is from fraction of a millimetre to 2.5 cm. and lengths upto few cms, giving banded pattern to the rock at some places. At some places the host rock and chromite, both are fine-grained and only the shining surface indicates the presence of chromite. This zone is about 60 m thick and is exposed for a length of about 210 m.

Some areas in this zone have upto 15% chromite and some lack it. Thin veinlets of chromite also occur along joints.

The most promising area for chromite occurs to the west-south west of Bar Kotkai village where small outcrops of chromite were found. These are present in altered serpentinites which have been changed into talc-carbonate rock at places.

These pockets are 1.8 x 1.2 m, 1.2 x 0.9 m, 0.6 x 0.45 m and 0.6 x 0.3 m. The former two pockets are about 3m apart from each other. It appears that their exposures may be the outcrops of the same body. The other two small out-crops are also within an area of 30 m from the first two showings.

These rocks are present in the lowermost part of the serpentinites which make a belt from Bar Kotkai to the north-west upto Lilauni. Some small boulders and pebbles of chromitite were also observed in the neighbouring streams.

In the serpentinites of Malam Jabba disseminated grains of chromite are present at places. At one place a veinlet of about 30 x 10 cm was also noted. The area does not seem to be promising.

PETROGRAPHY

The serpentinites are from fine to medium grained They may, at places, be subporphyrloblastic to porphyroblastic. They are, often strongly sheared and even schistose. Their modal compositions are given in Tables 2,3 and 5.

Serpentine minerals (antigorite and chrysotile) are generally predominant. Antigorite is the predominent serpetine mineral. It is colourless to pale green and from acicular to flaky, sheaf like and subradial. Chrysotile generally occurs as cross fibre discontinuous veins.

Olivine, pyroxene (and at places amphibole) occur as relict minerals. Talc and carbonate may or may not occur i.e they show erratic distribution. Magnetite, chromite and alpha Fe^{3+}, occur as accessories. Limonite, haematite, and goethite are secondary iron oxides, while pyrite, millerite, polydemite, and pentlandite are accessory to trace sulphides. Chlorite, picotite and iddingsite may also occur as accessories.

Talc-carbonate rocks of Shangla and Malam Jabba were studied in detail. Their modal mineral composition is given in tables 1 and 4. These rocks show large variation in mineral composition. The constituent minerals are irregularly and erratically distributed. These rocks are from fine to medium grained. They are from granoblastic to porphyroblastic and poikiloblastic. Sub-radial to sheaf like aggregates of talc, and serpentine (antigorite) are often seen. Talc and carbonate are the essential minerals while quartz, antigorite, magnetite, chromite, picotite, chlorite, iddingsite, bastite, pentlandite, millerite, haematite, goethite, limonite and pyrite are from minor to accessory minerals. The accessories are not ubiquitous. Olivine, pyroxene and amphibole may occur as irregularly distributed relics.

Five samples of chromitites from Shangla area were studied under the microscope. The results are given in Table 6. The chromitites occur as lensoid bodies. The samples show poorly developed foliation. The rocks are composed mainly of chromite/spinel (X = 73.60, S.D = 11.15). Chromite/spinel are mostly subhedral. Some euhedral crystals also occur. Antigorite is the second most important mineral (X = 22.60, S.D = 12.95). It occurs as subradial aggregates as well as elongated flakes. Chrysotile

Table 1

Petrographic Composition of the Talc-Carbonate rocks of Shagla Area

Sample No.	BK-77-SIJ-51	BK-77-NASF-73	BK-77 SR-161	KB-77-SSTR-166	BK-77-SS-165	BK-77-NASF 72	BK-77-RT 163	KB-77-SSTR 168	KB-77-SSTR 167	BK-77-SST 164	BK-77-SSR 173			BK-77-SR-160
Coordinates	606974	969020	606974	603971	603977	469020	605972	601969	602970	603976	602973			606973
Locality	Bar Kotkai	Bar Kotkai	Bar Kotkai	Kandba	Bar Kotkai	Bar Kotkai	Bar Kotkai	Kandba	Kandba	Bar Kotkai	Bar Kotkai			Bar Kotkai
Rock type	Talc antigo-rite rock	Talc rock	Soap-stone	Talc carbo-nate rock	Talc carbo-nate rock	Talc carbo-nate rock	Talc carbo-nate rock	Talc carbo-nate rock	Talc carbo-nate rock	Talc carbo-nate rock	Carbo-nate Talc Quartz rock			Amphi-bole talc-carbonate rock
												$\bar{X}$	S.D.	
Talc	74.0	62.0	62.0	61.0	61.0	57.0	55.0	44.0	40.0	19.0	8.0	49.36	20.09	20.0
Carbonate	–	2.0	–	15.0	14.0	16.0	30.0	20.0	45.0	50.0	67.0	23.55	22.13	25.0
Antigorite	20.0	6.5	22.7	8.0	10.0	8.0	5.0	–	–	–	–	7.29	7.19	10.0
Magnetite/ Chromite	3.0	3.0	3.0	6.0	–	4.0	4.0	6.0	5.0	4.0	5.0	3.91	1.70	6.0
Haematite/ Limonite	–	8.0	3.0	10.0	5.0	3.0	–	10.0	3.0	2.0	–	4.00	3.79	15.0
Pyroxene	–	–	–	–	–	4.0	–	–	–	–	–	–	–	4.0
Goethite	3.0	–	–	–	–	–	–	–	–	–	–	–	–	–
Sulphide	–	0.5	0.3	–	–	–	–	–	–	–	–	0.07	0.17	–
Amphibole	–	–	–	–	–	–	–	–	–	–	–	–	–	20.0
Quartz	–	18.5	–	–	2.0	–	1.0	21.0	7.0	25.0	20.0	8.55	10.20	–
chlorite	–	–	9.0	–	–	–	4.0	–	–	–	–	1.18	2.86	–
Iddingsite	–	–	–	–	8.0	–	–	–	–	–	–	–	–	–
Bastite	–	–	–	–	–	8.0	–	–	–	–	–	–	–	–

(X = 0.09, S.D = 1.02), magnetite, talc,. pyroxene, limonite, olivine and carbonate minerals may occur as accessories.

CHEMISTRY

Chemical composition of serpentinites, and talc-carbonate rocks are given in table 7,8,9 and 10.

A comparison of the average compositions of talc-carbonate rocks and serpentinites illustrates chemical gains and losses, during the formation of the former from the latter. The content of MgO decreases significantly while Al^2O3, CaO and volatiles often increase. The balance of MgO forms patches and veins of magnesite.

The serpentinites of Shangla, Alpurai and Malam Jabba are chemically very similar These serpentinites chemically match one another and contain high values of NiO.

The results of chemical analysis of chromitites are given in table-11. The samples are of the chromite ore and not the pure mineral as can be seen from their mineral composition.

The samples contain 36.38% and 19.27% Cr_2O_3, 16.9% and 18.34% Fe_2O_3 and 23.39% and 40.52% Al_2O_3. Their Cr/Fe ratios are 2 : 1 and 1 : 1. For variations in other constituents table-11 may be consulted.

The sample BK-77-SIJ-50 is a chromite while sample BK-77-SIJ-49 may be called a chromium spinel.

The Cr/Fe ratio shows that the ore is not of a metallurgical grade. However, the ores appear to be useful for refractory purposes.

PETROGENESIS

The metamorphosed ultrabasic rocks now represented by serpentinites and talc-carbonates contain relics of olivine, pyroxenes and at places pods, lenses and dissemina-

TABLE 2

Petrographic Composition of the Serpentinites of Shangla Area

Sample No.	KK-77-SIJ-17A	BK-77-SS-162	NS-77-S-302	KK-77-AS-43A	KK-77-AS-44A	KK-77-AS-44B	KK-77-SIJ-17	KK-77-SI-15	KK-77-AS-43	BK-77-SSR-172	BK-77-S-105A	KK-77-AS-43B	KK-77-SIJ-23A	BK-77-S-105
Coordinates	608993	605974	040784	605992	608994	607995	609994	611991	609993	602978	606973	606991	628003	604971
Locality	Kuz Kotkai	Bar Kotkai	Kandba	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Bar Kotkai	Bar Kotkai	Kuz Kotkai	Kuz Kotkai	Bar Kotkai
Rock type	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite
Antigorite	92.0	93.0	75.0	88.0	90.0	91.0	91.0	65.0	85.0	90.0	85.0	82.0	88.0	83.0
Chrysotile	2.0	–	18.0	4.0	2.0	1.0	1.0	25.0	5.0	–	4.0	7.0	–	5.0
Talc	–	–	1.5	–	–	–	–	2.0	–	–	–	–	–	–
Carbonate	–	0.5	–	–	–	–	–	–	–	–	–	–	9.0	–
Magnetite	6.0	6.5	5.0	8.0	7.0	7.0	8.0	6.0	10.0	10.0	2.0	10.5	0.5	1.5
Clay	–	–	–	–	–	–	1.0	–	–	–	0.5	–	1.0	–
Haematite/Limonite	–	–	0.5	–	–	–	–	2.0	–	–	–	–	1.0	–
Pyroxene	–	–	–	–	–	1.0	–	–	–	–	8.0	–	–	10.0
Picotite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Geothite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Olivine	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Garnaerite	–	–	–	–	0.5	–	–	–	–	–	–	–	–	–
Sulphide	–	–	–	–	0.5	–	–	–	–	–	0.5	0.5	0.5	0.5
Anthophylite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amphibole	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chlorite	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Garnet	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Apatite	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE 2 (Contd.)

Sample No.	KK-77-SIJ-18	KK-77-SIJ-19	KK-77-AS-44	KK-77-SIJ-23	SH-77-S-301	KK-77-SIJ-20B	KK-77-SI-16	KK-77-SIJ-25	KK-77-SIJ-20	KK-77-AS-42B	KK-77-SI-14	NG-77-S-27	NG-77-S-26	KK-77-SIJ-24	KK-77-SIJ-21		
Coordinates	609994	614995	609993	627003	040784	613994	611991	625009	614995	607990	611991	619001	620999	627003	613993		
Locality	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Shangla	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Kuz Kotkai	Nagha	Nagha	Kuz Kotkai	Kuz Kotaki		
Rock type	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	$\overline{X}$	S.D.
Antigorite	86.0	87.0	85.0	85.0	51.0	75.0	27.0	72.0	70.0	70.0	60.0	61.0	61.0	58.0	55.0)	81.41	12.10
Chrysotile	1.0	–	2.0	–	30.0	2.0	47.0	–	–	–	5.0	–	–	–	2.0)		
Talc	3.0	–	–	1.0	5.0	7.0	–	–	12.0	–	3.0	–	5.0	15.0	12.0	2.29	4.16
Carbonate	–	–	0.5	12.0	7.0	–	–	–	–	20.0	–	25.0	–	–	4.0	2.69	6.28
Magnetite	7.0	5.0	10.0	–	6.0	5.0	11.0	9.0	6.0	8.0	7.0	10.0	7.0	5.5	7.7	6.63	2.88
Clay	1.0	–	–	–	–	–	–	2.0	–	–	–	–	–	–	–	0.19	0.47
Maematite/ Limonite	–	–	–	–	1.0	–	–	1.0	–	2.0	–	–	–	0.5	–	0.28	0.58
Pyroxene	2.0	2.0	0.8	–	–	7.2	4.0	10.0	5.0	–	18.0	–	18.0	5.0	17.0	4.07	6.12
Picotite	–	2.0	–	–	–	–	–	–	0.0	–	–	–	–	–	2.0	0.14	0.52
Goethite	–	1.0	–	–	–	–	–	–	–	–	–	3.0	2.0	–	–	0.21	0.68
Olivine	–	3.0	0.5	1.0	–	3.0	–	6.0	6.0	–	5.0	–	–	–	–	0.84	1.85
Garnaerite	–	–	1.0	0.5	–	–	–	–	–	–	2.0	–	6.0	–	–	0.34	1.17
Sulphide	–	–	0.2	0.5	–	0.8	–	–	1.0	–	–	1.0	1.0	–	0. 3	(0.61	0.27)
Anthophylite	–	–	–	–	–	–	11.0	–	–	–	–	–	–	–	–	(0.25	0.35)
Amphibole	–	–	–	–	–	–	–	–	–	–	–	–	–	6.0	–	–	–
Chlorite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Garnet	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Apatite	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE 3
Petrographic Composition of the Serpentinites of Alpurai Area

Sample No.	LR-77-IJ-40B	KK-77-SIJ-23	AP-77-SI-12	AP-77-SIJ-8	LI-77-IJ-34A	LI-77-IJ-34	LR-77-IJ-39	BM-77-S-28	AP-77-IJ-37
Coordinates	631035	627003	628048	616994	633058	633058	632036	611004	630034
Locality	Lobaria	Kandogai	Alpurai	Alpurai	Lilauni	Lilauni	Lobaria	Bar Machar	Alpurai
Rock Type	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite
Antigorite	93.0	85.0	83.0	80.0	73.0	75.0	68.0	72.0	68.0
Chrysotile	–	–	–	3.0	4.0	–	5.0	–	2.0
Talc	–	1.0	–	–	1.5	–	–	–	8.0
Carbonate	–	12.0	–	4.0	1.0	–	–	–	–
Magnetite	6.0	–	8.0	7.50	8.0	10.0	5.0	7.0	6.0
Clay	1.0	–	–	1.0	1.0	–	1.0	2.0	–
Haematite/limonite	–	–	–	0.5	1.0	–	–	–	–
Pyroxene	–	–	6.0	–	8.0	12.0	5.0	15.0	14.0
Picotite	–	–	1.0	–	–	–	4.0	1.0	–
Geothite	–	–	–	–	–	–	–	–	–
Olivine	–	1.0	2.0	–	2.0	2.50	12.0	3.0	2.0
Garnaerite	–	0.50	–	–	–	–	–	–	–
Sulphide	–	0.50	–	–	0.50	0.50	–	–	–
Anthophylite	–	–	–	–	–	–	–	–	–
Amphibole	–	–	–	–	–	–	–	–	–
Chlorite	–	–	–	4.0	–	–	–	–	–

TABLE 3 (Contd.)

Sample No.	LR-77-IJ-38	ZG-77-S-30	LI-77-IJ-35	LI-77-IJ-36	AP-77-SI-13	KM-77-SIJ-48	KM-77-SIJ-48A		
Coordinates	631035	622016	603049	642045	623027	621008	621008		
Locality	Lobaria	Zaregai	Matani	Matani	Alpurai	Machra	Machra		
Rock Type	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinte	Serpen-tinite	Serepn-tinized peridotite		
								$\bar{\bar{X}}$	S.D.
Antigorite	68.0	68.0	64.0	64.0	61.0	51.0	50.0)	71.06	11.78
Chrysotile	–	–	–	–	–	–	–)		
Talc	6.8	2.0	–	–	–	–	–	1.21	2.51
Carbonate	–	–	–	–	–	–	–	1.06	3.09
Magnetite	5.0	7.0	6.0	6.7	3.50	7.0	10.0	6.42	2.41
Clay	–	–	–	–	–	–	–	0.38	0.62
Haematite/ limonite	–	1.0	–	–	0.50	–	0.5	0.22	0.36
Pyroxene	15.0	12.0	18.0	12.0	31.0	9.3	7.0	10.27	7.90
Picotite	1.0	–	–	–	–	2.5	1.0	0.66	1.14
Goethite	–	–	–	–	–	–	–	–	–
Olivine	4.0	10.0	12.0	17.0	4.0	30.0	31.0	8.28	10.00
Garnaerite	–	–	–	–	–	–	–	–	–
Sulphide	0.2	–	–	0.3	–	0.2	0.5	0.17	0.22
								0.39	0.15
Anthophylite	–	–	–	–	–	–	–	–	–
Amphibole	–	–	–	–	–	–	–	–	–
Chlorite	–	–	–	–	–	–	–	–	–

TABLE 3 (contd.)

Petrographic Composition of the Serpentinized Peridotites and Talcose Serpentinite, Alpurai Area

Sample No.	LR-77-IJ-40	AP-77-SIJ-9	ZG-77-S-99
Coordinates	631035	615027	619012
Locality	Lobaria	Alpurai	Zaregai
Rock Type	Talcose Serpentinite	Serpentinized Peridotite	Serpentinized Peridotite
Antigorite	49.0	30.0	25.0
Chrysotile	–	1.0	–
Talc	36.0	–	–
Carbonate	–	–	–
Magnetite	15.0	7.0	3.0
Clay	–	2.0	–
Haematite/limonite	–	0.8	–
Pyroxene	–	18.0	9.0
Picotite	–	–	1.0
Goethite	–	–	–
Olivine	–	41.0	60.0
Garnaerite	–	–	–
Sulphide	–	0.2	–
Chlorite	–	–	1.0
Spinel	–	–	1.0

TABLE 4

Petrographic Composition of Talc-Carbonate Rocks of Kishora-Spin Obo Area (Malam Jabba)

Sample No.	SO-77-SRM-180A	SO-77-M-177	KA-77-ST-174	KA-77-SR-175			SO-77-SM-178
Coordinates	570935	566927	557926	557927			570935
Locality	Spin OBO	Spin Obo	Kishora	Kishora			Spin Obo
Rock Type	Talc Carbonate rock	Talc Carbonate rock	Talc Carbonate rock	Carbonate Talc Chlorite rock			Talc. Serpentine rock
					$\bar{X}$	S.D.	
Talc/Pyrophylite	85.0	63.0	45.0	3.0	49.00	34.76	35.0
Carbonate	4.0	29.0	40.0	65.0	34.50	25.30	–
Antigorite	–	–	5.0	–	–	–	56.0
Chrysotile	–	–	–	–	–	–	5.0
Magnetite/Chromite	7.0	2.0	7.0	2.0	4.50	2.89	0.6
Haematite/limonite	4.0	6.0	2.0	–	3.00	2.58	3.0
Sulphide	–	–	1.0	3.0	1.00	1.41	0.4
Chlorite	–	–	–	27.0	–	–	–

TABLE 5

Petrographic Composition of the serpentinites of Kishora-Spin Obo Area (Malam Jabba)

Sample No.	KA-77-SSTR-176	GP-77-SM-132	GP-77-SM-131	SO-77-AS-129	SO-77-AS-129A			SO-77-M-179A
Coordinates	557926	566926	564926	568933	568933			569932
Locality	Kishora	Gul Paiga	Gul Paiga	Spin Obo	Spin Obo			Spin Obo
Rock Type	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite			Olivine Amphibole Pyroxene rock
						$\bar{X}$.	S.D.	
Antigorite	89.0	87.0	87.0	84.0	83.0	86.00	2.45	–
Chrysotile	–	–	–	1.0	2.0	0.60	0.89	–
Talc	3.0	7.0	–	–	–	2.00	3.08	–
Carbonate	–	–	–	–	–	–	–	–
Magnetite	8.0	2.0	8.0	–	4.0	4.40	3.58	2.0
Clay	–	–	1.0	–	–	–	–	–
Haematite/limonite	–	2.0	–	3.0	1.0	1.20	1.30	3.0
Pyroxene	–	2.0	4.0	12.0	10.0	5.60	5.18	31.0
Sulphide	–	–	–	–	–	–	–	–
Garnet	–	–	–	–	–	–	–	–
Epidote	–	–	–	–	–	–	–	–
Anthophyllite	–	–	–	–	–	–	–	34.0
Olivine	–	–	–	–	–	–	–	30.0

TABLE 6

Petrographic Composition of Chromitites of Shangla Area

Sample No.	BK-77-SIJ-49	BK-77-SIJ-50	BK-77-SIJ-53	BK-77-SIJ-59	AP-77-S-65		
Coordinates	606974	606974	606975	606973	598967		
Locality	Bar Kotkai	Bar Kotkai	Bar Kotkai	Bar Kotkai	Alpurai		
Rock Type	Chromite	Chromite	Chromite	Chromite	Predotite		
						$\overline{X}$	S.D.
Picotite/Chromite	81.0	84.0	56.0	77.0	70.0	73.60	11.15
Antigorite	16.0	8.0	41.0	18.0	30.0	22.60	12.95
Chrysotile	1.0	–	1.0	2.5	–	0.90	1.02
Magnetite	2.0	–	–	–	–	–	–
Talc	–	6.0	–	2.5	–	1.70	2.64
Pyroxene	–	2.0	–	–	–	–	–
Limonite	–	–	1.0	–	–	–	–
Olivine	–	–	0.5	–	–	–	–
Carbonate	–	–	0.5	–	–	–	–

Table 7

Chemical Composition of the Talc-Carbonate Rocks
from Shangla Area

Sample No.	BK-77-NASF-73	KB-77-SSTR-166	BK-77-NAFS-72	KB-77-SSTR-168	KV-77-SSTR-167	BK-77-SST-164	$\bar{X}$	S.D.	BK-77-SR-160
Coordinates	969020	603971	469020	610969	602970	603976			606973
Locality	Bar Kotkai	Bar Kotkai	Bar Kotkai	Kandba	Kandba	Bar Kotkai			bar Kotkai
Rock type	Talc rock	Talc Carbonate rock	Talc Carbonate rock	Talc Carbonate rock	Talc Carbonate rock	Talc Carbonate rock			Amphibole Talc Carbonate rock
SiO_2	58.36	50.17	43.68	30.30	31.33	32.99	41.14	11.53	29.42
TiO_2	0.00	–	0.00	–	–	–	–	–	–
Al_2O_3	5.18	2.03	1.64	7.56	6.39	2.40	4.10	2.64	10.77
Fe_2O_3	10.88	9.84	10.72	4.90	4.90	3.65	7.48	3.33	6.76
MnO	0.18	–	0.06	–	–	–	0.12	0.08	–
MgO	19.41	24.02	27.94	31.95	31.95	33.52	28.13	5.50	28.68
CaO	0.33	Traces	1.74	4.92	4.92	1.02	2.59	2.19	3.79
NiO	0.41	0.06	0.18	0.18	0.18	0.54	0.26	0.18	0.38
I/L	4.53	13.78	13.91	20.07	20.07	25.69	16.34	7.31	19.86

Table - 8

Chemical Composition of the Serpentinites from Shangla Area

Sample No.	BK-77-SS-162	SH-77-S-302	KK-77-SI-15	BK-77-SSR-172	KK-77-SIJ-19	KK-77-AS-44	SH-77-S-301	KK-77-SIJ-20	KK-77-SI-14	NG-77-S-27-A	NG-77 S-26		
Cordi-nates	605974	040784	611991	602978	614995	609993	040784	614995	611991	619001	620999		
Locality	Bar Kotkai	Kandba	Bar Kotkai	Bar Kotkai	Shahgai	Kuz Kotkai	Shangla	Kotkai	Kotkai	Nagha	Nagha		
Rocktype	Serpen tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite	Serpen-tinite		
												$\bar{X}$	S.D.
SiO_2	41.02	38.27	40.00	40.00	39.63	38.86	36.30	41.51	43.71	41.29	42.34	40.27	2.04
Al_2O_3	2.01	4.26	2.30	2.28	2.91	0.73	0.99	2.36	2.12	4.29	1.79	2.37	1.13
Fe_2O_3	7.05	5.89	7.84	9.30	8.80	13.67	11.00	7.62	9.23	2.93	7.38	8.25	2.76
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.16	0.02	0.00	0.00	0.02	0.05
MgO	35.23	38.20	35.83	36.66	34.70	35.74	38.05	39.02	32.82	39.71	37.29	36.67	2.05
CaO	0.62	0.83	1.06	0.00	1.07	0.00	0.80	0.00	3.45	0.00	1.69	0.87	1.02
NiO	0.34	0.58	0.29	0.38	0.30	0.15	0.28	0.45	0.37	0.14	0.42	0.34	0.13
CaO	0.00	–	–	0.00	0.00	–	–	–	–	–	–	–	–
Cr_2O_3	–	–	0.00	–	0.06	0.00	–	0.09	0.07	–	0.18	0.07	0.07
I/L	13.62	11.82	12.60	11.52	12.81	10.89	12.36	8.86	8.13	11.53	8.61	11.10	1.80

Table - 9

Chemical Composition of the Serpentinites from
Kishora-Spin Obo Area (Malam Jaba)

Sample No	KA-77-SSTR-176	GP-77-SM-132	GP-77-SM-131	SO-77-AS-129	$\overline{X}$	S.D.
Coordinates	557929	566926	564926	568933		
Locality	Kishora	Gul-Paiga	Gul-Paiga	Spin-Obo		
Rock type	Serpentinite	Serpentinite	Serpentinite	Serpentinite		
SiO_2	40.51	41.06	40.12	43.78	41.37	1.65
TiO_2	–	–	–	–	–	–
Al_2O_3	2.65	2.51	3.02	2.71	2.72	0.22
Fe_2O_3	9.65	8.76	7.79	8.38	8.65	0.78
MnO	–	–	–	–	–	–
MgO	34.98	33.94	34.97	30.14	33.51	2.30
CaO	0.00	0.00	3.64	1.57	1.30	1.73
NiO	0.30	0.49	0.38	0.54	0.45	0.08
I/L	11.69	12.41	9.61	12.61	11.58	1.37
Total:	99.86	99.17	99.53	99.73		

Table 10

Chemical Composition of the Serpentinites from Alpurai Area.

Sample	KK-77-SIJ-23	AP-77-SI-12	LI-77-IJ-34	BM-77-S-28	AP-77-IJ-37	LR-77-IJ-38	ZG-77-S-30	LI-77-IJ-35	KM-77-SIJ-48	$\overline{X}$	S.D.
Coordinate.	627003	628048	633058	611004	630034	631035	622035	603049	621008		
Locality	Kandaogai	Alpurai	Lilauni	Bar Machar	Alpurai	Lobaria	Zaregai	Matani	Machra		
Rock type	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite	Serpentinite		
SiO_2	40.54	40.01	40.71	40.81	40.98	41.81	40.61	40.38	35.38	40.24	1.93
Al_2O_3	1.49	1.19	1.21	1.08	1.07	1.03	1.19	1.12	2.02	1.27	0.31
Fe_2O_3	7.70	11.29	11.77	9.38	11.48	10.43	11.00	8.18	15.66	10.77	2.34
MnO	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–	–
MgO	35.51	36.96	34.10	38.87	38.68	38.38	36.41	38.79	39.36	37.45	1.81
CaO	2.07	1.42	0.00	1.40	0.54	0.52	1.51	0.35	0.26	0.90	0.71
NiO	0.43	0.32	0.13	0.38	0.38	0.31	0.29	0.35	0.47	0.34	0.10
I/L	12.13	8.93	11.42	7.94	6.62	7.43	8.06	10.84	6.40	8.86	2.11
Total:	99.87	100.17	99.34	99.98	99.75	99.99	100.07	100.01	99.55		

Table - 11

Chemical Composition of Chromitites of Shangla Area

Sample No.	Bk-77-SIJ-50	Bk-77-SIJ-49
Coordinates	606974	606974
Locality	Bar Kotkai	Bar Kotkai
SiO_2	6.63	12.15
TiO_2	—	0.00
Al_2O_3	23.39	40.52
Fe_2O_3	16.93	18.34
MnO	—	0.03
MgO	15.62	7.58
CaO	0.00	0.00
Na_2O	—	—
K_2O	—	—
Cr_2O_3	36.38	19.27
NiO	0.12	0.20
I/L	0.77	2.11
Total:	99.84	100.20
Co	0.07	0.07
Cu	0.03	0.03
Zn	0.05	0.05
Ag	1 ppm	1 ppm
Cr	24.89	13.18
Fe	11.84	12.83
Cr/Fe	2:1	1:1

tions of chromite and chrome spinel.

These rocks were, therefore, originally mostly peridotites containing chromite and chrome spinel.

Smaller quantities of talc developed alone in peridotites represents autometasomatism at higher temperatures (between 625° and 500C°). Serpentine (antigorite) which would normally develop below 400C° probably started developing at 500C° because of the presence of CO_2 and H_2O (Deer et al. 1962).

The mineral assemblages of the talc-carbonates can be seen in the tables giving petrographic composition. Pyroxene and olivine occur as relics. Paragenesis of the type talc-antigorite-carbonate-quartz is significant and points close to an invariant point which develops at low XCO_2 and between temperatures 325° to 360C° depending upon pressure (Winkler, 1979).

The presence of relict anthophyllite in some rocks indicates changes between 550° and 700C° depending upon mole fraction of CO_2. If tremolite or actinolite were present their formation would be related to serpentinisation. From the above probable conditions of main metamorphic changes range between 325° to 500C°. That would correspond to very low grade to low grade metamorphism of Winkler (1979) or greenschist facies metamorphism. The presence of earlier talc and anthophyllite suggest small scale alterations at higher temperatures. But these were probably very minor autometasomatic changes and did not effect the rock as a whole.

Where do these ultrabasics belong? Do these bodies represent compliments of basic lavas of oceanic crustal derivation, layer three of the Tethyes of which layer two are now amphibolites of tholeiitic character or simply up thrusted mantle slices? This requires further study on isotopes and trace elements. But presence of chromite lenses, layers and disseminations, higher values of NiO (> 0.18%, Malpas and Stevens, 1977), and absence of feldspar would indicate these bodies to belong to the mantle domain rather than crustal derivatives or lower parts of an arc or arc related dismembered layered mass.

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PRE-CAMBRIAN OIL IN THE SALT RANGE AND POTWAR PAKISTAN

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ABSTRACT: – Precambrian rocks, both sedimentary and nonsedimentary types, hold good promise of commercial resources of oil/gas in Pakistan.

Field evidences indicate important relationship between the intrusive Khewra Trap and the oil/gas shows of Salt Range Formation (Precambrian). Future development of Precambrian hydrocarbons would, to a considerable extent, depend on the correct understanding of this relationship.

In addition to the conventional structures within the immediately overlying reservoir rocks and the internal structures of carbonate zones within the Salt Range Formation, there are quite good prospects of Precambrian basement reservoirs in all regions of Salt Range Formation and basement, at workable depths.

INDRODUCTION

Although the Oil and Gas Development Corporation of Pakistan has classified (O.G.D.C./1978) the Salt-Range Formation (Precambrian) as a good source rock of oil yet references to the possibilities of commercial deposits of Precambrian oil/gas in Pakistan appear strange to the majority of geologists of this country.

It is important to note that unmetamorphosed Precambrian sediments with indications of oil constitute a good and in parts the bulk of the sedimentary prism of the Punjab and part of North West Frontier Province of Pakistan. This huge hydrocarbon potential has not yet been duly considered and tested. This paper is intended to bring this important source into lime light.

Back Ground:– Until forties and in some quarters until fifties the Precambrian rocks were generally considered to be completely devoid of life and whatever kerogenous matter found in these rocks was attributed to migration or contamination from the younger rocks. But from time to time since thirties from different parts of the World individual workers have been pointing out the existence of life in the Precambrian as against the then accepted evolution of life in the Cambrian.

Both microscopic and megascopic fossils were reported from undoubted Precambrian rocks belonging to different parts of the world e.g. North America, South America, South India, Africa and Australia (Fenton and Fenton, 1936; Srinivasa Rao, 1943; Almeida, 1944; Pallister, 1955 and Glaessner, 1959). Later, important contributions have been made in the field of chemical and organic evolution in the Precambrian by Barghoon, (1971) Schopf (1975, 1978) and Cloud (1976).

Upto 1964 about 300 papers on the evidences of Precambrian life had been published. In 1965 alone the number of such papers totalled a little over forty. This steadily progressed, touching the figure of 160 papers in 1972 and 158 papers in 1974 whereafter the graph declines once again. By now it is understood that over 2000 papers have already been published on Precambrian life.

Despite the aforementioned considerable work on Precambrian life due attention to the possible hydrocarbon potential was not paid except by Russian and Australian geologists. Commenting on this state of affairs Murray et al. (1980) remark :–

"Whereas the economic significance of these developments appear to have been overlooked considerably by Western Hemisphere geologists, the message has not been lost on those in the USSR and Australia.

Several wells drilled in the Amadeus basin of Australia encountered only minor shows and a small gas flow. Adequate porosity and permeability appear to be primary *problems, but neither the shows nor all the potentially prospective straigraphic sequence were tested adequately.*

The Soviet story is different. An oil discovery in 1962 in lower Cambrian rocks at Markovo in the irkutsk basin of the Siberian platform area, about 600 k.m. north north-east of Irkutsk near Lake Baikal presaged events to come. By 1970 four non commercial and eight commercial fields had been discovered in lower Cambrian and Proterozoic strata in the area".

But the matter did not end at the Soviets. The thread has also been picked up by Swedish geologists for the expected deep-seated oil/gas deposits in the Swedish Precambrian Shield. The Swedish approach is however different. It has nothing to do with the presence or absence of life in Precambrian. It is based on the inorganic origin of hydrocarbons.

The Kerogen Contents:– It has been indicated that there is hardly any difference between the amount and type of the Kerogen contents of Precambrian and of the younger formations including those producing commercial oil. In this connection the following extracts would be of interest :–

(i) "Precambrian Kerogens yielded abundant amounts of hydrocarbons. Also large quantities of methane, ethane and propane were formed.

(ii) "Average organic carbon contents of Precambrian shales is mostly indistinguishable from that of normal, in some places petroleum producing Phanerozoic shales (J.W. Schopf, personal communication quoted by Murry et al, 1980).

Precambrian Basement Reservoirs :– The above discussion pertained to accepted indigenous Precambrian oil occurrence. A number of important oil fields are operating on Precambrian basement rocks throughout the world. Oil of these reservoirs is presently believed to have migrated down from the overlying source or primary reservoir rocks. Oil reserviors of this type occur in Kansas (USA), Venezuela (?) and China. Detailed study of the geologic parameters of these oil fields indicated that at least in some of these cases the otherwise indigenous oil reservoirs have been remotely assigned to some of the overlying formation. It is quite probable that at some further date they would ultimately be declared as indigenous Precambrian deposits parts of which have migrated upwards. In this way the present picture is expected to be reversed.

Table 1 (modified after Chung-Hsiang, 1982) summarises the presently known main Precambrian basement oil fields.

BRIEF HISTORY OF PRECAMBRIAN OIL IN THE SALT RANGE & POTWAR

"Warth (1872) obtained a dark 'mineral oil' by distillation of the 'bituminous shales' found in the Saline Series (Salt Range Fm) at Khewra gorge". . . . . reports A.B Wynne, in his ';Geology of the Salt Range in the Punjab' (1978).

In his own observations, Wynne (1878) reports the occurrence of Eearth oil' intercalated with gypsum and a 'foetid variety' of dolomite at Khewra gorge. At another place he describes the stuff as coaly-looking highly bituminous shales occurring as a pocket or small lenticular mass. Referring to the result of a fire test, he narrates: "Some of the shale made a fine blazing fire, decrepitating while burning and leaving much ash, also giving off sulphurous fumes".

After Wynne a number of workers worked on the so called bituminous, coaly or oil shales found associated with the salt of the Salt-Range and of Kohat. (The author, like some of the previous workers, maintains that Kohat salt and Salt Range salt are homotaxial.) Amongst them Stuart (1919) and Lahiri (1945) deserve special mention. Stuart demonstrated that the Kohat salt not only contains liquid oily matter but also gas under pressure. He suggested that the oil had been caught up by the salt during an overthrust. Stuart also found intermediate characters in both colour and composition at Nand Rakhi (Kohat) and Kalabagh (Salt Range) salts. Lahiri carried out detailed studies on the so called 'bituminous shales' which he collected from Makracn, Warcha and Kalabagh (Salt Range) and from Jatta etc. of Kohat salt area. He demonstrated similarities between the stuff of the two areas. Lamba (1945) reported indication of oil associated with gypsum in the cores of bore holes sunk below the workings of Khewra Salt Mine.

Gee (1944) makes important observations on the nature and origin of the 'bituminous shales' of the Salt Range Formation in these words:

"A band of black bituminous shales that occurs at intervals in the upper gypsum- dolomite stage of the series was closely examined. This band occurs as a definite oil-shale in the Nawabi Kas above Makrach. Certain small, rounded inclusions of bright vitrain-like material, lenticular in cross section and showing fine rediating striations suggested a possible vegetable origin, but an examination by palaeobotanical specialists failed at the time to produce any evidence of definite vegetable structure. That at least a primitive form of vegetable or animal life was in existence during the period of formation of these oil-shales, and of the oil-shales occuring at various places in the lower gypsum-dolomite

stage appears certain, for it is difficult to imagine the oil to be other than indigenous".

In his 1945 paper Gee reverts back to the subject in these words:–

"It is agreed that the kerogen and free oil is indigenous in the shales, and that it has been derived from either vegetable or animal remains. No evidence of animal remains within the oil shales has been met with, though many geologists have made an intensive search. What is the evidence of the plant remains that have so far been recognised in the oil shales strata; can they not possibly represent a Cambrian flora? That is one of the most important question to decide".

Finally in the same 1945 paper Gee also makes a reference to the occurrence of oil in older rocks elsewhere outside the Salt-Range in these words:–

"As regards the occurence of oil at such an early geological age, one might draw attention to the foetid dolomites of definite Cambrian age at Saiduwali in the Khasor Range (Trans-Indus), to indications of oil in the Vindhyan (Precambrian) limestones of the Katni area (India) and to the occurrence of bituminous anhydrite and dolomite in a bore hole in the Vindhyans at Nagour, Jodpur State (India). As evidence of plant life in early Palaeozoic times, one might also refer to the oil shale deposits of Ordovician age in Esthonia" (Russia).

Main Prospects:– **Main prospects of Precambrian oil/gas originate from the Salt Range Formation* Some workers assign late Precambrian to early Cambrian age to the Salte-Range Formation which consists of a thick evaporite sequence in its type area i.e. the Salt-Range. In the southern plains of the Punjab this formation consists of a mixture of regressive (evaporites) and transgressive (shallow water marine) facies.**

In the Potwar, Kohat and the Salt Range, the Salt Range Formation is behaving diapiric, migrating from the Potwar and accumulating/extruding at and from the Kohat and Salt Range diapirs to the west, south-west and south.

At the southern Punjab plains its total thickness as encountered at the Karampur test well of the Pak Shell Oil Company (1959) is 934 m. At the Salt Range proper its total thickness is not known. The Attock Oil Company's Dhariala well (1953) crossed a gross thickness of 2148 m without hitting its base. As per careful assessment made by the author through geologic projection total thickness of Salt-Range Formation's diapiric mass is about 5486 m in Kalabagh area, western Salt-Range. A seismic section of the Oil and Gas Development Corporation ot Pakistan run through Kallar Kahar area eastern Salt Range indicates a thickness of 3 to 3.7 thousand metres for the same.

Commerical Find:– **At well No. 5, Adhi eastern Potwar area, the Pakistan Petroleum Ltd. (PPL) and American Oil Co. (AMOCO) have hit Salt Range Formation's oil trapped in the overlying sandstone of Khewra Formation (Cambrian) in 1978. Adhi area is presently producing about 300 barrels per day. So far Adhi is the only area in Pakistan where Precambrian oil is being produced. Adhi oil is Precambrian belonging to the Salt Range Formation because in between the Salt Range Formation and Khewra Formation there is no other formation with a source rock and Khewra sandstone has no source rock of its own. It has a red shale zone at its lower part which is not kerogenous in any part of the Salt Range and adjoining areas.**

Relatively Rare Occurrences: **Rich indications of oil in the carbonate zones of the Salt-Range Formation but its rarer accummulation in workable deposits in the overlying reservoirs of the Khewra and Kussak Formations is explained by:–**

a) The oil of the Salt Range Formation occurs within the dolomite-anhydrite – marl zones which are usually punctured by sills/dykes of the Khewra Trap (Trachyte). These zones are irregularly distributed as free floating detached masses of generally complexly folded strata within the salt mass of the Salt Range and Kohat. Since these rocks are completely enclosed by the impervious-to-oil salt (except at localities where they occur at the Salt Range Formation-Khewra Formation contact), migration of oil to the reservoir rocks is not possible under normal conditions.

b) Unfortunately the effective seal rock of the lower shaly zone of Khewra Formation occurs in between the source rock (Salt Range Formation) and the reservoir rock (the upper massive sandy zone of the Khewra Formation). This set up does not allow, the migration and accumulation of the Salt Range Formation's oil in workable deposits in the reservoirs of Khewra sandstone or the still overlying Kussak Formation's glauconitic siltstones/sandstones.

Composition of Bituminous Shales/Oil Shales: **A closer examination of the nature and behaviour of the 'bituminous shales' of Salt Range Formation at different localities has revealed that most of the occurrences are not bituminous shales or oil shales in the real sense and thus not the conventional source rocks of oil rather themselves are solidified residual oils or asphaltites. Accordingly, they yield crude oil on distillation with values much higher than the normal** oil shales. For example the oil shales of Khewra and Makrach areas, have yielded 12% to over 25% (by weight) crude oil during a recent series of distillation tests at PMDC Exploration Cell, Rawalpindi. Corresponding mean figures of the famous Lothian oil shales of Scotland are 8.07% (Macleod Mathews, 1975). Lothian oil shales have been commercially exploited for the production of crude petroleum for about 100 years since early 1860s till 1962. Moreover the residue (spent shale) of Lothian-oil shale is a light coloured (reddish) clayey stuff very low in carbon while that of the Khewra-Makrach 'oil shales', is a jet black mass till analysing over 25% fixed carbon. The following are analysis reports of two residue samples belonging to the 'oil shales' of Makrach (no. 793) and Khewra (no. 794) areas.

S.No.	Locality	Fixed carbon %	CaO %	MgO %	SO_4 %	Al_2O_3 %	Fe_2O_3 %	SiO_2 %	CO_3 %	Analysed by
793	Makrach	26.89	8.21	7.93	14.95	18.06	11.67	18.48	0.006	PCSIR Labs. Lahore
,,	,,	19.7	8.0	8.5	9.3	4.0	9.1	30.1	10.7	PMDC Labs. R'Pindi
794	Khewra	28.65	6.32	10.53	5.37	6.87	6.27	37.17	0.0058	PCSIR Labs. Lahore
,,	,,	25.57	2.7	14.4	1.6	5.3	5.4	39.1	6.3	PMDC Labs. R'Pindi

The 'oil shales' of the Salt Range Formation may be defferentiated into two main types:–

a) At most localities in the Salt Range they are what may be termed as solidified oil, bitumin or gilsonite and not shales of sedimentary origin. Examples are Khewra gorge, Makrach valley, Sohal valley (Pir Khara), Dulmial test well, Warcha (part) and Kalabagh (part) occurrences.

b) At other localities where they could at least partly be termed as oil shales, these are either grey dolomitic marls and gypseous marls (with secondary laminae or impregnations of solidified oil originally introduced along bedding planes, joints and fractures etc) or normal oil shales, oil wetted mud lenses and oil-wetted carbonate pipes. Examples are Warcha (part), Kalabagh (part) in the Salt Range and Jatta in Kohat.

SURFACE DISTRIBUTION OF PRECAMBRIAN BITUMIN IN THE SALT RANGE AND KOHAT.

At numerous localities throughout the Salt-Range and Kohat salt area where considerable thickness of the Salt Range Formation is exposed, bitumin bands or impregnations may be observed associated frequently with anhydritic cherty dolomite, platty anhydrite/gypsum, dolomitic limestone and less frequently with salt, gypsum and saliferous gypseous marl. But this is true of the Salt-Range. In Kohat salt area petroleum impregnation is more common with salt, anhydrite/gypsum and saliferous gypseous marl than with the anhydritic cherty dolomite. Petroleum impregnation in grey hard limestone (unfossiliferous-?) has been observed only in Kohat (Jatta-East area) and nowhere in the Salt Range except of course in the limestone of Chorgali Formation in the Khabaiki oil seepage area Central Salt Range.

In the Salt Range, sills or dykes of the intrusive Khewra Trap (trachyte) are almost always associated with the bitumin films, bands or zones or any other representation of oil (oil shales, muds, marls etc). No such association has as yet been noted in Kohat. But this may be due to our failure in recognising the altered intrusive (s) there.

The following are main localities with marked bitumin developments within the Salt-Range Formation at the surface:–

Khewra gorge	Eastern Salt Range.
Makrach valley	,, ,, ,,
Sohal valley	Central Salt Range.
Warcha (Rukhla) valley.	
Kalabagh	Western Salt Range.
Jatta salt quarry	Kohat salt area.
Jatta-east area	,, ,, ,,

THE KHEWRA TRAP

Khewra Trap is so far understood to be an extrusive rock (trachyte) with stellate texture occuring as intercalations in the upper part of the Salt Range Formation in the eastern Salt Range only. Its maximum reported thickness is 6 metres.

Under the heading of 'stratigraphy' of his recently published geological map of the entire Salt Range, E.R. Gee, while briefly describing the Salt Range Formation, has referred to the Khewra Trap as follows (Gee, 1980).

"Salt Range Formation (Punjab Saline Series)-Massive gypsum/anhydrite, upper member with local oil-shales; in the east irregular intercalations of weathered? volcanic rock (khewra Trap) upto 6 m thick occur".

In the Geological Survey of Pakistan's 'Stratigraphy of Pakistan' (Shah, 1977) the Khewra Trap has been described in the following words under the heading of 'Salt Range Formation:–

"A highly weathered igneous body known as Khewra Trap has been reported from the upper part of the Formation. The Khewra Trap, also known as 'Khewrite' proposd by Mosebach (1956), is six metres thick and is purple to green in colour. It consists of highly decomposed radiating needles of a light-coloured mineral probably pyroxene".

Gee (1980) has given some idea regarding the mode of occurrence of the Khewra Trap within the Salt Range Formation but the Geological Survey of Pakistan (GSP) has been uncommital and generalised despite the fact that the stuff, both 'weathered' and fresh (unaltered), is exposed at the surface from place to place at numberous localities specially in the eastern & central Salt Range. The GSP's description also gives the impression as if Khewra Trap is one single body exposed somewhere with a definite thickness of 6 m.

Mode of Occurrence:– The mode of occurrence of the Khewra Trap, its relationship with the Salt Range Formation and still younger strata and its definite age are questions which are considered to have not so far been seriously thought upon and worked at. The issue is apparently not so simple and unifold as hitherto considered. As per field observations of the author the Khewra Trap is not only younger to the Salt Range Formation but also definitely younger to the Khewra Formation if not younger to the entire Salt-Range sequence from Precambrian to Eocene. As such, it may not be treated as a part of the Salt Range Formation in the stratigraphic sequence of the Salt Range. At the western flank of Khewra gorge it intrudes or 'affects' the basal part of the Khewra Formation and is clearly observed to have been deflected down back into the salt of the Salt Range Formation (fig. 5).

The Puzzling Relationship and Explanations:– The relationship of Khewra Trap (trachyte) with the pink-white banded cherty and petroliferous dolomite-anhydrite rocks and quite often with the bipyramidal quartz bearing marly anhydrite is interesting as well as puzzling. The close association of Khewra Trap and the two rock types and the termination of the latter with that of the former at the outcrops (fig. 5 & 15) gives the impression as if the whole suit is intrusive. Intrusiveness of the Khewra Trap may not be questioned but that of the dolomite-anhydrite rocks is a problem under the extents of present day geologic knowledge.

It is possible that the dolomite-anhydrite rocks are alteration products of some other rock type as has been with the violetish grey or violet-green mottled gypseous marl which, until the sinking of the Dulmial well, was considered to be evaporite. In such a case the oil would be assumed to have an inorganic origin.

It is also possible that the dolomite-anhydrite rocks represent the leached salt zones with rearranged and recrystallised residues of the salt as a result of the action of hot chemical solutions (associated with the instrusive Khewra Trap) on the salt. In this connection it is important to note that the average chemical composition of the impure anhydrite/dolomite rocks is roughly in conformity to the average composition of salt residue. The absence of much open cavities on account of such sizeable leaching may be explained by the continuous process of leaching and reprecipitation and massive migration of salt. In this case also the associated oil would be considered to have an inorganic origin.

The occurrence of oil in association with the Khewra Trap and the dolomite/anhydrite rocks could be explained by the maturity of the kerogen contents of the originally existing kerogenous dolomite and anhydrite from the heat and pressure generated by the intrusive Trap. This is supported by the intimate and non-exception tripartite relationship of Khewra trap, dolomite/anhydrite and oil. But the termination of the dolomite/anhydrite rocks and their intrusive nature alongwith that of the Khewra Trap as well as lack of intrusive effects on dolomite/anhydrite rocks remain to be explained.

Another plausible explanation of the co-occurrence of Khewra trap, dolomite/anhydrite and oil may be the detachment and dragging up of sheets of the more competent kerogenous dolomite-anhydrite beds from their original horizons by the up-thrusting Khewra trap dykes. This hypothesis solves one of the important aspects of the puzzle quite well. But the absence of intrusive effects: baking, recrystallization and mineralisation (skarn zones) of the much favourable impure dolomite host rock still remains to be explained specially in view of fact that the much intert Khewra Formation's shales show a marked skarn zone of about 3 to 15 m consisting of gypsified shales, TABLE – 1

Precambrian Basement Reservoirs of the World

S.No	Name of Field	Location of Field	Reservoir Rock	Nature of Porosity	Initial daily Production per well
1.	Orth	Rice County, Central Kansas Uplift U.S.A.	Precambrian quarzite	Fractures irregulary distributed	Average 20 barrels. Maximum 939 "
2.	Silica	" " "	" "	" " "	100 barrels.
3.	Beaver	Barton County Central Kansas Uplift U.S.A.	" "	" " "	55 barrels.
4.	Trapp	" " "	" "	" " "	173 barrels.
5.	Eveleigh	" " "	" "	" " "	434 barrels.
6.	Kraft Prusa	" " "	" "	" " "	108 barrels.
7.	Kraft Prusa	" " "	Arbuckle (?) dolomite	Fractures fissures, caverns irregularly distributed	From 0 to 3000 barrels. About 20% of wells produce 3000 barrels.
8.	Hall-Gurney	Russell County Central Kansas Uplift U.S.A.	Precambrian biotite granite	Joints, fractures irregularly distributed	Average 355 barrels.
9.	Gorham	" " "	Precambrian pink granite	" " "	306 barrels.
10.	Rengiu basement	Hebei Province, China	Precambrian dolomites and Cambro-Ordovician limestones	Fractures and caverns irregularly distributed both vertically and horizontally	7000 to 33,200 barrels.
11.	Xinglongtai basement oil and gas reservoir	Western part of Lower Liao River depression Lioning, China	Precambrian granite and Mesozoic Volcanic rocks	Mainly fractures	210 to 756 barrels.
12.	Bohai Bay Basin (Part)	E. China	Precambrian limestones and dolomites	Mainly fractures (?)	Data not available.
13.	La Paz	Maracaibo basin West Venezuela	Basements metamorphic and igneous rocks (Precambrian?)	Mainly secondary fractures irregularly distributed	Average 3600 barrels; maximum 11,500 barrels.
14.	Mara	" " "	" "	" " "	Average 2700 barrels, maximum 17000 barrels.

TABLE – 2

S.No.	Description	Locality	Chemical Composition: Fe %	SiO_2 %	Al_2O_3 %	CaO %	MgO %	SO_4 %	TiO_2 %	Na_2O %	Samples analysed by:	Mineralogical Composition	Samples analysed by:
745	Violet-green clayey rock.	Dhoda Wahan C. Salt Range	3.2	51.0	13.5	4.8	11.8	2.3	1.9	0.9	Ishtiaq Hussain Chief Chemist PMDC Labs. R'Pindi.	Clay–65.0%, Chlorite–20.0%, Quartz–4.0%, Sulphates–4.0%, Albite–0.5%, Microcline–1.0%, Hematite/Limonite–4.5%, Tourmaline–0.5%, Rutile–0.2% (as randomly distributed needles), Epidote – 0.3%.	M. Nawaz Chaudry Associate Professor Geology Deptt., Punjab University Lahore.
746	–do–	–do–	5.0	56.0	6.3	5.2	9.8	2.3	0.9	0.3	–do–	Clay–65.0%, Quartz–8.0%, (mainly as detrital grains) Chlorite–15.0%, Limonite/Hematite–6.0%, Gypsum/Anhydrite/Soluble sulphates–5.0%, Albite–0.5%, Tourmaline–0.3%, Rutile–0.2% (mainly as randomly distributed needles).	–do–
749	Greenish grey clayey rock.	Mari Indus W.Salt Range	2.0	52.3	16.5	4.8	10.7	1.8	1.7	1.5	–do–	Clay–45% (as a very heavy binding matter. In it float grains of quartz, feldspars and micas), Quartz–30%, Chlorite–16.0%, Microcline–1.5%, Albite–1.5% Muscovite–1.0%, Hematite/Limonite–2.0%, Sulphates–3.0%.	–do–
751	White-grey kaolinitic stuff	–do–	0.7	13.0	2.5	16.8	15.0	21.3	0.4	11.7	–do–	Clay–45% (as fine grained microcrystalline matter and as discrete crystals and crystal aggregates), Chlorite–15.0%, Soluble sulphates–8.0%, Chert–4.0% (with salt and pepper structure), Quartz –3.0% (mainly as sieve like crystals and grains), Anhydrite–20%, Carbonates–5.0%.	–do–
752	Dark grey, plastic clay	–do–	0.3	40.1	2.0	9.8	25.2	9.8	0.2	4.7	–do–	Clay–50.0%, Chlorite–20.0%, Anhydrite–20.0%, Soluble sulphates–8.0%, Quartz–2.0%.	–do–
754	Green, maroon, mottled clay	Kalabagh	2,1	31.8	5.6	14.0	17.7	14.4	2.1	0.2	–do–	Clay–40.0%, Gypsum/Anhydrite–25.0%, Chlorite–25.0%, Quartz–5.0%, Hematite/Limonite–3.0%, Albite–1.0%, Microcline–0.5%, Tourmaline–0.3%, Epidote–0.2%.	–do–

755	-do-	-do-	3.7	46.5	15.5	8.8	1.8	7.7	1.4	1.5	-do-	Clay-75.0%, Anhydrite-10.0%, Gypsum-6.0%, Chlorite-5.0%, Quartz-2.0%, Hematite/Limonite-2.0%.	-do-
756	Altered Khewra Trap from out-crop.	Makrach E.Salt Range	3.3	40.0	9.0	5.2	24.4	6.2	2.1	0.5	-do-	Clay-55.0%, Chlorite-20.0%, Limonite/Hematite-5%, Gypsum/Anhydrite -10.0%, Quartz-7.0%, Carbonates-3.0%.	-do-
759	Altered Khewra Trap core from Test Well.	Dulmial E.Salt Range	0.4	32.4	6.9	6.0	25.0	7.1	0.4	5.6	-do-	Clay-58.0%, Chlorite-18.0%, Anhydrite-15.0%, Gypsum-7.0%, Limonite/Hematite-2.0%.	-do-

flesh to red compact veins of banded anhydrite/gypsum and grey dolomite with films of oil (fig. 5) Detailed mineralogical studies have not yet been undertaken on the skarn zone for the presence of other minerals. This contact zone at Khewra has been mistaken by some of the previous workers as a transitional sedimentary contact between the Salt Range Formation and the Khewra Formation. Apparently an original and pre-existing sedimentary unit cannot be limited to and around some intrusive and absent elsewhere without a trace of it. At all places throughout the Salt Range where gypsum inclusions, veins or bands occur in the lower part of the Khewra Formation, it is in presence of Khewra trap below.

THE OIL BEARING CARBONATE ZONES AND THE KHEWRA TRAP.

The oil bearing carbonate zones of the Salt Range Formation appear to represent cyclic evaporites which were occuring in a normal sequence with the salt in the original Salt Range Formation. During salt diapirism these zones seem to have been disturbed, folded and 'uprooted' from their original places of occurrence and started migrating with salt toward the elongated rupture plane of the Salt Range diapir to be ejaculated with salt at the present day Salt Range.

Conditions indicate that prior to diapirism the Salt Range Formation was intruded from place to place by the sills and dykes of the trachyte (Khewra Trap). This circumstance resulted in the folding and displacement of the trachyte sills and dykes alongwith the cyclic evaporite zones during mass migration of salt. Quick alteration of the trachyte into an ash grey, violetish-greenish or rarely, malachite-green clayey stuff hindered its recognition at so many places in the Salt-Rang as an igneous rock until the drilling of the Dulmial test well for salt Solution Mining Project by PMDC during 1984-85. At this well the Khewra Trap occupies a total well length of 96.6 metres in two zones enclosing in between a 23.8 metres thick zone of rock salt, dolomite, anhydrite and bitumin. Against this the maximum thickness of Khewra Trap reported so far in the Salt Range is 6 metres. At the Dulmial well also all of the upper and altered Khewra Trap was reported as 'violetish grey rubbly gypseous clay' till encountering the unaltered trap below. A re-examination of various violetish-greenish clays occuring throughout the Salt Range and hitherto considered as a part of the evaporite suit of the Salt Range Formation, gave the impression as if most, if not all, of them were altered intrusives. Their chemical and mineralogical compositions also match well with that of the altered Khewra Trap from outcrops of Makrach etc. and from the Dulmial well. Table 2 gives a comparative study of the chemical and mineralogical compositions of the various suspected altered intrusives of Kalabagh, Mari Indus and Dhoda Wahan areas with that of the established Khewra Trap (altered from Makrach area and from PMDC's Dulmial Test well (core sample).

Fresh field studies have also indicated that the bipyramidal quartz crystals occuring within a complex marly anhydrite at Kalabagh, Mari Indus, Dhoda Wahan valley and in Warcha salt areas are always associated with the suspected intrusives. Their intrusive attitude specially in parts of Warcha and Kalabagh areas was previously explained as a result of differential movement and flowage of different evaporite bodies within the salt mass during salt migration.

TEST WELLS IN THE PRECAMBRIAN/CAMBRIAN STRATA.

Table-3 gives a brief account of the test wells which have partly or full explored the Precambrian/Cambrian strata in the respective regions:—

TABLE – 3

Precambrian – Cambrian Test Drilling Account.

Modified after M. Sajid Abid (1980) and Pakistani Texasgulf Inc (1976)

S.NO.	YEAR	WELL & COMPANY	TOTAL DEPTH FORMATION	REMARKS
1.	1947	Joya Mair-3 AOC (Potwar)	2748 m Salt Range Fm.	First Well to hit oil in Khewra Fm.(Cambrian)

2.	1953	Dhariala–1 POL (E. Salt Range)	2596 m Salt Range Fm.	Oil shows in Salt Range Fm.(Precambrian)
3.	1958	Kallar Kahar–1 POL (E. Salt Range)	2173 m Salt Range Fm.	Oil shows in Salt Range Fm.
4.	1958	Nand Rakhi–1 POL (Kohat)	1042 m Salt Range Fm.	No shows
5.	1959	Karampur–1 Shell Oil Multan	3034 m Basement	Shows of heavy oil, and bitumin in Salt Range Fm.
6.	1960	Mahesian–1 POL (E. Salt Range)	379 m Khewra Fm.	No shows
7.	1964	Dhulian–43 AOC (Potwar)	3788 m Salt Range Fm.	No shows
8.	1964	Bahadur Khel GSP (Kohat)	1375 m Salt Range Fm.	No shows
9.	1965	Kundian–1 PPL/POL (S. plains S. Range)	2160 m Khewra Fm.	No shows
10.	1970	Marwat PPL (Bannu)	2210 m Khisor Fm.	No shows
11.	1971	Karang OGDC (C. Salt Range)	1081 m Salt Range Fm.	No shows
12.	1974	Sarai Sidhu–1 AMOCO (Multan)	3280 m Salt Range Fm.	No significant shows
13.	1978	Adhi–5 PPL/AMOCO (E. Potwar)	2808 m Salt Range Fm.	Oil Tested/In production. Khewra Fm.
14.	1982	Varnali Shell Oil (S. Plains Salt Range)	2807 m Basement.	No shows
15.	1983	Lilla Shell Oil (S. Plains Salt Range).	1925 m Salt Range Fm.	No shows
16.	1985	Dulmial–1 PMDC (E. Salt Range).	792 m Salt Range Fm.	Shows of bitumin and gas in Salt Range Fm.

DETAIL OF IMPORTANT WELLS.

Attock Oil Company's Dhariala Test Well (Salt Range):– **AOC selected this site for oil apparently in view of a gravity low and the axis of the so called Khajula anticline. The well remained in the Salt Range Formation from 448 m to 2596 m. Details are as given in Table – 4 (modified after AOC):–**

TABLE – 4

S.No.	Lithologic Unit	Well depth (m) From	To	Net interval (m).	Calculated thickness according to dip (m).
1.	Silt stone; veins of gypsum, anhydrite with chert.	448 –	476	28	28
2.	Rock Salt				54
3.	Dolomite with bitumin bands.				7.3
4.	Khewra Trap	476 –	699	223	3 100
5.	Rock Salt				16.8
6.	Red marl.				4.3
7.	Rock Salt				14.6
8.	Marls with thinbeds of rock salt and in-traformational breccias (?) of marl & rock salt.	699 –	883	184	107
9.	Massive rock salt.	883 –	1041	157	61
10.	Massive rock salt with anhydrites and brecciated dolomites.	1041 –	1350	309	253
11.	Massive rock salt	1350 –	2596	1246	1045

N.B. Two saturated potash brine flows were encountered at 1200 m (1500 barrels per hour) and at 1346 m (8 barrels per hour).

POL's Kallar Kahar Well (Salt Range): **– The well is located at the northern flank of central Salt-Range. It touched the Salt Range Formation at 1969 m and remained within the same till 2173 m when it was abandoned. From 2016 m upto 2134 m the well remained in salt and from2134 m to 2173 m it crossed a zone of petroliferous dolomite which continued. In its unpublished report 'Exploratory Wells of Pakistan' (1976) the Pakistani Texasgulf Inc has reported 'traces of heavy oil' in the Saline Series (Salt Range Formation). However the POL's Drillers and Mud Engineer have reported (personal communication) bitunin bands and active evolution of gas from certain cores of the Salt Range Formation.**

Shell Oil Company's Karampur Well (Multan): **This well is located about 322 Km south of the Salt Range in the Multan plains of southern Punjab. Detailed log could not be made available. As recorded in the 'Exploratory Wells of Pakistan' by the Pakistani Texasgulf Inc the well encountered 'shows of heavy bitumin in dolomite intercalations from the Salt Range Formation'.**

The well crossed the entire thickness of the Salt Range Formation from 2100 to 3034 m.

PMDC Dulmial Well (Salt Range): **This well is located**

about five kilometres south-west of ACC's Dhariala well. It has been drilled as an exploratory well for PMDC's Salt Solution Mining Project and not for oil. Total depth of the well is 792 m. It entered the Salt Range Formation at 499 after crossing the Eocene-Cambrian section which was rather abnormal for the locality. It encountered three distinct oil/bitumin zones at 519, 583 and 593 m in association with a cherty dolomite. Upper zone was lean while the middle and lower ones were quite rich. The basal zone also bore considerable gas. The middle and basal zones were completely sandwiched in the intrusive Khewra Trap (a maroonish black trachyte) which was noted to be abnormally thick in this well as compared to other localities throughout the Salt-Range.

At fig. 7 appears log of the well. In the following is a brief description of various units crossed in the well from the upper (?) contact of the Sait Range Formation down to the start of massive salt:–

1. 498.9 to 499.5 m
A mechanical mixture of grey anhydrite and grey-black mainly friable and in places spongy or vesicular dolomite. At lower part occurs a vertically trending wavy band of grey-black dolomite.

2. 499.5 to 500.0 m
Reddish rubbly gypseous clay showing minor fractures with dislocations. Traversed by grey anhydrite/dolomite veins.

3. 500.0 to 502. 8m
Maroon marl with specks, inclusions and bands of greyish green marly stuff.

4. 502. 8m to 503. 3m
Grey to dark grey dolomite. Upper half brecciated but compact.

5. 503. 3m to 505. 10m
Dirty pink 'residual soil of salt' type mass consisting of a mixture of dirty while anhydrite/dolomite and pink rubbly marl. No regular layering in general but irregular fragments of anhydrite/dolomite at places inclined at 45°. Core recovery only about 50%.

6. 505.1 to 511.4m
Grey thin bedded surgary dolomite consisting of alternate layers of light and dark brownish grey colour. From place to place shows wavy bedding. Upper most part shows 35° dip, rest is almost horizontal. Core recovery almost 100%.

7. 511.4 to 518.7m
Grey-white gypsum/anhydrite with few bands of colourless rock salt ranging in thickness from 5 to 10 cm, core recovery of almost 100% (518.1-518.5 m non-coring).

8. 518.7 to 523.3m
It is the first oil zone consisting of jet black bitumin bands, films and inclusions in pink-grey porous cherty dolomite. Films of oil (bitumin) often underlie and overlie the impure cherty bands. Salt bands/veins and inclusions occur in association with the oil from place to place. Inclusions of anhydrite/gypsum also occur from place to place. Dip flat to mild. Core recovery about 100%.

9. 523.3 to 532.2 m
Grey-white gypsum with subordinate dolomite/anhydrite. Thin bands and inclusions of pink-colourless salt occur from place to place.

10. 532.2 to 574.4m
Altered Khewra Trap consisting of violetish grey rubbly gypseous clay bearing abundant angular to sub-angular fragments of gypsum and chert etc. Chert inclusions are characteristic of mainly the upper part. They are rust-brown and show cellular or relict structure, holes and other signs of secondary chemical activity. It may be remembered that quartz and chalcedony amygdules are found in the fresh Khewra Trap at Khewra gorge.

A characteristic feature of the altered trap is the fine greyish blue rounded gypseous (?) inclusions occurring throughout. At places the violetish grey colour is replaced by greenish grey with other characters remaining the same.

11. 574,4 to 579.9m
White-grey banded and solid unleached salt having a sharp and blunt contact with the overlying altered Khewra Trap which is badly leached. Upper part flat lower gently dipping, base quite steep. Basal contact with anhydrite band also sharp. Core recovery 100%.

12. 579.9 to 579.9m
Grey anhydrite. Dip . . . . .30°.

13. 579.9 to 580.0m
Grey salt with dolomite bands. Dip. 30°.

14. 580.0 to 583.1m
Pink dolomite and brownish grey chert alternating. Thin bedded to platy., A few salt filled fissures at upper and middle parts. Thin bitumin films between chert and dolomite bands. Dip. 50° to 18°. Core

recovery 100%.

15. 583.1 to 587.1m
2nd oil zone* consisting of jet black bitumin, pink dolomite and grey chert. Dolomite occurs as bands and lenses while chert as lenses and eyes. At lower part remifications of salt and anhydrite. The basal about 0,3m consists of angular fragments of dolomite and chert floating in black oil (bitumin), Dip irregular from 80° to 30°. Core recovery 100%.

16. 587.1 to 587.5m
Pink-brown dolomite platy, vesicular and disturbed.

17. 587.5 to 590.2m
White-grey and brownish grey smoky banded salt. Dip 15° to 20°. Core recovery 100%.

18. 590.2 to 590.7m
Grey anhydrite, upper contact with salt sharp lower with dolomite/chert gradational. Core recovery 100%.

19. 590.7 to 591.3m
Thin bedded platy dolomite and chert alternating. Dolomite is buff, chert is brownish grey. Dip 10° to 15°. Core recovery 100%.

20. 591.3 to 592.2m
Replacement zone. Core is roughly divided into two halves vertically. One half consists of alternating thin bands of dolomite and chert while the other of colourless salt with angular fragments of dolomite and chert. Orientation of isolated fragments of dolomite and chert in salt coinciding with that of the adjacent dolomite/chert in situ indicates as if the salt has successively eaten up or replaced the dolomite/chert.

21. 592.2 to 593.3m
Buff platy dolomite and grey-black chert alternating. Thin oil films at dolomite-chert contacts. Dip 10°. Core recovery 100%.

22. 593.3 to 596.3m
3nd oil zone, consisting of grey-black and brownish bitumin, brownish grey chert bands and eyes and subordinate pink-buff dolomite bands (fig 7). Cherty eyes prominent at lower part. At the base a typical salt remification and a thin band and few lenses of pyrite are characteristic. Gas bearing. Gas bubbles appeared in the suction pit during drilling while emission of gas bubbles continued from the core for a period of more than 25 hours since recovery of core from the well. Dip 10° to 15°. Core recovery 100%.

23. 596.3 to 596.7m
Grey anhydrite with irregular inclusions and remifications of salt at lower part Dip- Not clear. Core recovery 100%.

24. 596.7 to 597.2m
Pink to buff dolomite and grey chert alternating, thin to medium bedded. Dip 8°– 10°. Core recovery 100%.

25. 597.2m
Fault. Dip – 70°.

26. 597.2 to 597.9m
Grey and pink anhyrdite with grey pyrite inclusions at upper part and pink dolomite inclusions and a thin band of colourless salt at lower part. Basal contact with Khewra Trap irregular and undulating. Dip – 24°. Basal contact – 13°. Core recovery about 100%.

27. 597.9 to 636.5m
Altered Khewra Trap, consisting of violetish grey to greenish grey rubbly gypseous clay criss crossed by veins of red gypsum and colourless salt No dip in the rubbly clay. Gypsum and salt viens inclined generally at 0° to 20° but at places very steep to vertical. Core recoveryabout 100%.

28. 636.5 to 652.7m
Mainly unaltered Khewra Trap with altered clayey/rubbly zones from place to place. Red gypsum and colourless salt veins and inclusions occur throughout. The relatively unaltered trap is a maroon massive rock with rich distribution of greenish (altered) actinolite needles arranged as stars. The acicular stellate mineral is criginally some pyroxene of black colour as indicated by fresher samples elsewhere.

Preliminary geochemical pyrolysis results of the core samples belonging to the three oil zones described above under Nos. 8,15 and 22 are presented in table-5. Their details will be presented elsewhere.

PROSPECTS INDEPENDENT OF STRUCTURES OF UPPER STRATA.

While the enclosure by salt of the Precambrian oil's source/reservoir rocks (cherty dolomite and dolomitic marls), has prevented the upward migration of the oil into the more favourable and 'spacious' reservoirs of Khewra Formation etc., it has also been beneficial by way of extending the prospects of oil/gas in all areas underlain by

TABLE – 5

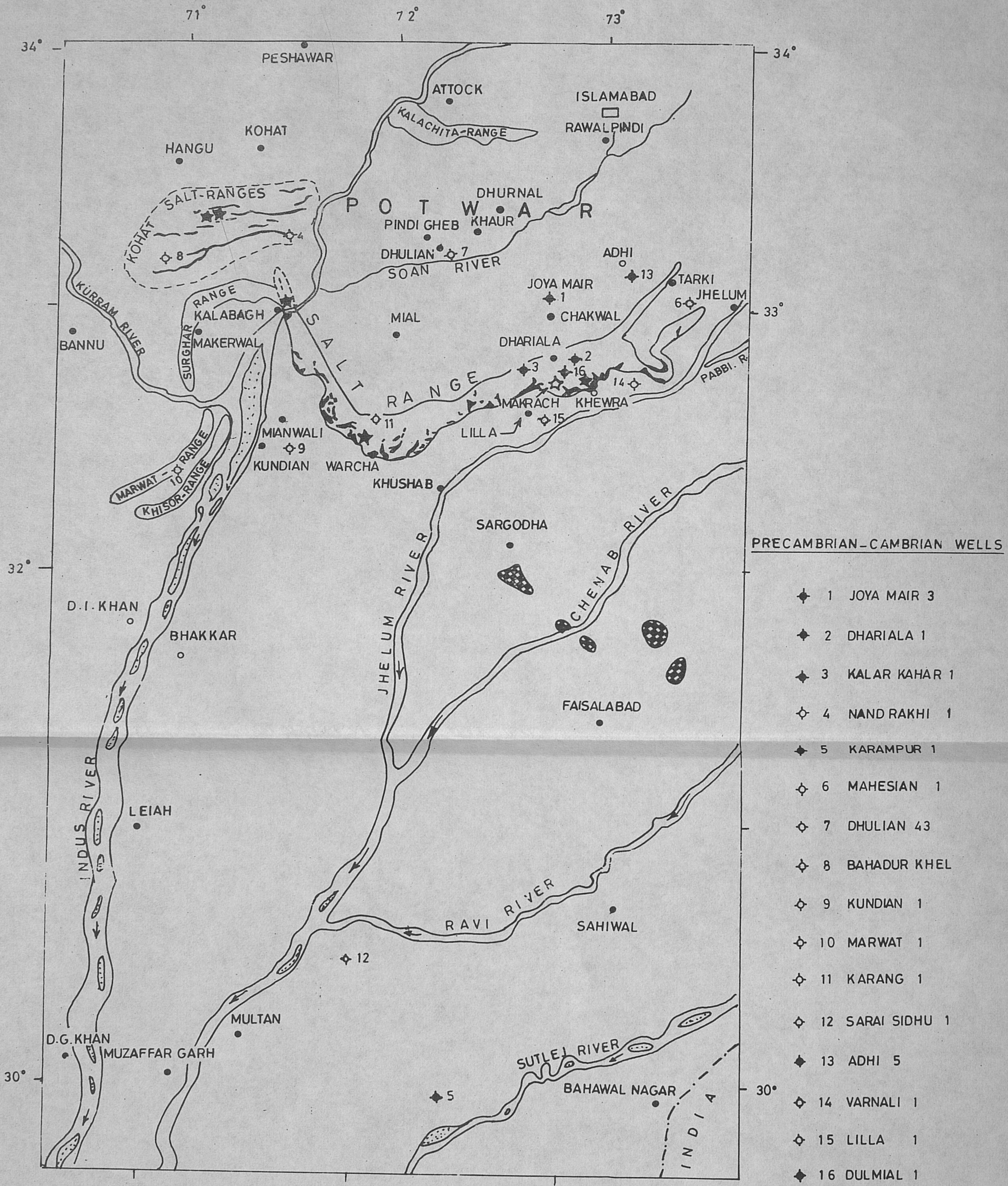
DULMIAL CORE SAMPLES ANALYSIS

BY OCCIDENTAL OF PAKISTAN INC.,

Preliminary Geochemical Pyrolysis results :

Depth	CO^3 Content (Percent)	Total Organic Hydrocarbon (Percent)	Free Hydrocarbon S1 (mg/gram)	Pyrolysis Hydrocarbon S2 (mg/gram)	S3 (mg/gram)	TMAX (°C)
1712.08'	28.6	7.52	6.58	38.72	0.78	435
1713.08'	54.6	9.49	11.74	55.75	0.75	436
1918.83'	88.7	7.43	19.10	57.74	0.99	435
1921.08'	30.2	7.37	7.10	47.50	0.85	436
1953.25'	7.7	20.07	19.62	116.85	0.61	434
1954.0'	14.6	5.63	6.75	38.92	0.81	436

Both S1 and S2 values are quite high, and thus could represent contamination by migrated hydrocarbons. Repeats of the above samples were solvent-extracted adn re-pyrolyzed These data will be available in the final geochemical report.



NB. 1 SALT EXPOSURES OF SALT RANGE AFTER.........E.R. GEE
2 SALT EXPOSURE OF KOHAT AFTER.........C.R. MEISSNER & OTHERS

SALT-RANGE FORMATION OUTCROPS

TEST WELL DRY

TEST WELL IN WHICH PRECAMBRIAN OIL/GAS SHOWS WERE ENCOUNTERED

PRECAMBRIAN OIL SHOW

PRECAMBRIAN GAS SHOW

PRECAMBRIAN BASEMENT OUTCROPS

SCALE 0 20 MILES / 0 30 Km.

FIG.NO.1

PRECAMBRIAN OUTCROPS, WELLS AND OIL/GAS SHOWS IN THE PUNJAB AND KOHAT

BY S.H.FARUQI

the Salt Range Formation. Further, this circumstance has also made the prospects of oil/gas in the said areas independent of structures of overlying formations from Cambrian to Pleistocene. This point may be elaborated as follows: Presently all of our hopes of getting oil/gas hang around the structures (mainly the anticlines) within the Cambrian to Pleistocene strata. But with the new thinking we shall not restrict ourselves to these upper or Cambrian-Pleistocene rock structures rather look for the deep seated structures within the Salt Range Formation as well. These structures are constituted by the cherty dolomite-trachyte zones' or simply the 'carbonate zones'. In the previous papers (Faruqi, 1983, 1984–a), these zones have been referred to as 'green zones'.

RE-INTERPRETATION OF GRAVITY LOWS.

It is quite probable that the various 'gravity lows' at the gravity map of the Salt Range by OGDC are reflecting the oil/gas reservoirs within the Salt Range Formation's internal traps constituted by the carbonate zones.

Test wells put at a number of gravity lows at the Salt-Range and at southern plains did not encounter any thing in the upper sequence which could account for the 'lows'.

PROSPECTS OF PRECAMBRIAN BASEMENT RESERVOIRS IN PAKISTAN.

"Oil may accumulate in an igneous, metamorphic or sedimentary rocks with secondary fissures, dissolved interstices and caverns or in sandstone and carbonate rocks with primary porosity . . . .

Basement reservoirs are characterised by thick reservoir rocks. Porosity and permeability are irregular. Production from basement reservoirs is usually high and reserves are large".

(Chung-Hsiang, 1982).

The hydrocarbon potential of the Precambrian rocks is not limited to Salt Range Formation. Since the oil bearing Salt Range Formation directly overlies the Precambrian basement of hard and brittle metasedimentary and igneous rocks, there are quite good chances of basement reservoirs. The chances of basement reservoirs further improve by the presence of carbonate (ankerite) detailed studies of the basement rocks at Kirana Hills near Sargodha by Davies and Carwford (1971).

This circumastance further increases the prospective hydrocarbon area in Pakistan to a great extent. It also follows that all test wells to be drilled for Precambrian-Cambrian reservoirs in Pakistan should, wherever possible, go upto and into the Precambrian basement for 60 to 90m at least. Special efforts are to be made to extend such exploratory or development wells upto the basement as located on basement 'highs' or uplifts which hold better prospects of basement reservoirs due to higher possibilities of secondary porosity. Higher secondary porosities are expected on such structural highs due to prolonged weathering and erosion which such highs are understood to have suffered.

CONCLUSIONS

In consideration of the foregoing duscussion it would not be unjustified to conclude that Precambrian rocks, both sedimentary and nonsedimentary types, hold good prospects for commercial sources of oil/gas of the future in Pakistan. Proper attention should therefore be paid for the exploration of this new field which however demands an exploration philosophy entirely different to what has been followed till now.

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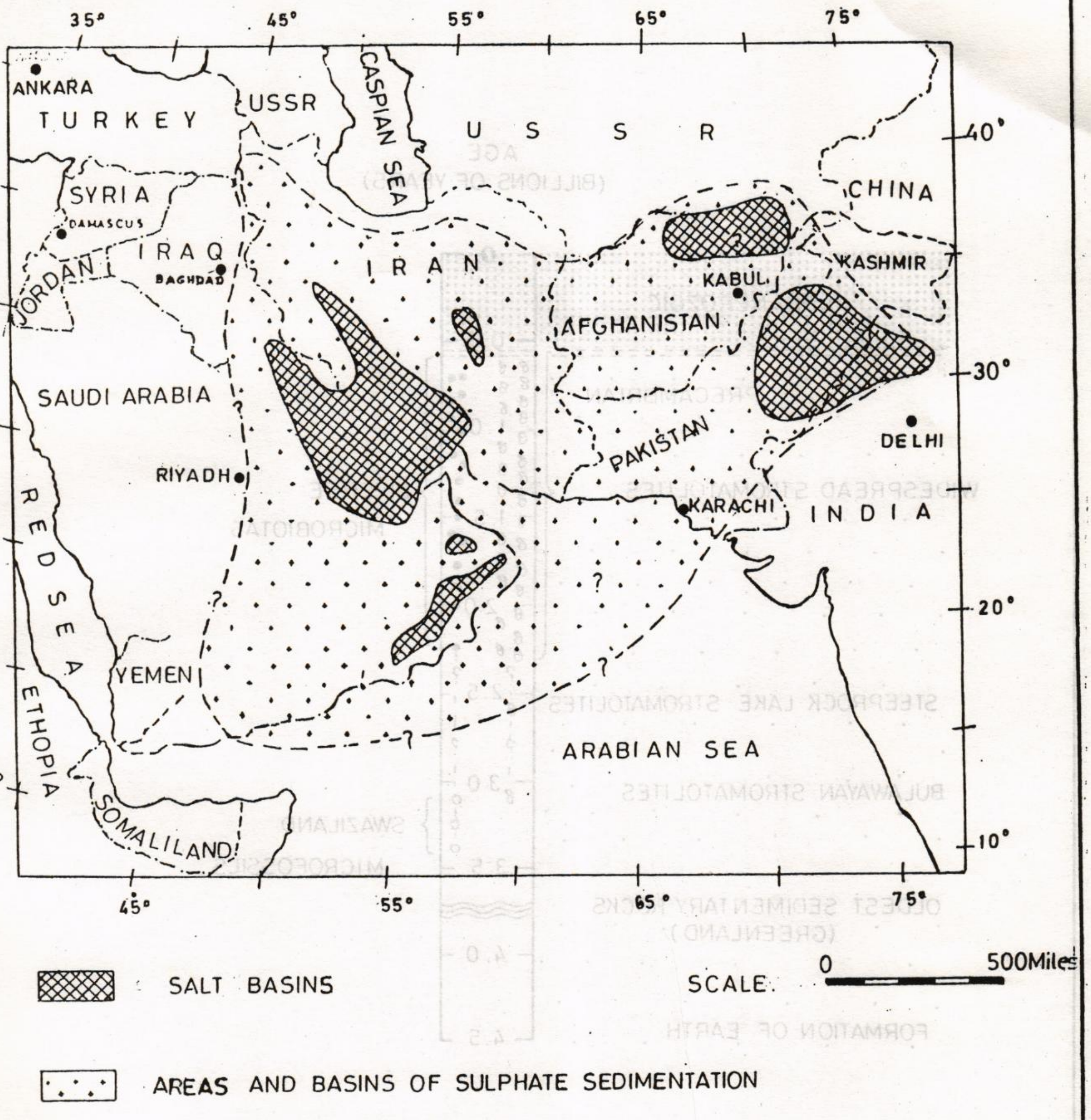


FIG. NO. 2

DISTRIBUTION OF LATE PRECAMBRIAN_UPPER CAMBRIAN IN PAKISTAN AND ADJOINING COUNTRIES

MODIFIED AFTER G.E GORIN et al.(1982) AND MICHAIL A.ZHARKOV (1984)

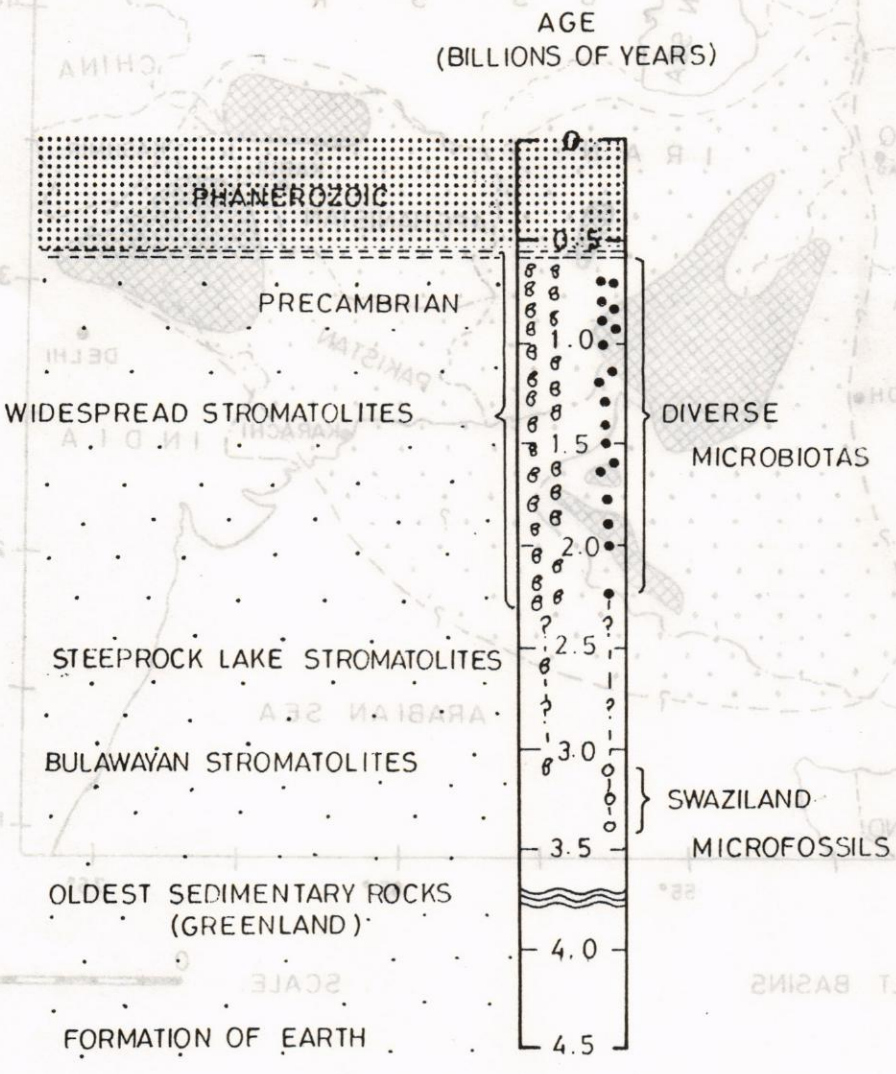


FIG. NO. 4

PRECAMBRIAN EVOLUTION AT A GLANCE

MODIFIED AFTER SCHOPF (1975_76)

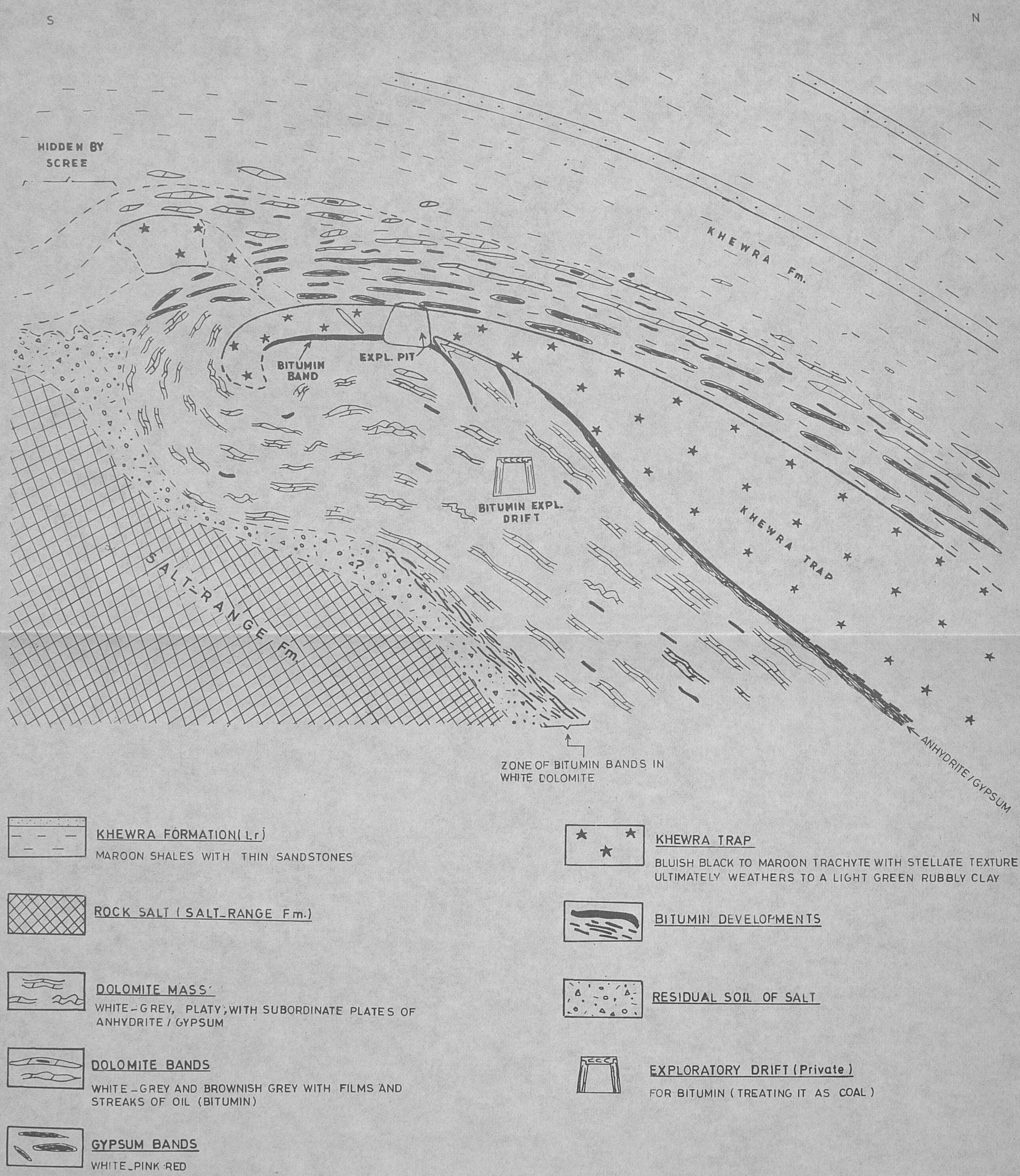
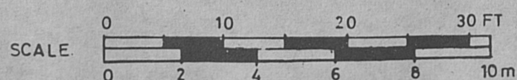
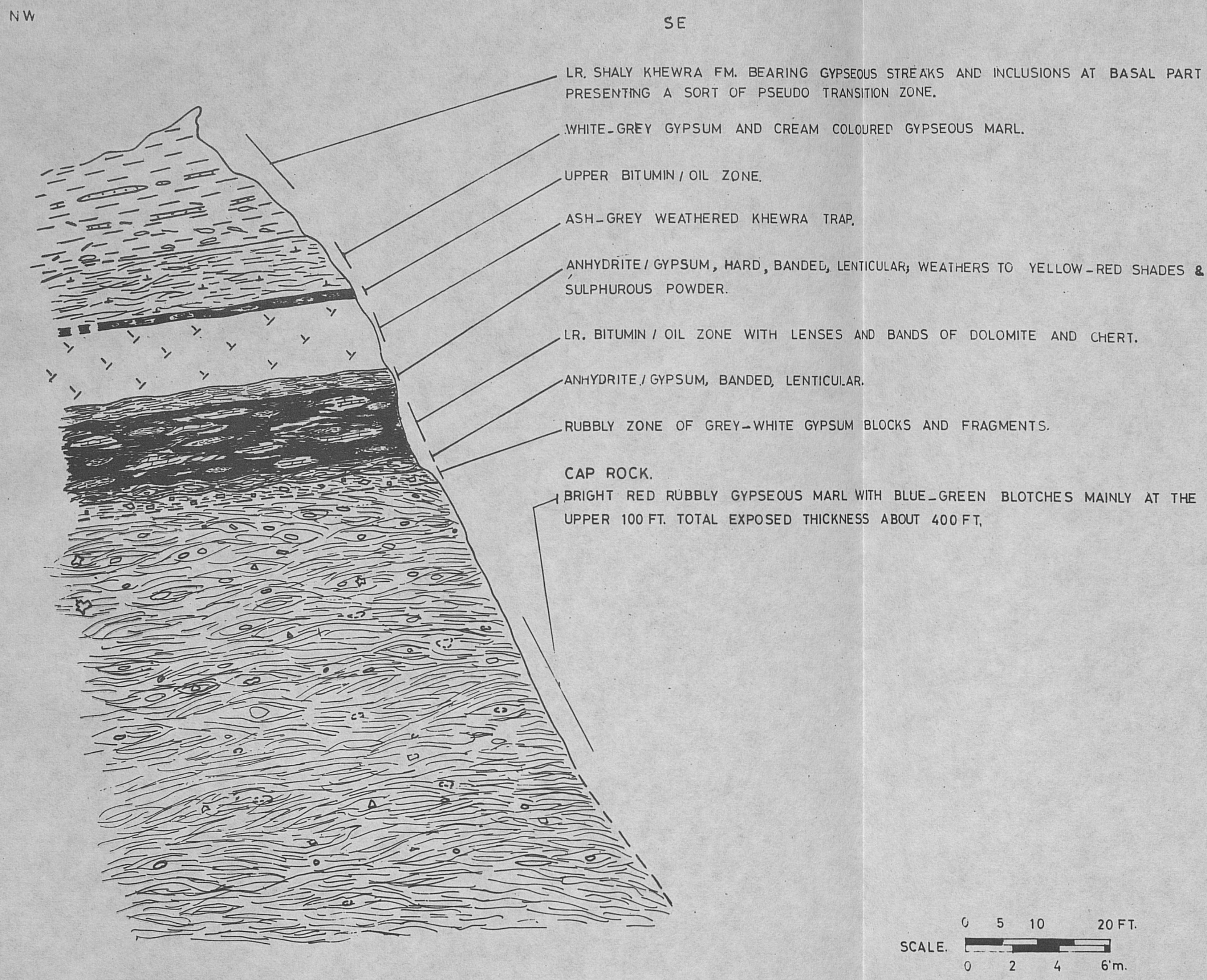


FIG. NO. 5

GEOLOGICAL SECTION ACROSS BITUMIN EXPL. DRIFT POINT WEST FLANK KHEWRA GORGE SHOWING RELATIONSHIP OF BITUMIN DEVELOPMENTS AND THE INTRUSIVE KHEWRA TRAP



DRAWN BY: S . H . FARUQI
TRACED BY. M. SAFDAR ASSTT. SURVEYOR



ENCL. NO. 9

GEOLOGICAL SECTION ACROSS THE UPPER TRAP/ OIL POINT NEAR 1ST SALT POST RIGHT FLANK SOHAL VALLEY PIR KHARA AREA CENTRAL SALT RANGE

BY S. H. FARUQI

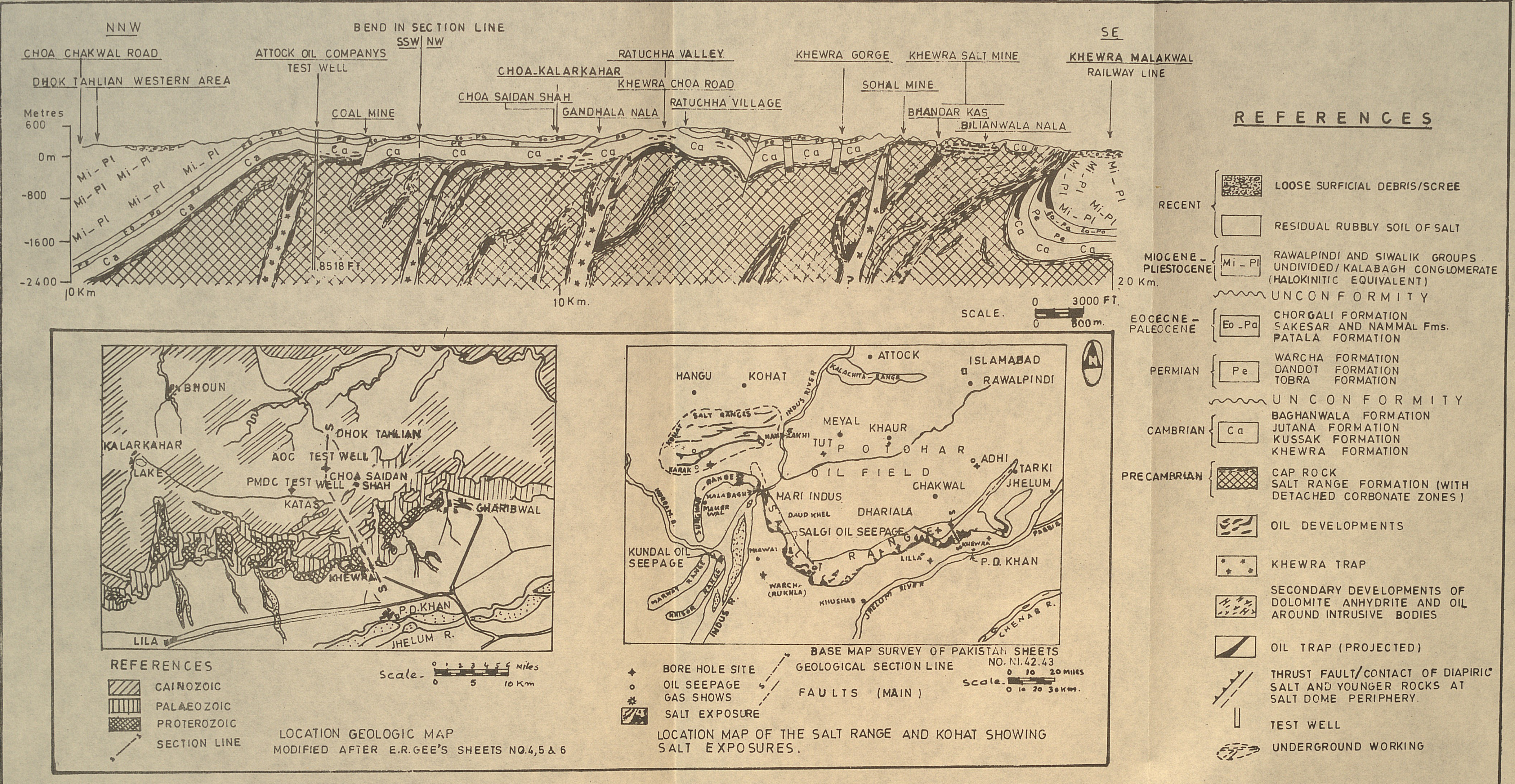


FIG. NO. 11

GEOLOGICAL SECTION ACROSS THE SALT RANGE FROM KHEWRA TO DHOK TAHLIAN

DRAWN BY S.H. FARUQI CHIEF GEOLOGIST
M. IQBAL QURESHI A.M. (TECH)

GEOLOGICAL INVESTIGATIONS IN THE RESHIAN AREA (Jhelum Valley, State of Azad Jammu and Kashmir)

ANTONIO GRECO

Geological Institute ETH,
CH-8092 Zürich, Switzerland.

ABSTRACT: - Petrographical and structural geology investigations have been carried out in the Panjal Volcanics, Triassic Limestone, and Salkhala Series exposed in the Reshian area. The study of the microstructures shows a complex relationship between deformation and metamorphism. The highest metamorphic grade - greenschist in the volcanics and amphibolitic in the Salkhala - has been reached before the main deformation phase. Retrograde mineral paragenesis is pre- to synkinematic. Only in the upper part of the investigated area the highest metamorphic conditions seem to persist during the deformation. Shear was the most important mechanism. Due to the thrusting of the Salkhala over the Panjal and over the Murree Fm. a penetrative, continuos schistosity has been developed. Its trend is subparallel to the bedding and the thrust planes, and it is accompanied by an intense stretching lineation, showing the NE-SW direction of tectonic transport. In a later phase the crenulation cleavage, which cuts the previous structures, has been developed in the less competent rocks. All these events agree with the tectonic model elaborated by Bossart et al. (1984).

INTRODUCTION

The present work includes an investigation of the rocks exposed along the road Lamnian-Reshian-Bratwar Gali (Jhelum Valley, Azad Jammu and Kashmir). The aim of the description of the different lithological units is to provide a framework for the discussion of the main petrographical and tectonical problems of this zone. A comprehensive description and interpretation of the different complex features is not given, as this requires a more systematical and regionally extended investigation. Nevertheless this work should be understood in the context of the structural studies of the Hazara-Kashmir Syntaxis of Bossart et al. (1984).

I would like to thank S.Tayyab Ali, Dr. M.Ashraf and all the staff of the Institute of Applied Geology,.University of Muzaffarabad (AJK), R.H.Malik and S.Qureshi of the Azad Kashmir Mineral and Industrial Development Corporation, Muzaffarabad, Prof. Dr. J.G.Ramsay, P.Bossart, Dr. D. Dietrich and R.Ottiger of the ETH Zürich (grants nr. 0.330.084.48/4 and nr. 0.330.010.10/9) for the cordial and precious help during the field work and the compilation of the manuscript.

GEOLOGICAL SETTING

The investigated area lies at the eastern limb of the Hazara-Kashmir Syntaxial bend. According to previous works (for ex. Calkins et al.,1975) the section is divided into three principal tectonic units, separated by two major thrust faults (Table 1, Fig. 1). From SW towards NE they are:

The *Murree Formation* is composed of graded sandstone and siltstone in cyclically alternated stratification. The frequent polarity changes of the strata and the development of dissolution cleavage mark the folding of this formation. The folds are asymmetrical (Fig.1) and related (parassitic) to the <<Muzaffarabad anticline>>. Nevertheless the stratas generally face NE towards the Murree Thrust. Although fossil finds in Chakothi (Jhelum Valley, 7 kms SE of Chinari ; Feistmantel, 1879) may suggest a Lower-middle Miocene age, recent investigations of Ottiger R. and Bossart P. (in prep.) on syndepositional nummulites and assilines collected in the Kaghan Valley show the Latest Paleocene to Middle Eocene age of the lower part of the Murree Formation.

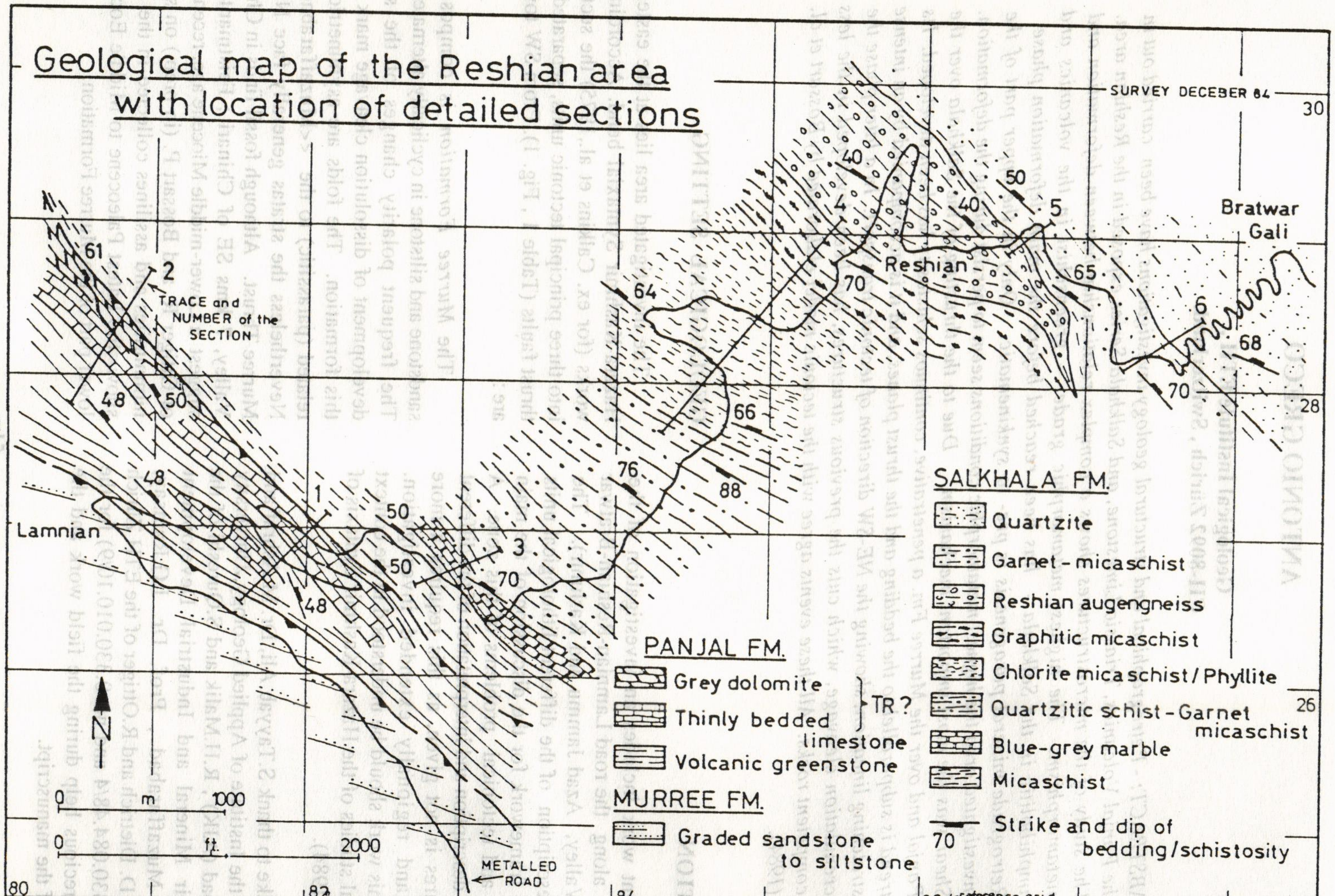


Table 1. Geological map of the Reshian area with location of detailed sections.

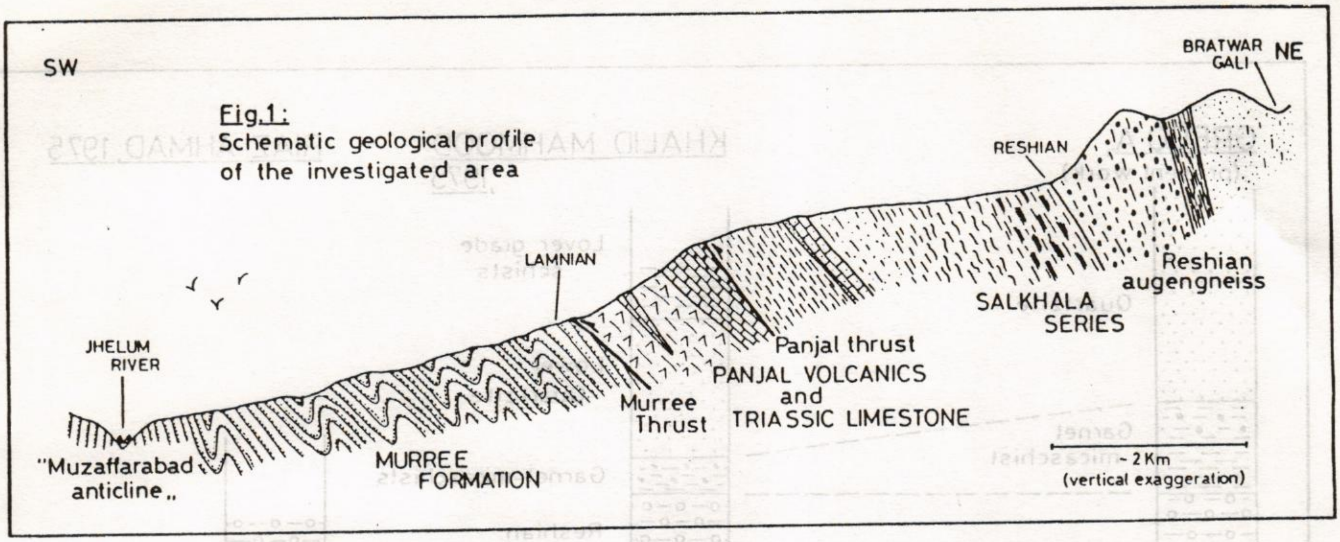


Fig.1 : Schematic geological profile of the investigated area.

The *Murree Thrust* trends about NW-SE and plunges 50 degrees to the NE. It divides the overthrusted metamorphic rocks from the anchimetamorphic Murree Fm.

The second unit consists of the Panjal Volcanics and of probably Triassic Limestone and Dolomite. The *Panjal Volcanics* are composed of characteristic greenstone, touffaceous layers, subordinated micaschists and interlayered thin beds of marble and limestone. The assumed age is Carboniferous to Permian. Towards the Panjal thrust the carbonaceous rocks become more important and similar to the *Triassic Limestone and Dolomite* of the Kaghan Valley (Bossart et al., 1984). These rocks lie also at the stratigraphical top of the volcanics.

The *Panjal Thrust* divides the volcanic rocks from the older crystalline Salkhala Series, with the same trend and plunge like the Murree Thrust. The fault is not so clearly defined : small lithological differences between the two units and other associated minor thrusts in the mica schist zone render the identification difficult.

The rocks of the *Salkhala Series* are mica schists, chlorite schists, garnet mica schists, graphitic schists, phyllites, amphibolitic schists, quartzites, marbles, quartzofeldspatic gneiss, gypsum and lenses of mafic rocks. This very complex rock sequence has been subdivided in different lithological units comparable to previous works (Fig.2). The accepted age is Precambrian.

THE PANJAL FORMATION

The rock is very schistose, finely grained, of green, sometimes violet colour, and composed dominantly of magnesium chlorite, epidote and plagioclase. Actinolite, muscovite, ores and quartz are subordinated minerals. The widespread rock type is also the finely grained and laminated chlorite epidote schist.

Characteristic is the spotted appearence due to the black to dark green amygdules and to the red and white mineral aggregates. Most of the <<black blebs>> are composed of ore minerals (a mixture of ilmenite-sphene) surrounded by epidote and dark green iron chlorite (ripidolite). These mineral aggregates are wrapped by the white grey magnesium chlorite (penninite), micas and epidote ; the colour contrast gives the spotted appearence. This texture should correspond with a primary structure (i.e. gas vescicules) now filled by metamorphic minerals and - as the shape of the blebs shows - deformed into prolate, constricted ellipsoids (X:Y = 3.51 , X:Z = 11.71 , Y:Z = 3.54 , k = 1.07). The red aggregates are remains of interlayered clays, whereas the white ones are composed of the original plagioclase which crystallized in the lava.

Flow banding and degassing structures are visible and define the trend of the original banding. A strong, pervasive tectonic schistosity is developed subparallelly and cuts only rarely the bedding. Other macroscopic structures are small shear zones, asymmetrical tight folds and mullions. Its fold axes are parallel to the stretching lineation (the longest axis of the black blebs).

Shearing is frequent along the schistosity planes itself and can be observed at conjugate shear zones in the plagioclase aggregates (Fig.3) or at the rotation of porphyroblasts. The shape of the folds, the high value of strain and the directly visible structures are evidences of the shear deformation mechanism, corresponding to the thrusting of the Panjal on the Murree formation.

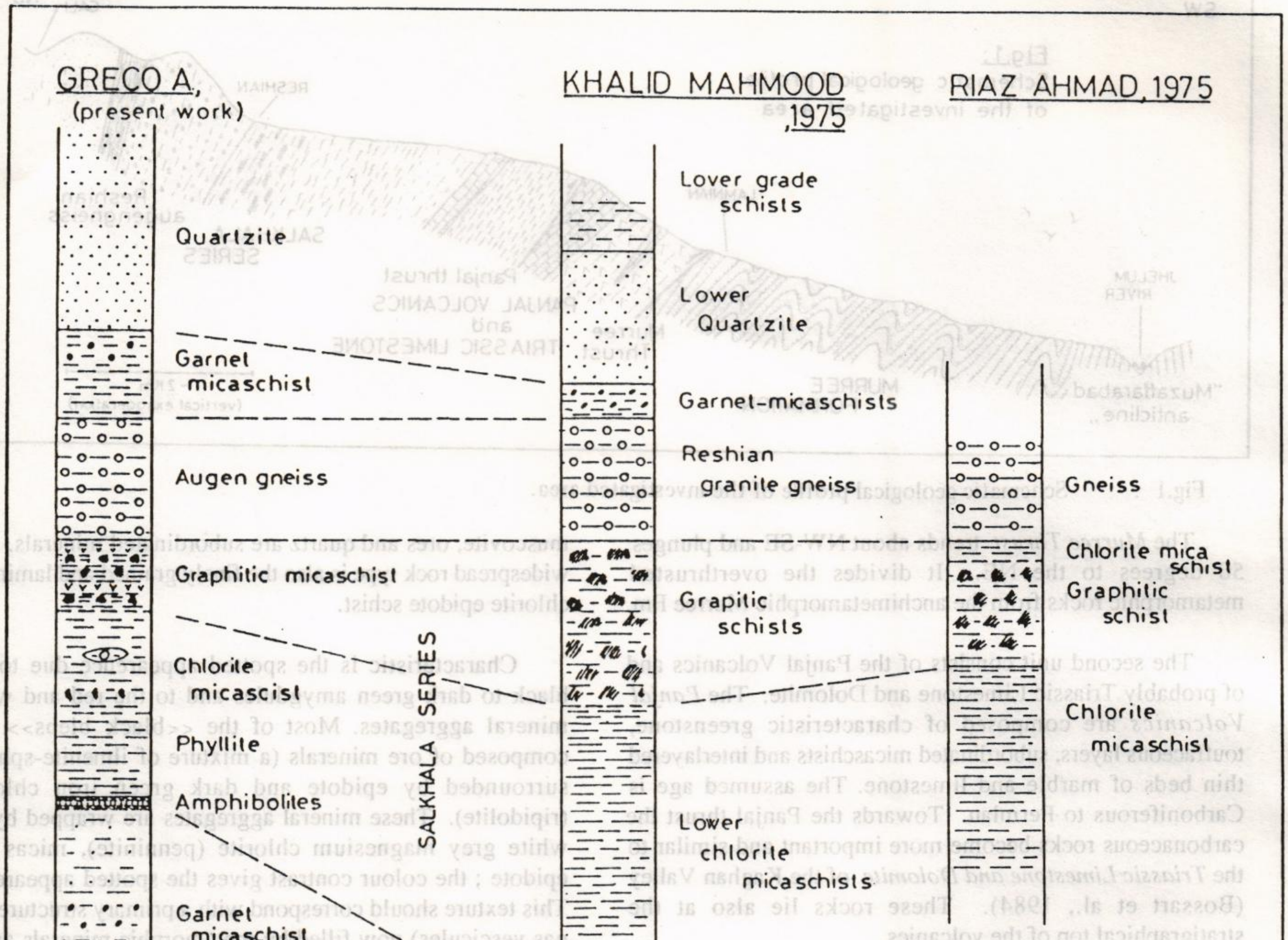
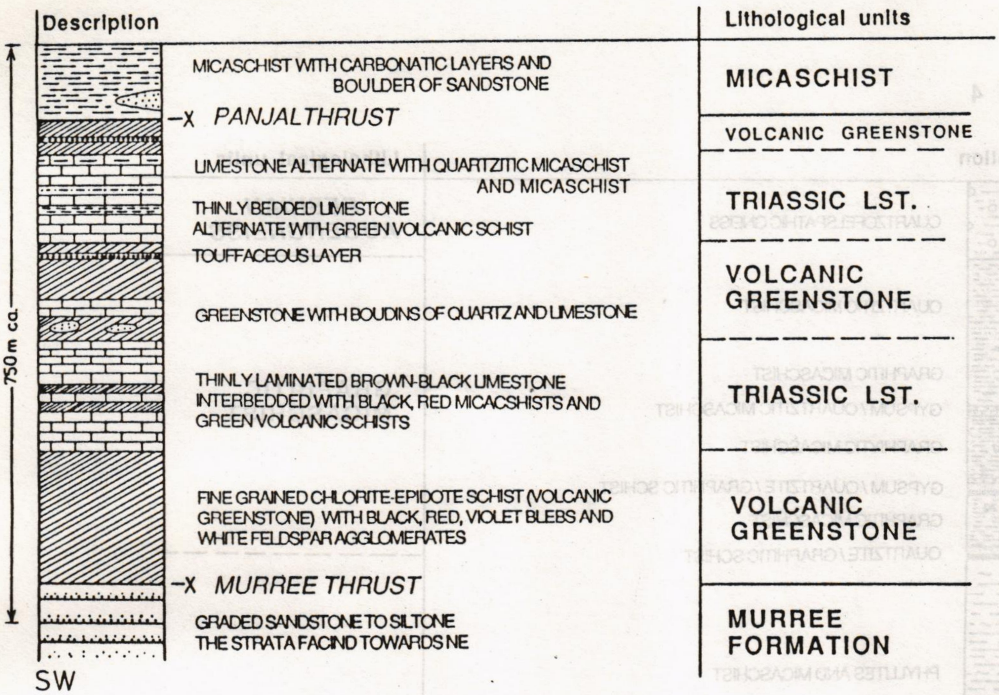


Fig.2 : Comparison between three different studies along the section Lannian - Bratwar Gali.

Table 2: Detailed geological sections. (x3)

SECTION 1



SECTION 2

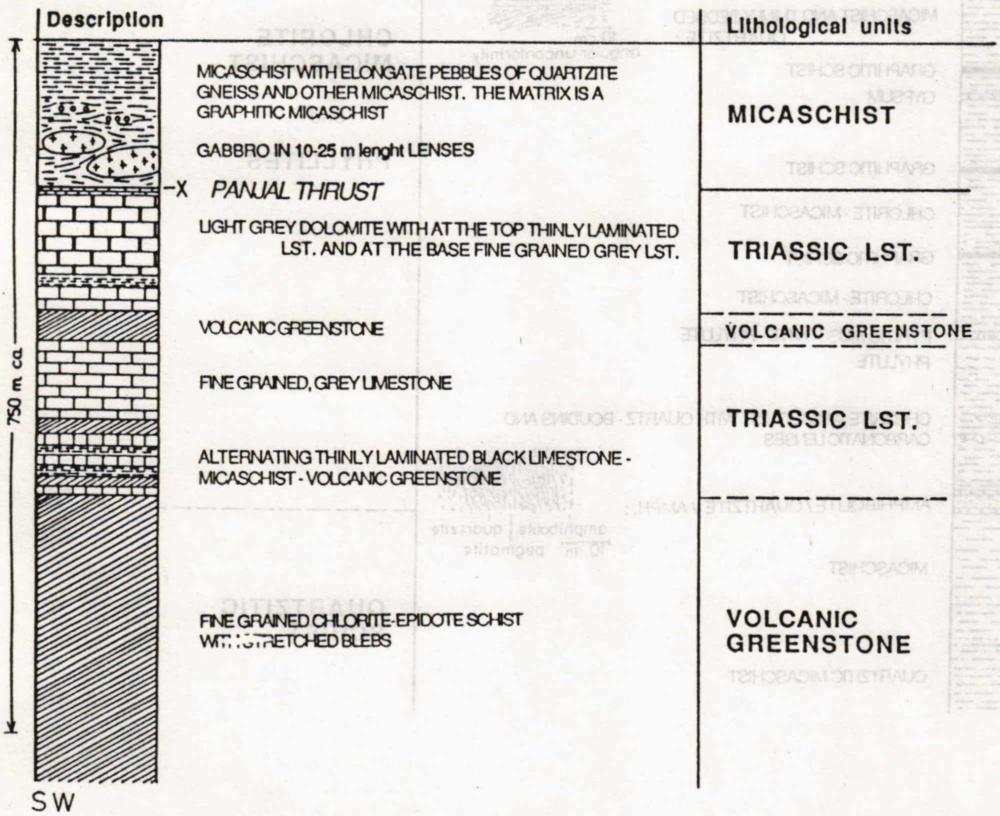


TABLE 2/1

SECTION 4

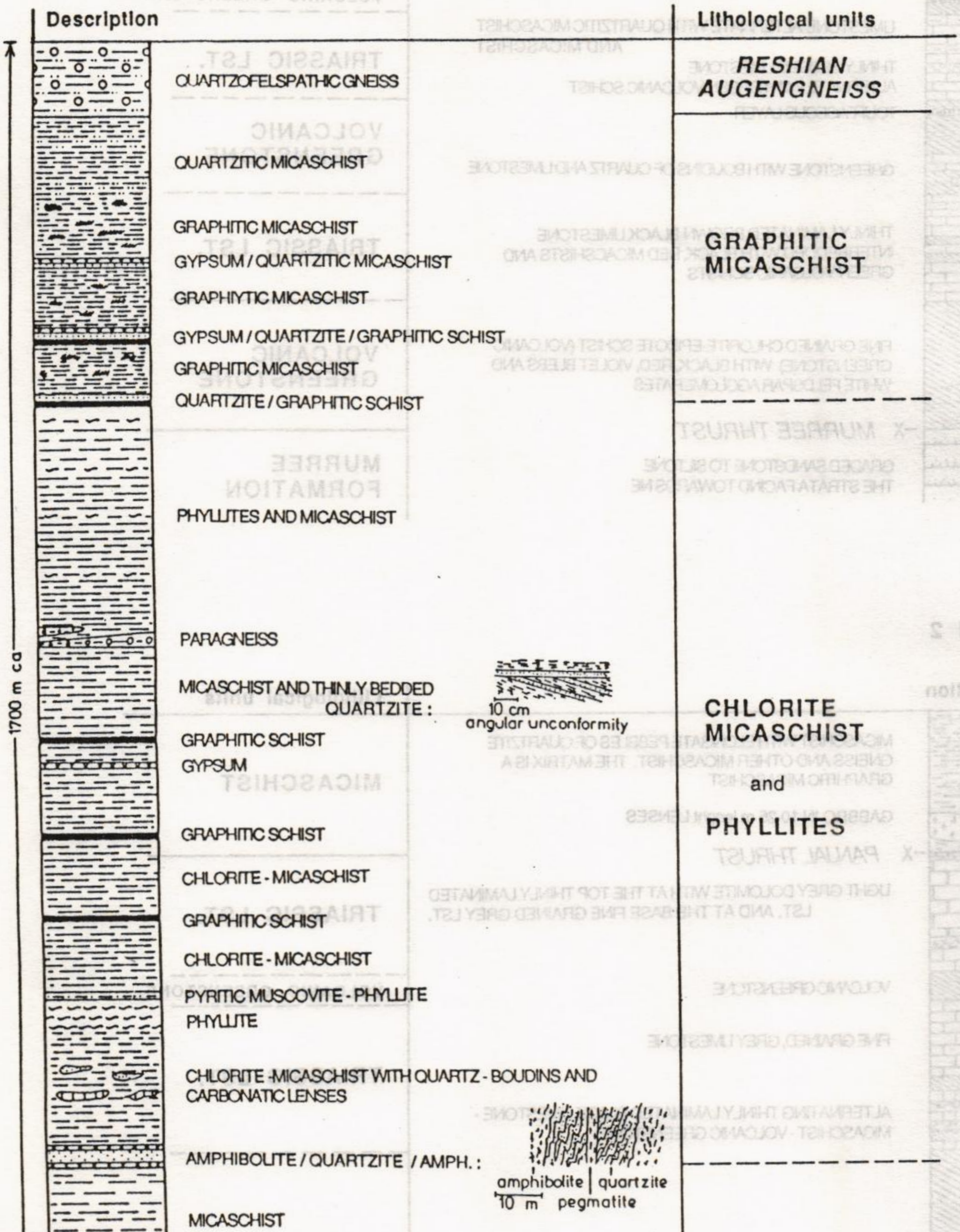


TABLE 2/2

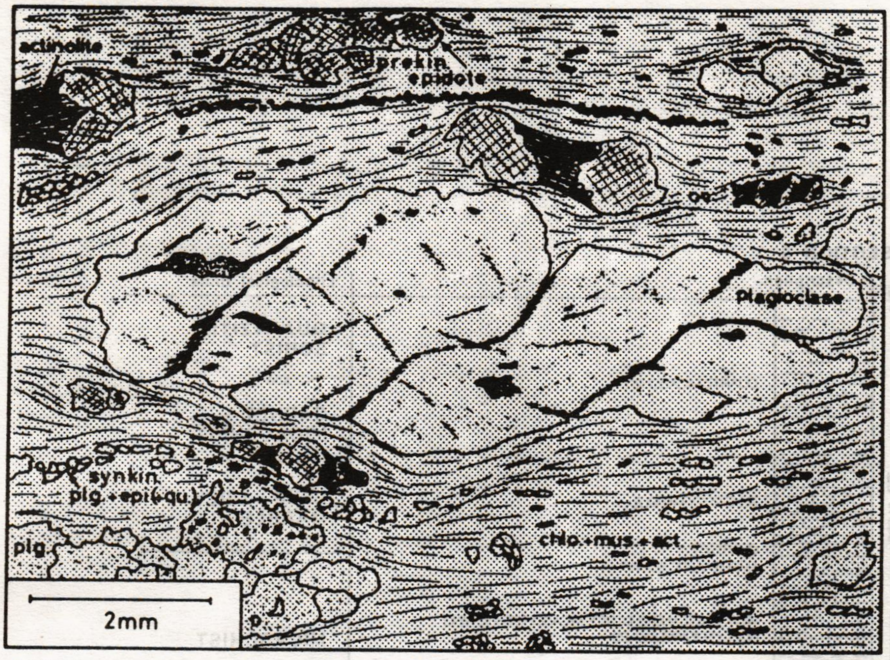


Fig.3 : Sheared plagiocalse in volcanic greenstone. Not the prekinematic smaller epidote agglomerates separated by ferroactinolite (Chlorite actinolite epidote schist with plagioclase agglomerates; grid ref.: 81102708).

The mineral paragenesis is typical for the greenschist facies of intermediate to basic rocks (epidote + plagioclase + chlorite + actinolite), where no signs of retrograde metamorphism are visible. The study of the microstructures shows that the principal metamorphic plagioclase and epidote minerals have crystallized before the formation of the schistosity and are also visible in form of prekinematic porphyroblasts. In particular the epidote is broken and recrystallized in very small individues accompanying chlorite and actinolite, which recrystallize continously during the formation of the schistosity. Therefore the highest metamorphic grade has been reached before the strong tectonic event.

THE TRIASSIC LIMESTONE AND DOLOMITE

In the valley, direct North of the Lamnian village (grid ref.: 800280 - 810290) the alternations of volcanic greenstone and thinly bedded limestone become more frequent (Table 2 , Section 2). The carbonaceous rocks increase in thickness forming two bodies of 40-50 m and 110-130 m, separated by volcanic greenstone. Thinly bedded, finely grained, brown black limestone, yellow if weathered, is the widespread rock type, accompanied by light grey dolomitic limestone in the upper part. Flattened very small (1-3 μ) calcite grains and subordinated mica flakes are aligned subparallel to the bedding. Oval bigger (0.5-2.0 mm) aggregates of calcite grains with deformed twins are found isolated and embedded in the groundmass. This texture shows their prekinematic origin : this can be detritic or organogenic (transformed skeletal parts of crinoids). In fact these rocks look like the crinoids bearing Triassic limestone observed by Ottiger and Bossart at the top of the Panjal Volcanics in the Kaghan Valley (Bossart et al.,1984 ; the <<Triassic Limestone>> of Wadia,1931; the <<Kingriali Fm.>> of Calkins et al.,1975). The same stratigraphical position is suggested here for the upper thicker bank, which lies in tectonical contact with the Salkhala mica schist. The lower thicker horizons of limestone (Table 2 , Sections 1,2) are considered to be tectonical interlayers (Fig.4), belonging to the same stratigraphical unit. On the contrary the minor and isolated beds of limestone and marble have been formed in shallow water between different volcanic episodes and are also members of the Panjal Volcanics.

THE SALKHALA SERIES

Rocks of Precambrian to Lower Paleozoic age occupy the outermost rim of the Hazara-Kashmir Syntaxis. Depending on their lithological character, degree of metamorphism, deformation and stratigraphical position they are divided into different Series and Formations (Salkhala, Tanol, Hazara ...). The geological mapping of Calkins et al. (1975) and of Bossart et al. (1984) underlines that the so called <<Salkhala Series>> (Wadia,1928) are preferably located on the hinge and on the eastern limb of the Syntaxis, showing a medium - high metamorphic grade.

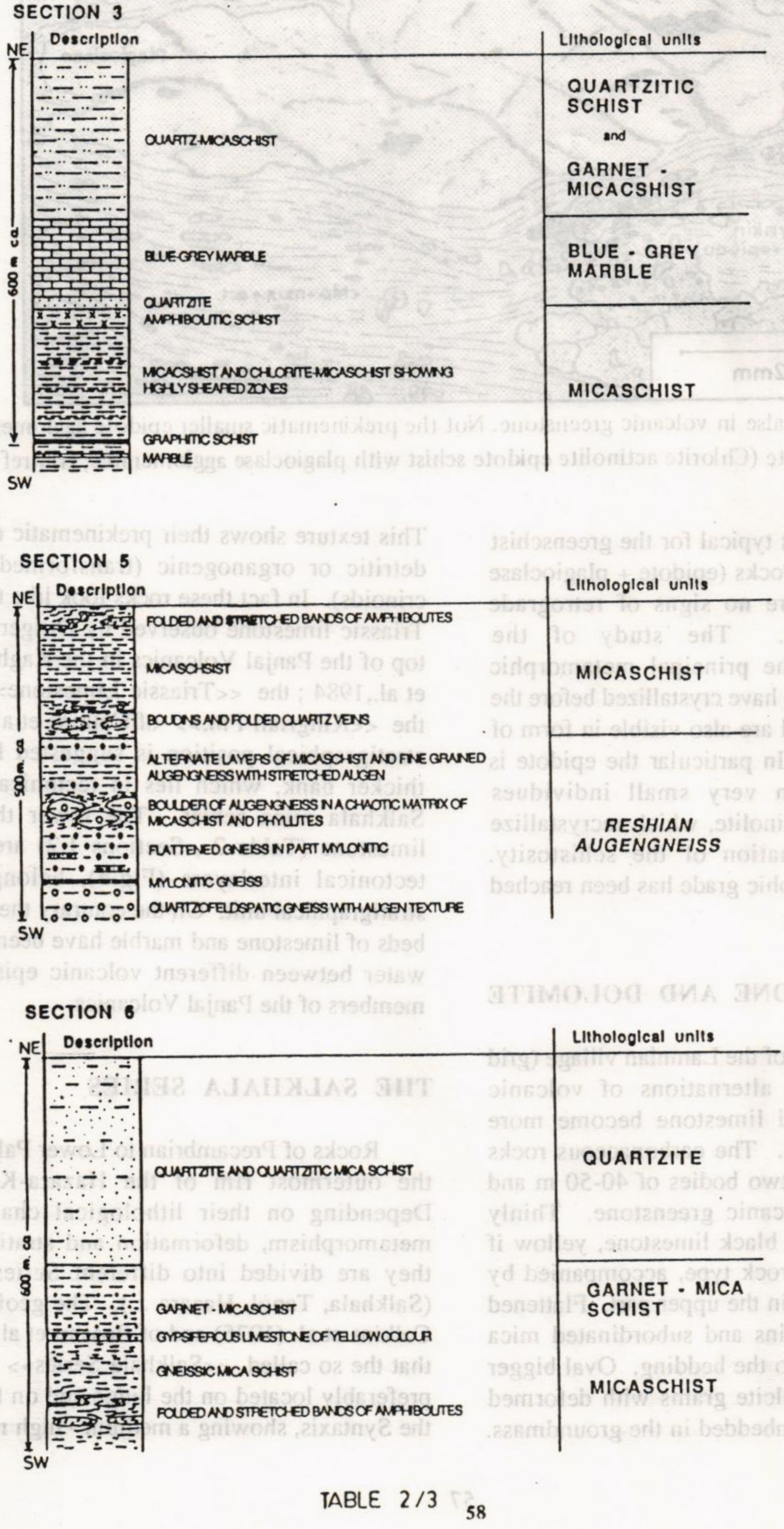

SECTION 3
NE
Description
Lithological units
QUARTZ-MICASCHIST
BLUE-GREY MARBLE
QUARTZITE
AMPHIBOLITIC SCHIST
MICASCHIST AND CHLORITE-MICASCHIST SHOWING HIGHLY SHEARED ZONES
GRAPHITIC SCHIST
MARBLE
SW
QUARTZITIC SCHIST
and
GARNET - MICACSHIST
BLUE - GREY MARBLE
MICASCHIST
SECTION 5
NE
Description
Lithological units
FOLDED AND STRETCHED BANDS OF AMPHIBOLITES
MICASCHSIST
BOUDINS AND FOLDED QUARTZ VEINS
ALTERNATE LAYERS OF MICASCHIST AND FINE GRAINED AUGENGNEISS WITH STRETCHED AUGEN
BOULDER OF AUGENGNEISS IN A CHAOTIC MATRIX OF MICASCHIST AND PHYLLITES
FLATTENED GNEISS IN PART MYLONITIC
MYLONITIC GNEISS
QUARTZOFELDSPATIC GNEISS WITH AUGEN TEXTURE
SW
MICASCHIST
RESHIAN AUGENGNEISS
SECTION 6
NE
Description
Lithological units
QUARTZITE AND QUARTZITIC MICA SCHIST
GARNET - MICASCHIST
GYPSIFEROUS LIMESTONE OF YELLOW COLOUR
GNEISSIC MICA SCHIST
FOLDED AND STRETCHED BANDS OF AMPHIBOLITES
SW
QUARTZITE
GARNET - MICA SCHIST
MICASCHIST

TABLE 2/3

Fig.4 : Tectonic contact between thinly bedded limestone and overlying volcanic greenschists.

In the Reshian area the rocks east of the Panjal Thrust have considerable contents in graphitic material, dyke rocks, dolerite and gabbro intrusions, characteristic of the Salkhala Series (Wadia,1931 ; Khan Tahirkheli, 1982), but the question whether they belong to one or more lithostratigraphical units is still open (see Ghanzafar et al.,1983). The old denomination maintained here is also susceptible to criticism.

The sections 3,4,5,6 (Table 2) show the complexity of this sequence : only a few units are characterized by well defined lithological boundaries and a homogeneous rock type. Principally the rock sequence is developed graditionally : mica schists of various type contain different bodies of gypsum, graphitic schists, amphibolite, quartzite and lenses of ultramafic rocks. Each lithological unit is also defined by a dominant or by a characteristic rock type. Correlations with other studies are possible (Fig.2). Towards the NE the Salkhalas are divided in the following way :

1. *The mica schist zone* : The mica schists are carbonatic with interlayered beds of marble ranging from mm-width to 5m thickness (grid ref.: 82602685). Other interbedded rocks are sandstones (grid ref.: 82102685), graphitic schists and quartz-mica schists (grid ref.: 82702682). Psammitic and psephitic mica schists are found.

Biotitic-amphibolitic schist contains biotite, chlorite and actinolite pseudomorphs on hornblende. Other minerals are pyroxene, white micas, plagioclase, epidote and calcite. The texture is schistose, but prekinematic microstructures are quite widespread. The retrograde minerals grow also on prekinematic amphibolite facies mineral paragenesis. This overgrowth takes place before (till during) the period of strong deformation. Gabbroic rocks are enclosed in big lenses of 10 to 25 m length (grid ref.: 80742857). This rock does not show any deformational feature because its very high mechanical competence shifts the deformation in the adjacent micaschists.

As the Fig. 5 shows, the bedding plane (S0) of the mica schist, given by the alternation of quartz- and mica-rich layers, is cut by the penetrative schistosity (S1). This is formed by the alignment of phyllosilicates and platy quartz and plagioclase grains, sometimes wrapping around old biotites, plagioclase and epidote. The crenulation of both planes brings to the developement - only in the mica-rich layers - of a second discrete crenulation cleavage (S2) along dissolution planes of quartz and feldspar. Strongly sheared zones, accompanied by limonitic crusts are frequent, and can be correlated with the principal Panjal thrust.

2. *The blue-grey marble* : This is a zone of relatively massive rocks, composed of quartzite and predominantly blue-grey marble, which is sometimes pyrite - bearing. According to Khalid M. (1975), these rocks extend NE-SE throughout the entire Reshian area, and are considered as a proper lithological unit. The study of the microstructures reveals the strong syntectonic recrystallisation of the mineral contents, and an old planar structure cut by the present pervasive schistosity.

3. *The quartz mica schist and garnet mica schist zone* : Gneissic mica schist is the most widespread rock type, where quartz and feldspar are confined in agglomerates, stretched and sheared between the mica layers.

Garnet mica schist is also found and shows a very complex relationship between at least two different deformational phases and the metamorphic mineral development. The curved trend of quartz grains, inside the garnet of Fig. 6 is not directly correlable with the

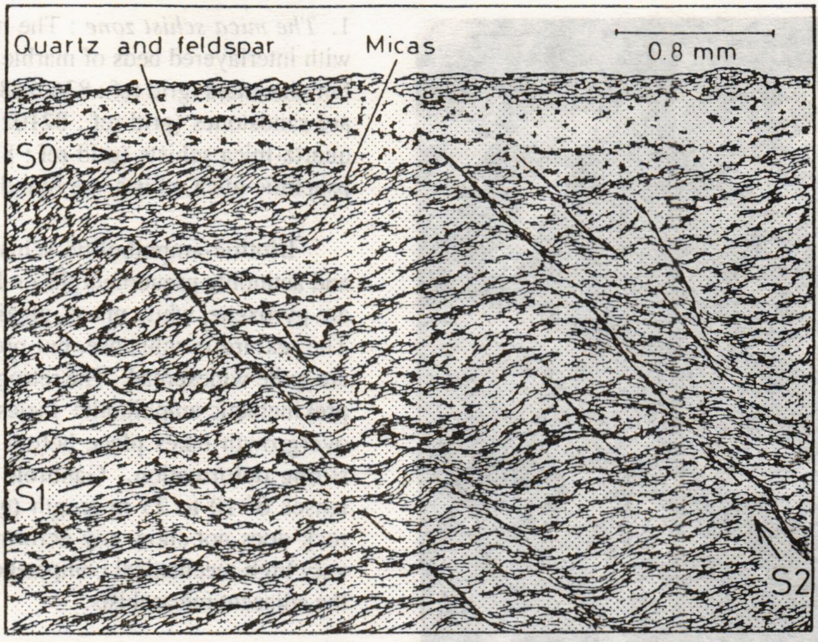


Fig.5 : Polydeformational texture in the mica schist zone; explanations see text. (grid ref.: 82702682).

muscovites of the continuos penetrative schistosity S2, wrapping around the porphyroblast, but reveals their rotation during the formation (<<snowball garnet>>). The enlargement shows that the old schistosity S1 (the degree of the mica differentiation is too high, to suppose a bedding trace) is strongly folded and overprinted by the axial plane schistosity S2. Therefore the formation of the garnet and S1 belong to the same deformational event <<F1>>. A second phase <<F2>> refolds S1 strongly and builds up S2, that surround the porphyroblast. To note that S2 corresponds to the today's penetrative schistosity, subparallel to the lithological boundaries and followed by open crenulation (Fig.5). A similar case is explained in Spry (1969, p.307 ff.).

In this rock the highest grade of mineral growth, shown by the garnet, is contemporaneous with a first deformational phase and predates the formation of the main schistosity, which is related to the thrusting phase. At the moment the evidences of a very early deformational phase are not so obvious as those for the pre-thrusting main metamorphic mineral growth.

4. *The chlorite mica schist - phyllite zone* : This zone shows various lithologies: amphibolitic schists and garnet bearing quartzites with complex structures (Table 2 , Section 4 ; grid ref.: 84682774), graphitic schists and gypsum (grid ref.: 84602861) and paragneiss (grid ref.: 8510/2840) with 2-5 cm big <<eyes>> composed only of quartz, recristallized after the deformation; on the contrary to the Reshian augengneiss feldspar is absent. The most widespread rock types are mica schists, phyllites and chlorite schists. The chlorite schist occurs frequently in crushed and sheared zones like cataclasite and protocataclasite. Relicts of pretectonic features, like angular unconformities, are observable near the lenses of paragneiss, which is also of sedimentary origin. This unit is suggested to be a transition zone between the more graphitic mica schists in the North and the more quartzitic schists in the South.

5. *The graphitic mica schist zone* : Characteristic of this zone is the graphite content. Amorphous grains of this black pigment are distribued along the schistosity planes. Other characteristic and frequent minerals are pyrite, tourmaline, chlorite, both micas, prekinematic epidote to clinozoisite and quartz in variable quantity. The principal foliation is frequently crenulated with development of a new axial plane schistosity. The sequence shown in Fig.7 is recognizable, often only a part of it. The contact to the augengneiss is clearly defined, while it is graditional towards the southern schistose zone. The pyrite dykes and the limonite mine of Reshian lie in this zone.

6. *The augengneiss of Reshian* : The characteristic rock is the so called <<augengneiss>> (germ. auge = engl. eye ; garnet bearing quartzofeldspatic gneiss). The micas, above all brown biotite, wrap around eyes of feldspar from 0.5-1.5 cm of diameter. These <<augen>> are composed of one big plagioclase grain, today strongly decomposed in sericite, epidote, albite and myrmekite, accompanied by smaller microperthites. The schistosity is formed by aligned biotites and muscovites. The biotite, bigger than the white

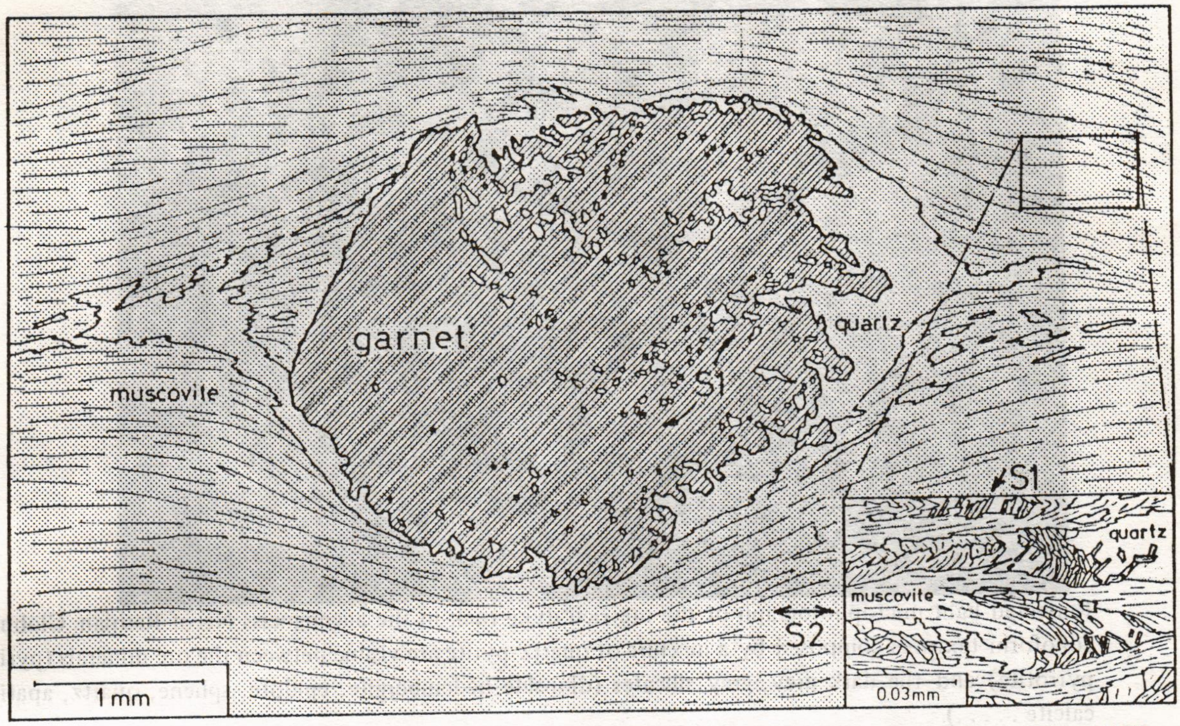


Fig.6 : Polymetamorphic texture in garnet mica schist; explanations see text. (grid ref.: 84212720).

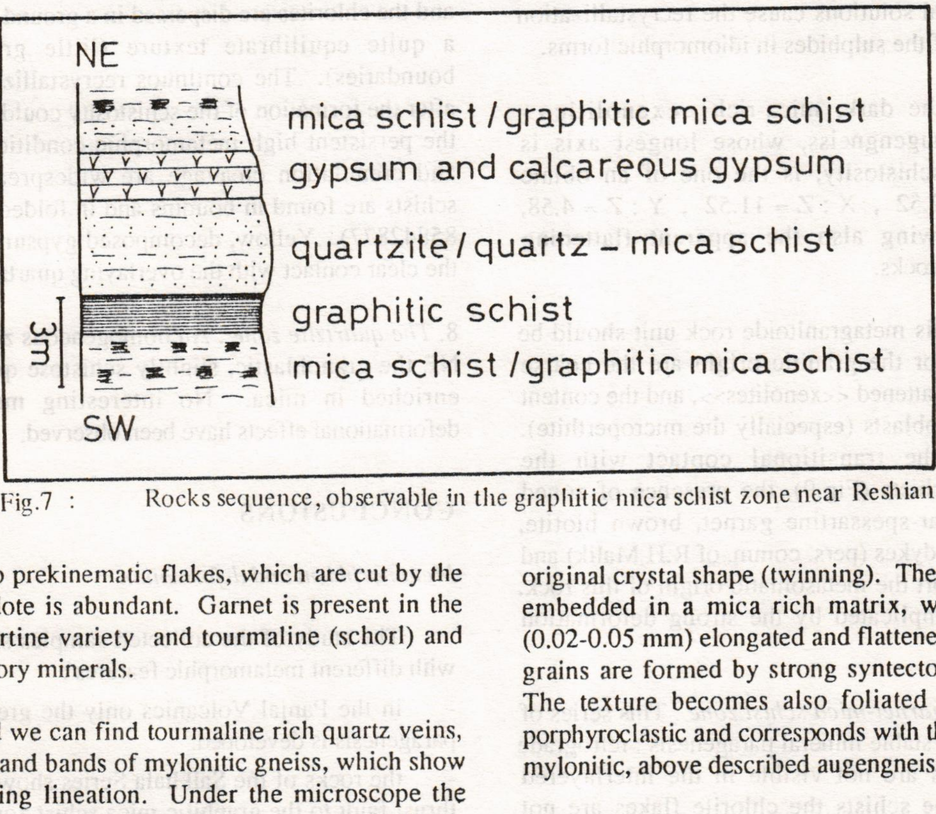


Fig.7 : Rocks sequence, observable in the graphitic mica schist zone near Reshian.

mica, shows also prekinematic flakes, which are cut by the new ones. Epidote is abundant. Garnet is present in the grossular-spessartine variety and tourmaline (schorl) and pyrite are accessory minerals.

Intercalated we can find tourmaline rich quartz veins, schistose gneiss and bands of mylonitic gneiss, which show a strong stretching lineation. Under the microscope the feldspars of the last mentionned rock appear strained, stretched, broken and rounded, but mainly retain their original crystal shape (twinning). These porphyroclasts are embedded in a mica rich matrix, where the very small (0.02-0.05 mm) elongated and flattened quartz and feldspar grains are formed by strong syntectonic recrystallisation. The texture becomes also foliated and fluidal, in part porphyroclastic and corresponds with the strongly deformed, mylonitic, above described augengneiss.

In this zone different pyrite-pyrrotite rich dykes are

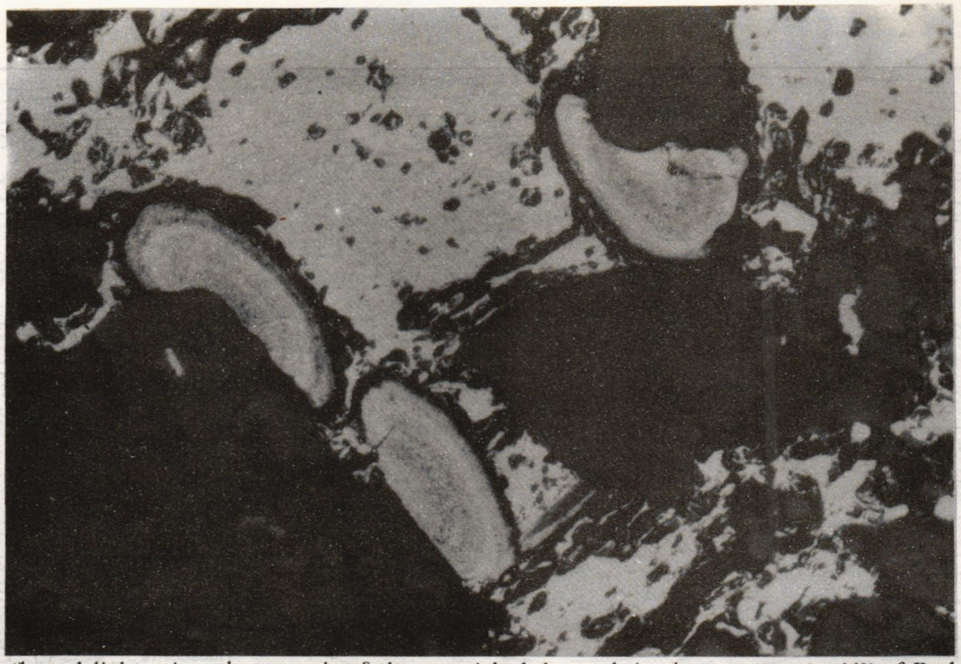


Fig.8 : Reflected light microphotograph of the ore rich dyke rock in the augengneiss NE of Reshian. Globular colloform textures composed by a mixture of quartz-pyrite are visible between the ore minerals (pyrite-pyrrotite) and the dark grey, grey silicates (diopside-hedembergite, epidote, sphene, quartz, apatite, calcite . . . . .).

exposed, concordant to the schistosity, NE of the Reshian village. The colloform texture found there (Fig.8) suggests a sedimentary origin of the iron sulphide mineral enrichment. Subsequent metamorphic heating and circulation of mineral solutions cause the recrystallization of the silicates and of the sulphides in idiomorphic forms.

The form of the dark, mica-rich <<xenolitic>> inclusions in the augengneiss, whose longest axis is subparallel to the schistosity, is the one of an oblate ellipsoid (X : Y = 2.52 , X : Z = 11.52 , Y : Z = 4.58, k = 0.425) showing also the apparent flattening deformation of these rocks.

The origin of this metagranitoide rock unit should be clarified : reasons for the granitic origin are the coarse grained texture, the flattened <<xenolites>>, and the content of feldspars porphyroblasts (especially the microperthite). On the contrary the transitional contact with the upperlaying mica schists (Fig.9), the presence of zoned tourmaline, grossular-spessartine garnet, brown biotite, skarn near the pyrite dykes (pers. comm. of R.H.Malik) and the colloforms support the metasomatic origin of this rock. This problem is complicated by the strong deformation which followed.

7. *The mica schist - garnet-mica schist zone* : This series of schists shows a more stable mineral paragenesis : retrograde metamorphic effects are not visible in the interlayered amphibolites. In the schists the chlorite flakes are not pseudomorphs on other minerals and the garnet is poikilitic also postkinematic. It is suggested that the amphibolite grade has been reached before and continued during the formation of the principal schistosity. The main deformation itself does not seem to be so strong : the micas and the chlorites are dispersed in a ground mass of quartz in a quite equilibrate texture (little grains with right boundaries). The continuos recrystallization during and after the formation of the schistosity could have been due to the persistent high metamorphic conditions. Crenulation and crenulation cleavage are widespread. Amphibolitic schists are found in boudins and in folded layers (grid ref.: 85842877). Yellow, decomposed gypsum is found before the clear contact with the overlaying quartzites.

8. *The quartzite zone* : An homogeneous zone : towards the NE the granoblastic, slightly schistose quartzite becomes enriched in mica. No interesting metamorphic and deformational effects have been observed.

CONCLUSIONS

Metamorphism and deformation

The study of the collected samples shows three zones with different metamorphic features :

- in the Panjal Volcanics only the greenschist mineral paragenesis is developed.
- the rocks of the Salkhala Series show, from the Panjal thrust fault to the graphitic mica schist zone, retrogression from the amphibolite to the greenschist metamorphic

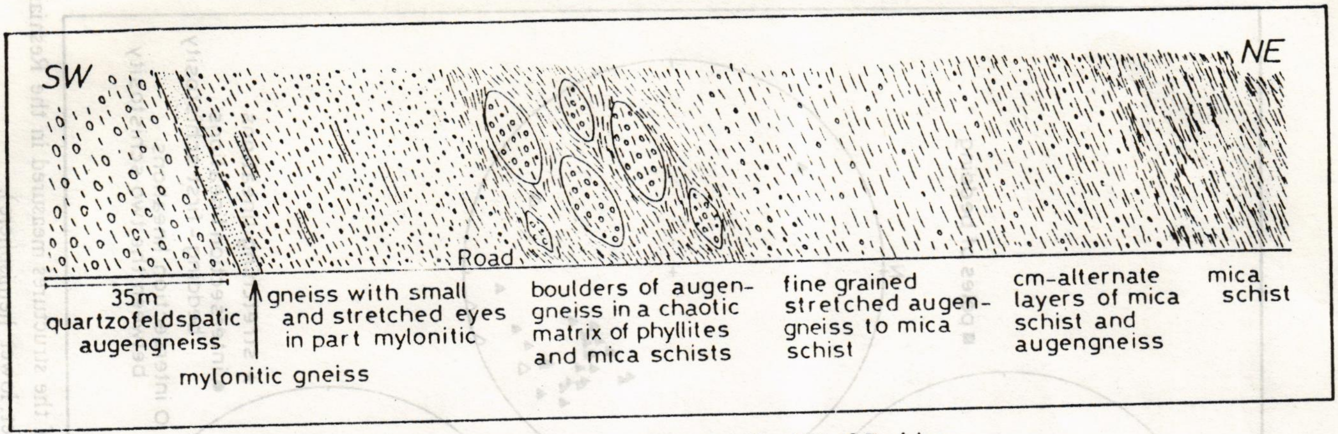


Fig.9 : Sketch profile at the contact gneiss - micaschist 1 Km NE of Reshian.

facies.

- the Salkhala rocks NE of Reshian show apparently only the amphibolite facies.

This pattern is investigated in detail in Fig.10, where the phase of the main foliation development corresponds to the thrusting movements.

In the Panjal Volcanics plagioclase and epidote are present as prekinematic minerals, showing the pre-thrusting development of the greenschist mineral paragenesis. These minerals are also involved in the formation of the schistosity through syntectonic recrystallization (grain size reduction). Actinolite, chlorite and muscovite recrystallize during the deformation and build up the principal foliation. Later, chlorite and muscovite form the crenulation cleavage.

In the Salkhala Series garnet, amphibole, biotite, feldspar and epidote developed before the penetrative schistosity. Garnet, biotite and muscovite in one observed case (Fig.6) are contemporaneous to a very early deformational phase. It is also suggested that the amphibolite facies has been reached before the main thrusting phase, perhaps contemporary to an early deformational event, which is unfortunately not recognized by the mapped macrostructures. The retrogression to the greenschist facies is pre- to syntectonic and underlined by the development of retrograde biotite, chlorite and actinolite. During the formation of the penetrative schistosity we can observe the recrystallization of quartz, feldspar, epidote, calcite, micas and chlorite. In the samples collected in the upper quartzite and garnet - mica schist zones the recrystallization continues after the main deformational event. A third generation of muscovite builds up the later crenulation cleavage.

Tectonics

The investigated area shows three tectonic units separated by two main thrust faults. Each unit is characterized by different stratigraphical positions, metamorphic grade and type of deformation. The folds of the Murree Formation are related to the development of the Muzaffarabad anticline and formed by the NE-SW oriented compression. The parallely oriented thrusting direction of the Salkhala's over the Panjal's over the Murree's is due to the alpine tectonical event which deforms the rocks in a pervasive manner. The main foliation is subparallel to the thrust planes and to the bedding (Fig.11). It has been formed during the thrusting phase. Microstructural relationship supports this interpretation because shearing effects are visible along the planar discontinuities. The well developed stretching lineation and the intersection lineation bedding-schistosity show the NE-SW transport direction. Other evidences of shearing deformation are the tight folds and mullions whose axes are parallel to the stretching lineation, the small shear zones and the mylonitic rocks. The distribution of the strain state, that shows apparent constriction in the volcanics and apparent flattening in the augengneiss, underlines the complex and unsteady deformational path. Another later schistosity is formed during the mm-wide open folding phase (crenulation) of the bedding and of the first foliation. Its E-W, N dipping, trend (Fig.11) cuts the faults and the lithological boundaries and also the crenulation postdates the thrusting phase. It is suggested that this late N-S compression is related to the NNW-SSE overthrust direction recognizable in the western limb of the Syntaxis and in the <<Gali's>> area.

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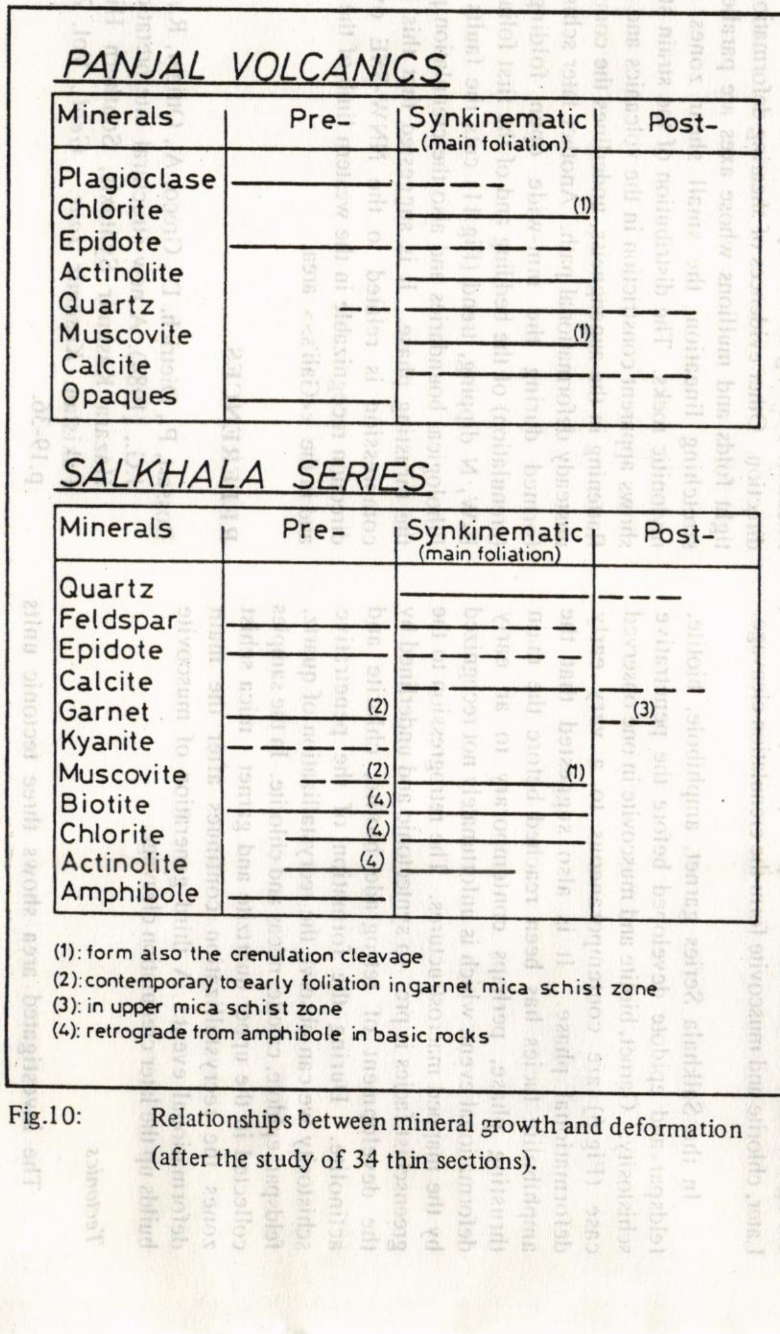

Fig.10: Relationships between mineral growth and deformation (after the study of 34 thin sections).

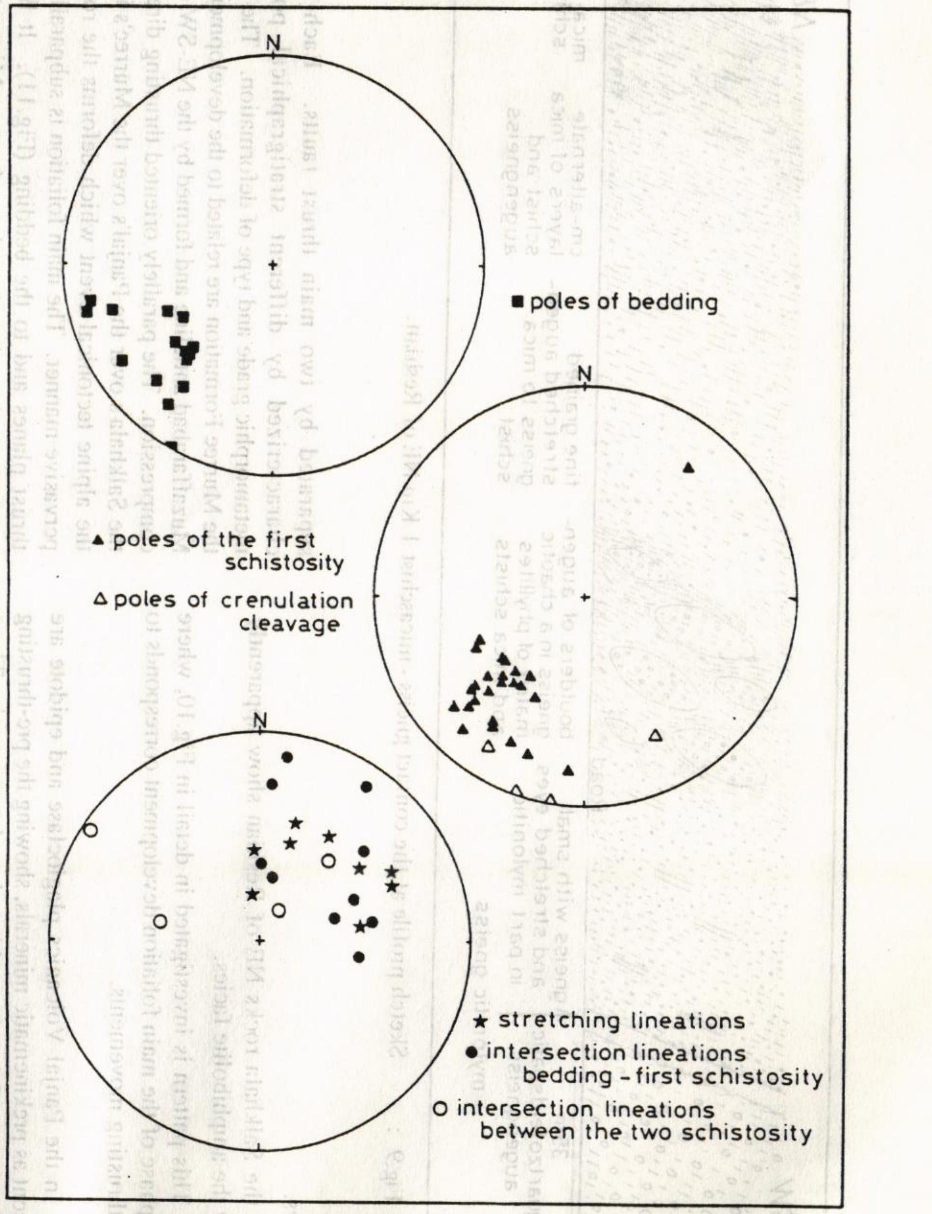

Fig.11: Stereographic projection of the structures measured in the Reshian area (Schmidt equal area net, lower hemisphere).

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GEOCHEMISTRY OF THE CLAY FRACTION OF LOWER OXFORDIAN AND CALLOVIAN SEDIMENTS FROM WARLINGHAM SOUTHERN ENGLAND

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Abstract: *This paper presents the interpretations of the geochemical investigations of the Clay fraction (< 2 um) of sub-surface samples of the Lower Oxfordian and Callovian (Oxford Clay and Kellaways Fms.) stages from Warlingham, Surrey area in southern England. Bi-variant correlation and R-mode Factor Analysis interpreted the possible relationships between the chemical and mineralogical data of the Clay fraction. Three factors, in R-mode Factor Analysis, were extracted which explained 62.37% of the total chemical variance. Control of kaolinite + chlorite and mixed-layers minerals, over the major part of the chemical variance has been explained by Factor. 1. Illite, has been recognised as the other important mineral showing its control over the entire variance loaded in Factor 2. The remaining chemical variance loaded in Factor 3, is being controlled by other detrital components e.g., feldspars and monazite etc.*

INTRODUCTION

This paper presents the interpretations of the chemical and mineralogical data of the Clay fraction (< 2 um) of sub-surface samples of the Lower Oxfordian and Callovian (Oxford Clay and Kellaways Formations) stages from Warlingham, Surrey area in southern England, based on the application of the Bi-variant correlation and R-mode Factor Analysis. Relationships, between the mineral phases and the chemical components in the clay fraction of these sediments, are being presented by this author, for the first time, none of the early workers have paid any attention towards this aspect. Therefore, the main objective of this study was to find out the possible associations of chemical components and clay mineral species in the studied sediments.

GENERAL INFORMATIONS

The Oxford Clay and Kellaways Formations, in the Warlingham area, are underlain conformably by the Cornbrash-the lowest succession of the Upper Jurassic age and are overlain by the Corallian Beds (Fig. 1).

The Lower Oxford Clay is rich in the contents of organic carbon; it is generally shaly and bitumenous, as compared to other divisions of the Oxford Clay Formation (Callomon, 1968: Worssam, 1971). The Middle and Upper Divisions are more calcareous and contain fewer fossils and are more plastic in nature. The Kellaways Formation consists of sandy clays and clays in its upper and lower parts, respectively. Mineralogically, the bulk-rock and clay fraction (< 2 um) samples, respectively, are composed of quartz, calcite, pyrite, feldspars, dolomite (ferroan), total clays, illite, kaolinite, chlorite and mixed-layer clay minerals.

MATERIAL

The clay fraction (< 2 um) of twelve representative samples of the Oxford Clay and Kellaways Formations, was separated by the conventional method of sedimentation, from the Warlingham Borehole samples, provided by the Institute of Geological Science, London.

METHODS

Chemical Analysis

All samples were analysed for ten major elemtns e.g., Si, Al, K. Na, Ca, Mg, Ti, Fe, S and P, on a Telsec B-300 Beta-probe and eighteen minor elements viz., V, Cr, Cu, Pb, Zn, Mn, Ni, Ba, Ce, Th, As, Rb, Sr, Nb, Zr, Y, Mo and La, were determined on a fully automatic Philips PW-1212 X-ray Fluorescence Spectrometer. Both equipments, were first calibrated by running the international standards of sedimentary rocks, being used in the Laboratory of the Geology Department, University of Southampton, England. Clay fraction (< 2 um), separated from the bulk-rock samples, was first dried overnight in an oven at 110° Co., then it was powdered in a 'Tema-mill' for ten minutes to particle size of 200 B.S.mesh. This powder was used to prepare pellets and discs for the analysis of major and minor elements, respectively. Cosgrove (1973), Baqri

(1979-80) and Baig (1982 and 1983), have described details of the sample preparation.

Mineral Analysis

Clay minerals were analysed by X-ray Diffraction method, in the oriented slides of clay fraction (< 2 um), which were prepared according to the method described by Cosgrove (1973), Baqri (1979-80) and Baig (1982). Three, diffractograms of each slide were obtained by running the three specially prepared slides, each marked as 'N' (Normal), 'H' (Heated at 450-500°C) and 'G' (Glycolated at about 150°C), on a Philips PW-1010 X-ray Diffractometer, settings on the X-ray Diffractometer were same as described by Baig (1984). The specific species of clay minerals were identified on the basis of characteristic d-spacings mentioned by Brown (1980) and Schultz (1964).

DATA ANALYSIS AND RESULTS

The chemical and mineralogical data, derived from the clay fraction (< 2 um) of the sediments under dicussion, were subjected to the bi-variant correlation and R-mode Factor Analysis to observe the possible relationships between the two variables, mentioned above. R-mode Factor Analysis programme written by Mather (1970) and modified by Clayton (1970), was used in the present study to confirm the mineral and elements relationship suggested by the bi-variant correlations.

Table 1, shows the promax factor loadings and the inter-factor correlations. Scores, shown on the promax factors, are tabulated in Table 2. Summaries, of the components loaded in the respective factors indicating the levels of significances and the correlation co-efficients matrix of clay minerals and the chemical components, are presented in Tables 3 and 4, respectively. Table 5 indicates the abundances of the clay minerals.

DISCUSSIONS

The three factors, extracted in the R-mode Factor Analysis, are described as under:

Factor 1: This factor is the major factor as it has explained 31.92% of the total variance. The strong loadings, shown on depth, Al, Zr, Cu, Mo, Ce, Sr, Ti and Cr, in the positive phase of this factor, tend to suggest the occurrence of kaolinite phase. Baig (1985a), in a study of the clay fraction (< 2 um) samples of these sediments from the Winterborne Kingston, Dorset area, in southern England, has noticed that 'Kaolinite+Organic Carbon', control over a similar group of chemical components. Weaver and Pollard (1973) Schultz (1964), and Van Olphen and Fripiat (1979), have mentioned that kaolinite contains about 40% of Al_2O_3. Considering the highest value of Al in this factor, it seems reasonable to assume that the loading of Al, in the positive phase of factor 1, is the indication of the presence of kaolinite phase. The association of typically known detrital elements e.g., Ti, Cr and Zr, further supports the occurrence of a detrital phase such as kaolinite. The presence of chalcophile elements e.g., Cu and Mo in this phase of factor 1, may be due to two reasons. Firstly, due to the creation of the anoxic condition, which were developed as a result of the rapid rate of sedimentation and quick burial of living organism, due to the presence of coarse grains of kaolinite in the detritus. Krauskopf (1956), has mentioned regarding the strong adsorptive ability of these elements onto the grains of sediments. The adsorptive ability of these elements may be the second good reason of their presence in this factor which has been recognised as 'Kaolinite' factor. Fig 2, shows a very strong positive correlation (r = +0.53), highly significant at the 99.99% level, between the abundances of Kaolinite + Chlorite (Table 5) and the scores of Factor 1 (Table 1), confirming the identification of kaolinite phase.

The negative phase of this factor shows, the association of strongly loaded components e.g., Fe, Ca and P, moderately loaded components e.g., K, and As, and low loaded components such as Mg and V. This assemblage of elements strongly suggests the occurrence of a mixed-layer mineral. It is well known that Ca, Mg and K, occur in the inter-layers and Fe_2O_3, in the octehedral sheet of mixed-layer minerals (Weaver and Pollard, 1973). The occurrence of a mixed-layer mineral (non-expanding), in association with degraded illite, in the under discussion sediments, has been reported by Baig (1982 and 1984). The presence of K_2O, can be explained in the light of the explanation given by Brown (1954) regarding the fixation of K_2O in a clay mineral, which is closely similar with the degraded illite found in the Oxford Clay. The negative phase of Factor 1, therefore, is being designated as the Mixed-layer (non-expanding) minerals phase. Fig 3, shows 95% level of significance of correlation (r = −0.53), between the factor scores of Factor 1(Table 2) and the abundances of the mixedlayer (non-expanding) clay mineral shown in Table 5.

Factor 2: This factor explained 18.5% of the total variance and has captured all elements in its positive phase. This factor showed strong loadings on elements e.g., K, Al, Rb, Ni, V, Mn and Zn. The association of K, Al and Rb, is of significant importance. Many research workers including Weaver and Pollard (1973), Grim (1968), Calvert (1976), Dunoyer-de-Segonzac (1970) and Van Olphen and Fripiat (1979), have mentioned that elements e.g., K, Al and Rb, are essentially present in the lattices of illite. The remaining elements e.g., Ni, V, Mn and Zr, also reside in the lattices of illite. Baig (1982; 1985a and 1985b), has notic-

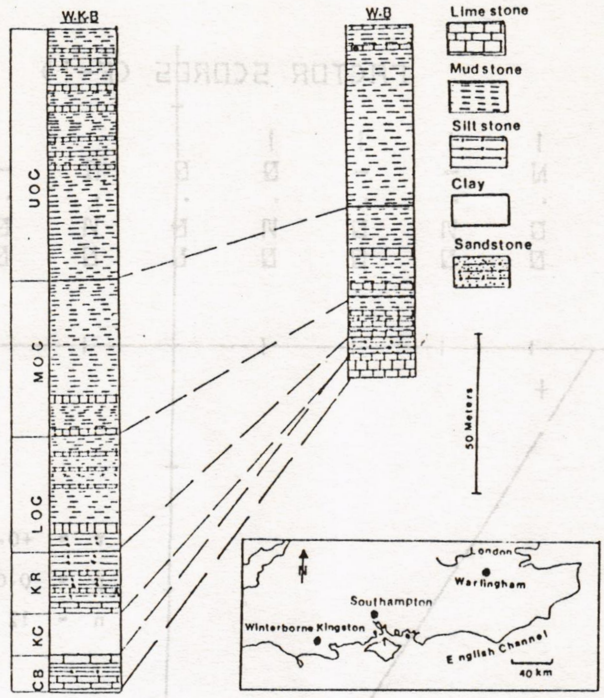

Fig. 1

Lithological logs and locations of the Winterborne Kingston and Warlingham Boreholes in Southern England.

ed the presence of these elements in the octahedral sheet and the inter-layers of the illite, present in the Oxford Clay Formation from Dorset and Surrey areas in southern England.

It is concluded, in the light of the above discussion that entire chemical variance loaded in this factor, is being controlled mainly by mineral illite. Fig 4 shows very strong positive correlation (r = +0.65), significant at 99.99% level, between the scores of Factor 2 (Table 2) and the abundances of illite (Table 5) and confirm the above conclusion.

Factor 3: This factor explained only 11.95% of the total variance. Its positive phase shows assemblage of Si, Mg and Ti elements. It is well known that these elements are typically associated with the lattices of mixed-layer minerals, therefore this association suggests the occurrence of mixed-layer mineral in this factor. The strong negative correlation between Factors 1 and 3 (Table 1), further supports the idea of the presence of a mixed-layer mineral in this phase of Factor 3.

The negative phase of this factor shows very strong loadings on Na, Ba, Sr, P, Y, La, Ni and Cu. The presence of Na, Ba, and Sr, strongly suggests the occurrence of Nafeldspar, because Na is easily replaced by Ba and Sr, being close similarity of the ionic radii of these elements (Krauskopf, 1979). The association of P. La and Y, is typical; it indicates the occurrence of a phosphate phase in this factor. Baig (1982 and 1985a) has mentioned the occurrence of a phosphate phase (monazite?), considering the association of Th, La and P, in the clay fraction of the Oxford Clay Formation from Dorset area.

The presence of Cu and Ni, in this phase of factor 3 is of lesser importance because these elements have shown much stronger loadings in Factors 1 and 2, indicating their major role in the respective phases of these factors. The negative phase of Factor 3, considering the above points, is being designated as the phase of 'resistates'. The loadings of the negative phase of Factor 3, are identical with the loadings shown by the 'detrital phase' identified by Baig (1985a), in the study of the clay fraction of the Oxford Clay Formation from the Dorset area in southern England.

CONCLUSIONS

This study may be concluded as follows:

1. Elements e.g., Al, Zr, Ti, Cr, Cu, Mo, Ce, are associated with the kaolinite phase which occurs abundantly in the studied sediments.

2. The association of typically chalcophile elements e.g., Cu and Mo, in Factor 1, indicates the occurrence of anoxic conditions in the bottom sediments of this

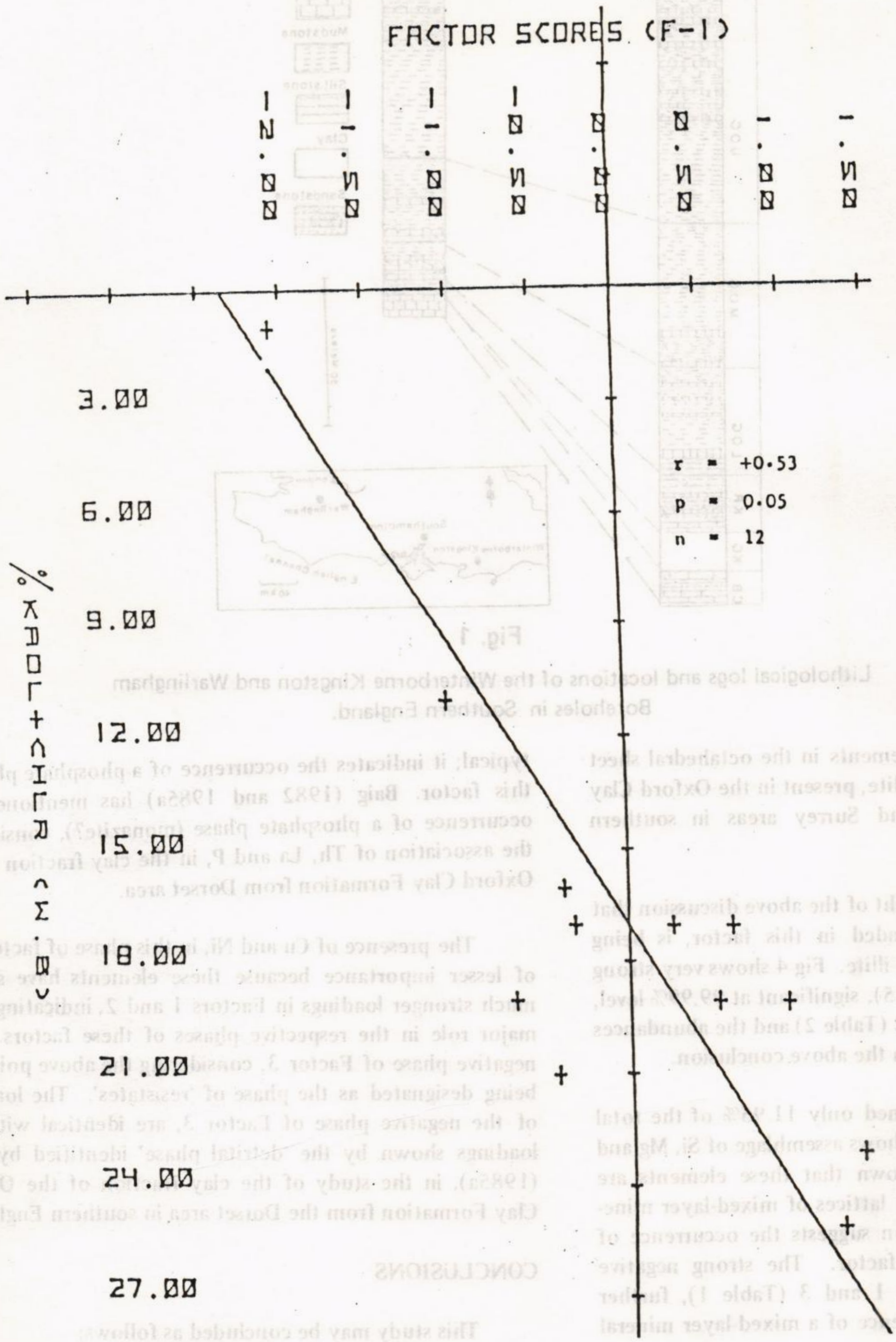

Fig.2: Shows highly significant positive correlation between the scores of Factor 1 and total of the abundances of kaolinite and chlorite., in the Warlingham Borehole Sediments.

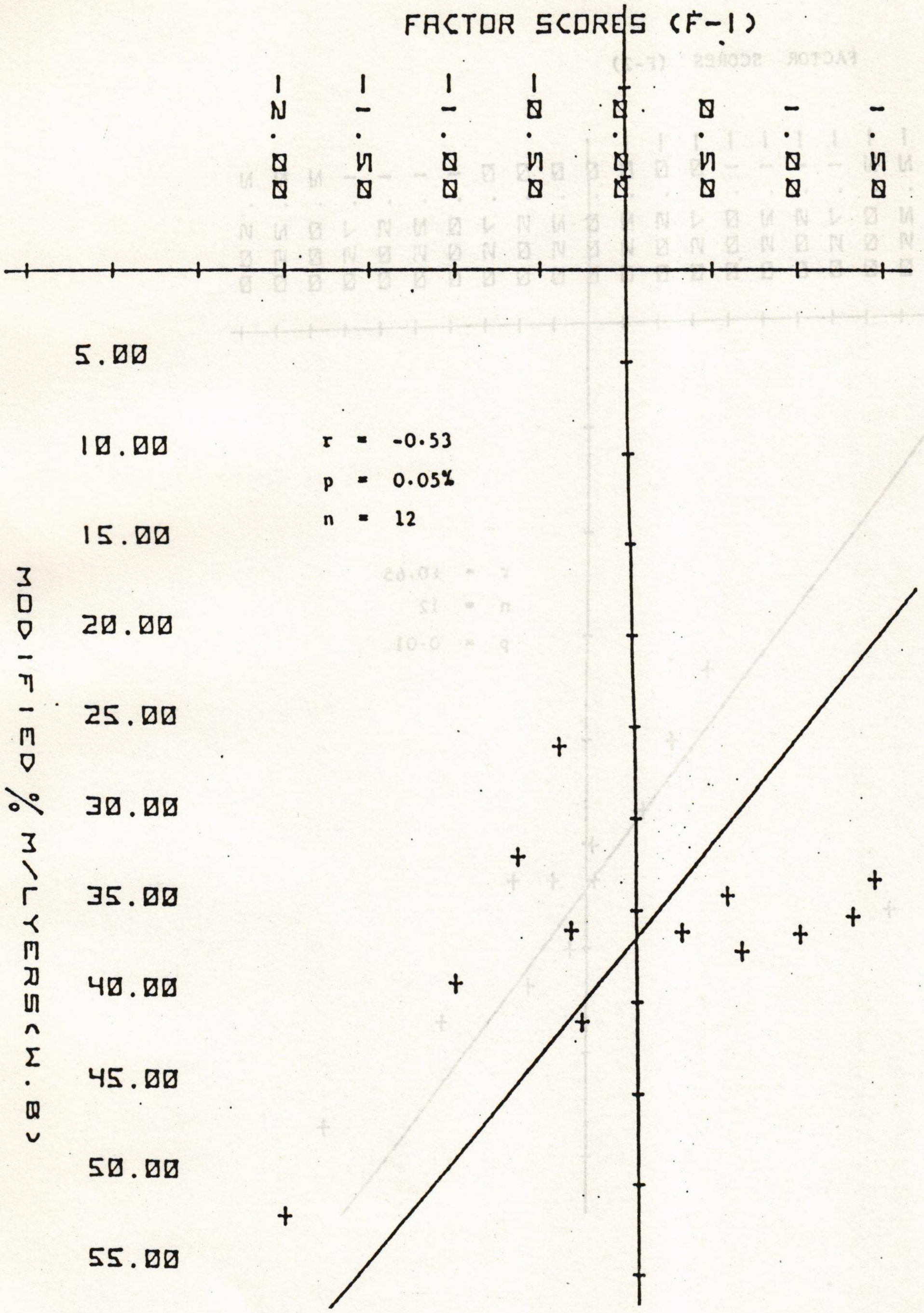

Fig.3: Shows highly significant correlation (r = -0.53), between the scores of Factor 1 and the abundances of mixed-layer mineral in the Warlingham Borehole Sediments.

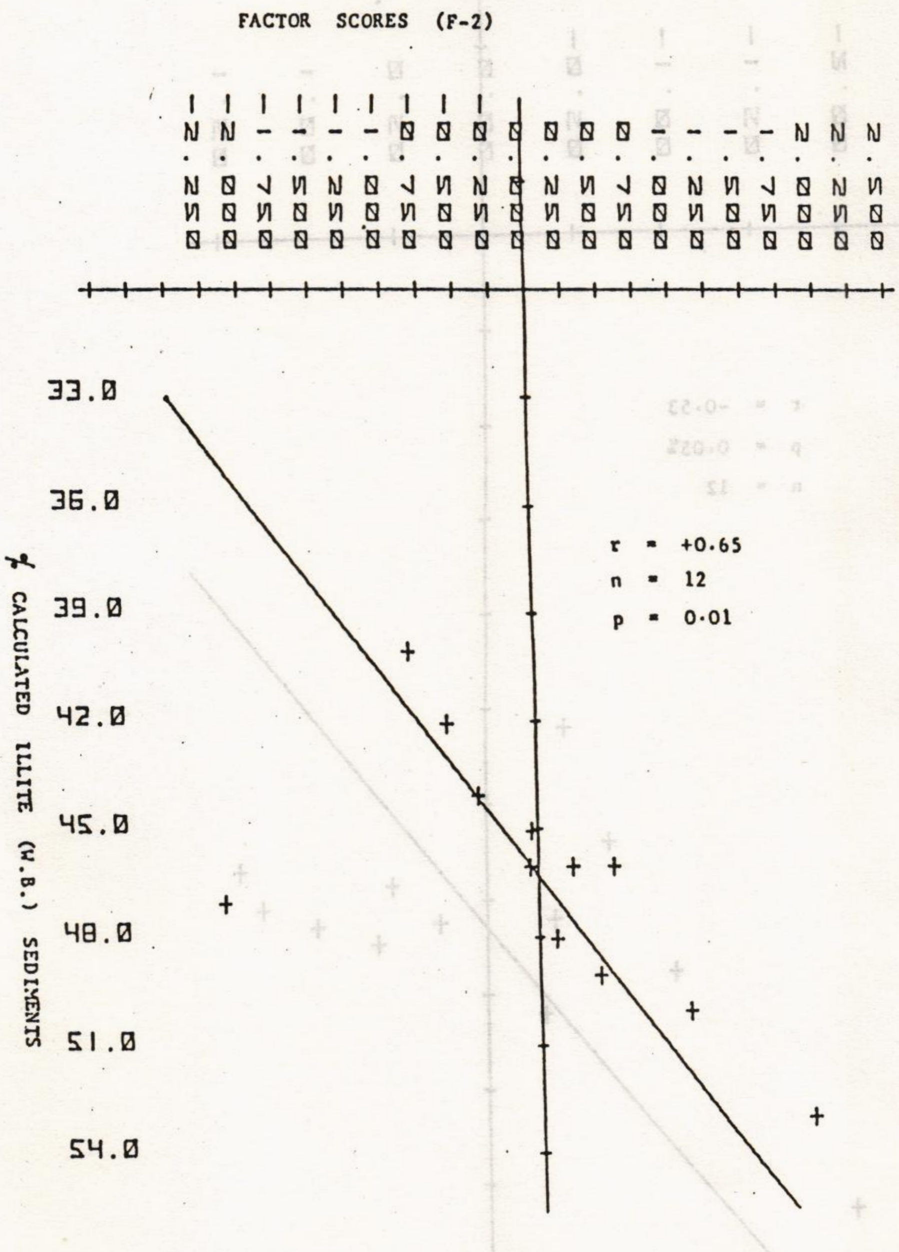

Fig.4: Shows highly significant positive correlation(r= +0.65), between the scores of Factor 2 and the abundances of illite in the Warlingham Borehole Sediments.

TABLE – 1

Promax Factor Loadings for K_{min} = 3 and Correlations between the Promaz Factors for K_{min} = 3 for the 12 clay fraction samples of the (W.B.) sediments

Components	Factor (F-1)	Factor (F-2)	Factor (F-3)
Depth in Borehol	0.91		
SiO_2	-0.245		0.67
TiO_2	0.47	0.49	0.28
Al_2O_3	0.62	0.58	
Fe_2O_3(T)	-0.86	0.25	
MgO	-0.39		0.57
CaO	-0.94		
Na_2O	0.32		-0.86
K_2O	-0.57	0.68	
P_2O_5	-0.64		-0.69
V	-0.39	0.81	
Cr	0.48		
Mn		0.87	
Ni		0.61	-0.35
Ba			-0.74
Ce	0.62	0.48	
Th			
Pb		0.55	
As	-0.565		
Zn		0.79	
Cu	0.62		-0.39
Rb		0.84	
Sr	0.57	0.32	-0.44
Y	0.39		-0.52
Zr	0.63	0.24	
Nb		-0.66	
Mo	0.60		
La	0.27		-0.40
Percentage	31.92	18.5	11.95

Correlations between the Promax Factors for K_{min} = 3.

F-1	1.000		
F-2	0.0665	1.0000	
F-3	-0.2379	0.0414	1.0000
	(F-1)	(F-2)	(F-3)

Note : Factor loadings <0.24 were omitted. W.B. = Warlingham Borehole.

TABLE – 2

Scores on Promax Factors of 12 Clay Fraction Samples (W.B.)

Factor (F-1)	Factor (F-2)	Factor (F-3)
- 2.069	- 2.176	1.465
- 0.698	0.414	- 1.317
- 1.073	1.032	0.769
- 0.447	1.881	1.066
- 0.388	0.116	0.137
- 0.334	- 0.619	- 0.450
0.257	- 0.062	- 1.919
0.530	0.518	- 0.670
0.615	0.237	0.695
0.952	- 0.048	0.389
1.261	- 0.873	0.044
1.393	- 0.417	- 0.209

TABLE – 5

Abundances of clay minerals in the Oxford Clay and Kellaways Formations from Warlingham, Surrey area, southern England.

Sample No.	Illite	Kaolinite	M/Layers	Chlorite
BR-167	47	0	52	1
BR-278	49	10	32	9
BR-468	50	10	39	1
BR-627	53	11	26	10
BR-826	48	10	36	6
BR-988	42	12	41	5
BR-1194	46	11	36	7
BR-1301	46	12	34	7
BR-1339	46	11	37	6
BR-1583	45	14	36	5
BR-1676	40	18	35	7
BR-1755	44	16	33	7

TABLE – 3

Summary of components loaded in the respective factors indicating 10%, 5% and 0.01% levels of significance in the (W.B.), samples.

	Significance levels	Factor (F-1)	Factor (F-2)	Factor (F-3)
	10%	Cr	Ti, Ce, Pb	
+ve	5%	Al, Ce, Cu, Sr, Zr, Mo	Al, K, Ni	Si, Mg
	0.01%	Depth, LOI	V, Mn, Zn, Rb	NONE
	0.01%	Fe (Total), Ca	NONE	Na, Ba
-ve	5%	K, P, As	Nb	P
	10%			Y
Percentage of Explanation		31.92%	18.5%	11.95%

Cumulative Explanation = 62.4%

Factor loadings indicate the significance levels for 10%, 5% and 0.01% levels. For 10 degrees of freedom these leves are:

10%	⩾0.49
5%	⩾0.57
0.01%	⩾0.70

TABLE – 4

Summary of the Correlation Coefficient Matrix of Clay Minerals and Clay Fraction chemistry of the (W.B.) sediments

	Significance levels	Illite	Kaolinite	Mixed-Layers	Chlorite
	10%	Rb, M.L.	Ti, Sr, Chlr.	Mg	Sr, Kaol.
+v	5%	Mn	Ce, Cu	Nb	Al, Ce, Cu
	0.01%	None	Depth, Al, Zr		Pb, Zr
	0.01%	None	Fe, Ca, M.L.	Al, Zr, Kaol.	
-ve	5%	None	Mg	Rb, Chlr.	Mg, M.L.
	10%	None	None	Ti, Mn, Ce, Ill.	Si

n = 12

For 10 degrees of freedom the significance levels for 10%, 5% and 0.01% correlation coefficients are as under:

10%	⩾0.49
5%	⩾0.57
0.01%	⩾0.70

sequence.

3. Elements e.g., Ca, Fe, Mg, K, Na, As and V, reside in the lattices of the mixed-layer mineral in these sediments.

4. Elements K, Al, Rb, Ni, V, Mn, Zn, reside in the octahedral sheet and the inter-layers of the illite which is present as a dominant component in these sediments.

5. Detrital phases such as Na-feldspar and monazite, control the variance of Na, Ba, Sr and P, La, and Y, respectively.

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TRACE METAL DISTRIBUTION IN STREAM SEDIMENTS AND THEIR RELATION TO MINERAL DEPOSITS OF LISKEARD-LAUNCESTON DISTRICTS OF CORNWALL, U.K.

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ABSTRACT:– Geochemically anomalous amounts of trace metals dispersed in the streams are traceable up to their source, and this method has proved its validity for reconnaissance gecchemical survey of Liskeared-Launceston area of Cornawall. The geology of the area is represented by the Bodmin Moor Granite surrounded by metasediments of Devonian and Carboniferous ages. The veins and lodes of the area are mineralized with lead, zinc, copper, tin, manganese, tungsten and iron which were detected by analysis of stream sediments on Atomic Absorption Model 360 (Perkin-Elmer).

The distribution and inter-relationships of trace metals were examined by using histograms, frequency plots, correlation coefficients and variation coefficients. Polymodal metal distribution may have been caused by analytical bias, heterogeniety of lithological units and derivation from anomalous metal content from mineral deposits of the area. The spread of different populations is very well defined in the minus 80 mesh.

Different statistical techniques were used to define the anomalies from the background values by the methods described by Sinclair (1976) and Lepeltier (1969). The analytical techniques are those described by Stanton (1966). Analytical and sampling precisions are calculated by the method described by James (1970) and Garrett (1973).

INTRODUCTION

Cornwall has a very long history of mining, where within a belt of 120 k.m long and 32 k.m wide (see fig.1), more than 600 underground mines have been operated for metallic minerals. In this respect the Liskeard-Launceston districts of Cornwall are of particular significance where copper, lead, zinc, tin, tungsten, together with small stringers of cobalt and nickel, have been mined for centuries in the past.

Geochemical prospection technique have proved very useful for delineating the mineralized area in the Liskeard-Laumceston districts of Cornwall. This method consists of detecting very small amounts of trace or minor elements in stream sediments collected from the active streams of the area. The underlying rationale behind this method is that many elements, from the primary environments, get dispersed in the secondary environments by the agents of weathering. Thus by detecting the trace element content in the secondary products i.e. stream sediments, soils and water, an indirect approach to the source mineralization is possible. In this regard stream sediment surveys are more useful while delineating mineralized sources of an area.

After the trace element content data of certain area is obtained, it becomes very difficult to separate, visually, the high background values from the anomalous ones, which are mostly thought to be included in the data due to mineralization. To overcome this problem, certain simple statistical techniques, such as, plotting of histograms, frequency curves, use of correlation coefficients and variation coefficients can be of great help.

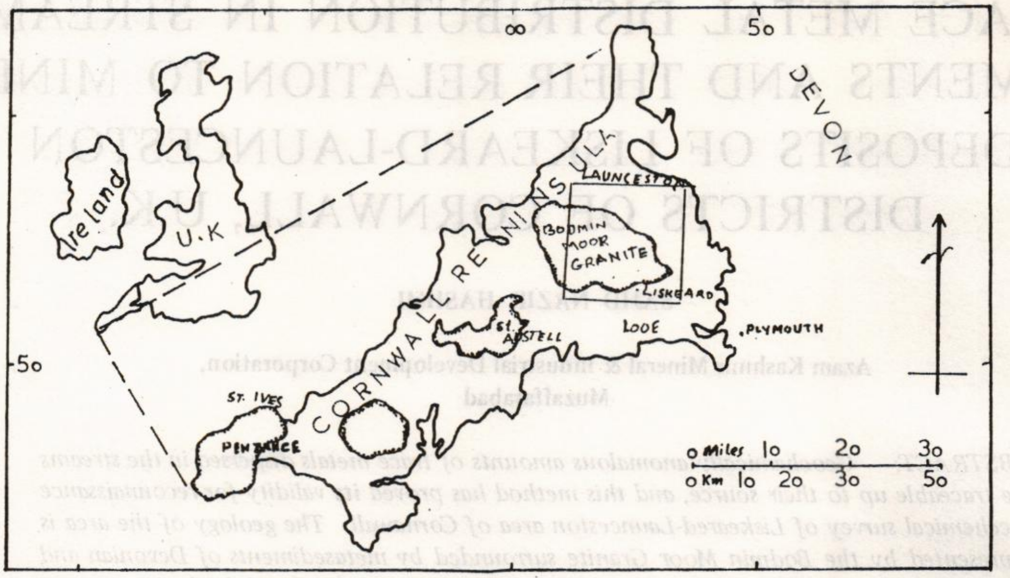

FIG. 1 INDEX MAP OF U.K AND CORNWALL SHOWING STUDY AREA

SAMPLING AND ANALYTICAL METHODS.

About 115 stream sediment samples (consisting of silt sized material) were collected from the active stream channels, alongwith 25 duplicate samples to compute the sampling errors, at a density of 2 duplicate samples for 10 routine samples.

Samples were then oven dried in the laboratory at 95°C, sieved and minus 80 mesh fraction was retained for analysis. The analyses were carried out on Atomic Absorption Spectrometer Model 360 (Perkin Elemer).

The method used for digestion of the samples for determination of hot extractable metals was essentially that described by Stanton (1966). After this digestion metals like Cu, Zn, As, Pb, Co, Ni, Fe and Mn were detected. The analytical precision of above method was calculated for Pb ± 12.9% and for copper ± 10.5% at 95% confidence level, by the method described by James (1970) which calculates the variance and takes into account the lowest and highest values obtained during analyses.

HISTOGRAMS

This graphical method discriminates the numerous background values from the anomalous values. Examination of a histograms usually shows larger peaks representing background, and the anomalous values as a separate peak. A value away from large back-ground peak may be useful as a first approximation to the anomaly discrimination (Fig. 3).

The metal values for Cu, Pb, Zn, As Ni, Co, Mn, and Fe were plotted as histograms, (Fig. 3). The classes and class intervals were obtained by the method described by Levienson (1980).

CUMULATIVE FREQUENCY CURVES

The cumulative frequency curves for Cu, Pb, Zn, As, Ni, Co, Mn and Fe were plotted on arthmatic probability papers (Fig. 4) and bar intervals were selected, so that the values were log-normally distributed on the graph. The frequencies were cumulated from the highest to the lowest values after the method described by Le-Peltier (1969) and sinclair (1976).

CORRELATION COEFFICIENT

This is the Pearsons Product Moment Coefficient of Linear Correlation, which is simply called the Correlation Coefficient, and referred to as 'r'. This is used to assess the linear relationship between the two elements in a given environment and is calculated by the method described by Roger Till (1980).

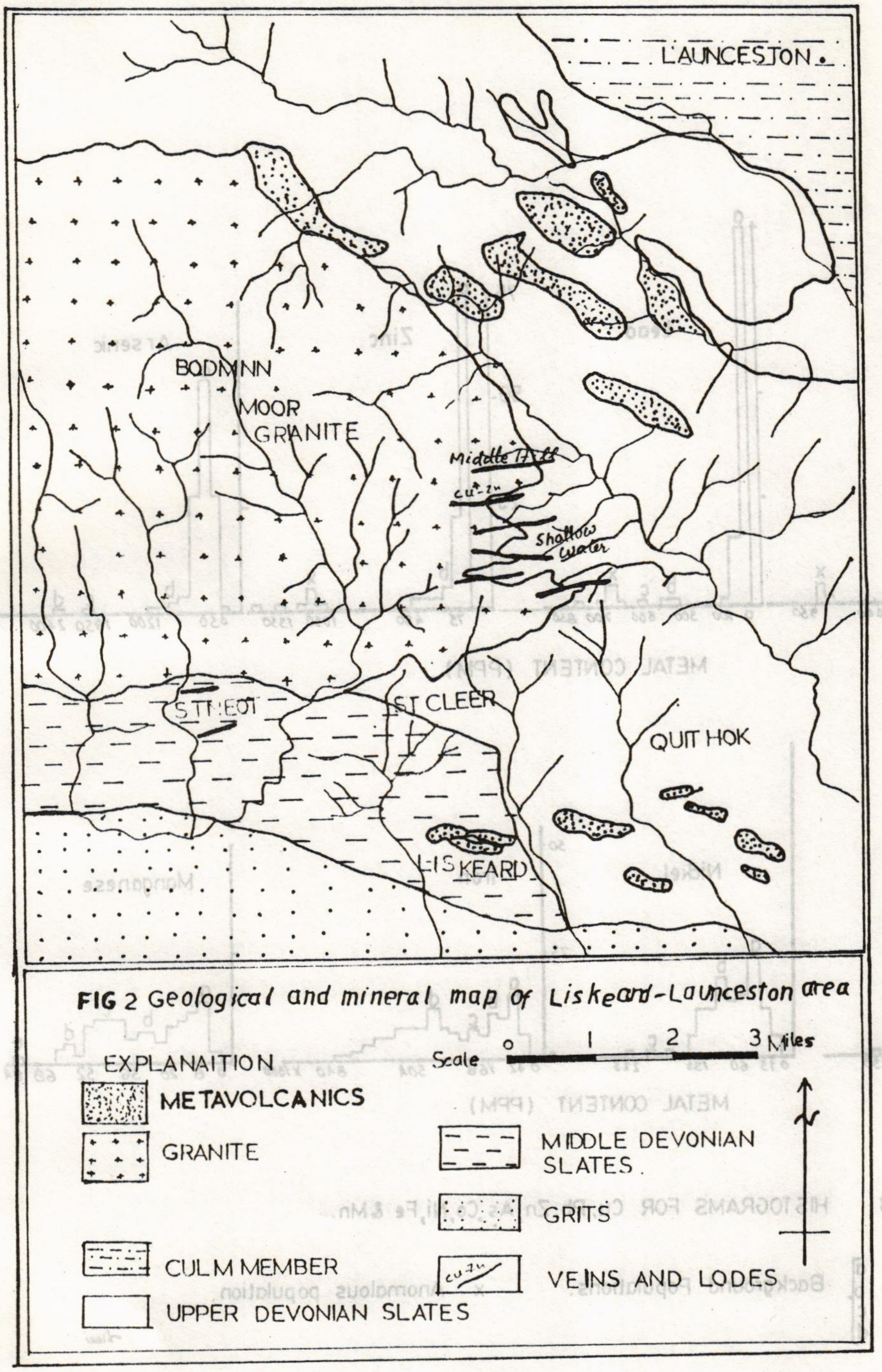

FIG 2 Geological and mineral map of Liskeard-Launceston area

The value of 'r' can vary between +1 and –1. So when 'r' = +1, it indicates that two variables vary together indicating a sympathetic relation or positive correlation. This correlation is perfect at +1. When 'r' = –1, a negative correlation exists having antipathic relation which is perfect at –1. When 'r' = 0, it shows no relation at all (see table 1).

GEOLOGY OF THE AREA

The Liskerard-Launceston area consists of Upper and Middle Devonian slates and grits which are affected by faults and repeated by innumerable folds. These slates are dark and at places due to faults are indistinguishable from each other in the field. Usher (1907), however was able to

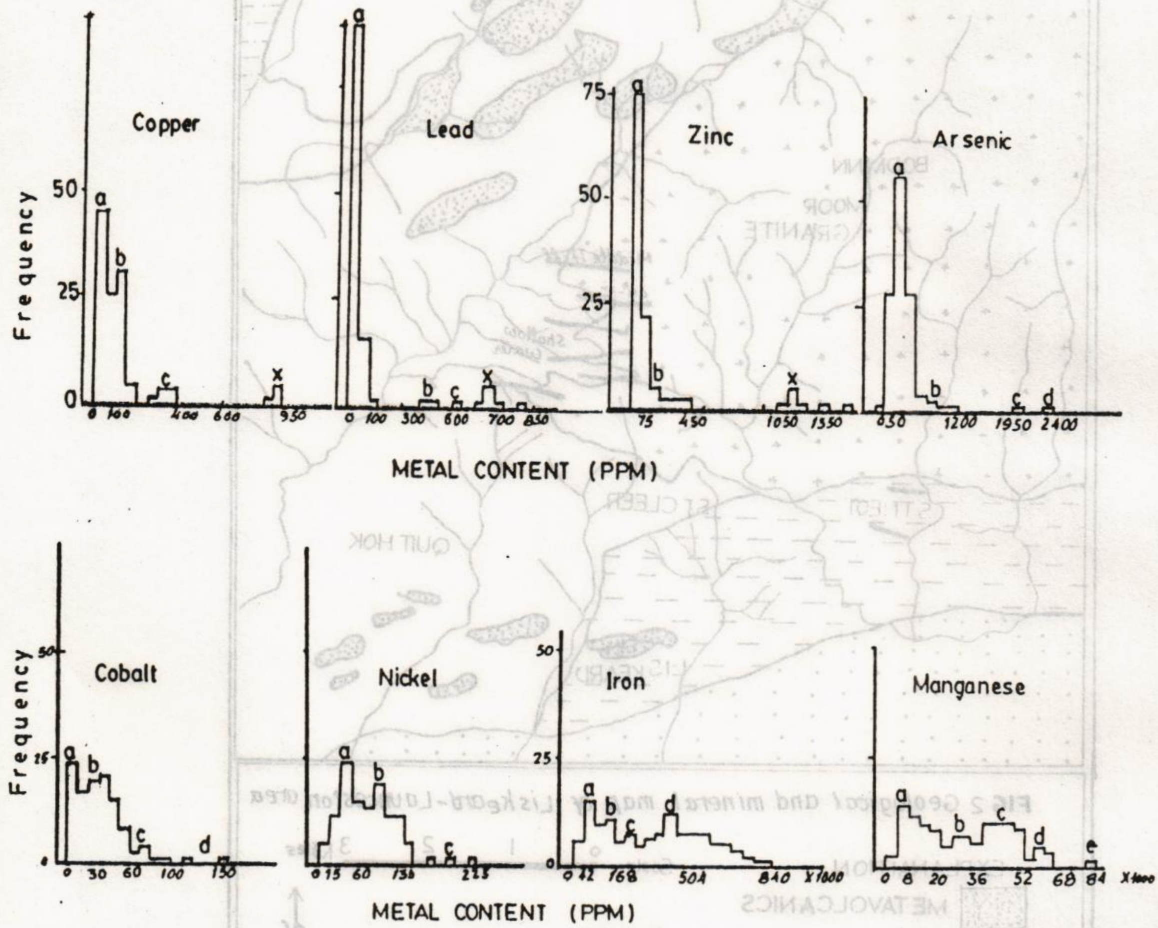

FIG: 3 HISTOGRAMS FOR Cu, Pb, Zn, As, Co, Ni, Fe & Mn.

a, b, c, d — Background Populations. x Anomalous population.

map the approximate boundaries of the Middle and Upper-Devonian slates, which run westwards along the metamorphic aureole of the Bodmin Moor Granite (see fig. 2).

Within the aureole of the granite, the rocks are metamorphosed to mica schists or more rarely splintery hornfels. These beyond the zone of alteration, are fine silky slates usually dark grey coloured, (Barton 1961).

BODMIN MOOR GRANITE

This is the granitic body occupying a part of the study area (see Fig. 2) and all the mineralized venis and lodes are probably related to its emplacement. It mainly contains feldspar, quartz, muscovite and biotite, the tourmaline being
very common accessory mineral.

feldspar, quartz, muscovite and biotite, the tourmaline being very common accessory mineral. Also, present in small amounts are andalusite, cordierite, apatite, pinite, zircon and topaz. The granite is usually grey in colour and porphyritic in texture.

It has been proposed that during the process of crystalization of the granite, hot volatile gasses were emitted from the residual magma, including water vapours at high pressure containing boron, flourine, sulphur dioxide and carbon dioxide. These chemically active volatiles forced their way into the fissures and shrinkage cracks of the granite crust and into the country rocks, bringing about the formation of metallic mineral deposits (Barton 1964).

MINERAL DEPOSITS

The Liskeard-Launceston area of Cornwall had been famous for its minerals and mines in the past and known mineralization is mainly around the Bodmin Moor Granite. Lead-Zinc lodes with quartz and siderite as gangue minerals, are reported in Shallow Water and Middle Hill areas. These carry chalcopyrite and pyrite in minor amounts. The tin – copper lodes are generally clustered around the granite where swarms of intrusive greenstone crop out (Dine 1956). The important lode deposits of lead-copper pyrite type also cropout near St. Cleer.

Relation Between Anomalies and Mineral Deposits: –

The usefulness of above method within the study area can be assessed by the degree to which anomalous values can be used to trace out known mineral deposits. A total of six anomalous values were obtained from the streams which reflect anomalous Pb, Cu, and Zn contents of veins and lodes.

Two Samples from St. Neot area have successfully traced out the Cu (Sn) viens with associated Pb and Zn. Other two anomalous samples are from Shallow Water and from nearby lodes and veins. Similarly sample No. 235 from St. Clear area have picked anomalous metal disperson for Pb, Cu and Zn having probable source in lodes and viens of the area.

TABLE 1

Mean, Standard Deviation, Coefficient of Variation and Correlation Coefficient.

	Mean	Standard deviation	Coeff. of Variation C. V.	Correlation Coeff.	
Cu	149.00	214.80	1.435	Cu/Zn +	0.970
Pb	109.30	177.50	1.620	Pb/Zn +	0.930
Zn	159.80	287.60	1.800	Pb/Cu +	0.700
AS	433.20	289.30	0.700	Cu/As +	0.040
Co	347.70	22.59	0.660	Pb/Co +	0.077
Ni	69.54	36.60	0.510	Ni/CO +	0.860
Fe	31330	20059	0.640	Cu/Fe +	0.082
Mn	29621	17708.80	0.600	Fe/Mn +	0.860

Coefficient of Variation: The coefficient of variation is considered a measure of relative variability which takes into account the mean and the standard deviation. For instance, as mean increases C.V. for most of the observed geochemical distribution tends towards zero. Conversely, for quantities present in very small amounts, C.V. for the observed data distribution tends towards infinity. In particular, values of the C.V. above 2 or 2.5 are usually only for substances in trace amounts. (See Table 1).

TABLE 2

Sampling and Analytical Errors at 95% Confidence Level

Metals	σ^2D	σ^2E	Degrees of Freedom	F. Calc (σ^2D/σ^2E)
Cu	0.3300	0.00030	112	1100.00
Pb	0.0752	0.00798	112	9.40
Zn	0.2860	0.00420	112	68.10
As	0.9100	0.00300	112	–
Co	0.1087	0.00254	112	15.41
Ni	0.2126	0.01380	112	1522.49
Fe	0.1979	0.00130	112	32077.00
Mn	0.4100	0.00140	112	2722.40

Validity of data: Before using the analytical data as a base towards defining a mineralization source area, it is essential to be sure about the precision of the numerical values to be used to define anomaly. Garrett (1969) had described a method for calculating errors using a single factor, that is fixed analysis of variance modal i.e. analysing the duplicate samples. This method uses F-test to determine whether the overall data variability σ^2D is significantly greater than the variability σ^2E introduced by sampling and analytical errors.

The analysis of variance is carried out by Suedecor's Factor (F) which is equal to σ^2D/σ^2E and is the variance ratio. Garrett (1969) suggests that F should be greater than 4 for the sampling and analytical errors to be significantly small at 95% level. Table-2, indicates that the combined smapling and analytical variance (σ^2E) is significantly smaller than the overall data variability σ^2D and thus the data is acceptable as being of a satisfactory quality for statistical analysis.

Discussion: The absence of glacial or other transported deposits over much of the area implies that most of the stream sediments and its contained metals are derived largely from nearby bed rock or from the source above sample point. Hence, metal content in the stream sediments of study area may be considered as being roughly proportional to the average metal content of the rocks underlying the corresponding drainage area.

CAUSES OF MULTIMODAL DISTRIBUTIONS

Analytical Bias: The analytical bias may cause several breaks on the cumulative frequency curve. The curve for most of the elements do not have any break below 20 ppm, which shows sufficient accuracy maintained in the analytical process, except Zn, which shows one break below 20 ppm, that might be the result of analytical bias (see fig-5).

Heterogeneity of lithological units: The inclusion of more than one lithologic unit may cause multi-modal distribution if the unit comprises two or more different rock types having different trace metal characters. Otherwise the effect of lithologic heterogeneity causes merely to increase the standard deviation of the population. The negative Zn anomalies in stream sediments from areas of metasediments and metavoleanics, (Fig-5) may have been caused by lithologic heterogeneity.

Background population: This is the normal range of concentrations for an elemen in unmineralized samples from a given area which can be slightly higher than Clarke's Values. These background values or populations are represented by different peaks on histograms and as breaks in the frequency curves below mean plus two standard deviation. Many back ground populations were defined for all the metals on histograms and cumulative frequency curves (see figs 4-5).

Anomalous Populations: Those metal values which exceed Clarkes Value considerably and are plotted above mean plus two standard deviation on probability paper are considered to be Anomalous Populations. This statistical limit has proved useful in defining anomalous values from high background values which otherwise, visually becomes impossible. (Sinclair 1976).

(i) *Copper Lead, Zinc and Arsenic:* These are chalcophile elements and are found associated with Ag, Cd, Sb, Bi, Mo, Ni and Co in different types of deposits: These are adsorbed on clays, organic matter, and Fe-Mn oxides and hence mobility is reduced. The mobility in secondary environments under oxidizing acidic conditions is high for Cu and Zn, fair for As and low for Pb.

The frequency curves for these elements show at least three log normal background populations (fig. 5). The anomalous populations are well defined on the curves, which point towards economical mineral concentrations.

(ii) *Cobalt and Nickel:* These are lithophile elements and are found associated with Cu, Pt and Mg minerals in mafic and ultramafic rocks. Mobility in secondary environments under oxidizing, acidic conditions is good but can reduce due to adsorption on Fe-Mn oxides, clays and change in pH. Nickel is immobile in alkaline or reducing hydrogen sulphide environments (Rose and Webb 1979; Levinson 1980).

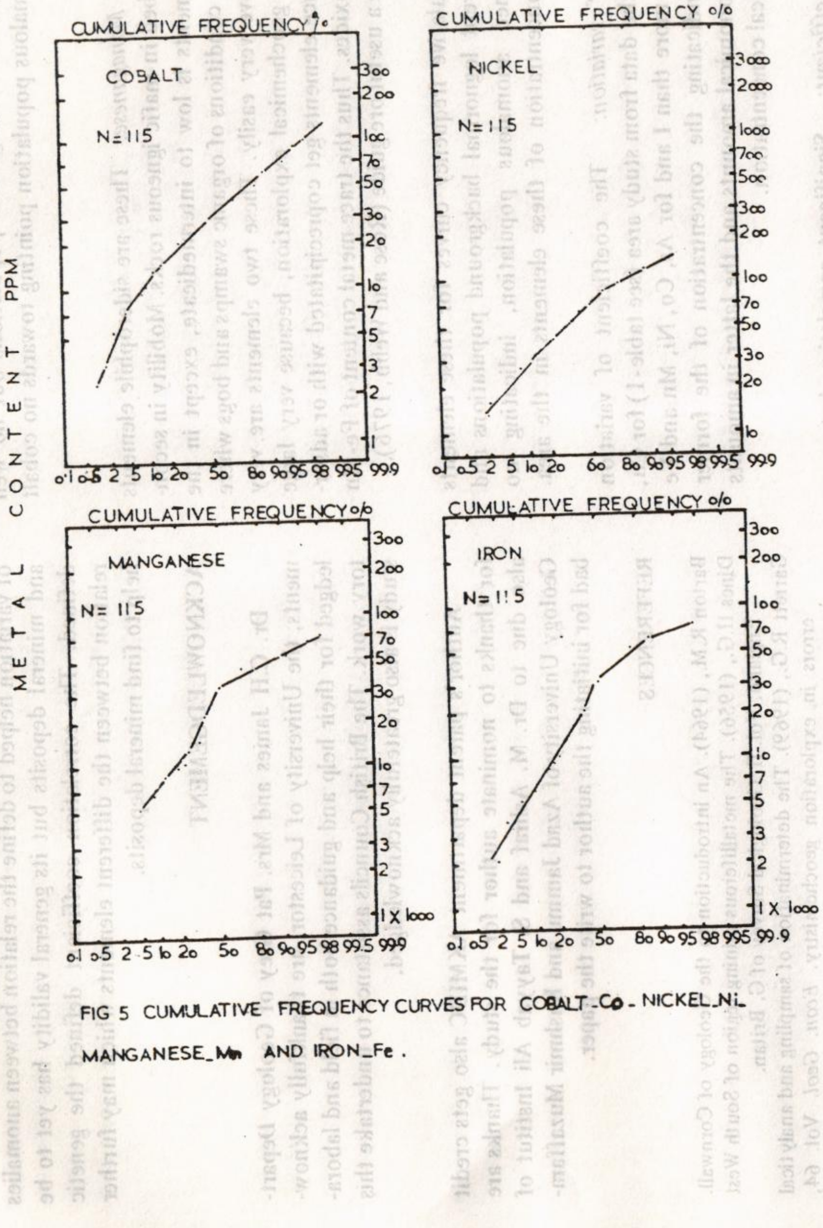

FIG 5 CUMULATIVE FREQUENCY CURVES FOR COBALT_Co - NICKEL_Ni_ MANGANESE_Mn AND IRON_Fe .

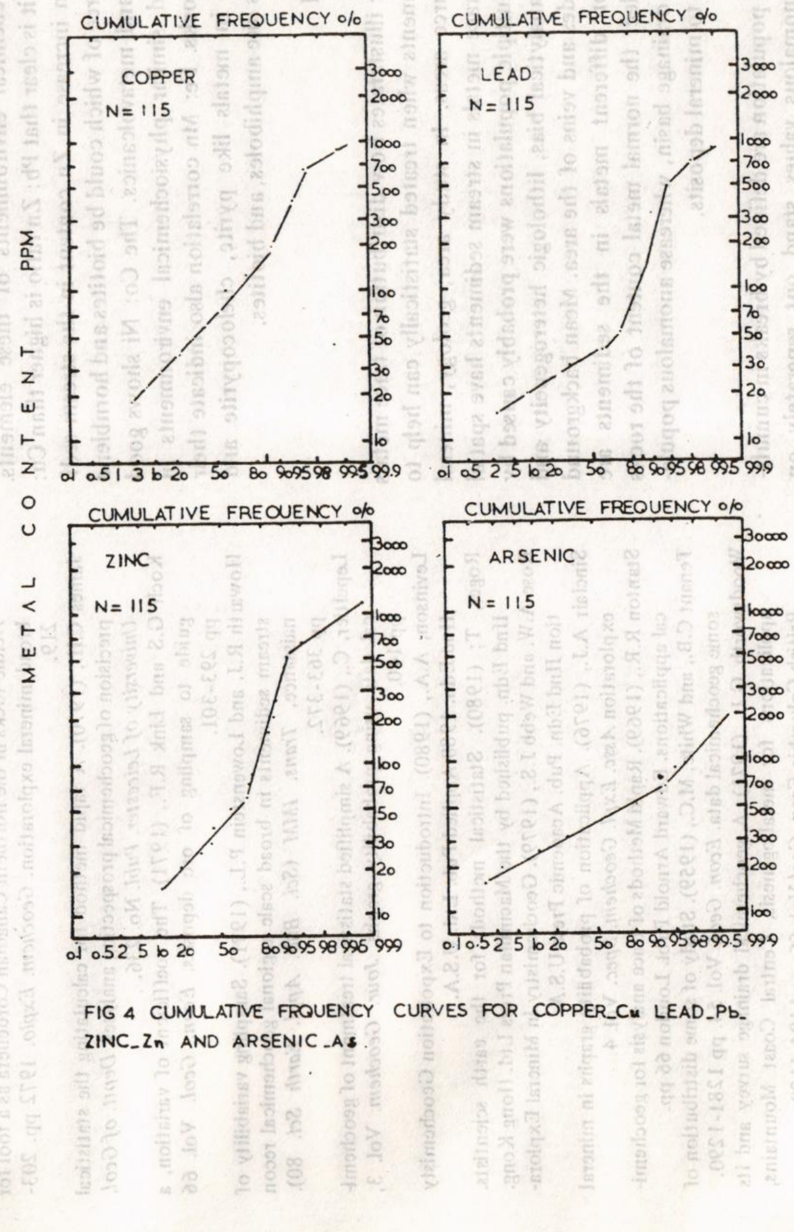

FIG 4 CUMULATIVE FRQUENCY CURVES FOR COPPER_Cu LEAD_Pb_ ZINC_Zn AND ARSENIC_As .

The frequency curves for these elements show more than two lognormal background populations but no well defined, anomalous population pointing towards no cobalt and Nickel.

(iii) *Iron and Managanese:* These are siderophile elements and get enricbed in mafic igneous rocks. Mobility in secondary environments is low to intermedieate, except in the acid reducing conditions of organic swamps and bogs where these can move very easily. These two elements are very important in geochemical exploration, because very large number of trace elements get coprecipitated with or adsorbed on their oxides. Thus the trace metal content of Fe-Mn oxides may be a useful ore guide (Rose and Webb, 1976).

The cumulative frequency curves for these elements indicate different lognormal background populations and no well difined anomalous population, indicating no economical concentration of these elements in the area.

Coefficient of variation: The coefficient of variation measured for the data from study area (see table-1) for Cu, Pb, and Zn is more than I and for As, Co, Ni, Mn and Fe less than I, indicating the concentration of the former elements in economical amounts and the latter in amounts below economical concentration.

Correlation coefficient: Significant correlation between Cu: Zn, Cu: Pb, Co: Ni, and Fe: Mn (Table 2) suggest similar physiochemical environments of these elements. From table-2; it is clear that Pb: Zn ratio is higher than Cu: Pb, showing an increase in Zn content in the stream sediments, the source of which could be biotites and hornblend from granites and metavolcanics. The Co: Ni shows good correlation and similar physiochemical environments in metavoldanic rocks. Fe: Mn correlation also indicate their presence both in metals like pyrite, chelocopyrite and silicate minerals like amphiboles, and biotites.

CONCLUSION

This study illustarates how distribution of trace metals in stream sediments when treated statistically can help to locate the source areas. In study area, geology, mineral deposits and trace metals in stream sediments have spatial relationship. Multiple populations were probably caused by sampling and analytical bias, lithologic heterogeneity and mineral rich lodes and veins of the area. Mean background populations for different metals in the sediments are thought to reflect the normal metal content of the rocks underlying the drainage basin, wherease anomalous population are related to mineral deposits.

Lognormal population are defined by breaks in cumulative curves. Anomalous values stand out seperately on histograms and as a tail on frequency curves. The coefficient of variation helped to define the relation between anomalies and mineral deposits but its general validity has yet to be defined. The correlation coefficient defined the genetic relation between the different elements which may further help to find mineral deposits.

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GENETIC DELINEATION OF DELTAIC ROCK TYPES IN TERMS OF LOG CURVE SHAPES IN THE ALGYO"-2 HYDROCARBON RESERVOIR, HUNGARY

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ABSTRACT. – Most of the deltaic sandstone reservoirs exhibit complex lithofacies as well as petrophysical variations in both time and space. Facies analysis and reconstruction of facies patterns for the Algyo"-2reservoir rocks encountered in fourth five bore-holes have been elucidated, using the log curve shapes. Vertical profiles of the log response against the studied intervals were categorized for three superimposed, deltaic rock types in most bore-holes. There-upon, the defined vertical units were mapped as their geographical distribution to throw light on both the location of the palaeoshoreline and the deltaic phase relationships.

In addition, the facies marker horizons reflecting orientation, geometry and palaeogeographic distribution of the Algryo"-2 Sandstone were depicted.

INTRODUCTION

The Late Miocene (Pannonian) Algyo"-2 reservoir is one of twenty one superimposed potential sandstone reservoirs drilled in the Algyo" field, which had been discovered by the authorities of the Hungarian oil and gas Trust (OKGT) in 1965. The Algyo" field lies on the southeastern part of Hungary; some 10 kms north of the Szeged town (Fig.1). The Algyo"-2 Sandstone shows fundamental lithofacies changes. The sedimentary sequence is characterized by a general upward increase in the number of cycles and amount of intergranular clay and silt size particles. Sandstone microlenses of 20-30 cm length and 25-50 cm thickness are commonly present, and the dark-brown coal as well as carbonaceous clay interclations are rather frequent. The environment of deposition of the Algyo"-2 Sandstone has already been differently outlined by different authors (Mucsi, 1973; Mucsi and Révész, 1975; Magyar and Révész, 1976 and El-Sayed, 1981) using the interpretation of the depositional sedimentary facies (lithology, sedimentary structures, palaeocurrents, and fossils) in combination with the grain size parameters. This has led to the conclusion that the Algyo"-2 Sandstone is a shallow-lacustrine deposit (Mucsi and Révész, 1975). While El-Sayed (1981) concluded that the most likely depositional environment is a fluvially dominated delta.

For each bore-hole, a direct calibration between log motifs and vertical profile of a median grain size must be made to check rock type upon log response. The response of several wire line logs (spontaneous potential, gamma and resistivity) is very helpful in reservoir zonation and deltaic rock genetic type identification (Le Blance, 1977).

If the log motifs are harmonically concordant with the rock type, then the log curve shapes can be directly related to the rock genetic types, its associated textures and primary structures. The reservoir rock interval is commonly subdivided both vertically and horizontally into bay zones that are either completely or partially separated by impremeable rocks. The palaeogeographic distribution of genetic type reservoir rocks in combination with their vertical separation and identification of various separate units are important in reservoir description, as well as in planning optimum hydrocarbon recovery operations and predicting reservoir performance more economically.

In the present work, both spontaneous potential and the short-normal resistivity curves opposite the various intervals of the Algyo"-2 Sandstone encountered in forty five bore-holes have been used for recognizing different reservoir rock (genetic) types in both vertical profiles and areal distributions.

METHODS AND TECHNIQUES

Interpretation of sand bodies and their environment of deposition, using both vertical grain size profiles and the response of several geophysical logs, have already been discussed by a number of investigators (Galloway, 1968; Fisher, 1969, Pirson, 1981 ; and Selley, 1982) and widely applied in oil industry (Sneider and others, 1977; Berg, 1979; and El-Sayed, 1981). Different deletaic rock types have been recognized by observing the physical criteria by which these may be distinguished on spontaneous potential and resistivity curves. Several recognizable patterns of spontaneous potential curve shapes for charged sandstone reservoirs have been categorized by both Gilreath and Stephens (1975) and Swanson (1980).

The vertical profiles of the Algyo"-2 reservoir log curves (in forty five drilled wells) have been investigated, categorized and mapped in both time and space (with respect to well locations) and two stratigraphic cross-sections have been constructed in order to meet the objectives of the present study.

RESULTS AND DISCUSSIONS

A comparison of the log curve shapes with the lithologic succession in the studied intervals shows that the rock types can be interpreted from a combination of the median grain size with both the spontaneous potential and the resistivity curves. Typical relationships between rock types and log cruve shapes are shown in Fig. 2. The permeable beds exhibit moderate to well developed spontaneous potential curve. While, the none-permeable zones show characteristically hashy separation on the microlog curve. In addition, the fine grained sediments exhibit low resistivity, while the increase in grain size is accompanied by a gradual increase in resistivity.

The log curve shapes of the studied rock sequences were investigted and categorized according to their depositional energy (Table 1). These were found to be characteristically distinguishable by both their grain size and spontaneous potential versus depth curves in which, different genetic sand bodies could be depicted (Table 1). Some of these sand bodies were missed or repeated in some of the studied wells, but regional correlation could be easily established.

In the studied wells, the rock sequence was found to be rather heterogeneous, i.e. the sand bodies of more than one genetic type are found in a cyclical regime. The prevalent superimposed genetic sand units depicted are channel, river mouth bar, deltaic front, and barrier bar (Tabel 2).

An attempt was made to subdivide the hybrid genetic sand units in each bore-hole into three major periods of delta development. Thereupon, the obtained rock genetic types (Table 2) were mapped as older, middle, and younger Algyo"-2 deltaic phase (Fig. 3). This map shows that the delta palaeoshoreline can be distinguished and that both the geometry and the distribution of the reservoir genetic sand units can be predicted in time as well as in space. The direction of the drawn arrows represents the probable directions of the movement of the palaeoshoreline with time and can indicate the most likely directions of the deltaic fluvial flow during the deposition of the recognized deltaic phases with varied flow rate. Both the regressive and the transgressive marine cycles were found to be generally different in direction during the time of deposition of the Algyo"-2 sediments.

The beginning of both the older and the younger prograding delta phases can be attributed to a regressive palaeoshoreline (the serrated curve type– while the smooth log curve shape can be attributed to stable palaeoshorelines as presented in some wells (No. 6,29,202 & 299). A transgressive palaeoshoreline type (Table3) is indicated in well-77 but the middle delta phase seems to be the dominant one in the Algyo"-2 prograding delta with marine regression and sediments introduced at points on the delta periphery (Fig. 3) of a water body, faster than it can be removed by coastal waves. This phase can be attributed to a regressive palaeoshoreline.

The stratigraphic cross-sections (fig. 4) reveal that the Algyo"-2 reservoir sand bodies are geometrically arranged in a lateral-stacking manner, while in some places, especially in the southern and south-eastern parts of the field, the vertical stacking type of reservoir geometry is predominent. Several genetic sand units have been identified (channel and barrier bar rock type) on the basis of the curve shape patterns. These display phenomena of sand pinching-out in which a favourable hydrocarbon entrapment situation could be developed. Fig. 4 shows, on one hand, a good reservoir continuity in delta upstreams and on the other hand, a bad reservoir continuity in both south and south-western parts of the investigated area.

CONCLUSIONS

1. The Algyo"-2 reservoir is rather heterogeneous in both time and space.
2. The Algyo"-2 reservoir rocks are genetically subdivided into three superimposed deltaic phases, while they were mapped as their geographical distribution.
3. Both the Algyo"-2 reservoir geometry and continuity were depicted.

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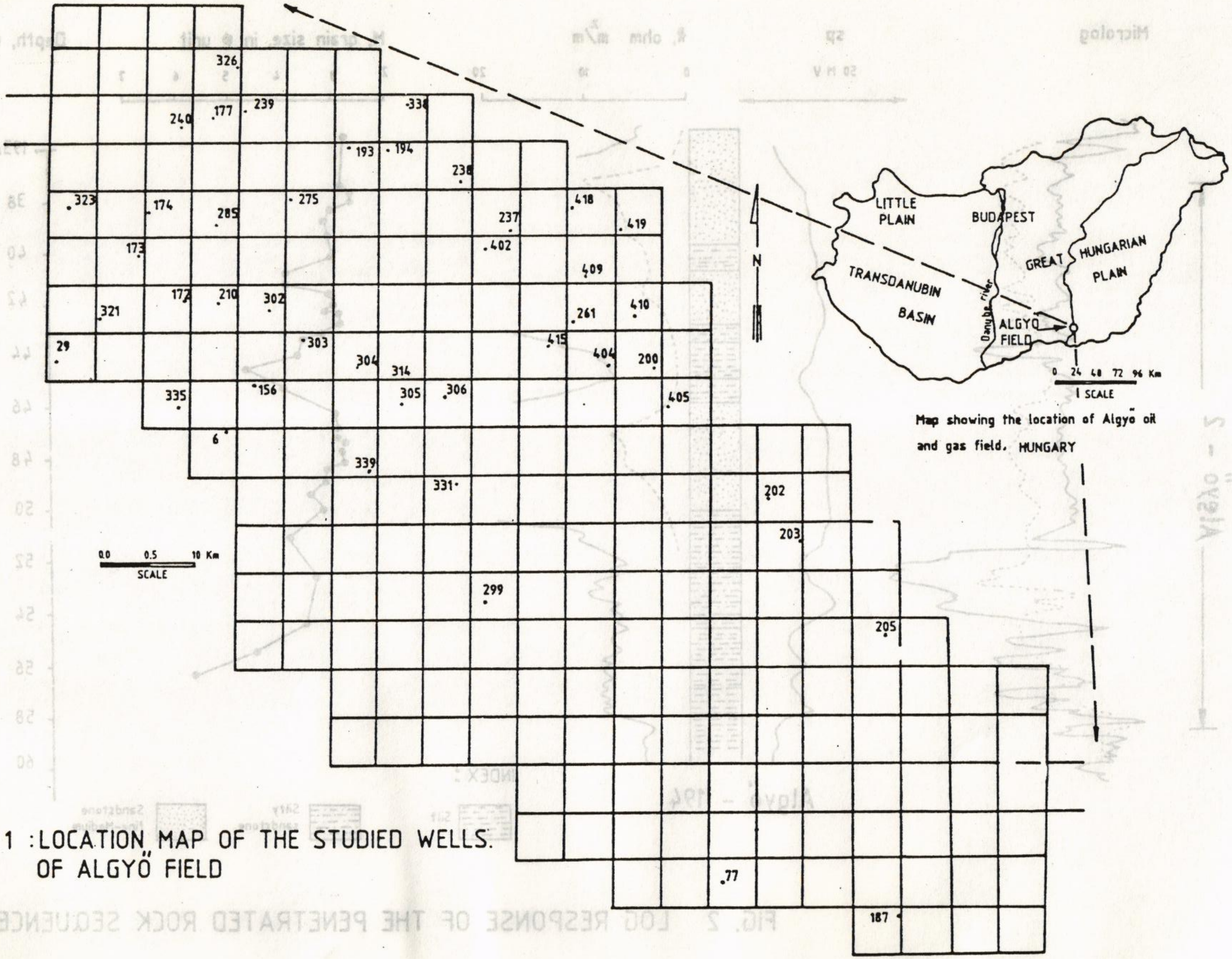


FIG 1 : LOCATION MAP OF THE STUDIED WELLS. OF ALGYÖ FIELD

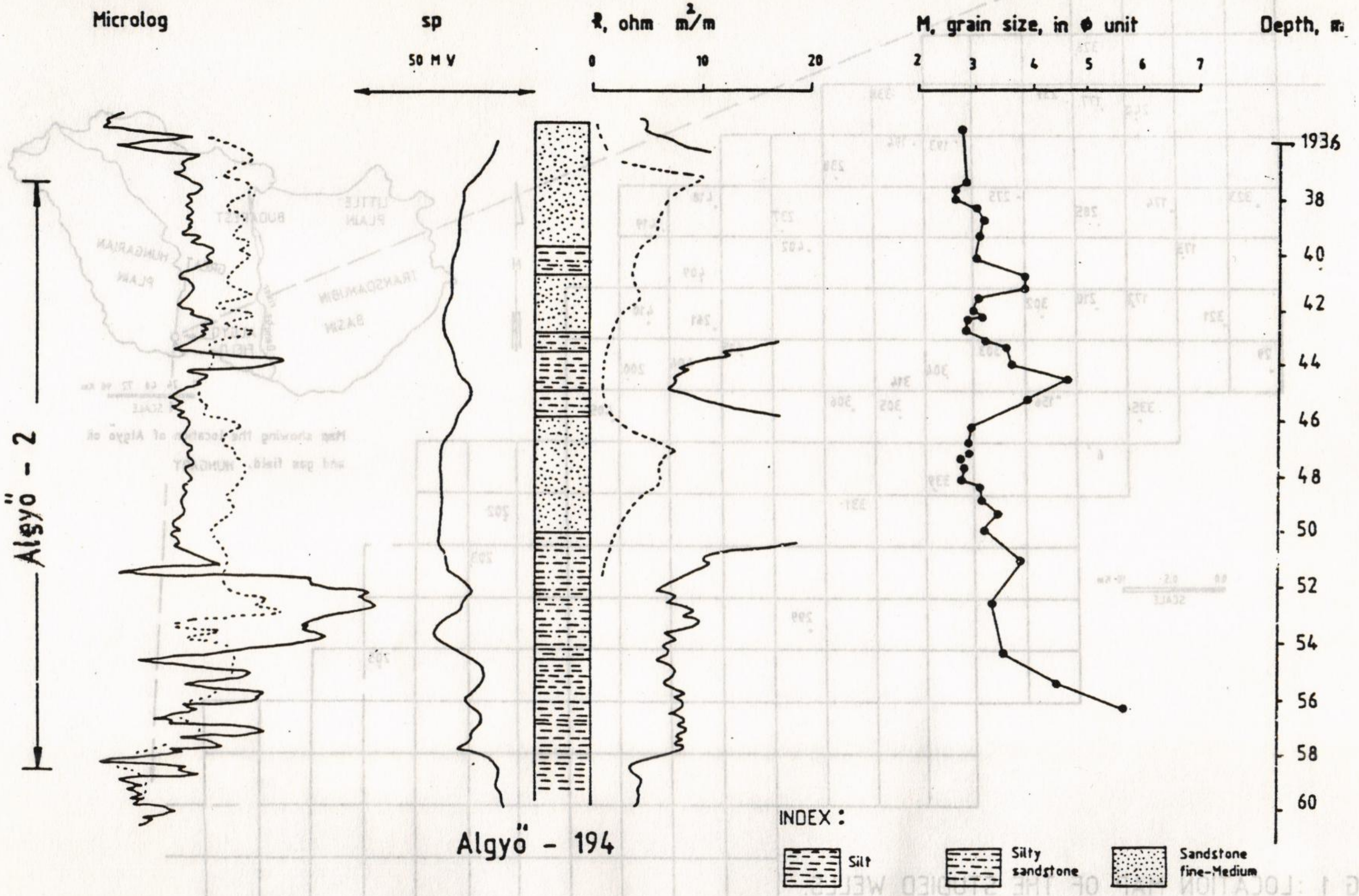


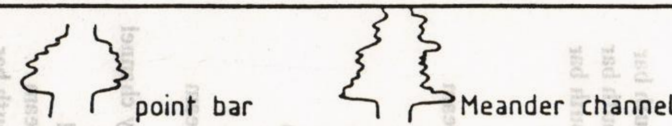
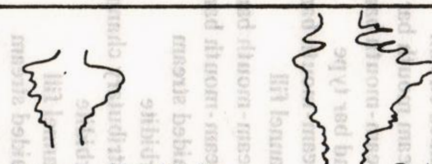
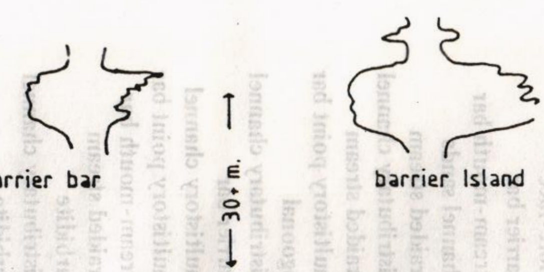
FIG. 2 LOG RESPONSE OF THE PENETRATED ROCK SEQUENCE.

Table 2

Delta Rock Genetic Types Depicted in the Studied Wells.

Well No.	Algyo"-2 Rock Genetic Types Upper	Middle	Lower
240	shore-face	stream-mouth bar	stream mouth bar
302	barrier bar	stream-mouth bar	stream-mouth bar
321	stream-mouth bar	stream-mouth bar	stream-mouth bar
285	channel sands	sand bar type	shore-face
331	braided stream	shore-face	point bar
299	distributary channel	barrier bar	point bar
174	braided stream	braided stream	braided stream
177	multistory point bar	stream mouth bar	shore-face
419	lagoonal	stream-mouth bar	shore-face
6	distributary channel	sand bar type	shore-face
418	barrier bar	stream-mouth bar	shore-face
275	multistory channel	channel fill	bay lagoon
326	multistory point bar	stream-mouth bar	shore-face
410	stream-mouth bar	stream-mouth bar	shore-face
329	braided stream	braided stream	braided stream
77	turbidite	turbidite	turbidite
187	distributary channel	distributary channel	distributary channel
203	turbidite	turbidite	shore-face
205	channel fill	channel fill	channel fill
193	braided stream	braided stream	braided stream
194	distributary channel	distributary channel	stream-mouth bar
172	channel fill	channel fill	channel fill
200	stream-mouth bar	stream-mouth bar	stream-mouth bar
173	distributary channel	distribitary channel	delta front
303	barrier bar	lagoonal	lagoonal
210	distributary channel	sand bar type	shore-face
304	barrier island	barrier bar	stream-mouth bar
202	aluvial fan	aluvial fan	shore-face
306	stream-mouth bar	distributary channel	distributary channel
261	point bar	stream-mouth bar	shore face
314	stream-mouth bar	point bar	delta front
323	stream-mouth bar	stream-mouth bar	stream-mouth bar
338	distributary channel	distributary channel	distributary channel
402	barrier bar	stream-mouth bar	stream-mouth bar
404	barrier bar	sand bar type	shore face
405	barrier bar	sand bar type	shore face
415	multistory channel	multistory channel	multistory channel
156	distributary channel	delta front	delta front
239	braided stream	braided stream	braided stream
237	braided stream	meander channel	meander channel
238	braided stream	meander channel	meander channel
335	barrier bar	transgrissive marine	delta front
305	barrier bar	stream-mouth bar	stream-mouth bar
339	multistory channel	multistory channel	multistory channel
409	barrier bar	multistory bar type	shore face

Tab. 1: Log curve shapes of the encountered Algyő-2 rock sequence.

		ENVIRONMENTS		LOG CURVE SHAPE	Ref.
TRANSATIONAL ENVIRONMENT (← increasing water depth)	DELTAIC	UPPER DELTAIC PLAIN	Channels and point bars	 point bar; Meander channel	well-205 well-261
		LOWER DELTAIC PLAIN	Distributary Channels	 Distributary channel	well-194
		DELTAIC FRINGE	River- Mouth bars and Delta front	 stream- Mouth bar; Delta front	well-321 well-418
	COASTAL INTERDELTAIC	COASTAL PLAIN	Barrier Island and Barrier bars	 barrier bar; ← 30+ m. →; barrier Island	well-405

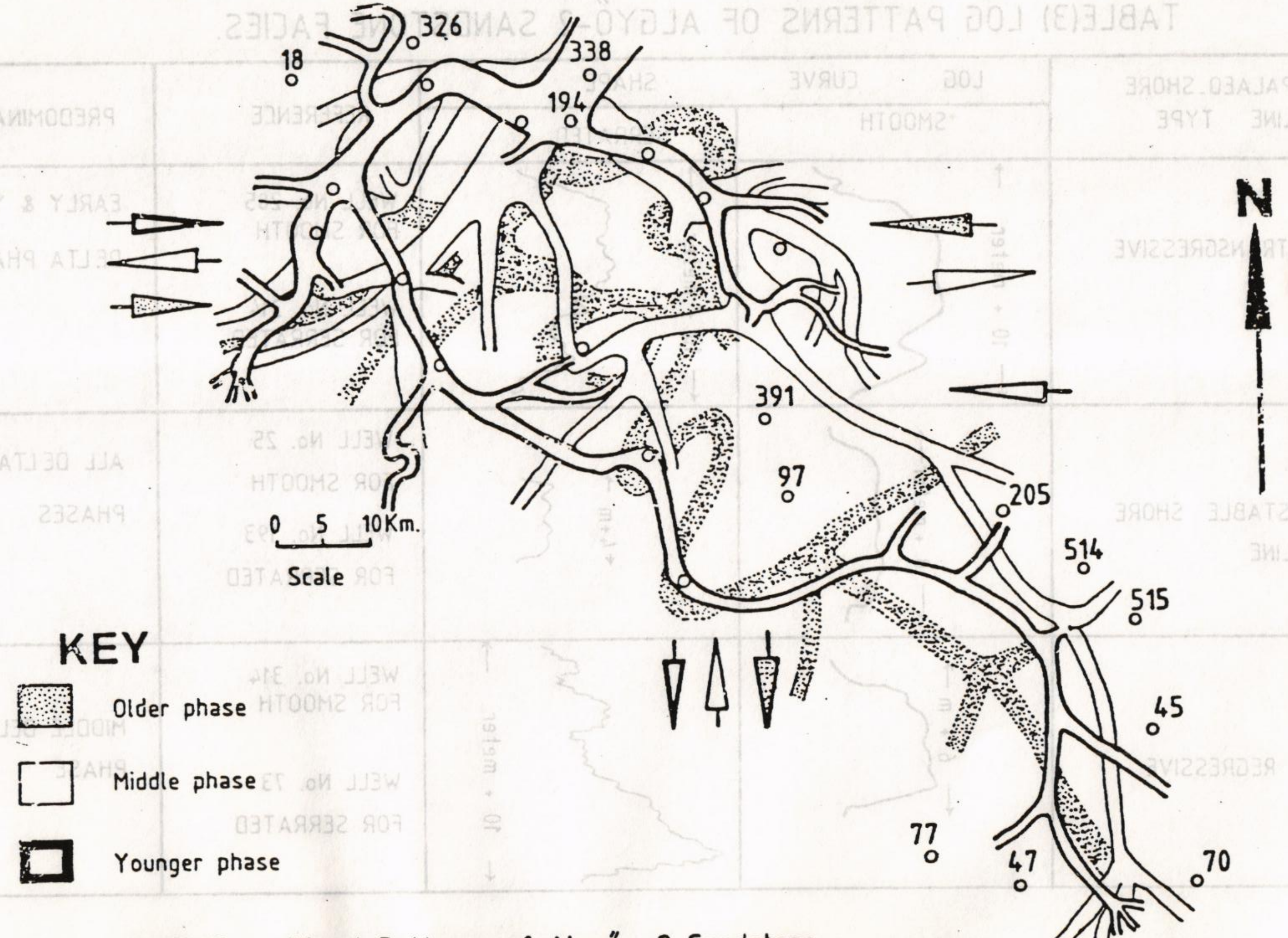
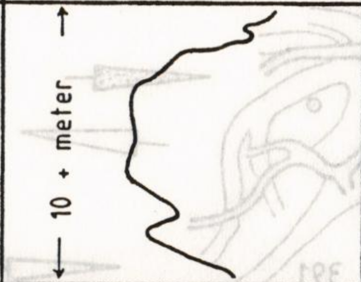
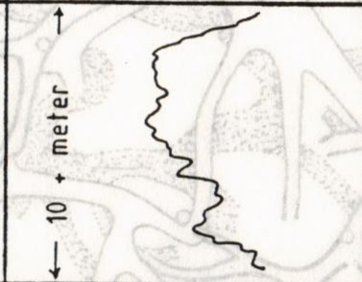
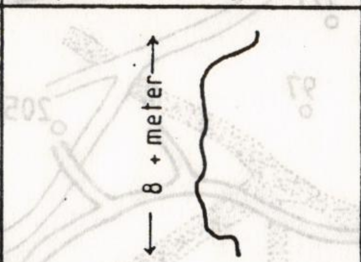
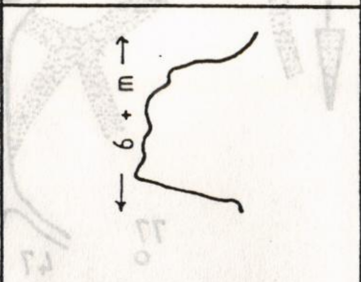
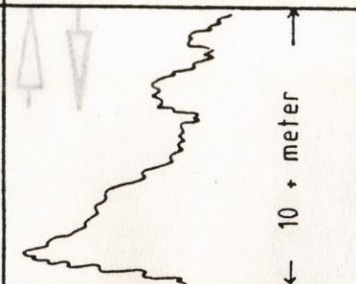


Fig.(3) Depositional Patterns of Algyő - 2 Sandstone

TABLE(3) LOG PATTERNS OF ALGYŐ-2 SANDSTONE FACIES.

PALAEO. SHORE LINE TYPE	LOG CURVE SHAPE: SMOOTH	LOG CURVE SHAPE: SERRATED	REFERENCE	PREDOMINANT IN :
TRANSGRESSIVE			WELL No. 285 FOR SMOOTH WELL No. 314 FOR SERRATED	EARLY & YOUNGER DELTA PHASE
STABLE SHORE LINE			WELL No. 25 FOR SMOOTH WELL No. 193 FOR SERRATED	ALL DELTA PHASES
REGRESSIVE			WELL No. 314 FOR SMOOTH WELL No. 73 FOR SERRATED	MIDDLE DELTA PHASE

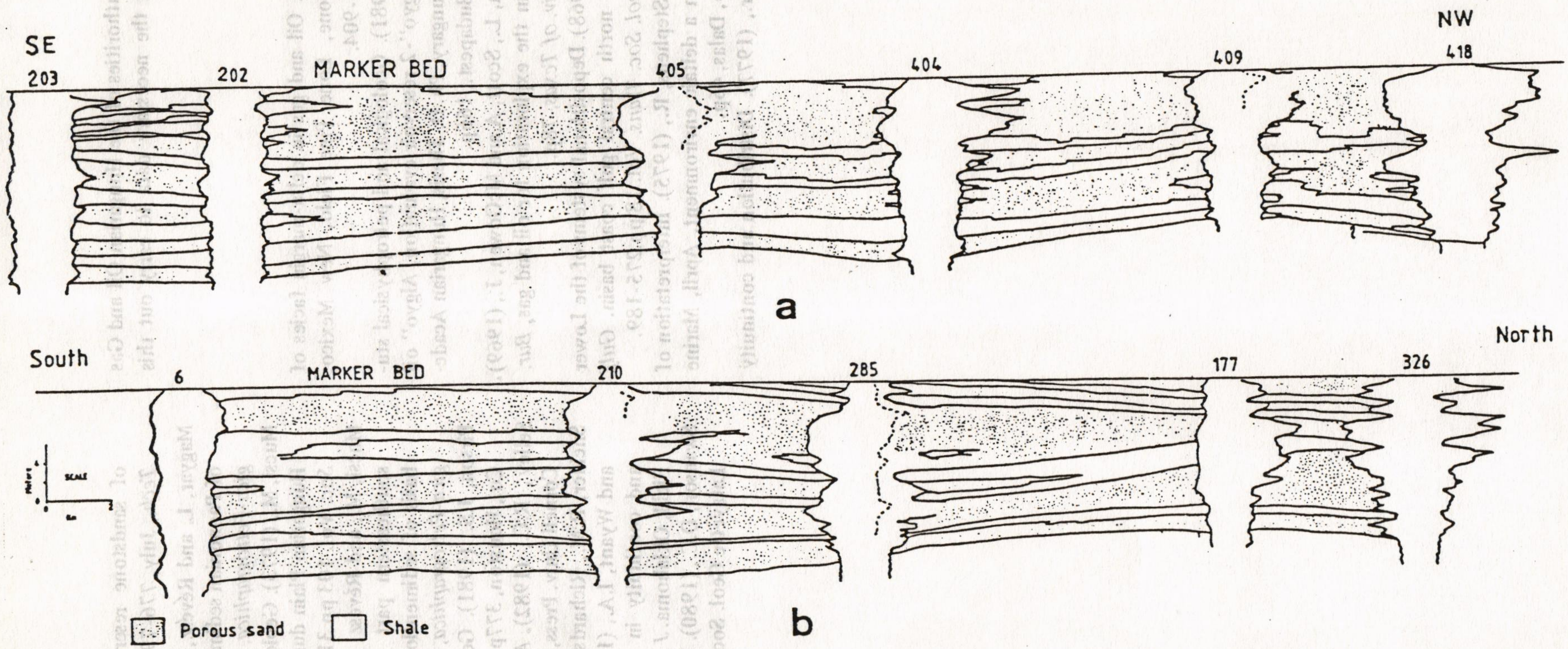


Fig.(4) Stratigraphic cross-sections (a&b) for Algyö-2 sandstone reservoir.

I thank the authorities of the Hungarian Oil and Gas Trust for providing the necessary data to carry out this work.

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Mucsi, M., and Révész, I. (1975). Neogene evolution of the southeastern part of the Great Hungarian Plain on basis of sedimentlogical investigations. *Acta Mineralogica-Petrographica, Szeged,* Vol. XXII/1 pp. 29-49.

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Selley, R.C., (1982). Ancient sedimentary environments, Cornell Univ. Press, New York, 287p.

Sneider, R.M., Richardson, F.H., Paynter, D.D., Eddy, R.E. and Wyant, I.A., (1977). Predicting reservoir geometry and continuity in Pennsylvanian reservoris, Elk City Field, Oklahoma. *J Petroleum Tech.*, July, pp. 851-866.

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ELECTRICAL RESISTIVITY SURVEY FOR GROUND WATER EXPLORATION IN MARDAN TOWNSHIP AREA N.W.F.P. PAKISTAN

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ABSTRACT: A detailed electrical resistivity survey was carried out in Mardan Township area to give location for instalation of tubewells. The geoelectric investigations were conducted at 23 sounding stations by using Schlumberger array, applying Georesistivitymeter (GEA-76). The apparent resistivity data for various electrode spacing was computed by apparent resistivity formula, and plotted against their respective electrode spacing (AB/2) on logrithmic graph paper of modules 62.5 mm to obtain the field resistivity curves.

To evaluate the thickness and true resistivity values of different subsurface layers 2,3 and 4 layer curves matching methods were applied. On the basis of true resistivity values the trends of resitivity curves and water quality, the subsurface strata of the area was classified into three distinct true resistivity zones for the purpose of groundwater exploration. Prominent fresh water zones are demarcated from east to west in the northern part of the area.

INTRODUCTION

Township area is one of the under developed areas of Mardan. Electrical Resistivity Survey was carried out in this area during the month of October, 1982.

The purpose of this investigation was to delineate the subsurface geology and to locate a suitable site for the installation of the tube-wells.

Vertical electrical sounding was executed with georesistivity meter (GEA-76) using Schlumberger electrode configuration. In the Mardan Township area twenty three probes were run. Out of which twenty two were selected for evaluation and interpretation. The common depth of exploration was nearly 600 meters. The depth of the water table was recorded in the project area and water samples were also collected from different open dug wells.

The field area is located 10 km south of Mardan city and lies with

Longitude 72° 1' 2" to 70° 4' 0" E
Latitude 34° 8' 16" to 34° 9" 27" N

Mardan township area is nearly 3.5 square km which is connected with Mardan city by a matalled road and railway line as shown in fig. 1.

PREVIOUS WORK: In the past no detailed groundwater Investigations were taken up within the area. However, groundwater investigation was carried out by Janisteel by resistivity method in Mardan Township area and two test holes also sunk. The discharge of both test holes are only $^1/_5$ cusic.

EQUIPMENT

In the area, the apparent resistivity data at 23 observation stations was collected by using the Schlumberger electrode configuration with Georesisitvity meter. The four electrodes, two outer current electrodes and two inner potential electrodes were driven into the ground in a straight line. The two outer current electrodes were connected to the two terminals of the power unit. The two inner potential electrodes were linked to resistivity receiver. The distance between the potential electrodes was one fifth of the distance of current electrodes.

Current from battery via power unit was passed into the ground through the two outer current electrodes. The input current in milliampere between the two outer current electrodes and resulting potential drop in millivolts between the two inner potential electrodes were measured by Georesistivit meter. The apparent. resistivity was calculated by using the following formula.

$$\rho_a = K \frac{\Delta V}{I}$$

Were ρ is the apparent resistivity in ohm-m, K is the geometeric factor in meter and ΔV is the potential difference in millivolts. I, is the current in milliampere.

INTERPRETATION AND PRESENTATION OF TRUE RESISTIVITY DATA

The calculated apparent resistivity was plotted on the biologrithmic graph paper of modules 62.5 mm against the respective spacing AB/2. Thus by plotting "ρ_a" for each AB/2 give the vertical electrical sounding curves which must be smoothed and devoid of kinks. The field curves are then subjected to various processes which are as follows:–

1. Interpretation of vartical electrical sounding curves by partical curve matching method.
2. Subsurface true resistivity zoning.
3. Sub-surface geological cross section based on true resistivity zoning.

Vertical Electrical Sounding Cruves Interpretation

In the field area twenty three probes were run among which twenty two are selected for interpretation by using two and three layers theoretical curves with auxilliary point charts of Orellana and Mooney (1966). For interpretation, these curves were classified and labelled for their types which give the resistivity variation of $\rho_1, \rho_2, \rho_3, \rho_4, \ldots$ etc. These curves were then interpreted by partial curves matching techniques in order to determine the thickness and true resistivity of each layer. Two out of twenty three interpreted curves are given fig. 4.

Sub-surface True Resistivity of Area

On the basis of true resistivity values, obtained by quantitative interpretation of the sub-surface, hydrological units have been classified into three distinct zones which are as follows.

a. Low Resistivity Zone (0-20 Ohmm)

b. Low Medium Resistivity Zone (20-40 Ohmm)

c. Medium Resistivity Zone (>40 Ohmm)

Low Resistivity Zone: The low resistivity zone represents the presence of argillaceous material i.e. clay, silty clay, shale or the presence of mineralized water. This zone may yield very little groundwater.

Low Medium resistivity Zone: This zone indicates the Presence of interlayering or admixture of clay, silty clay, shale and sand. This Zone may yield limited supply of groundwater.

Medium resistivity zone: This zone represents the presence of coarse and fine material i.e. admixture of clay, silty clay, sand, gravel. This zone may yield limited to fair supply of groundwater.

Subsurface geological cross section based on true resistivity values

The geological cross-section is to establish a three dismensional picture of the subsurface lithological units and to visualize the vertical and horizontal extent of the sub-surface formations and aquifers.

The schematic representation of some cross-sections of the field area are shown in Fig 2 and 3.

INTERPRETATION BASED ON SUBSURFACE GEOLOGICAL CROSS SECTION.

Four resistivity lines namely A-A' B-B' C-C' and D-D' are selected in the field area which approximately covers all the resistivity stations in the area. A brief and general interpretation of each resistivity lines is as follows:-

Resistivity line (R.L) A-A'
Probe No. 3-2-17-9 & 23. Low resistivity values are observed throughout the resistivity line at varying depths interpreted as fine material. Below this zone low medium resistivity values are formed which may be due to the interlayering of clay, silty clay and fine sand. The remaining depth below this zone shows low resistivity values which indicates the presence of orgillaceous material.

Resistivity Line (R.L) B-B'

Resistivity Line (R.L) B-B'
Probe No. 4-3-2-1-7 & 8. Along resistivity line (R.L) B-B' generally low resistivity values are found at all probe sites. Low medium resistivity zone is present below this zone. Low mediumresistivityzones are due to fine matęrial medium resistivity zone is present below this zone at P-7, and P-8 and is absent at P-4, P-3 and P-1 medium resistivity zone is present due to interbedding or admixture of fine and coarse material i.e. clay, sand and gravel.

MAP SHOWING PROJECT AREA

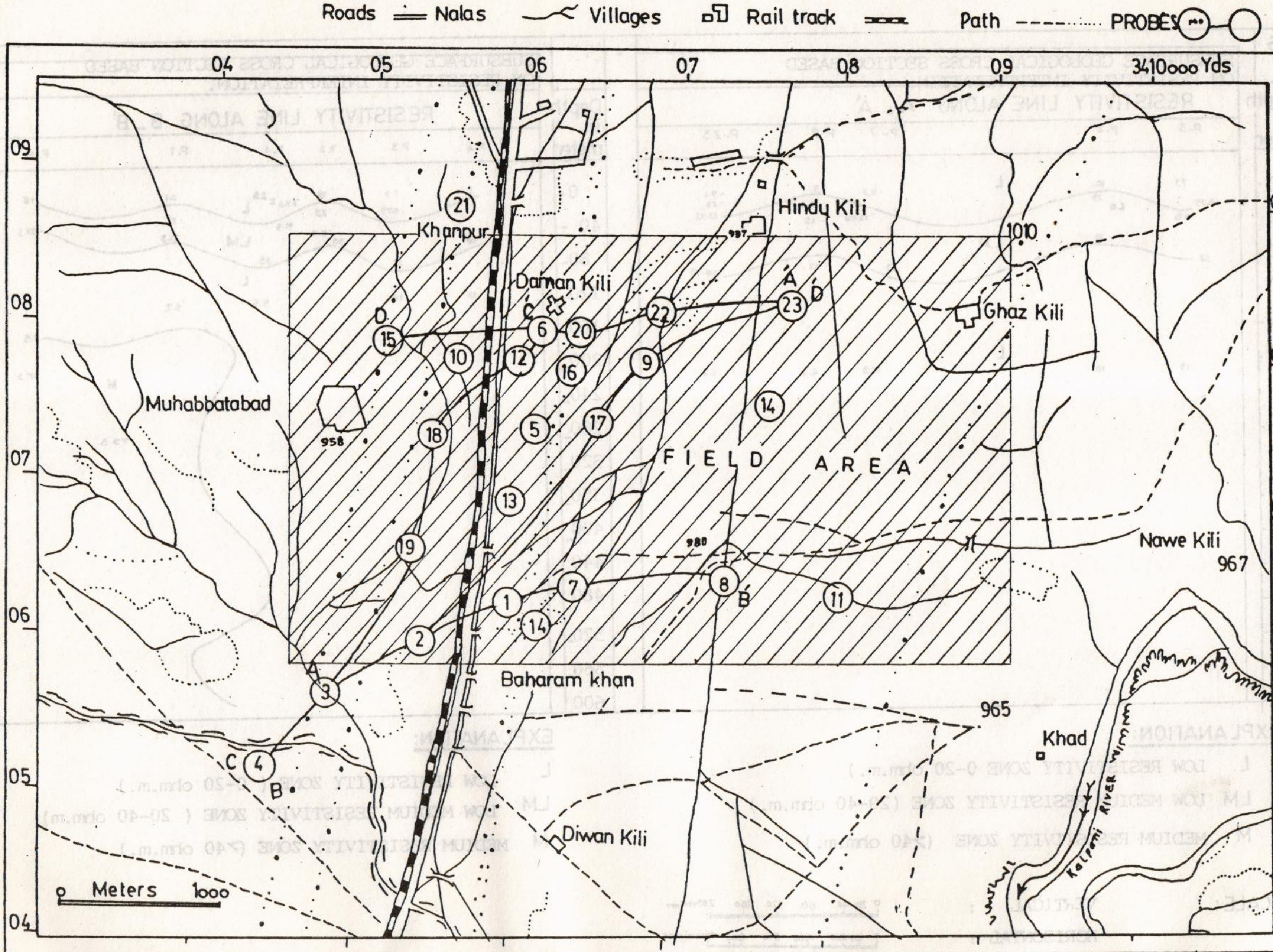
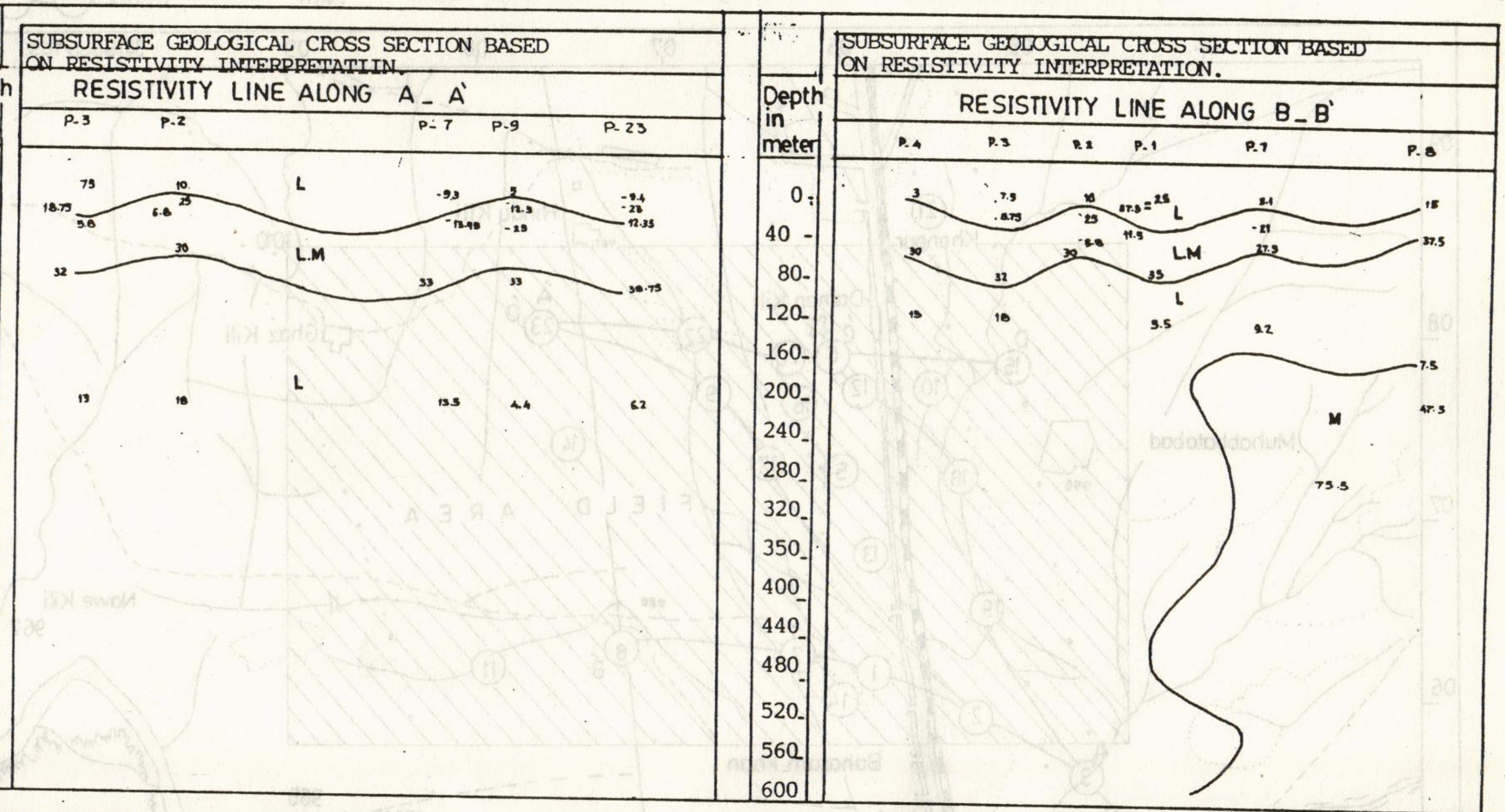


FIG:1

FIG 2



EXPLANATION:

L. LOW RESISTIVITY ZONE 0-20 ohm.m.)

LM LOW MEDIUM RESISTIVITY ZONE (20-40 ohm.m.)

M MEDIUM RESISTIVITY ZONE (>40 ohm.m.)

SCALE: VERTICAL : 0 20 40 80 120 160 200 meters

HORIZONTAL : 0 100 200 400 600 800 1000 meter

EXPLANATION:

L LOW RESISTIVITY ZONE (0-20 ohm.m.)

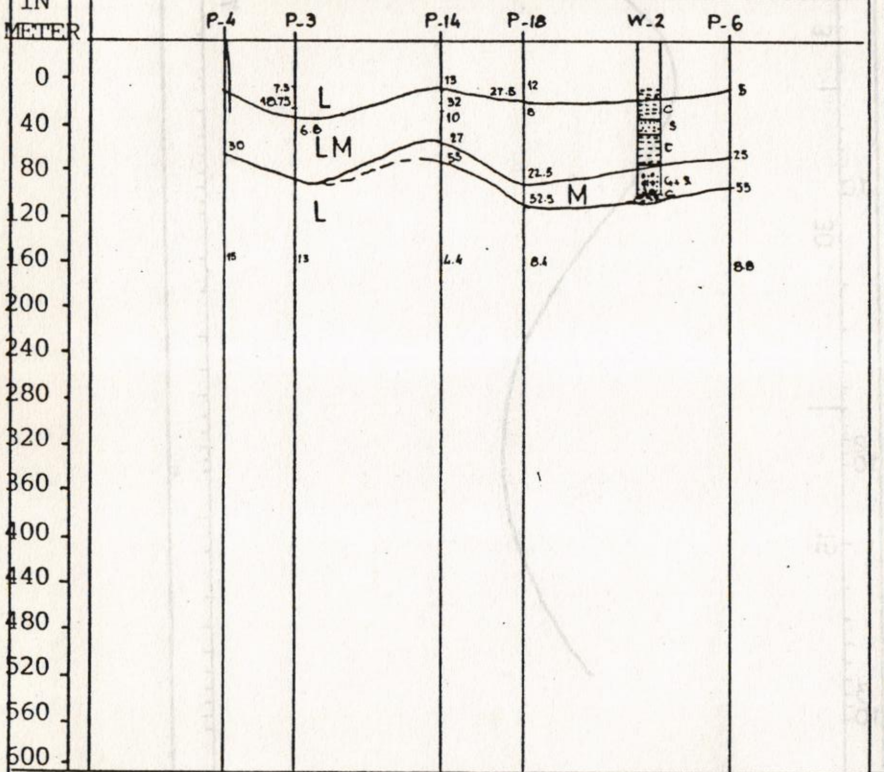
LM LOW MEDIUM RESISTIVITY ZONE (20-40 ohm.m)

M MEDIUM RESISTIVITY ZONE (>40 ohm.m.)

FIG. 3

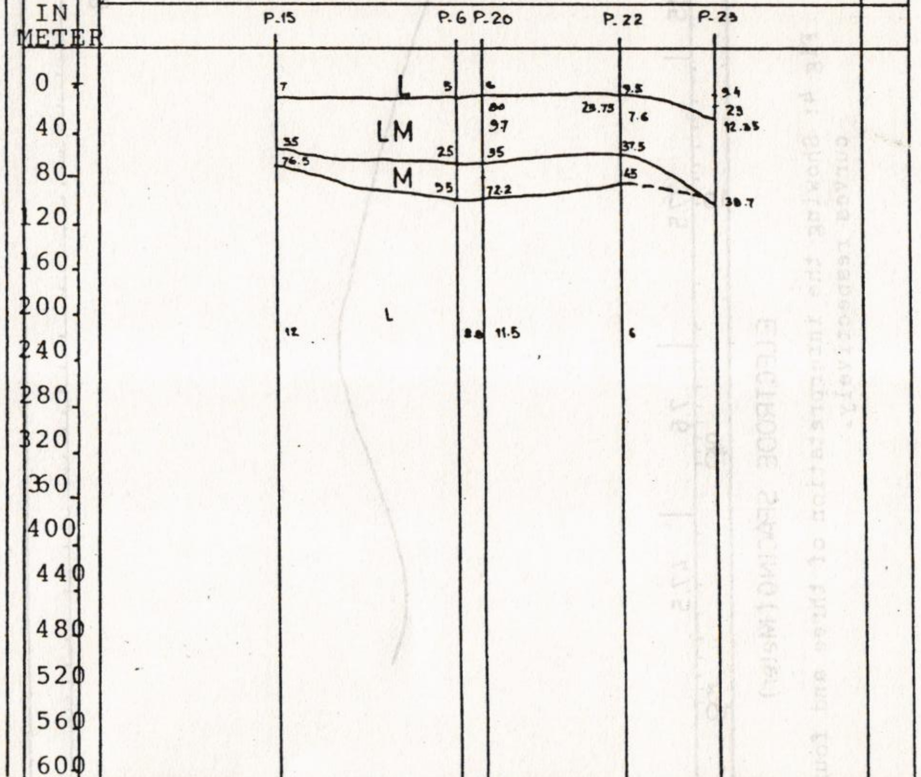
SUBSURFACE GEOLOGICAL CROSS SECTION BASED ON RESISTIVITY INTER-PRETATION.

RESISTIVITY LINE ALONG C_C'



SUBSURFACE GEOLOGICAL CROSS SECTION BASED ON RESISTIVIT'/ INTER-PRETATION.

RESISTIVITY LINE ALONG D_D'



EXPLANATION:

L: LOW RESISTIVITY ZONE (0.20 ohm.m)

LM: LOW MEDIUM RESISTIVITY ZONE (20-40 ohm.m)

M : MEDIUM RESISTIVITY ZONE (>40 ohm-m)

EXPLANATION:

L: LOW RESISTIVITY ZONE (0.20 ohm.m)

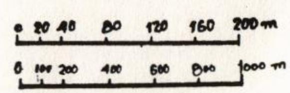
LM: LOW MEDIUM RESISTIVITY ZONE (20-40 ohm.m)

M : MEDIUM RESISTIVITY ZONE (>40 ohm.m)

SCALE:

VERTICAL :

HORIZONTAL:



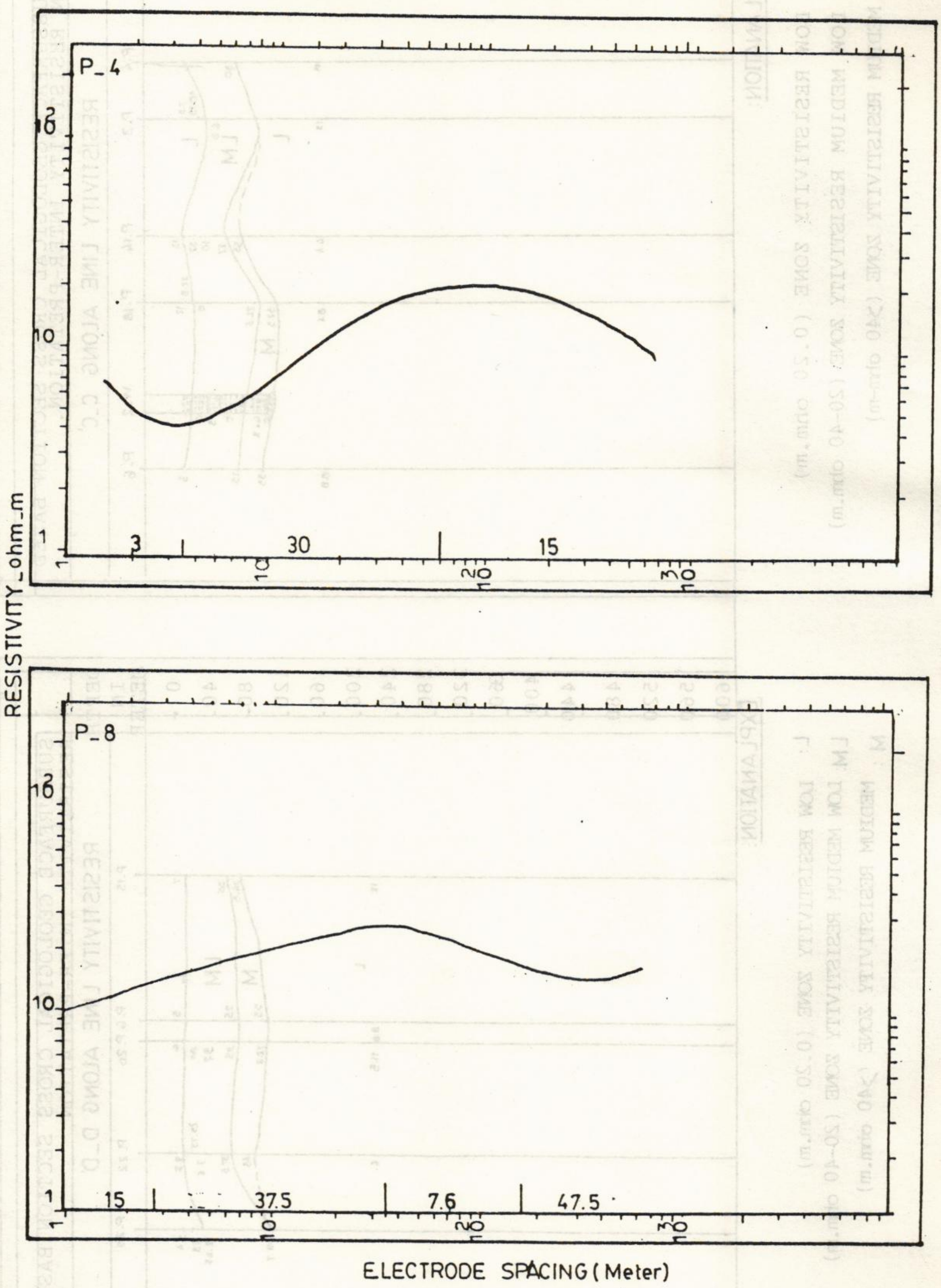


Fig 4: Showing the interpretation of three and four layer curves respectively.

Resistivity Line (R.L) C-C'

Probe No, 4-3-19-18 & 6 At resistivity line (C-C)' low resistivity is detected upto different depth. The low resistivity may be due to clay, silty clay and shale. A thick low medium restivity zone is detected throughout the resistivity line (C-C). The low resistivity zone may be due to clay, silty clay and fine sand. The medium resistivity material lies under the low medium resistivity zone. This resistivity material is present at P-16 P-18, P-19, and absent at P-3, P-4. Medium resistivity material is minimum at P-6, and decreases gradually toward P-4. The medium resistivity material is completely absent at P-3 and P-4 as shown in interpretation of the resistivity results.

Resistivity Line (R.L) D-D'

Proble No. 15-6-20-22 and 23. Low resistivity values are present throughout the resistivity line at varying depths. Below this zone low medium resistivity material are present which may be due to the interlayering or admixture of clay, silty clay, or shale and fine sand. Medium resistivity values are observed below this zone at P-15, P-6, P-20 P-2 and is absent at P-23 below medium resistivity values again low resistivity material is present.

CONCLUSIONS

The probe site Nos. 6, 20 and 22 show the maximum thickness of aquifer 24-32 meters, which are the most promising for groundwater development and are most suitable for installing the tube wells of significant capacity.

The probe site Nos. 15, 18 and 19 where the fresh water is indicated to be from 9 to 16 meter in thickness may be suitable for tubewells of significant capacity because the thickness of the aquifer is not quite thick.

The chemical analysis of water samples collected from the areas indicate that the water is alkaline. Therefore the groundwater may be neutralized by chemical treatments.

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GENERAL GEOLOGY AND PETROLOGY OF A PART OF JURA GRANITE NEELUM VALLEY, DISTRICT MUZAFFARABAD (AZAD KASHMIR)

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ABSTRACT:– Jura Granites (granite gneiss and porphyritic granite) are small plutons intruded in pelitic-psammatic rocks of Salkhala formation, Neelum Valley, Muzaffarabad. A strip of about 27 sq. miles have been mapped on 1 : 12,500 (for the sake of publication the map is reduced to 1 : 50,000) covers both sides of River Neelum (toposheet No. 43F/14, 43F/15). The granites are named after their exposure near Jura. The contact of both the granites is in Kucchi Nar extending in NE and SW direction. A detailed geological description with general petrography for each is made. Mineralogically granites (granite gneiss and porphyritic granite) are rich in Potash feldspar, quartz, plagioclase, muscovite/biotite etc. 16 thin sections, 8 for each were modally analysed and data were plotted on Streckiessen's triangle diagram which indicates metasomatic derivation from metasediments of pelitic psammatic origin.

INTRODUCTION

This work was carried out by author in order to fulfill the Master of Sciences Degree is Geology. Jura occurs at a distance of about 70 km from Muzaffarabad in Neelum Valley (Azad Jammu and Kashmir). The studied area covers an elongated strip along both side of River Neelum between Longitude 73° 5' 30" east, latitude 34° 3' 30" north in toposheet No. 43 F/14, 43 F/15 of Survey of Pakistan. It covers 27 sq. miles around Jura area (Fig. 1).

The area is accessible by metalled road up to Shahkot for about 15 km from Jura while unmetalled fair weather roads connects the whole area.

The Neelum Valley is identified by its rugged, mountaineous topography with high relief and thick forests. The investigated area has maximum height of about 8,000 feet.

The studied area has been neglected by many workers since long, however, work of preliminary nature was carried out by Wadia (1957), 31). He recognized the oldest formation in Himalayas (Salkhala series) intruded by certain granitic rocks without separating different rock types and their proper lighologies.

Shakoor (1976) mapped the Neelum Valley area from Muzaffarabad to Chalhana (Tithwal) emphasizing on the general geology and engineering behaviour of the rocks.

Ghazanfar et al. (1983) discussed the area by making drastic changes in Wadia's work. They found the Salkhala formation of Wadia equivalent to Tanol formation due to its pelitic-psmmatic nature and lacking in the carbonaceous and calcareous lithologies.

GENERAL GEOLOGY

Jura granites occur as intrusives in the Salkhala metasediments. They are classified as two separate bodies because of texture and structural difference. (Fig. 1).

1. Jura granite gneiss.
2. Jura porphyritic granite.

Both the bodies lie side by side near Jura Bazar in Kucchi Nar Nala. The contact extends westward following Kucchi Nar, Lugra Nar to Kaghan watershed. It is observed occasionally because of colluvial cover. In Kucchi Nar the contact is well defined where granite gneiss and porphyritic granite are sheared. In granitic bodies are also found veins of pegmatities, aplites and dykes of dolerite.

Jura granite gneiss: Jura granite-gneiss is brownish grey to whitish grey foliated making parallel to sub parallel layers. The gneissic structure is common and quartz and feldspar becomes more pronounced from Barian towards Kucchi Nar and Bandi area. Augen shaped porphyroblasts are arranged along foliation trend.

In Kucchi Nar augens developed are generally 2 to 3 cm at coordinates 855785 while many augens are larger in size, about tens of cm. The augen structure vanishes while proceeding towards southern contact. The feldspar contents decrease and the foliations show local variation in thickness. Thin quartz and feldspar layers alternate with mica layers in Ranjwara-da-Katha. At many places layers shows pinch and swells structure. The foliation in Jura Granite gneiss is parallel to the foliation of schist near the contact.

Porphyritic granite: Jura porphyritic granite outcrops upstream from Jura Bazar on both side of Neelum River and also towards North West extending to Kaghan water-shed. It makes sharp contact with pelitic psammatic rocks near Dhanbella. The granite shows dull brownish to greyish colouration on wathered surface and whitish grey at fresh surface with xenolith of about 2 to 5 cm as well. The phenocrysts have haphazard orientation and sometime subparallel (Fig 2). Toward south the contact shows foliation with granite gneiss as well. It shows less strain effects and well developed porphyroblasts. The size of porphyroblasts is reduced towards northern contact as well as in Sandok Nala.

PETROGRAPHY

In order to estimate petrogenesis of the granites, petrographic composition of 16 thin sections (8 each of granite gneiss and porphyritic granite) was studied on Swift point counter. Data is presented in tables 1-2.

Jura Granite Gneiss

Texture: Medium to coarse grained foliated (gneissic) holocrystalline, hypidiomorphic granular. Phenocryst are found at places.

Mineral Composition:

Quartz: It is generally present as medium sized (1-2 mm) anhedral to subhedral arranged in an interlocking manner sometimes swelling in to strained porphyroblast. In some sections aggregates of quartz-o-feldspar grains occur.

K. Feldspar: It is present as microcline with few perthitic development as well. Euhedral to subhedral perthitic development is either twinned or untwinned. The K-feldspar shows cross-hatched twinning (Fig-3) as well as carlsbad twinning.

Plagioclase: It is present as albite to oligoclase, mostly enclosed in K-feldspar. They show albite twinning (Fig-4) Inclusions of quartz and sericite are observed in some thin sections.

Mica Minerals: Both muscovite and biotite are present by making layers of interwoven flakes. Muscovite is colourless to light yellow showing very weak pleochroism. Biotite is brownish green to reddish brown and strongly pleochroic.

Tourmaline: Occurs as prismatic crystals pale yellow confused for biotite but crystal outline, irregular fracture and strong absorption help to distinguish it from latter.

Sericite and clays are present as alteration products. Other accessories are iron, ore, sphene, garnet, epidote, apatite, etc.

Jura porphyritic granite

Texture: Medium to course grained, hypidiomorphic granular and porphyritic.

Mineral Composition:

Quartz: Medium to coarse grained anhedral to subhedral which contains very few inclusions of sericite. At places it shows aggregates which are enclosing feldspar crystals.

K-feldspar: It is present as microline, microcline perthite (euhedral to subhedral perthitic development in Microcline phenocryst). The K-feldspar occurs as carlsbad twinned megacryst.

Microcline grows showing cross-hatched twinning. In one thin section porphyroblast of microcline are crushed showing suture margins with straight extinction.

Plagioclase: Crystal are euhedral and equidimensional which shows albitic twinning (Fig. 5) showing albite/carlsbad twinning. Small mica flakes are found as inclusions.

Muscovite: Colourless flakes of muscovite shows dispersed arrangement.

Biotite: It is present as greyish yellow to brownish green and strongly pleochroic.

Sericite is present as alteration products. Other

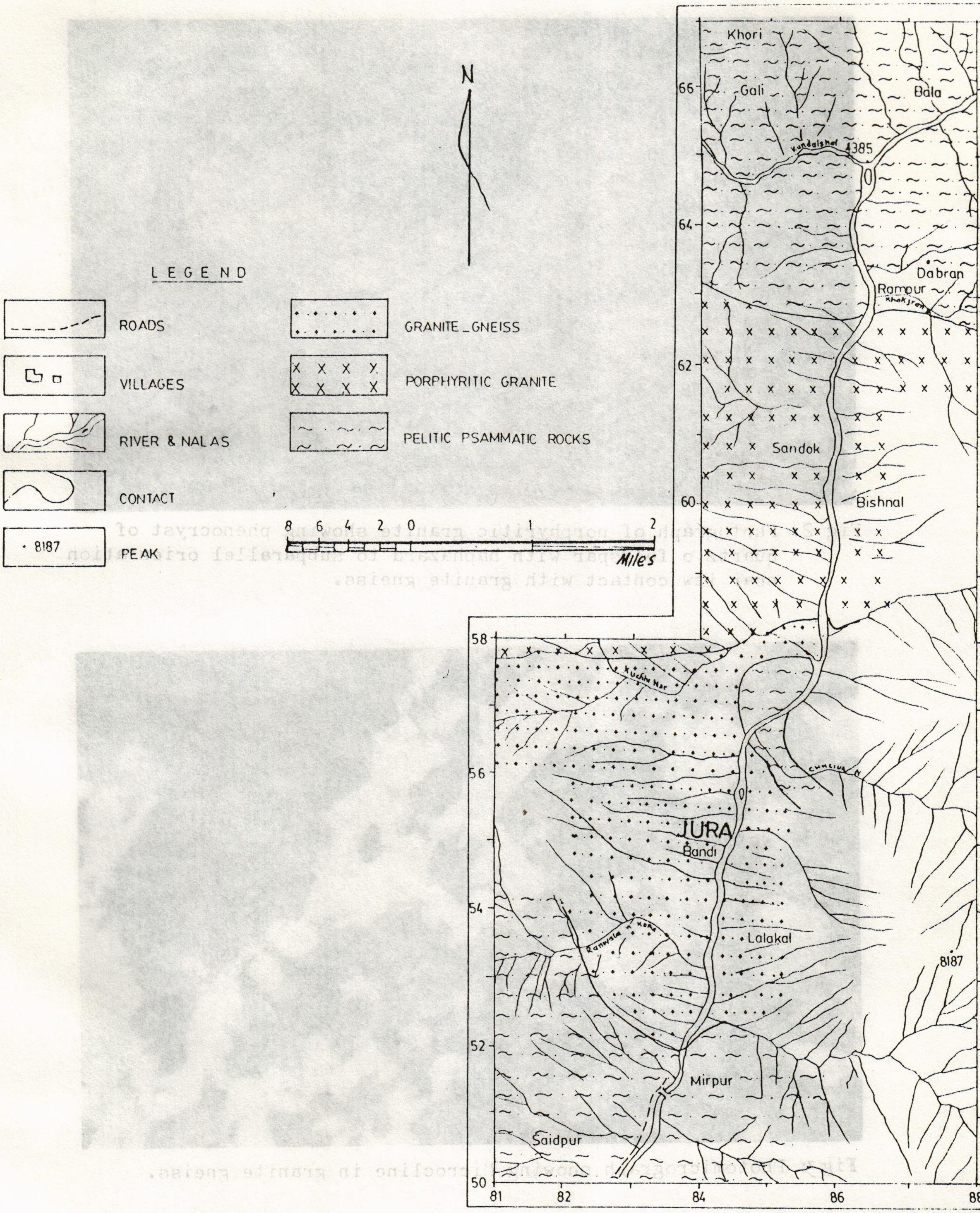

FIG:1 Toposheet NO. 43_F/14 & F/15

FIG:1 GEOLOGICAL MAP OF JURA AREA NEELUM VALLEY, MUZAFFARABAD.

Fig 2: Photograph of porphyritic granite showing phenocryst of quartz o feldspar with haphazard to subparallel orientation near itw contact with granite gneiss.

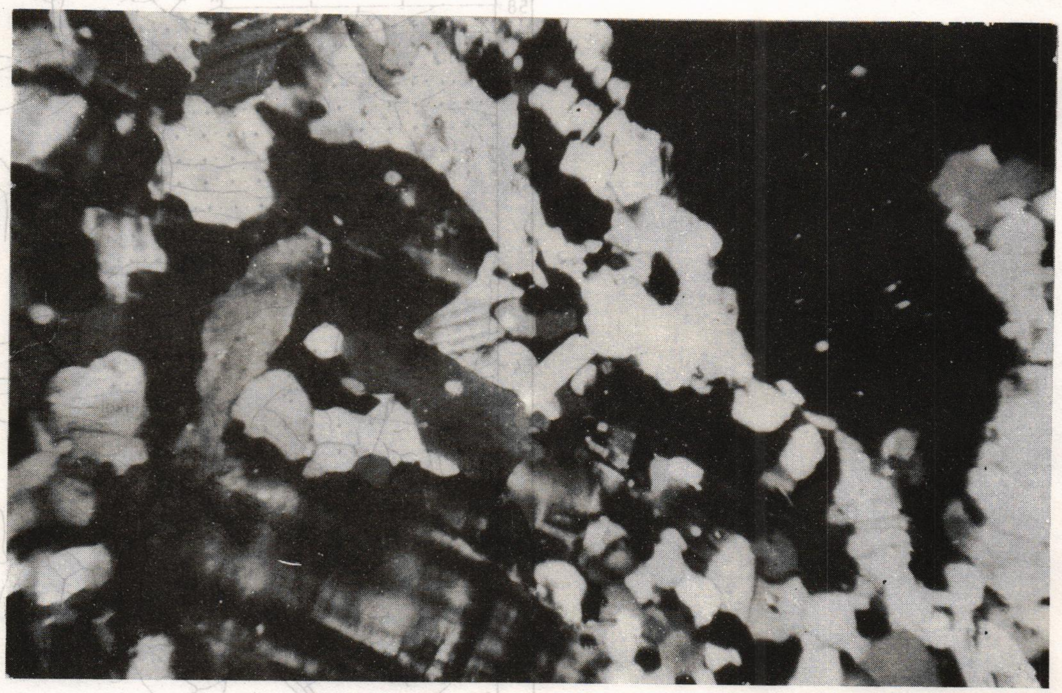

Fig 3: Photomicrograph showing Microcline in granite gneiss.

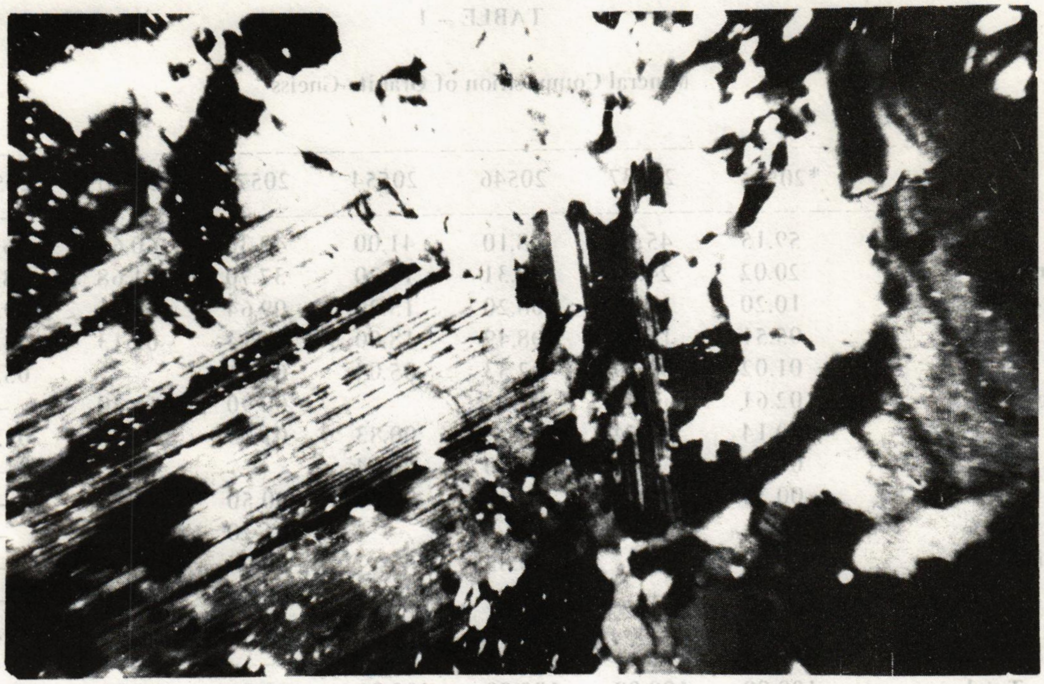

Fig 4: Photomicrograph showing Polysynthetic twining of plagioclase phenocryst in granite gneiss.

Fig 5: Photomicrograph of plagioclase showing albite - carlsbad twining in porphyritic granite.

TABLE – 1

Mineral Composition of Granite Gneiss

Slide No.	*20535	20537	20546	20554	20574	20581	20589	20597
Quartz	59.15	45.07	48.10	41.00	40.30	60.60	46.64	68.48
K-Feldspar	20.02	24.08	30.31	19.20	37.70	21.68	28.26	11.12
Plagioclase-Feldspar	10.20	12.79	08.20	15.20	09.64	03.26	09.43	08.34
Muscovite	05.51	14.33	08.49	18.00	06.14	02.13	08.06	09.46
Biotite	01.02	02.19	02.53	05.04	01.51	–	05.70	01.47
Tourmaline	02.61	–	01.02	–	00.90	11.40	–	00.98
Sphene	00.14	01.54	–	00.83	01.03	00.55	01.17	–
Iron ore.	01.01	–	00.50	00.64	–	–	–	–
Garnet	00.34	–	–	00.09	00.50	00.38	–	00.15
Sericite	–	–	–	–	01.20	–	–	–
Clay Material	–	–	00.85	–	00.24	–	–	–
Apatite	–	–	–	–	00.84	–	–	–
Epidote	–	–	–	–	–	–	00.74	–
Total :–	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE – 2

Mineral Composition of Porphyritic Granite

Slide No.	*20538	20540	20556	20565	20570	20572	20588	20591
Quartz	45.10	40.89	51.24	39.12	34.25	33.07	37.92	52.59
K-Feldspar	31.41	33.79	25.15	19.24	41.79	47.31	37.54	21.36
Plagioclase-Feldspar	10.66	12.41	11.87	12.84	10.22	11.97	12.10	12.08
Muscovite	10.00	11.04	07.76	18.43	10.23	04.76	08.82	09.06
Biotite	01.66	–	02.75	06.61	01.00	01.29	02.70	03.49
Garnet	–	1.31	–	00.45	01.63	01.20	–	–
Sphene	01.17	0.54	00.45	0.15	00.61	00.40	00.92	00.12
Sericite	–	–	–	1.53	–	–	–	01.30
Chlorite	–	0.02	–	–	00.27	–	–	–
Epidote	–	–	0.78	–	–	–	–	–
Apatite	–	–	–	0.78	–	–	–	–
Iron Ore	–	–	–	0.85	–	–	–	–
Total :–	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*This number and such others are catalogue Nos. of Mineralogy/Petrology Laboratory of Institue of Geology Punjab University Lahore.

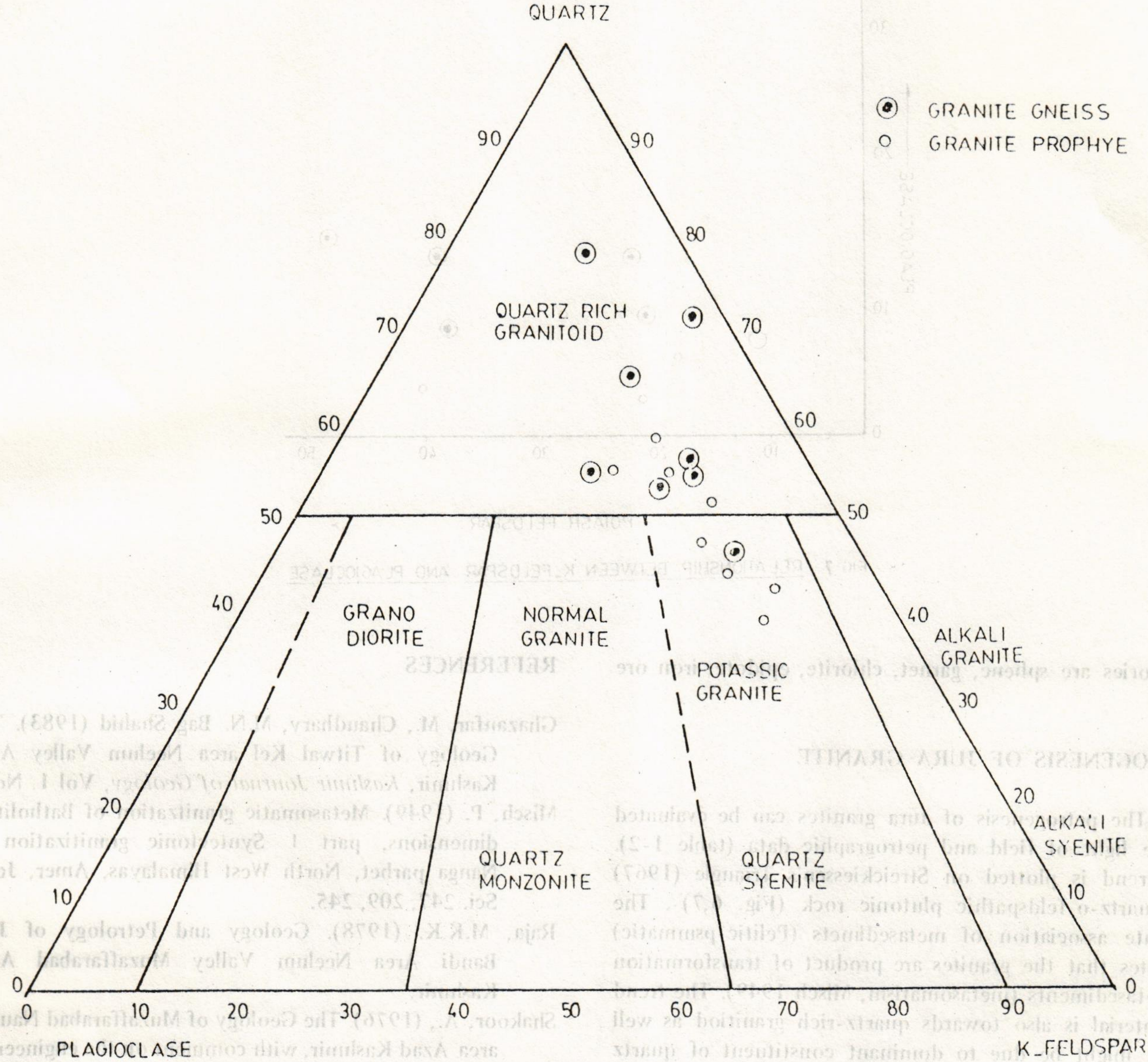

FIG:6 PLOT OF GRANITE GNEISS AND PORPHYRITIC GRANITE OF JURA IN THE STRECKEISENS CLASSIFICATION TRIANGLE FOR QUARTZO_ FELD_SPATHIC ROCKS.

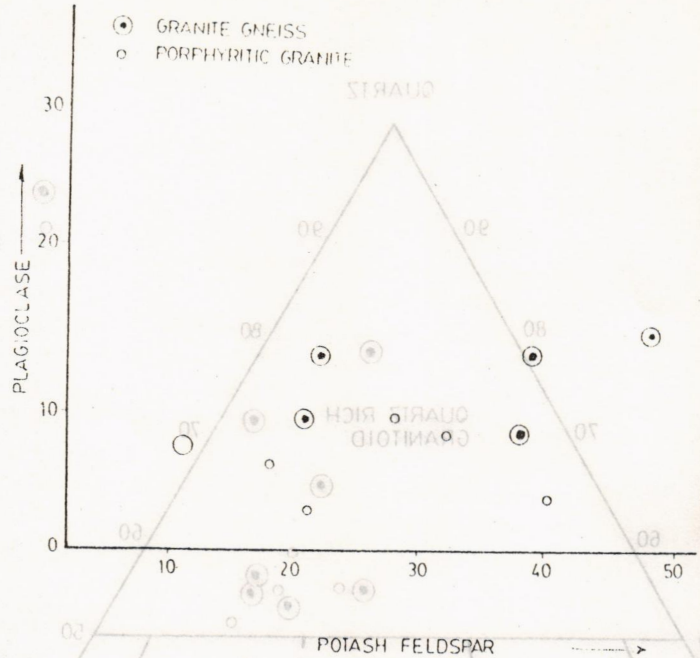

FIG. 7 RELATIONSHIP BETWEEN K_FELDSPAR AND PLAGIOCLASE

accessories are sphene, garnet, chlorite, epidote, iron ore etc.

PETROGENESIS OF JURA GRANITE

The petrogenesis of Jura granites can be evaluated in the light of field and petrographic data (table 1-2). The trend is plotted on Streickiessen's Triangle (1967) for quartz-o-feldspathic plutonic rock (Fig. 6,7). The intimate association of metasedimets (Pelitic-psmmatic) indicates that the granites are product of transformation of metasediments (metasomatism, Misch 1949). The trend of material is also towards quartz-rich granitiod as well which might be due to dominant constituent of quartz (40-70%) in the metasediments (Raja, 1978 unpublished).

Structurally granites have two separate entities i.e. one is gneissic and other is porphyritic. As mineralogy, field relations shows close resemblances to each other but differ due to structural relation i.e. porphyritic and gneissic. It is, therefore, assumed that later part have been remobilized to form gneissic structure.

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RATE OF DEPOSITION OF SIWALIK SEDIMENTS IN POTWAR BASIN, PUNJAB, PAKISTAN

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ABSTRACT.– Sedimentation rates for different-Siwalik formations have been calculated in different areas of the Potwar Basin in Kamlial times (17–13 m.y.B.P.), 0.04 mm/yr. was the minimum rate of deposition among the Siwalik formations, whereas in Nagri times (8-10 m.y. B.P.), 0.20-0.25 mm/yr. was the maximum rate of deposition. High sedimentation rates imply rapid subsidence of the depositional basin, while low sedimentation rates suggest general uplift of the area. The data shows that there is a systematic increase in sedimentation rate during 17-08 m.y. B.P. After reaching the maximum, it started decreasing, until the sedimentation was completely stoped. The rate of deposition of sandstone and clays increases and decreases alternatively and systematically in different formations. In the Potwar basinthe sedimentation started between 18-17 m.y. B.P. and was brought to hault at about 0.4 m.y. B.P.

INTRODUCTION

This paper is mainly based on the stratigraphic sections, measured by the authors during the period 1975–1985 while carrying out the geological mapping of Potwar Region. Thicknesses of Siwalik formations in different areas of Potwar basin have been taken into account to determine the rate of deposition of sandstone and clay. The ages of the Siwalik formations, mentioned herein are after Tahirkheli (1985) and Johnson and Tahirheli (1985).

RATES OF DEPOSITION

MIOCENE

Kamlial Formation (Lower Siwaliks)

Age: 17–13 million years
Duration: 4 million years

Rate of sandstone deposition:

Dina area	(43 G/12)	0.02 mm/yr.
Sohawa area	(43 G/8)	0.02 mm/yr.
Jatli area	(43 G/4)	0.03 mm/yr.
Riwat area	(43 G/3)	0.10 mm/yr.
Chauntra area	(43 G/15)	0.09 mm/yr.
Gali Jagir area	(43 G/11)	0.02 mm/yr.
Pindi Gheb area	(43 C/8)	0.05 mm/yr.
Tabi Sar area	(38 0/12)	0.09 mm/yr.
Chinji area	(43 D/6)	0.07 mm/yr.

Average 0.05 mm/yr.

Rate of Clay Deposition:

Dina area	(43 G/12)	0.01 mm/yr.
Sohawa area	(43 G/8)	0.01 mm/yr.
Jatli area	(43 G/4)	0.02 mm/yr.
Riwat area	(43 G/3)	0.08 mm/yr.
Chauntra area	(43 C/15)	0.06 mm/yr.
Gali Jagir area	(43 C/11)	0.01 mm/yr.
Pindi Gheb area	(43 C/8)	0.03 mm/yr.
Tabi sar area	(38 0/12)	0.04 mm/yr.
Chinji area	(43 D/6)	0.06 mm/yr.

Average 0.03 mm/yr.

Chinji Formation (Lower Siwaliks)

Age: 13–10 million years B.P.
Duration : 3 million years.

Rate of Sandstone–Deposition:-

Dina area	(43 G/12)	0.07 mm/yr.
Sohawa area	(43 G/8)	0.03 mm/yr.
Jatli area	(43 G/4)	0.06 mm/yr.
Riwat area	(43 G/3)	0.12 mm/yr.
Chauntra area	(43 C/15)	0.09 mm/yr.
Gali Jagir area	(43 C/11)	0.13 mm/yr.

Pindi Gheb area	(43 C/8)	0.05 mm/yr.
Tabi Sar area	(38 0/12)	0.04 mm/yr.
Chinji area	(43 D/6)	0.05 mm/yr.

Average 0.06 mm/yr.

Rate of Clay Deposition:

Dina area	(43 G/12)	0.01 mm/yr.
Sohawa area	(43 G/8)	0.10 mm/yr.
Jatli area	(43 G/4)	0.17 mm/yr.
Riwat area	(43 G/3)	0.16 mm/yr.
Chauntra area	(43 C/15)	0.13 mm/yr.
Gali Jagir area	(43 C/11)	0.20 mm/yr.
Pindi Gheb area	(43 C/8)	0.12 mm/yr.
Tabi Sar area	(38 0/12)	0.16 mm/yr.
Chinji area	(43 D/6)	0.17 mm/yr.

Average 0.13 mm/yr.

PLIOCENE

Nagri Formation (Middle Siwaliks)

Age: 10–8 million years B.P.
Duration: 2 million years B.P.

Rate of sandstone deposition:

Dina area	(43 G/12)	0.11 mm/yr.
Sohawa area	(43 G/8)	0.17 mm/yr.
Jatli area	(43 G/4)	0.27 mm/yr.
Riwat area	(43 G/3)	0.09 mm/yr.
Chauntra area	(43 G/15)	0.35 mm/yr.
Gali Jagir area	(43 C/11)	0.27 mm/yr.
Pindi Gheb area	(43 C/8)	0.35 mm/yr.
Tabi Sar area	(38 0/12)	0.23 mm/yr.
Chinji area	(43 D/6)	0.22 mm/yr.

Average 0.23 mm/yr.

Rate of Clay Deposition:

Dina area	(43 G/12)	0.07 mm/yr.
Sohawa area	(43 G/8)	0.07 mm/yr.
Jatli area	(43 G/4)	0.12 mm/yr.
Riwat area	(43 G/3)	0.06 mm/yr.
Chauntra area	(43 C/15)	0.15 mm/yr.
Gali Jagir area	(43 C/11)	0.12 mm/yr.
Pindi Gheb area	(43 C/8)	0.25 mm/yr.
Tabi Sar area	(58 0/12)	0.15 mm/yr.
Chinji area	(43 D/6)	0.15 mm/yr.

Average 0.13 mm/yr.

Dhok Pathan Formation (Middle Siwaliks)

Age: 8–5 million years B.P.
Duration: 3 million years B.P.

Rate of Sandstone Deposition:-

Dina area	(43 G/12)	0.04 mm/yr.
Sohawa area	(43 G/8)	0.11 mm/yr.
Jatli area	(43 G/4)	0.09 mm/yr.
Riwat area	(43 G/3)	0.06 mm/yr.
Chauntra area	(43 G/15)	0.13 mm/yr.
Gali Jagir area	(43 C/11)	0.13 mm/yr.
Pindi Gheb area	(43 C/8)	0.04 mm/yr.
Tabi Sar area	(58 0/12)	0.10 mm/yr.
Chinji area	(43 D/6)	–

Average 0.12 mm/yr.

Rate of Clay Depsition:

Dina area	(43 G/12)	0.09 mm/yr.
Sohawa area	(43 G/8)	0.16 mm/yr.
Jatli area	(43 G/4)	0.14 mm/yr.
Riwat aeea	(43 G/3)	0.13 mm/yr.
Chauntra area	(43 C/15)	0.16 mm/yr.
Gali Jagir area	(43 C/11)	0.17 mm/yr.
Pindi Gheb area	43 C/8)	0.05 mm/yr.
Tabi Sar area	(38 0/12)	0.07 mm/yr.
Chinji area	(43 D/6)	–

Average 0.12 mm/yr.

PLEISTOCENE

Soan Formation (Upper Siwaliks)

Age: 5–4 Million years B.P.
Duration: 4 Million years B.P.

Rate of Sandstone Deposition:

Dina area	(43 G/12)	0.07 mm/yr.
Sohawa area	(43 G/8)	0.06 mm/yr.
Jatli area	(43 G/4)	0.05 mm/yr.
Riwat area	(43 G/3)	0.04 mm/yr.
Chauntra area	(43 C/15)	0.05 mm/yr.
Gali Jagir area	(43 C/11)	0. –
Pindi Gheb area	(43 C/8)	–
Tabi Sar area	(38 0/12)	0.11 mm/yr.
Chinji area	(43 D/6)	–

Average 0.06 mm/yr.

Rate of Clay Deposition:

Dina area	(43 G/12)	0.13 mm/yr.
Sohawa area	(43 G/8)	0.09 mm/yr.
Jatli area	(43 G/4)	0.10 mm/yr.
Riwat area	(43 G/3)	0.08 mm/yr.
Chauntra area	(43 G/15)	0.04 mm/yr.
Gali Jagir area	(43 C/11)	–
Pindi Gheb area	(43 C/8)	–
Tabi Sar aea	(38 0/12)	0.04 mm/yr.
Chinji area	(43 D/6)	–
		Average 0.08 mm/yr.

Rate of Conglomerate Deposition:

Dina area	(43 G/12)	0.02 mm/yr.
Sohawa area	(43 G/8)	0.02 mm/yr.
Jatli area	(43 G/4)	–
Riwat area	(43 G/3)	–
Chauntra area	(43 C/15)	0.01 mm/yr.
Gali Jagir area	(43 C/11)	–
Pindi Gheb area	(43 C/8)	–
Tabi Sar area	(38 0/12)	0.10 mm/yr.
Chinji area	(43 D/6)	–
		Average 0.04 mm/yr.

DISCUSSION

During 4 m.y. Span of Kamlial Formation (17-13 m.y. B.P), the average rate of sandstone deposition was 0.05 mm/yr. and that of clay 0.03 mm/yr. the formation had an average rate of deposition at 0.04 mm/yr. Total duration of Chinji Formation is 3 m.y. B.P. (13-10 m.y. B.P.). The average of deposition of sandstone was 0.06 mm/yr. and that of clay 0.13 mm/yr. being 0.10 mm/yr. average rate of deposition for sandstone and clay suit. During 2 m.y. of the Nagri time (10-8 m.y. B.P.), the average rate of deposition of sandstone was 0.23 mm/yr. and clay 0.13 mm/yr. with an average rate of deposition being 0.18 mm/yr. The deposition of Dhok Pathan Formation took place in 3 m.y. (8-5 m.y. B.P.). The average rate of sandstone deposition was 0.10 mm/yr. and that of clay 0.12 mm/yr. having an average rate of deposition at 0.11 mm/yr. The Soan Formation had a span of 4 m.y. (5-04 m.y. B.P.). The average rate of deposition of sandstone was 0.06 mm/yr., clay 0.08 mm/yr. and that of conglomerate 0.04 mm/yr. being 0.06 mm/yr. as an average rate of deposition for sandstone, clay and conglomerate.

It is evident from the above statistics that the deposition at the rate of 0.04 mm/yr. was the minimum one during Kamlial times (17-13 m.y. B.P.), while it was maximum one i.e. (0.20 ± mm/yr.), during the Nagri time. (10-8 m.y.B.P.).

There is a systematic increase in the sedimentation rate during the period, 17-08 m.y.B.P., after reaching its maximum (0.20-0.25 mm/yr). in the Nagri time, the rate of deposition started decreasing gradually, until it completely stopped at about 0.4 m.y.B.P.

CONCLUSIONS

In the Potwar basin, the sedimentation started between 18-17 m.y.B.P. and was brought to hault at about 0.4 million years B.P. when the area was uplifted under the influence of the later phase of the Himalayan orogeny (Tahirkheli and Johnson, 1985).

Sedimentation rates of different areas of Potwar basin, have been calculated for the Siwalik Formations. During a period of 4 m.y. from 17 to 13 m.y.B.P., the Kamlial time, the average rate of deposition i.e. 0.04 mm/yr. was the minimum rate of deposition while, 0.20±mm/yr. was the maximum rate of deposition among the Siwalik formations, which was observed during 2 m.y. time of Nagri deposition, from 10-8 m.y.B.P.

High sedimentation rates indicate rapid subsidence of the depositional basin, while low sedimentation rates suggest aggradation of the depositional basin or general uplift of the area. It is evident from these studies that there were two main phases of uplift. The earlier uplift occurred at about 2.5 m.y.B.P. and the second at about 0.5-0.4 m.y. B.P.

However, in the Trans Indus Salt Range, only the younger phase of uplifting is evident and the entire sequence is conformable. This shows that at about 2.5 m.y.B.P. when the Potwar Plateau was undergoing structural deformation the area now occupied by the Trans Indus Salt Range was a site of continuous deposition and was not being affected by the tectonics of Potwar Plateau. The later phase of uplifting, of course, affected the entire region and the Siwalik sedimentation was brought to hault (Tahir Kheli, 1985), today, the Potwar area is no longer a site of deposition, but rather a site of erosion and a source of reworked sediments. The brown sands of the Soan Formation is an evidence of reworked or recycled sediments.

The data shows that there is a systematic increase in sedimentation rate over time (Fig. 1, 2 Tab.1) from 17-08 m.y. B.P. After reaching its maximum 0.20-0.25 mm/yr. in the Nagri time the rate of deposition started decreasing systematically, until it compeletely haulted at about, 0.4 m.y. B.P.

The rates of deposition of sandstones and clays increase and decrease alternatively and systematically, during deposition of different Siwalik formations.

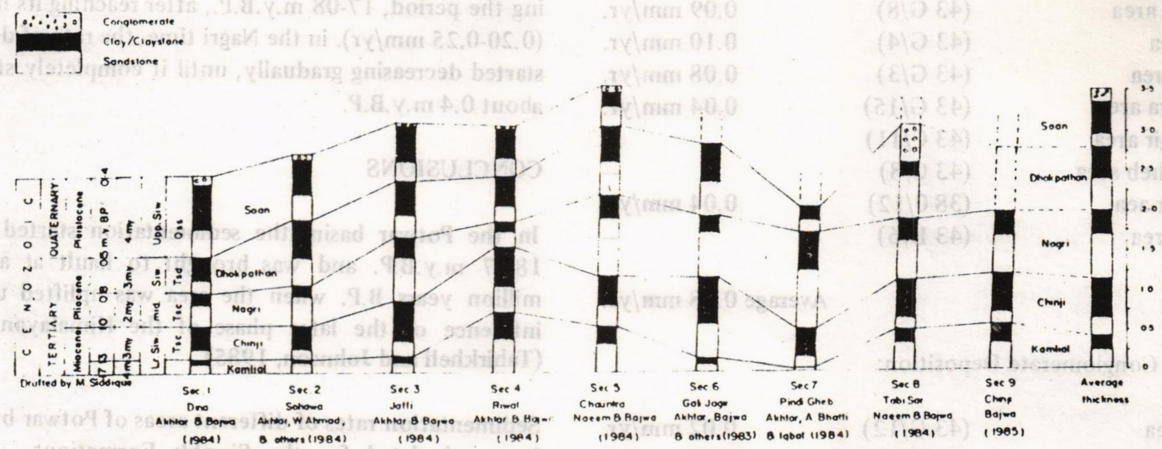

FIG 1 TIME LITHOLOGIC CORRELATION OF STRATIGRAPHIC SECTIONS OF SIWALIK SEDIMENTS IN POTWAR BASIN, PUNJAB, PAKISTAN.
Prepared by - M S Bajwa

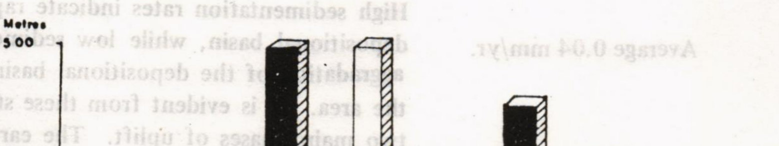

FIG. 2 : AVERAGE SANDSTONE CLAY RATIOS IN SIWALIK FORMATIONS IN POTWAR BASIN, PUNJAB, PAKISTAN.

TABLE : 1

THICKNESSES AND RATE OF DEPOSITION OF SIWALIK ROCKS IN POTWAR

S. No.	Stratigraphic Section	LOWER SIWALIKS Kamlial Formation Miocene 17 – 13 million years B.P.					SIWALIKS Chinji Formation Miocene 13-10 Million years B.P.				
		Total thick. in m.	Thick. of Sst. in m.	Rate of deposit. mm/yr.	Thick. of Clay in m.	Rate of deposit. mm/yr.					
		1	2	3	4	5	1	2	3	4	5
1.	Dina area 43 G/2 (Akhtar & Bajwa, 1984)	170	110	0.03	60	0.013	60	20	0.007	40	0.01
2.	Sohawa area 43 G/8 (Akhtar, W. Ahmad & others (1984)	150	100	0.025	50	0.012	400	100	0.03		0.10
3.	Jatli area 43 G/4 (Akhtar & Bajwa, 1984)	200	120	0.03	0.02	700	175	0.06	525		0.17
4.	Riwat area 43 G/3 (Akhtar & Bajwa, 1984)	750	410	0.10	340	0.08	800	320	0.12	480	0.16
5.	Chauntra area 43 C/15 (Naeem & Bajwa, 1984)	600	360	0.09	240	0.06	650	260	0.09	390	0.13
6.	Gali Jagir area 43 C/11, (Akhtar, Bajwa and others, 1983)	150	90	0.02	60	0.01	1000	400	0.13	600	0.20
7.	Pindi Gheb area 43 C/8, (Akhtar, A. Bhatti and Iqbal, 1984)	20	12	0.005	08	0.003	500	150	0.05	350	0.12
8.	Tabi Sar area 38 O/12, (Naeem & Bajwa, 1984).	500	350	0.09	150	0.04	600	120	0.04	480	0.16
9.	Chinji area, 43 D/6, (Bajwa, 1985, unpublished)	550	300	0.07	250	0.06	650	150	0.05	500	0.17
	Average thickness.	340	210	0.05	140	0.03	600	190	0.06	410	0.13

Table : 1 (Contd.)

MIDDLE Nagri Formation Pliocene 10-8 Million years B.P.					SIWALIKS Dhok Pathan Formation Pliocene 8-5 Million years B.P.							UPPER SIWALIKS Soan Formation Pleistocene 5-0.4 Million years B.P.					Thick. of Congl. in m.	Rate of deposit. mm/yr.
1	2	3	4	5	1	2	3	4	5	6	7	1	2	3	4	5	6	7
380	230	0.11	150	0.07	400	120	0.04	280	0.09	–	–	1000	320	0.07	580	0.13	100	0.02
500	350	0.17	150	0.07	800	320	0.11	480	0.16	–	–	800	300	0.06	420	0.09	80	0.02
800	550	0.27	250	0.12	700	280	0.09	420	0.14	–	–	700	230	0.05	465	0.10	05	–
300	180	0.09	120	0.06	550	170	0.06	380	0.13	–	–	600	200	0.04	395	0.08	05	–
1000	700	0.35	300	0.15	850	380	0.13	470	0.16	–	–	500	240	0.05	190	0.04	70	0.01
800	550	0.27	250	0.12	900	400	0.13	500	0.17	–	–	–	–	–	–	–	–	–
1200	700	0.35	500	0.25	300	135	0.04	165	0.05	–	–	–	–	–	–	–	–	
775	470	0.23	305	0.15	1200	500	0.17	200	0.07	500	0.17	1180	500	0.11	200	0.04	480	0.10
750	450	0.22	300	0.15	–	–							–	–	–	–		–
720	460	0.23	260	0.13	710	290	0.10	360	0.12	–	–	800	300	0.06	375	0.08	120	0.04

ACKNOWLEDGEMENTS

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GROUNDWATER INVESTIGATION AND DEVELOPMENT IN AND AROUND KARACHI.

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ABSTRACT: Groundwater investigations were carried out in Karachi Metropols, Gadap, Khadeji, Kalukuhar and Pakistan Steel Mills area to meet the requirements of water from independent sources for the use of domestic and industrial purposes.

The results of these investigations for groundwater at these five areas indicate that sufficient water is available at all above mentioned places in different geological formations, at different depths and in different types of aquifers. The quality of water varies from slightly brackish (at Gadap) to sweet at Kalukuhar and Khadeji.

Three groundwater basins Hub, Lyari and Malir are the sources of water supply in the areas under study. Good aquifers of fair to high permeability are reliable sources of water supply in large quantity shallow and deep wells drilling programme would be necessary.

It is presumed from the data available that shallow and deep wells of 33-200 meter would provided ample supply.

INTRODUCTION

Study of groundwater development in five different areas of lower Sind were selected. The basis of the selection was that these five sites provide a markedly different conditions in which the groundwater has been studied, proved and developed. It will thus provide a typical example of carrying out of all the phases of groundwater development. The five areas selected for this are Karachi Metropol site area, Khadeji area (approx. 31km from Karachi), Kalukuhar area (approx. 6 km. NE of Khadeji and about 15 km. from Karachi), Gadap area (approx. 8 km WNW of Pipri and about 25 km. from Karachi Pakistan Steel Mills area (approx 37 km. from Karachi)(Fig. 1).

The five areas selected for groundwater investigation and development work from the north western part of the Sind province, extending from 24° 56' to 24° 07'N and between 67° to 67° 46'E. The area is shown on Survey of Pakistan topo-sheet No. 35 '0' at the scale of 1:250,000. The five areas covering Karachi and adjacent regions of southern Sind were investigated. Groundwater investigation has been carried out where basic informations are available. It is to see if any common conditions exist about any of the groundwater factors and if so, to correlate them if not, to examine the point of difference.

Blandford (1876) described the geology of the area. Kazmi (1979), Kalim M. (1980), Hasan M.S. and Anisuddin investigated the geology and groundwater conditions of Mausoleum area. No systematic work has yet been done on groundwater in the area under study. This work is the first of its kind. The reasarch work has been carried out with the collaboration of Oil and Gas development Corporation and Geological Survey of Pakistan (1979-84).

GEOLOGY

The area has been under constant review for a long time and various authors have contributed their works since 1876. Blandford first referred this area and identified two main divisions. According to Blandford (1876), the divisions are;

(A) Recent-Subrecent (Recent-Lower Pleistocene) and (B) Manchhar system.

The type section of Manchhar Formation is exposed west of Manchhar lake near Sehwan Sharif in Dadu District. Manchhar formation has further been divided in to a) Upper Manchhar. b) Lower Manchhar of Lower Pleistocene to Lower Pliocene and Lower Pliocene to Middle Miocene respectively.

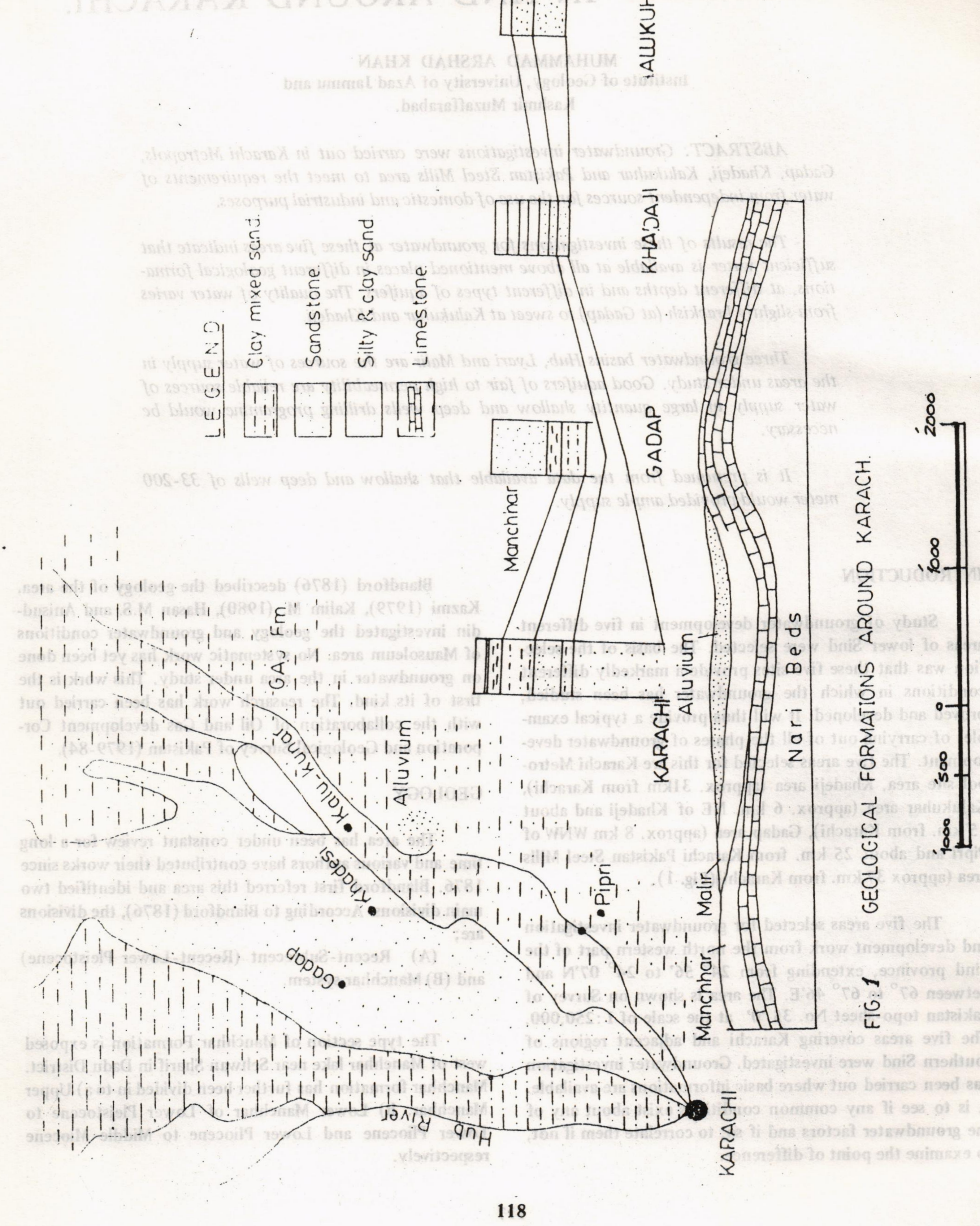

FIG 1 GEOLOGICAL FORMATIONS AROUND KARACH.

The Lower Manchhar is mainly composed of sandstone with subordinate clay, shale and conglomerate. The upper Manchhar consists of orange, Pink, reddish brown clay, subordinate beds of yellow conglomerate and yellow to bluish grey sandstone exposed in the hills of north west of Pipri area.

Stratigraphically the area can be said to have the Recent (Recent-Lower Pleistocene) and Manchhar (Lower Pleistocene to Middle Miocene) sediments in the area. The boundary between the recent and Manchhar sediments are marked by an unconformity where the contact is established between the gravelly, pebbly, recent loam and the clay of Manchhar.

The recent sediments are mostly composed of sand (fine-medium and coarse grained), gravels and pebbls, sandy loam and brownish grey loam. The Manchhar formation comprises orange to pink and reddish brown clay and subordinate conglomerate with thin layers of sands.

The geological formations which make up this area that is the Kohistan and coastal deltaic plain range from Early Eocene to Recent. The stratigraphic units that are exposed in the area are shown in table-1.

TABLE 1

Stratigraphic succesion and description of rocks in the area.

Stratigraphic units	Description
Flood plain deposits	Sand and silt with gravels.
Terrace deposits	Sand and gravels slightly compact.
Manchhar Formation	Mostly conglomerate with some sandstone and limestone.
Gaj Formation	*Limestone:* a) Upper part brown, hard compact, thin bedded, arenaceous and fossiliferous. b) Lower part sandstone, grey, brown, soft to medium hard, fine-grained with quartz grains, ferrugenous and calcareous.
Nari Formation	*Limestone:* ferrugenous, medium to coarse grained. *Sandstone:* coarse grained highly ferrugenous.
Brouhi Limestone	Lower member of Kirthar mainly limestone, dirty white to buff; hard, compact, crystalline and at places argillaceous.
Tiyon Formation	*Limestone:* Buff, grey, pink, cream, brown coloured, chalky medium hard, argillaceous with shally bands.
Laki Formation	*Limestone:* creamish white, hard, chalky, nodular, highly fossiliferous, middle and lower parts have shale Bands. There is a thick shale bed at the contact.

. . . . Base is not exposed. . . . .

TABLE 2

Geophysical investigation at Karachi Metropol area under study.

S.No.	Depth in meters	Material
a)	0-36.5	Saline clay or shale.
b)	36.5-100	Sanday clay.
c)	100-150	Silty sand and sandstone.
d)	150-133.4	Sanday shale.
e)	133.4-333.3	Sandstone.

TABLE 3

Total depth drilled at Karachi Metropols area.

	Probable depth of water bearing horizon.	Total depth drilled in meters.
a)	14-18.33 meters 20-26.6 30-40	40
b)	16.6-20 23.3-26.6 30-53	53.3
c)	18.3-18.6 36.6-53.3	40
d)	13.3-16.6 25-2 6.3	36.6
e)	18.3-23.3 35-40 53.3-60	60
f)	9.3-16.3 23.3-30	53.3

TABLE 4

Showing the site proposed for tube well installation.

Site	Water bearing Layer	Total depth drilled
a)	14-18.3 meters 20-23.3 30-40	53.3 meters
b)	13.3-20 21.6-28.3	36.6
c)	9.3-16.3 23.3-30	53.3

TABLE 5

Drill hole data from Gadap area at different depths and their description.

	Depth in meters	Description
a)	0-32 meters	Sand with silt and clay.
b)	32-60	Sand mixed with silt, khaky to orange in colour.
c)	60-65.3	Sand and Silt.
d)	65.3-87.6	Silty sandstone of light grey to bluish grey colour generally fine grained.
e)	87.6-113.3	Complete water loss.
f)	113.3-151.3	Sandy clay bluish grey in colour.

In the Southern part of Gadap plain no water has been observed down to depth of 120 meter.

Water table in the area is at a depth of 28.6 meters.

Average yield	=	10 gallons/minutes
Average drawdon	=	3.3. meters/6 hours
Quality of water	=	slightly brackish.

TABLE 6

Drill hole data at Khadeji area at different depths.

	Depth in meters	Description
a)	0-2	Alluvium, silty snad and sandy material.
b)	2-20	Sandy limestone of yellowish in colour, hard and compact.
c)	20-30	100% water loss.
d)	30-61.6	Sandy limestone with marl, pale and yellowish in colour. Sandy material is fine grained.
e)	61.6-64.6	Calcareous sandstone of bluish grey and khaky colour. Clay is mixed with silt and sandy material.
f)	64.6-95.3	Siltstone of bluish grey to chalky in colour, fine grained, soft and medium hard
g)	95.3-118.3	Sandstone with light green colour, fine grained and medium hard.

Discharge of water	=	10 gallons/minutes.
Drawdown	=	0
Water table	=	13.6 meter from ground surface.
Quality of water	=	Fresh.

DISCUSSIONS

The aquifers present in the area under study are at Karachi Metropols, Gadap, Khadeji, Kalukuhar and Pakistan Steel Mills area. The thickness of the aquifer ranges from 150-200 meters in the Metropols area. The water available from this aquifer is from Gaj formation. They are known to contain water at various places surrounding the metropols and the Lyari basins.

***Metropol area:* The data available from the Metropol area shows that the groundwater yield in PECHS and Newtown areas varies from place to place with changing water table from 2 to 5 meter below the ground level. At a depth of 36 meters saline clay and sands are present in which very small amount of water is available. The saline water available at 100 meter depth is in sandy clay.**

The water available from 150 meters is brackish and

at places it is saline. The material is fairly conductive and is likely to co.sist of saline clay and shale with interlayering of sandstone and conglomerate. The alluvial material in the area is thin and extends down to a depth of 1.5 to 3.5 meters. The acquifer present at E, is fairly good. The thickness of the aquifer ranges from 166-333 meters. The localities A, B, and C are also suitable for sinking tubewells for supplying large quantity of water. The water available from the Metropols area is fairly good other than domestic purposes.

Gadap area: The depth of the hole drilled in the area is 151.3 meters. There is a sandy and silty clay bed at a depth of 32 meters. The rate of percolation is comparatively slow, but at a depth of 60 meters silty sand become good aquifer in which the rate of percolation increases. Complete water loss has been observed at a depth of 46.5 meters.

The aquifer available at a depth of 151 meters is saturated with fresh water and the yield is high. The average yield of this aquifer is 10 gallons/minutes. Water-table at this place is at a depth of 28 meters. Average drawdown in this aquifer is 3 meters. At a depth of 91 meter aquifer material is fine sandstone mixed with silt and clay. Quality of water in this aquifer is slightly brackish.

Physical properties and the textural characteristics of the aquifer material encountered in the test holes drilled indicate that the co-efficient of permeability and the transmissibility of these materials be expected to be good if tube wells are installed in the investigated area at the sites recommended.

Yield of the aquifer present in this locality is 500 to 10,000 gallons/hour with a maximum draw-down of 5.5 to 30 meter. The quality of water after treatment is good.

Khadeji: The test hole from Khadeji, has been drilled to a depth of 117 meters and good quality of goundwater has been found in a sandstone aquifer. Pumping test shows that the water table before pumping remains at 19 meters and after pumping per 6 hours the total drawdown is 2.3 meters. The water table after 6 hours pumping is at 22.5 meters. The quality of water in this aquifer if fresh and the yield is high.

Kalukuhar: The aquifer material available from the test hole at a depth of 0-10 meters is gritty, pebbly and fine to coarse sand which is highly permeable and high yield. Total thickness of the good aquifer is 105 meters. The results obtained from the hole drilled in Kalukuhar shows that good quality water is available at a depth of 73 meters. Water-table varies from 16 to 19 meters and average yield of the aquifer is 10 gallons/minute. Total drawdown is

TABLE 7

Lithology of the aquifer at various depths in Kalukuhar area.

Depth in meters	Description
a) 0-10	Gritty sand with pebbls, fine to coarse grained.
b) 10-53.3	Sandstone of brownish colour. Fine to medium grained and soft.
c) 53.3-56.6	Claystone light grey to grey.
d) 56.6-108.3	Silty sandstone with little clay of grey in colour, fine grained and hard.

Water table in the area before pumping = 19.3 meters
Average yield = 10, gallons/minutes
Duration of pumping = 6 hours
Water table after 6 hours = 31.3 meters
Total drawdown = 2.6 meters
Recharge = 1.6 meters/hour

2.5 meters offer 6 hours and recharge is 2 meters. Total yield of the aquifer is 10,000 gallons/hour. quality of water is fresh.

It reveals from the above data that tube wells can be installed at Kalukhuhar for fresh water development. The acquifers present in Karachi Metropols, Khadji, and Gadap contains brackish to saline water and is not good for domestic purposes. Development of the aquifers in the above mentioned areas would provide water for gardening, but after treatment it may also be used for domestic purposes. Installation of tube wells would be economic for the country.

CONCOLUSIONS

Groundwater conditions have been established in the areas in which the aquifers are located. The geologic horizon, depth from surface and thickness have been shown in the tables attached. Groundwater available at site A and B have not proved to be of much importance. In both the cases the quality of water is not good except for use in restricted purposes.

It is observed that the groundwater potential at locations C,D and E are quite good, although the aquifer thickness, the composition and the discharge are not of high yield. The quality of water is good at these places.

The quality of water available from locality D is the maximum. It may be possible that the same may be true if such aquifer is trapped in other areas, when required in addition to the aquifer A. Two aquifers D & E in the locality have been preferred there because they are near the surface. The groundwater conditions are favourable in Hub, Lyari and Malir river basins. Pumping tests carried out at these places show that the water table is reestablished in six hours showing that the permeability is of fair nature. Withdrawals are replaced in short time.

After a comparative study of the above areas it is recommended that a comprehensive study of the entire Karachi and surrounding be carried out comprising surface geology, geophysics and drilling to establish the true prespective of such development. The quantity of water available from different aquifers is as:

i) Khadeji 50,000 gallons/6 hours
ii) Kalukuhar 6,32000 gallons/6 hours
iii) Karachi Metropols 25,000,000 gallons/6 hours
iv) Gadap 2,6000 gallons/6 hours

After development of groundwater in Karachi Metropols and surrounding areas sufficient supply would be possible for industrial as well as domestic purposes.

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LITHOFACIES STUDIES AND A TENTATIVE DELINEATION OF A BARRIER, SEPARATING THE SULAIMAN AND KOHAT-POTWAR PROVINCES OF INDUS BASIN, PAKISTAN DURING LOWER EOCENE.

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ABSTRACT:– *Lithofacies map and a correlation chart of Lower Eocene in the Kohat-Potwar Basin including Hazara and Azad Kashmir has been prepared. A small tongue of the area to the west and south-west of Kohat, a little away to the west of Bahadur Khel and major area to the south and south east of Issa Khel are not represented by Lower Eocene deposits. West of a tentative line passing close to Bannu shows the presence of an altogether different facies closer to that of Ghazij Formation of Sulaiman Province. It is inferred that during Lower Eocene the two regions were separated by a barrier, the area to the west of the barrier relating to the Sulaiman Province etc. and that in the East to Kohat Potwar Province, consisting of a lagoon with in-let from open sea extending towards Hazara, Kashmir, Simla, Gharwal and Nepal Himalayas.*

INTRODUCTION

Kohat-Potwar Province of the Upper Indus Basin, exhibits a great variety of facies during Lower Eocene as per workers given below. Elphinston M.S. 1808, Wynne, A.B. 1875–89, Middlemiss, C.S. 1896, Pinfolds, E.S. 1918; Pascoe, E.H. 1920; Davies, L.M. 1924, Fox C.S. 1928, Gee E.R. 1935, Eames F.E. 1952, Gill, W.D. 1952, Haque A.F.M. 1956, Latif M.A. 1969, 1976, Meissner, C.R. 1974, 1975.

In this work attempt is made for the first time to synthesise the accumulated published data and the information gathered from outcrops to develop a paleoenvironmental and facies picture of the area during Lower Eocene. In the absence of bore hole data the boundaries separating various facies have in places been shown as tentative which could later on be further polished and properly delineated after the availability of the subsurface information.

GEOLOGICAL SETTING

The Paleocene in the area under discussion is represented by Hangu Formation, Lockhart Limestone and Patala Formation and the Middle Eocene by Kuldana and Kohat formations. Between these two groups of formations i.e. Paleocene and Middle Eocene, a total of nine formations are represented described with ammendments after Ibrahim Shah (1977) as follows:-

Ghazij Formation in Dera Ismail Khan Division; Panoba Shale. Shekhan Formation, Bahadur Khel Salt and Jatta Gypsum in Kohat; Nammal Formation and Sakesar Limestone in Salt Range and Surghar Range. Margala Hill Limestone and Chorgali Formation in Nizampur Hills, Northern Potwar Kalachitta, Southern Hazara and Azad Kashmir.(Fig. 1).

Ghazij Formation

The "Ghazij group" of Oldham (1890) was redefined as "Ghazij formation" by Williams (1959) and is adopted here to represent also the "Shales with Alabaster, Rubbly limestone, Green and Nodular Shales, Ghazij Shales, Upper Rakhi Gaj Shales and Zinda Pir Limestone (upper part)" of Eames (1952) from the Rakhi Nala-Zinda Pir Sections, the "Chat beds" of Nagappa (1959), and the "Ghazij shales", "Tiyon formation" and upper part of "Gidar Dhor group" of Hunting Survey Corporation (1961).

Two members are differentiated in the upper part of

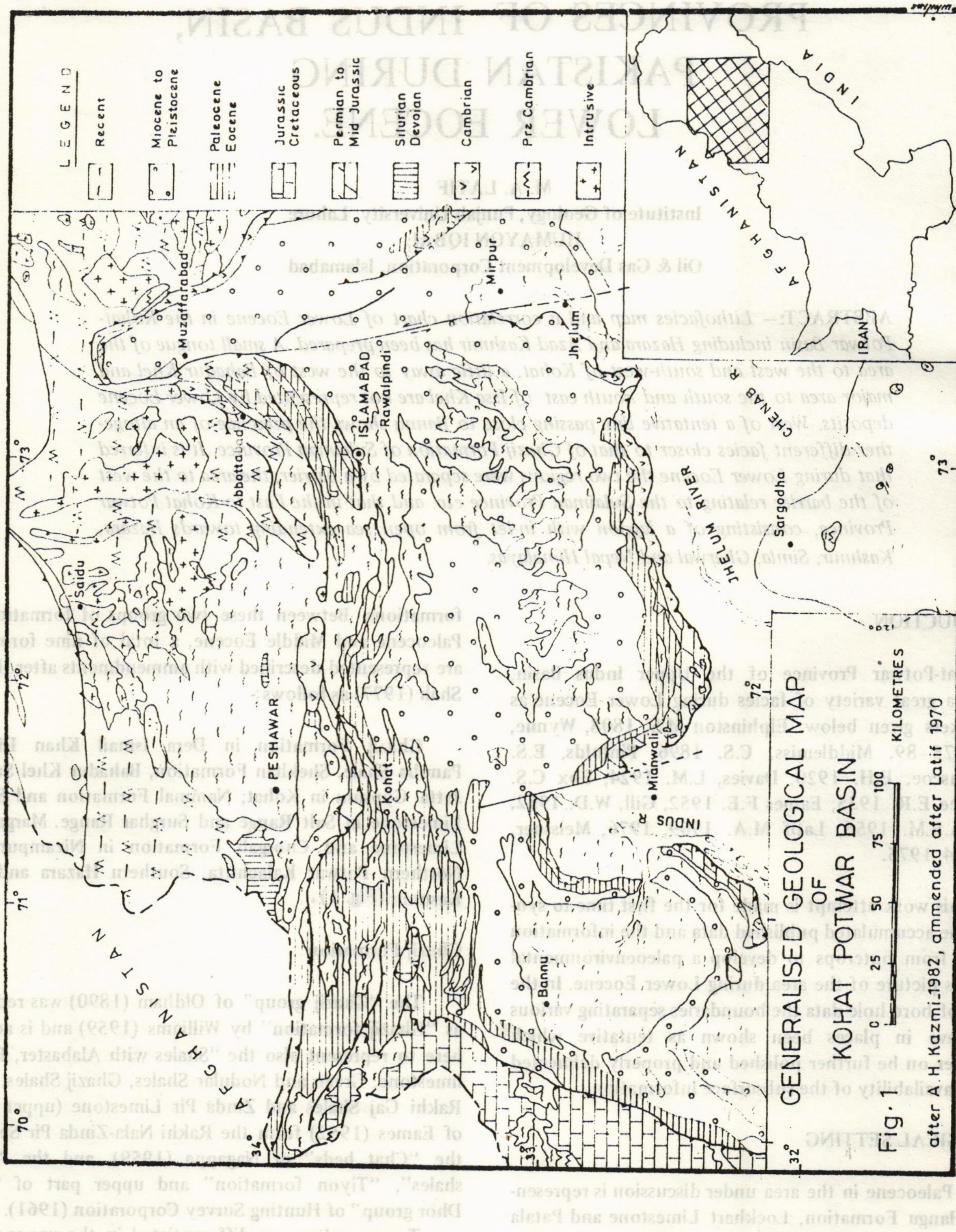


Fig. 1 GENERALISED GEOLOGICAL MAP OF KOHAT POTWAR BASIN

after A.H. Kazmi 1982 ammended after Latif 1970 the formation in different areas. In the eastern and south-eastern parts of the Sulaiman Province, the Baska shale and Alabaster member is designated herein to represent the "shales with Alabaster" of Eames (1952) and "Baska shale" of Hemphil and Kidwai (1973). Conglomerate, which is present in subordinate amounts in western Sulaiman Province and Axial Belt becomes abundant in the southern Axial Balt. This conglomerate unit is here named Marap conglomerate member after the "Marap formation" of Hunting Survey Corporation (1961).

Williams (1959) designated the section at Spintanigi (lat. 29° 57' N: long 68° 05' E) as type section of the formation. A section exposed about 2 km east-northeast of Baska Village (lat. 31° 29' N: long. 70° 08'E) is designated as type section for the Baska shale and Alabaster member after Hemphill and Kidwai (1973). The north west edge of Marap Valley is designated here as the type locality of the Marap conglomerate member after Hunting Survey Corporation (1961).

The formation consists dominantly of shale with subordinate claystone, sandstone, limestone, conglomerate, alabaster and coal that becomes abundant locally. In the Kirthar and Sulaiman provinces, the formation consists of pale greenish grey or brown shale and white or light grey limestone that increases in proportion upward. The shale is calcareous, hard, flaky and in places grades into marl and limestone. The limestone is thin to thick bedded and weathers yellowish white or chalky white. Subordinante greenish grey or brown sandstone, which is calcareous and grades into arenaceous limestone, is also present locally. In the upper part of the formation green and greenish grey shale with beds, nodules and veins of alabaster is present that represents the Baska shale and Alabaster member.

In the Axial Belt and parts of the Sulaiman Province, the formation consists of olive, brown maroon, purple and yellow shale and green, grey or brown sandstone with interbeds of arenaceous limestone and some conglomerate.The shale is earthy or hard blocky, flaky and in places gypsiferous. The sandstone is coarse-grained to pebbly, thick-bedded, cross-stratified and carbonaceous where associated with coal. The coal generally is dark lignite or poor grade bituminous type.

The Marap conglomerate member consists of poorly sorted and well-rounded pebbles and boulders of grey, white and pink limestone, green shale, marl and sandstone derived from the underlying strata which are as old as the Shirinab formation of the present report. Some shale, sandstone and rare limestone are also interbedded and these are similar in lithology to the rest of the formation. In the area between the Central Axis and Kalat Plateau, the member represents the whole formation.

The formation is widely developed in the Sulaiman Province, parts of the Kirthar Province and Axial Belt. It has been reported to extend into North Waziristan. It is 590 m thick at the type section and maximum thickness of about 3300 m has been recorded at Mughal Kot. The formation is about 1,220 m at Zinda Pir and about 160 m a Bara Nai. The Baska shale and Alabaster member is 190 m thick at its type section and only 48 m thick near Jandola in North Waziristan. The Marap conglomerate member is about 910 m thick at its type locality.

The formation conformably overlies the Dungan formation, Laki formation and the Ranikot group in different areas. In the major part of the Axial Belt., it unconformably overlies various older strata like the Dungan formation. Parh group, Shirinab formation, Chiltan limestone and others. In the Sulaiman and Kirthar provinces, it is conformably overlain by the Kirthar formation. In the Thano Bula Khan area, however the Nari formation unconformably overlies it. In the Axial Belt, it is unconformably overlain by the Kirthar formation.

The fossil fauna includes foraminifers, gastropods bivalves, echinoides, algae and other groups (Eames, 1952; Hunting Survey Corporation 1961; Latif, 1964; Iqbal, 1969 b). The foraminifera include *Coskinolina* cf. *C. balsilliei, Lockhartia* cf. *L. hunti var. pustulosa, Assilia sub minosa, Flosculina globosa, Dictyoconus indicus* Among the bivalves *Cardita mutabilis, corbula* (*Bicorbula*) *subexarata, Anomia sp., perinomya sp.* and others are abundant. The formation is assigned an Early Eocene age.

The formation is correlated with the lower part of the Saindak, Kharan, and Nisai formations in parts of the Axial Belt and the Baluchistan Basin, and with the Laki formation in parts of the Kirthar Province. It is also correlated with the Chharat Group of Kohat-Potwar province.

Panoba Shale

The term Panoba Shale was introduced by Eames (1952) for a rock unit represented by the "Green Clay" of Wynne (1879), the upper part of "group f-1" of Griesbach (1892), part of group z (e, b) and (3) eec" of Pascoe (1920) the "Green Shales" of Parson (1926) and the "Green Clay and Sandstone" of Gee (1934), all in the Kohat area.

The section exposed south of Panoba Village (lat. 33° 37' N: long. 71° 35'E) has been designated as the type section for the formation.

The formation consists of shale with occasional bands of sandstone. The shale is greenish grey to light grey, slightly silty and is calcareous towards the base. In places, greenish grey alum shale, with ferruginous and calcareous partings and veins of gypsum are common. Flaggy limestone bands occur at different levels. The unit grades southward into rock salt (Bahadur Khel Salt).

The formation is confined to the Kohat area and its thickness ranges from 66 m at Tarkhobi to 160 m at Uch Bazar. It is 100 m thick at the Panoba Section, over 4 m at Pitau, over 142 m at Togh, over 17 m at Pungi, over 150 m at Gulguri, over 36 m at Abbasi Banda, over 7 m at Dallan, over 187 m at Mardan Khel and 63 m at Shekhan Nala. It is present at Chilli Bagh and Summari Payam.

The formation conformably overlies the Patala Formation and is, in different areas, conformably overlain by the Shekhan Formation or Jatta Gypsum or Bahadur Khel Salt. Only in few places is the Panoba Shale unconformably underlying the Kohat Formation, e.g. in the Uch Bazar Section.

Foraminifers including Globorotalia aequa, Assilina pustulosa, Orbitolites complanatus, Nummulites sp., and Eponides sp., have been reported by Meissner et al. (1968, 1969). The foraminiferal evidence indicates Early Eocene age of the formation.

The formation is correlated with the lower part of the Margala Hill Limestone, Nammal Formation and parts of the Jatta Gypsum and Bahadur Khel Salt of the Kohat-Potwar Province. It is also correlated with parts of the Ghazij, Laki, Kharan, Rakhshani, Saindak and Nisai formations in different parts of the Lower Indus Basin, Axial Belt and Baluchistan Basin.

Shekhan Formation

The term "Shekhan Limestone" of Davies (1926 b) has been formalized by the Stratigraphic Committee of Pakistan as Shekhan Formation to represent the "Gypsiferous beds", Upper Shekhan Limestone", "Middle Shekhan Limestone" and "Lower Shekhan Limestone" of Eames (1952) in the Kohat area.

The section exposed in the Shekhan Nala (lat. 33° 35' N: long. 71° 30' E) of the Kohat area has been designated as the type section.

The formation consists of limestone and shale. In the Shekhan Nala, the limestone is yellowish grey to grey, thin bedded to massive and nodular. The shale is gypsiferous; limestone and shale occur as interbeds in the upper part. At Tarkhobi, the limestone being the dominant lithology in the lower part. At Panoba, limestone with shale partings occurs in the lower part followed by dirty yellow shale which is capped by argillaceous limestone with gypsum beds near the top. At Mami Khel, finely crystaline and light grey limestone occupies the lower part and is followed by shale in the upper part.

The outcrops of the formation are restricted to the Kohat area and pinch out southwest ward. It is 54 m thick at Shekhan Nala, 30 m at Mami Khel and 16 m at Panoba.

Both the lower and upper contacts of the formation with the Panoba Shale and Kuldana Formation, respectively, are conformable.

The formation has yielded larger foraminifers, corals, molluscs and echinoids. The foraminifers, as reported by Nagappa (1959) and Pascoe (1963) include Alveolina oblonga. Assilina daviesi, A. laminosa, Nummulites atacicus and Orbitolites complanatus, and indicate an Early Eocene age.

The formation is correlated with the Sakesar Limestone and the upper part of the Margala Hill Limestone in part of the Kohat-Potwar Province.

Bahadar Khel Salt

Meissner et al. (1968) introduced the term Bahadur Khel Salt for the "Kohat Saline Series" of Gee (1945) in the Kohat area.

Bahadur Khel Salt Quarry (lat. 33° 09' 54" N: long. 70° 59' 53" E) in the Kohat District is designated as the type section for the unit.

The salt is white with black stringers, in places dark grey to black in the upper part, bedded to massive and contains some clear salt crystals. The upper dark coloured salt is bituminous with field odour and is slightly pyritic in places. The sodium content is 37% and the chlorine content 60%.

The rock salt, near Bahadur Khel, outcrops over a length of about 12 km and width of about a half kilometer. At Bahadur Khel Salt Quarry, a thickness of 480 m of the salt has been penetrated, but true thickness is around 300 m. Maximum exposed thickness is about 100 m.

The Jatta Gypsum conformably overlies the Bahadur Khel Salt, while its lower contact, where exposed, is conformable with the Panoba Shale.

Fossil plant leaves have been reported by Gee (1945) in certain bands of sandstone and clay which are interstratified with the rock salt, since it grades laterally into the Panoba Shale. Early Eocene age is assigned to the Bahadur

Khel Salt.

Jatta Gypsum.

Meissner et al. (1968) introduced the term Jatta Gypsum for the upper part of the "Kohat Series" of Gee (1945) in the Kohat area.

A section at Jatta Gypsum quarry (lat. 33° 18' N: long. 71° 17'E), in the Kohat area has been designated as type section.

The gypsum is greenish white in colour massive to bedded, and hard. Thin clay partings of red, purple and green colour occur at different intervals.

Its thickness is 25 m at Jatta Salt Quarry, 69 m at Bahadur Khel, 42 m at Mami Khel, & present at Chashma Ghunda.

The Jatta Gypsum conformably overlies the Bahadur Khel Salt, Panoba Shale and Shekhan Formation in different areas, but conformably underlies the Kuldana Formation throughout.

No fossils have been reported from the unit. However, its conformable contacts with the lower Eocene formations, above and below indicate an Early Eocene age.

The unit is equivalent to the Chorgali Formation of the Kohat-Potwar Province. It may also be correlated with the Baska shale and Alabaster member of the Ghazij formation.

Margala Hill Limestone

The term Margala Hill Limestone of Latif (1970a) has been formally accepted by Stratigraphic Committee of Pakistan for the "Nummulitic formation" of Waagen and Wynne (1872), the upper part of the "Hill Limestone" of Wynne (1873) and Cotter (1933), and part of the "Nummulitic Series" of Middlemiss (1896). The name is derived from the Margala hills north of Islamabad.

The Shahdara Section (lat. 33° 48' N : long 73° 10 E) of southeastern Hazara is considered the type section of the formation. A section exposed to the south of Sir Burjianwala, northwest of Jhallar, Kala Chitta Range is the principal reference section of the formation.

The formation consists of limestone with subordinate marl and shale. The limestone is grey, weathering pale grey, fine to medium grained, nodular, medium fine to thick bedded and rarely massive. The marl is grey to brownish grey while the shale is greenish brown to borwn in colour.

The unit is well-developed in the Hazara Kala Chitta, eastern Kohat and in parts of Potwar areas. It is 100 m thick at Shahdara and 80 m at its reference locality.

The lower and upper contacts with the Patala Formation and the Chorgali Formation, respectively, are conformable.

Foraminifers, molluscs and echinoids are common in the formation. Raza (1967), Cheema (1968) and Latif (1970 c) recorded a number of forminifera from the formation including *Assilina granulosa, A laminosa, A papillata, A. spinosa, Discocyclina rankotensis, Fasciolites delicatissima, F. elliptica, Lepidocyclina (Polylepi dina) punjabensis, Lockhartia conditi, L hunti L. tipperi, Nummulites atacicus, N. globolus, Operculina jiwani O. patalensis and Rotalia trochidiformis.*

The above listed foraminifers indicate an Early Eocene age of the formation.

Nammal Formation

The term Nammal Formation has been formally accepted by the Stratigraphic Committee of Pakistan for the "Nammal Limestone and Shale of Gee (in Fermor, 1935) and "Nammal Marl" of Danilchik and Shah (1967) occurring in the Salt and Trans Indus ranges.

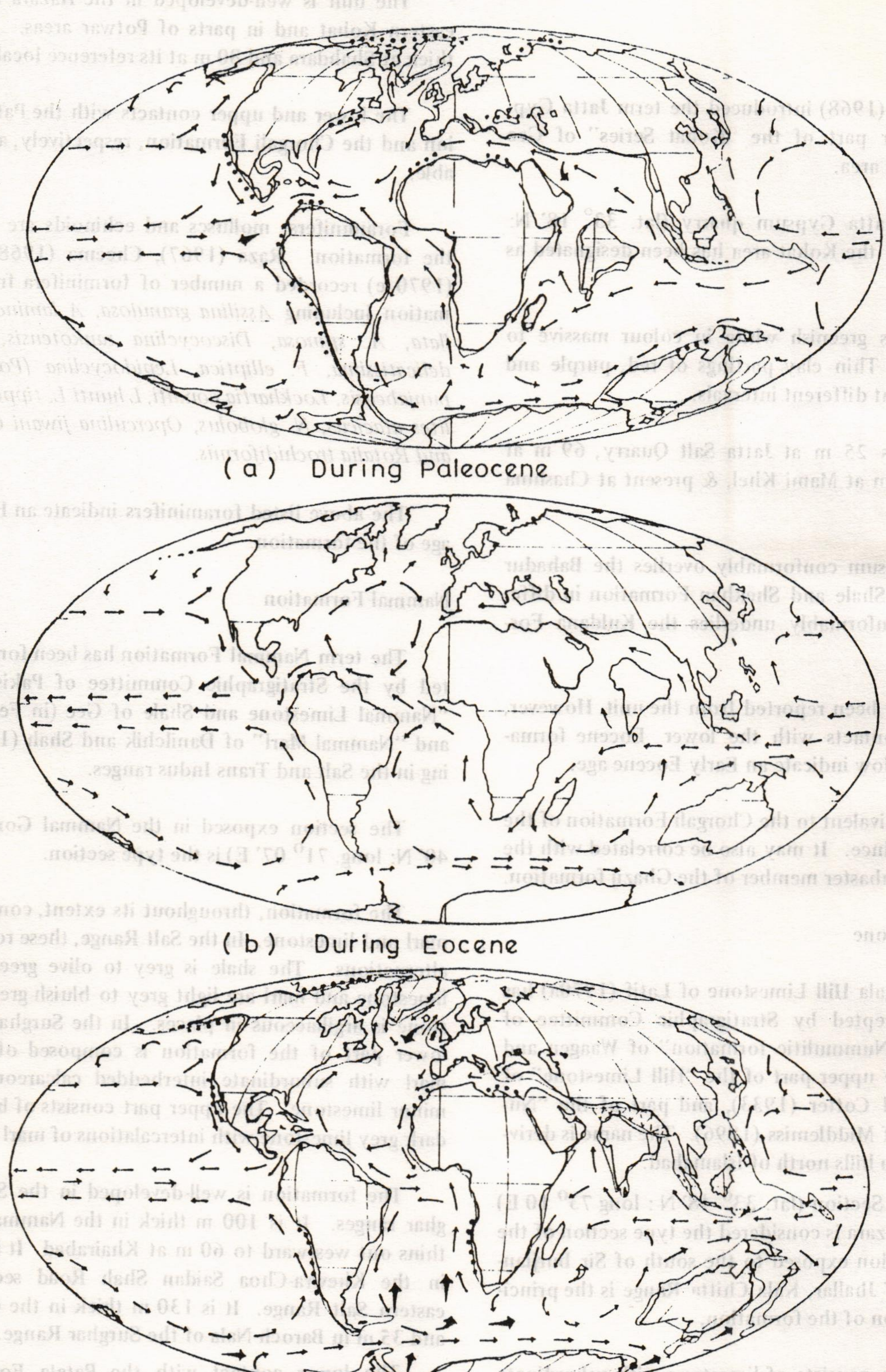
The section exposed in the Nammal Gorge (lat. 32° 40' N: long. 71° 07' E) is the type section.

The formation, throughout its extent, comprises shale, marl and limestone. In the Salt Range, these rocks occur as alternations. The shale is grey to olive green, while the limestone and marl are light grey to bluish grey. The limestone is argillaceous in places. In the Surghar Range, the lower part of the formation is composed of bluish grey marl with subordinate interbedded calcareous shale and minor limestone. The upper part consists of bluish grey to dark grey limestone with intercalations of marl and shale.

The formation is well-developed in the Salt and Surghar ranges. It is 100 m thick in the Nammal Gorge and thins out westward to 60 m at Khairabad. It is 40 m thick in the Khewra-Choa Saidan Shah Road section in the eastern Salt Range. It is 130 m thick in the Chichali Pass and 35 m in Baroch Nala of the Surghar Range.

The lower contact with the Patala Formation and upper contact with the Sakesar Limestone are transitional.

Abundant fossils, mainly foraminifers and molluscs, have been reported from the formation. The following



(a) During Paleocene

(b) During Eocene

(c) During Oligocene

Fig- 4 : Inferred global paleocirculation. after B U Haq 1981 & 1984

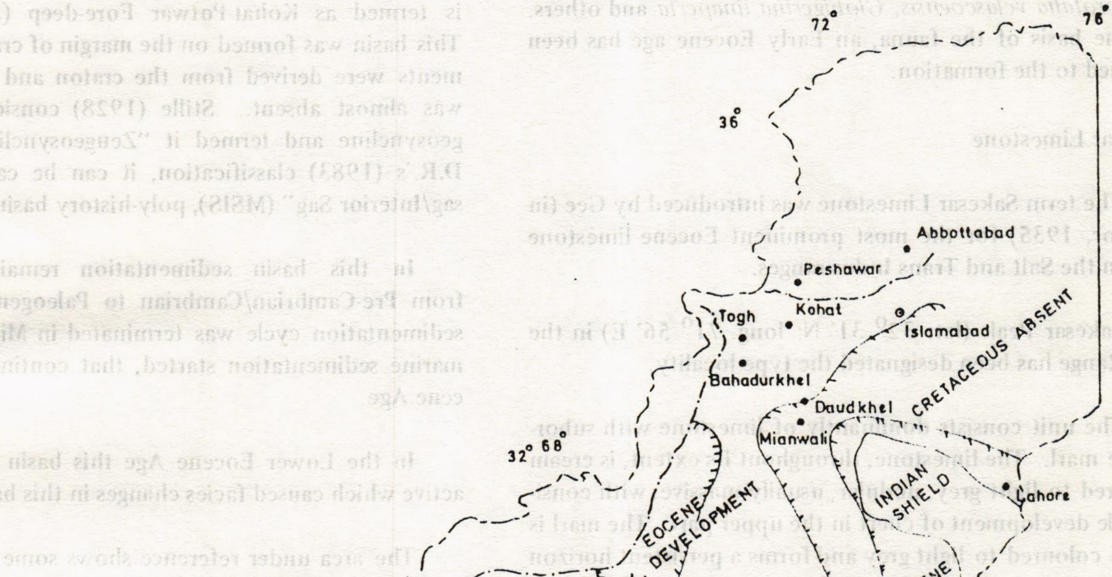


Fig. 5

Amended after A.H. Kazmi & Rana A. Riaz, 1982.

larger foraminifers have been reported by Khan, M. H. (personal communication, 1969): *Nummulites atacicus, N. lahirii. N. Irregularis, Assilina granulosa, A. Laminosa, A. spinosa, Lockhartia tipperi, L. hunti, L. conditi, Operculina nummulitoides, Discocyclina ranikotensis and Fasciolites ablonga.* Haque (1956) recorded abundant samller foraminifers from the type section which includes *Textularia crookshanki, Quinqueloculina gapperi, Alabamina wilcoxensis. Loxostonum applinae, Dentalina plummerae, Gumbelina trinitatensis, Coleites reticulosus, Globorotalia velascoensis, Globigerina linaperta* and others. On the basis of the fauna, an Early Eocene age has been assigned to the formation.

Sakesar Limestone

The term Sakesar Limestone was introduced by Gee (in Fermor, 1935) for the most prominent Eocene limestone unit in the Salt and Trans Indus ranges.

Sakesar Peak (lat. 32^{0} 31' N: long. 71^{0} 56' E) in the Salt Range has been designated the type locality.

The unit consists dominantly of limestone with subordinate marl. The limestone, throughout its extent, is cream coloured to light grey, nodular, usually massive, with considerable development of chert in the upper part. The marl is cream coloured to light grey and forms a persistent horizon near the top. Near Daud Khel in the western Salt Range the limestone grades into white to grey and massive gypsum. In the Surghar Range, the chert lenses increase in number.

The formation is widely distributed in the Salt Range and the Surghar Range. In the Salt Range its thickness varies between 70 m and 150 m. It is 220 m at Chichali Pass and about 300 m in other parts of the Surghar Range.

The lower contact with the Nammal Formation is conformable. In the eastern Salt Range, the upper contact with the Chorgali Formation is conformable, whereas in the central and western Salt Range and in the Surghar Range, the Rawalpindi or Siwalik groups unconformably overlie the formation.

The formation has yielded a rich assemblage of foraminifers, molluscs and echinoids. Some of the important foraminifers are *Assilina leymeriei, A. laminosa, Fasciolites oblonga, Flosculina globosa, Lockhartia conditi, L. hunti, Operculina nummulitoides, Orbitolites complanatus, Sakesaria cotteri and Rotalia trochidiformis.*

The above listed foraminifers indicate an Early Eocene age of the unit.

The formation is equivalent to the Shekhan Formation and the upper part of the Margala Hill Limestone in the Kohat, Kala Chitta and Hazara areas. The formation may also be correlated with parts of the Laki, Kharan, Rakhshani, Ghazij and Saindak formations in different parts of southern Pakistan.

TECTONIC SETTING

The area under discussion is a part of fore-deep, which is termed as Kohat-Potwar Fore-deep (Sokolov, 1970). This basin was formed on the margin of craton, where sediments were derived from the craton and igneous activity was almost absent. Stille (1928) considers it as False-geosyncline and termed it "Zeugeosyncline". Kingston, D.R.'s (1983) classification, it can be called as "margin sag/Interior Sag" (MSIS), poly-history basin.

In this basin sedimentation remained continuous from Pre-Cambrian/Cambrian to Paleogene. The marine sedimentation cycle was terminated in Miocene when non marine sedimentation started, that continued into Pleistocene Age.

In the Lower Eocene Age this basin was tectonically active which caused facies changes in this basin.

The area under reference shows some major faults i.e. Panjal Fault, Nathiagali Fault and Murree Fault. Though facies of the areas in Hazara and Azad Kashmir situated between Panjal and Murree Faults have been incorporated, the main area of this exercise centres around the area situated east and south of the Murree Fault. Information South East of Murree Fault in Azad Kashmir has been plotted but could not be completed for lack of data.

DISCUSSION

After the breaking up of the Pangaea, the Indian Plate started to drift northwards, and incursion of Tethys Sea took place. The position of Indian Plate and the inferred global circulation as shown in figure 4(after Haq 81-1984), indicates that during Early and Late Paleocene there was a free circulation of waters between the Arabian Sea and the Bay of Bengal directly as well as via north of the Indian plate. As per Haq Fig. 4 there was free circulation on the northern margin of the plate during Middle Eocene and the plate was near collision position during oligocene.

A reconnaissance of the tectonic map of Pakistan, Kazmi et al. 1982, with relevant extracts as given in Fig. 5 indicates the position of the Indian shield surrounded by a line showing non-deposition during Eocene towards the shield area. This is almost surrounded outwardly by a line

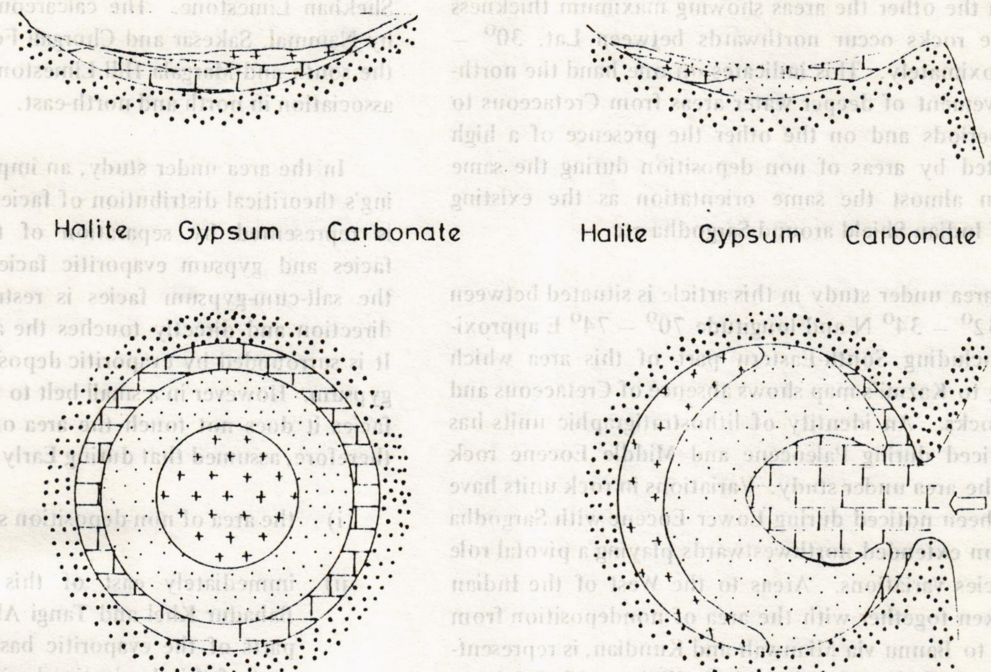
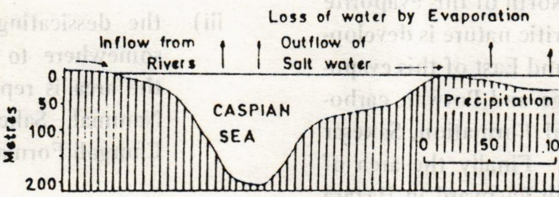


Fig. 6 – Theoretical facies distribution in a desicating basin (A) and in a barred basin (B) after Hsü 1972



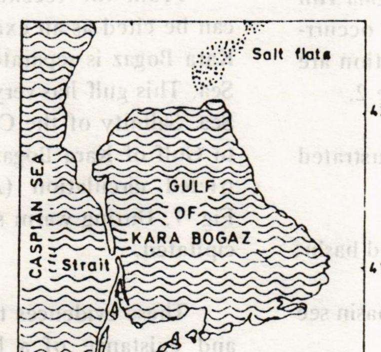


Fig. 7 – Map and section to illustrate the accumulation of saline precipitates ('evaporites') in the Gulf Kara Bogaz, Caspian Sea.

showing the absence of Cretaceous. On one hand the maximum thickness of Cretaceous deposits has been noticed between latitude 28° – 30° N and longitude 70° E see fig. 5, on the other the areas showing maximum thickness of Eocene rocks occur northwards between Lat. 30° – 32° approximately. This indicates on one hand the northward movement of deeper water areas from Cretaceous to Eocene periods and on the other the presence of a high as indicated by areas of non deposition during the same period, in almost the same orientation as the existing tongue of Indian Shield around Sargodha etc.

The area under study in this article is situated between latitude 32° – 34° N and longitude 70° – 74° E approximately including South-Eastern part of this area which according to Kazmi's map shows absence of Cretaceous and Eocene rocks. An identity of lithostratigraphic units has been noticed during Paleocene and Middle Eocene rock units in the area under study. Variations in rock units have however been noticed during Lower Eocene with Sargodha high region extended northwestwards playing a pivotal role in the facies variations. Areas to the West of the Indian Shield taken together with the area of nondeposition from Sargodha to Bannu via Mianwali and Kundian, is represented by Ghazij Shale with lithological affinites with Sulaiman Province. East of this line are found evaporites represented by Panoba Shale, Bahadur Khel Salt and Jatta Gypsum developed at Bahadur Khel, Jatta etc. all overlying the Patala Formation of Paleocene age. Except for the western contact of these evaporite deposits with the area of non-deposition, the evaporite belt generally speaking, is surrounded by another evaporitic facies without salt as represented in Moussam Khulla, Daud Khel etc. North of this evaporite belt the Shekhan Limestone of evaporitic nature is developed in Panoba, Shadi Khel etc. South and East of this evaporitic belt in Salt Range, Surgar Range and Potwar, carbonate facies is represented by Nammal Formation, Sakesar Limestone and Chorgali Formation. Finally the area of Northern Potwar northward and north-Eastward in Hazara Azad Kashmir respectively are represented by Margala Hill Limestone and Chorgali Formation. Details of the occurrence of various facies including area of non-deposition are shown in scale, at location in correlation chart figure 2.

Reading (1978 – pp. 205) discussed and illustrated evaporitic facies model as

a. theoritical facies distribution in a dessicated basin;

b. theoritical facies distribution in a barred basin see fig. 6.

As it is evident from the figures, facies of the barred basin seems to be represented in the area under discussion. Similar to the diagram given above the evaporites are restricted only to one end of the basin. There seems to be a passage belt between evaporite and calcareous facies in the form of Shekhan Limestone. The calcareous facies is represented by Nammal, Sakesar and Chorgali Formation association in the south and Margala Hill Limestone, Chorgali Formation, association in north and north-east.

In the area under study, an improved version of Reading's theoritical distribution of facies in a dessicating basin is represented by separation of the salt-cum-evaporitic facies and gypsum evaporitic facies. The former that is the salt-cum-gypsum facies is restricted in an east west direction and directly touches the area of non-deposition. It is surrounded by evaporitic deposits consisting mainly of gypsum. However in a small belt to the west of the gypsum facies it does not touch the area of non deposition. It is therefore, assumed that during Early Eocene: (Fig. 3)

i) the area of non-deposition served as a barrier.

ii) immediately east of this barrier the areas of Bahadur Khel and Tangi Algad constituted deeper parts of the evaporitic basin and constituted the part of this dessicating basin where salt in addition to gypsum was formed after conditions were ripe for the formation of Salt after evaporation of major quantity of water with suitable increase in salinity. This dessicating basin, therefore was temporarily cut-off by the barrier from the western side from the waters of the Arabian Sea at least in the areas under-study.

iii) the dessicating basin had a saddle like opening somewhere to the east north-east beyond which the area is represented by calcareous deposits of Nammal, Sakesar, Margala Hill Limestone and Chorgali Formation.

From the recent sedimentation, Gulf of Kara Bogaz can be cited as an example of such deposition. The Gulf of Kara Bogaz is separated by a narrow passage from Caspian Sea. This gulf has very high salinity as compared to Caspian Sea. Salinity of the Caspian Sea is about 13% as compared to Gulf of Kara Bogaz where it is about 18.5% due to restricted circulation (A. Holms 1964), pp. 138-139) see Fig. 7. During warm season salt as well as gypsum are precipitated.

These evidences therefore indicate regression of the sea and existance of a barrier separating Sulaiman Province from Kohat-Potwar Province and development of evaporites in the area under discussion, whether or not the collision of plate actually took place in early Eocene.

CONCLUSIONS

In the area under-study, Lower Eocene deposits of evaporitic and mixed facies are found, sandwitched between open marine deposits of Paleocene and Middle Eocene. The presence of a mixed facies during Lower Eocene is attributed to the presence of a barrier, due to the regression of the sea separating the marine facies of the Sulaiman Province from the mixed facies of the Kohat Potwar Province. On the Potwar side of the barrier this led to the formation of a lagoon due to sub-marine topography with an opening to the open sea to the East. The collision of Indian Plate at present is generally considered to be during Post Eocene times. Keeping in view the Evaporitic and mixed nature of sediments, the presence of a barrier separating Sulaiman facies from Kohat Potwar facies, he possibility of collision during Early Eocene can not be ruled out. More information is however desirable in support of the apprehension. The presence of marine deposits during Middle Eocene may be attributed to the accumulation of displaced waters coupled with transgression of the sea.

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VARIATION OF POINT RESISTANCE AND SKIN FRICTION OF PILES WITH DEPTH

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ABSTRACT:– The ultimate load which can be carried by a pile is equal to the sum of the point resistance and shaft resistance. The point resistance is the product of the base area and the ultimate bearing capacity or end bearing (q_o). The shaft resitance is the product of the perimeter area of the shaft and the average value of the ultimate shearing resistance per unit area (f_o) generally referred to as the 'skin friction' between the pile and the soil. This paper is an attempt to put the results of a laboratory based research project during which the point resistance and skin friction variations were measured on driving model piles in dense sand. Model piles were instrumented, calibrated and then driven by a drop hammer to the full embedment depth of 750 mm. It was found out that point resistance is directly proportional to depth and the skin friction is maximum at about 2.5 pile diameter.

INTRODUCTION

By the mid-19th century, many efforts had been made in an attempt to assess the value of the bearing capacity of a pile but without conviction. Engineers therefore came to rely solely on the test load method. A single pile would be driven to a set penetration and loaded to failure. The failure load F of the pile was then divided by the required safety factor S to give the design load D.

Load bearing capacity of piles may be understood better by considering a vertical pile subjected to a vertical load. The pile load will be carried partly by:

(a) Skin friction (which is mobilised through the increasing settlement of the pile and compression of the pile shaft itself) and

(b) point resistance or end bearing.

POINT RESISTANCE AND SKIN FRICTION:

Pile tests conducted by Kerisel (1969) and Vesic (1964) in homogeneous sands indicated that both point resistance (q_o) and skin friction (f_o) increases proportionally with depth at relatively shallow depth only ($L/B < 4$) where L is embedment depth and B is pile diameter. They also observed that q_o and f_o approach constant values at a critical depth depending on the relative density of sand.

In loose sand constant values were obtained at L/B ratio of about 10 and in dense sand, of about 30. Results obtained for load tests by Vesic (1970) on a 15 m long, 450 mm diameter instrumented pile in sand indicated that both skin friction and point resistance increased approximately linearly for penetration less than 10 pile diameter. It became constant after depth greater than 20 diameter was reached. This distribution of skin friction was found to be parabolic.

Variations of point resistance of penetrometers were measured by Kerisel (1964) in heavily compacted and slightly compacted sand His results are shown in Figure 1.

THE EXPERIMENTAL PROGRAMME

The purpose of the Author's experimental programme was to measure the variations in point resistance and skin friction with depth of model piles. The piles were driven in sand of the known density and other soil parameters. To achieve this target different types of apparatus were used and they are as follows:–

(i) Sand Container

A circular concrete pipe having an internal diameter of 1.2 m and a depth of 1.2 m was used as a sand container. The inner wall of the container was coated with paint and marked to give an indication of the level of sand filled during preparation of the sand beds.

The sand used was an air dry leighton Buzzard sand. The sand was light yellow in colour, clean and free from large particles and any impurities. The sand particles passed a No. 14 B.S. Sieve (Opening 1.2 mm) but were retained on a No. 72 B.S. Sieve (Opening 0.21 mm). The sand sample in

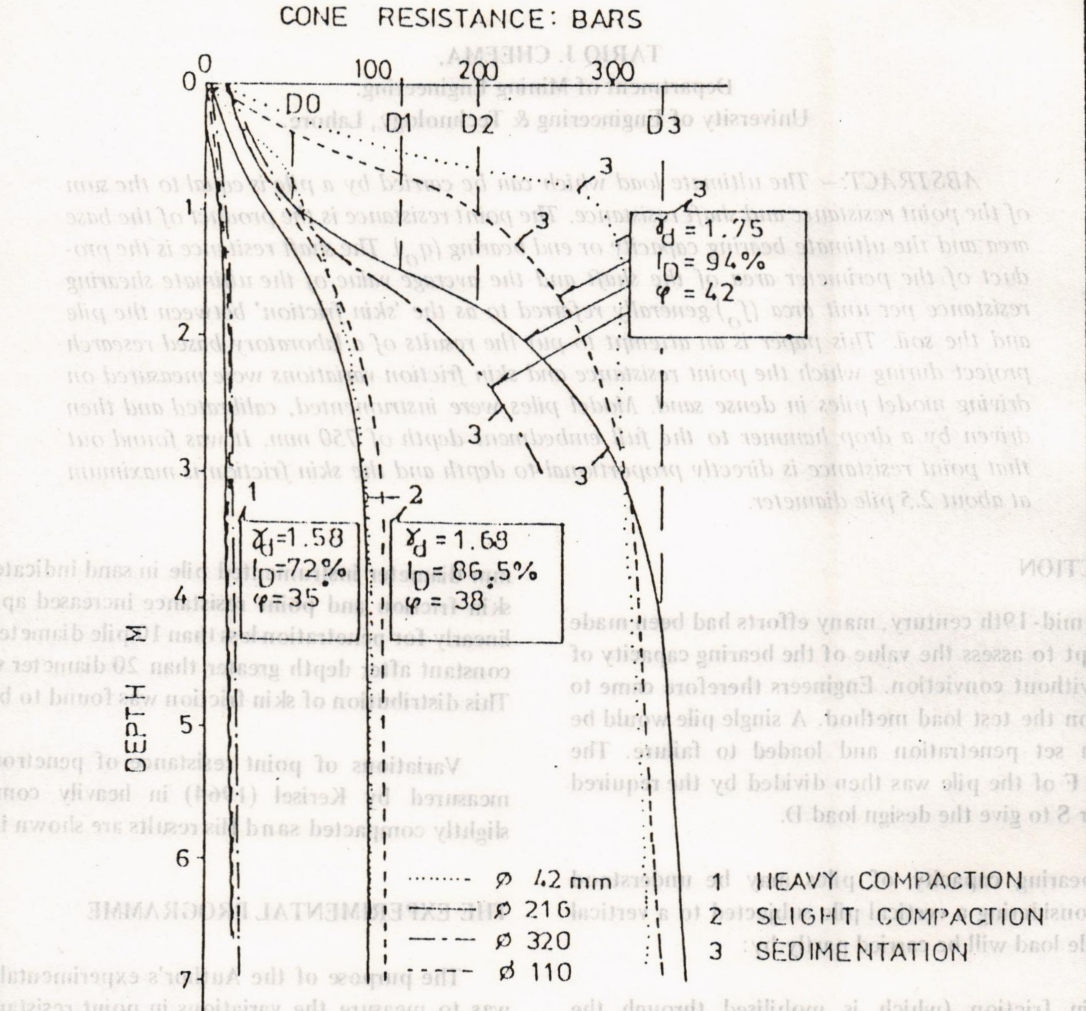

FIG. 1 VARIATION OF POINT RESISTANCE OF PENETROMETERS WITH DEPTH (KERISEL, 1964)

the sand container was formed using a raining device which deposits the sand through perforated plates by traversing across the tank in a sweeping motion.

(ii) Pile Group

A total number of 5 piles were used during the experimental programme, two of which were instrumented and the other were dummy piles. General considerations in selecting dimensions of a pile were:

- That it would provide a reasonable distribution of skin friction along the length.
- That it would not introduce serious problems druing the instrumentations and construction stage, and
- That the stresses induced in soil during pile driving would not be influenced by container.

Previous tests conducted by other investigators indicated that a pile 1 m long with an external diameter of 40 mm and an embedment depth of 750 mm would be suitable for the sand container used in this programme. All the piles used have the same dimensions.

(a) *INSTRUMENTED PILES.* They are called instrumented because of the presence of skin friction load cells and toe load cells to measure the variation in skin friction and point resistnce respectively.

Each pile was assembled from a 200 mm long solid steel core and a 200 mm long pile head which was screwed directly onto the upper end of the steel core. 16 skin friction load cells, each 50 mm long and having a wall thickness of 1.5 mm were also fitted at a regular distance of 50 mm on each pile. A cylinderical toe load cell was fixed to the lower end of this steel core and a circular flat base having and external diameter of 40 mm was screwed to the bottom end of the pile.

Each skin friction load cell consisted of a double ended cantilever and operated on the principle that friction loads cause bending of the cantilevers. By strain gauges these cantilevers, the shearing loads acting on the steel sleeves could be obtained.

The toe load cell was used to measure the load transmitted to the pile base. The cell was actually a thin steel cylinder fitted with strain gauges along the longitudinal as well as in the circumferential direction. These guages were connected to form a full wheatstone bridge.

(b) *DUMMY PILES.* These are called dummy because no friction load cells are fitted on and the piles consist of a hollow cylindrical steel core However toe cell was fitted at the base of each pile to know the load transmitted piles in another respect that the weight of each pile is only 4.45 Kgs as compared with 8.66 Kgs of the instrumented one.

(iii) The Piling Rig:–

The apparatus which was used as a piling rig consisted of a drive assembly, a drop hammer, a hammer guide and a pile guide. To ensure that the drop hammer will fall through a constant height for every blow, a drive assembly consisting of a motor, a gearing system, a steel pick-up dog and some sprockets were used.

Drop hammer was a hollow steel cylinder with grooves throughout its whole length of 900 mm. The total mass of the hammer was 7.795 Kgs.

Two vertical steel rods were screwed directly on to the base of the piling rig to align the pile during driving. 2 tufnol plates were also used for the same purpose. A pile holder was used to hold the pile in position before driving.

EXPERIMENTAL PROCEDURE

After calibrating the load cells and instrumented piles with load applied, the instrumented pile was erected in sand tank. A junction box and a twelve channel portable strain indicator were used during calibration and actual pile testing. The load cells were connected to junction box in which potentiometers were incorporated.

Two pile tests were conducted. A group of 4 piles were driven one by one in Test – 1 and 5 in Test – 2. Strain readings for all load cells were taken at the following stages.

i) Before pile penetration.

ii) When piling was stopped at penetration depth of 200 mm, 400 mm and 600 mm.

iii) After full penetration depth of 750 mm was reached.

RESULTS

Table 1 gives the values of point resistance and skin friction as registered by the load cells at full penetration of 750 mm. The point resistance variations at different penetration depths are shown in Table-2 and skin friction distribution of Test-1 and Test-2 are shown in Figure-2 and Figure-3, respectively.

i) *POINT RESISTANCE:* The data shown in Table-2 clearly indicates that there is a direct relationship of point resistance with depth, i.e. point resistance is directly proportional to depth. Test-1 in which a group of 4 piles were driven to a depth of 750 mm indicates that the point resistance for pile-2 was only 80 Newtons at a penetration depth of 200 mm. This value gradually increased with depth and attained a constant value of 117 Newtons at full embedment depth of 750 mm. thus showing a net increase

TABLE 1

POINT PRESISTANCE AND SKIN FRICTION REGISTERED BY LOAD CELL AT FULL PENETRATION

PILE TEST NO.	PILE NO.	POINT RESISTANCE	SKIN FRICTION
1.	1	107	2141
,,	2	117	146
,,	3	360	
,,	4	547	
2.	1	56	2773
,,	2	2802	1028
,,	3	178	
,,	4	75	
,,	5	673	

of 37 N. Similar type of behaviour was observed druing the driving of pile 3 and pile 4.

Test-2 in which 5 pile were driven one by one to the full embedment depth of 750 mm also confirmed the results already collected in Test-1

The ascending values of point resistance with depth can be explained with the help of insitu density measurements while the piles are being driven. Pile driving results in increasing the sand density and the shearing strength of sand.

Table-1 indicates that in the beginning most of the load is carried by the skin friction and as the embedment depth increases the point resistance gets mobilised and all the load applied is carried by the pile shaft.

ii) *SKIN FRICTION:* Figure-2 and Figure-3 indicate that the skin friction increases with depth from near zero value at the sand surface to a maximum at a certain depth, after which the skin friction starts to decrease with depth. In both the tests, the maximum was found to occur at about 2.5 pile diameters above the pile point. These figures confirmed the skin friction variations reported by Zweck (1953), Mansoor and Kaufman (1958), Mohan et al. (1963), Vesic (1970) and other investgators.

The increase of skin friction with depth 9before attaining the maximum value) is to be expected as the normal stresses acting on the pile shaft will increase with depth. The descrease of skin friction with depth (after the maximum value) is related to the formation of sand arches in the vicinity of pile shaft.

TABLE 2

VARIATION OF POINT RESISTANCE WITH PENETRATION DEPOTH (N)

PENETRATION (DEPTH (MM)	PILE TEST 1				PILE TEST 2				
	PILE-1	PILE-2	PILE-3	PILE-4	PILE-1	PILE-2	PILE-3	PILE-4	PILE-5
200		80	112	546	17	70	80	15	268
400		83	116	558	26	2347	124	24	100
600		90	340	563	46	2542	70.4	68	308
750	107	117	360	546	56	2802	178	75	673

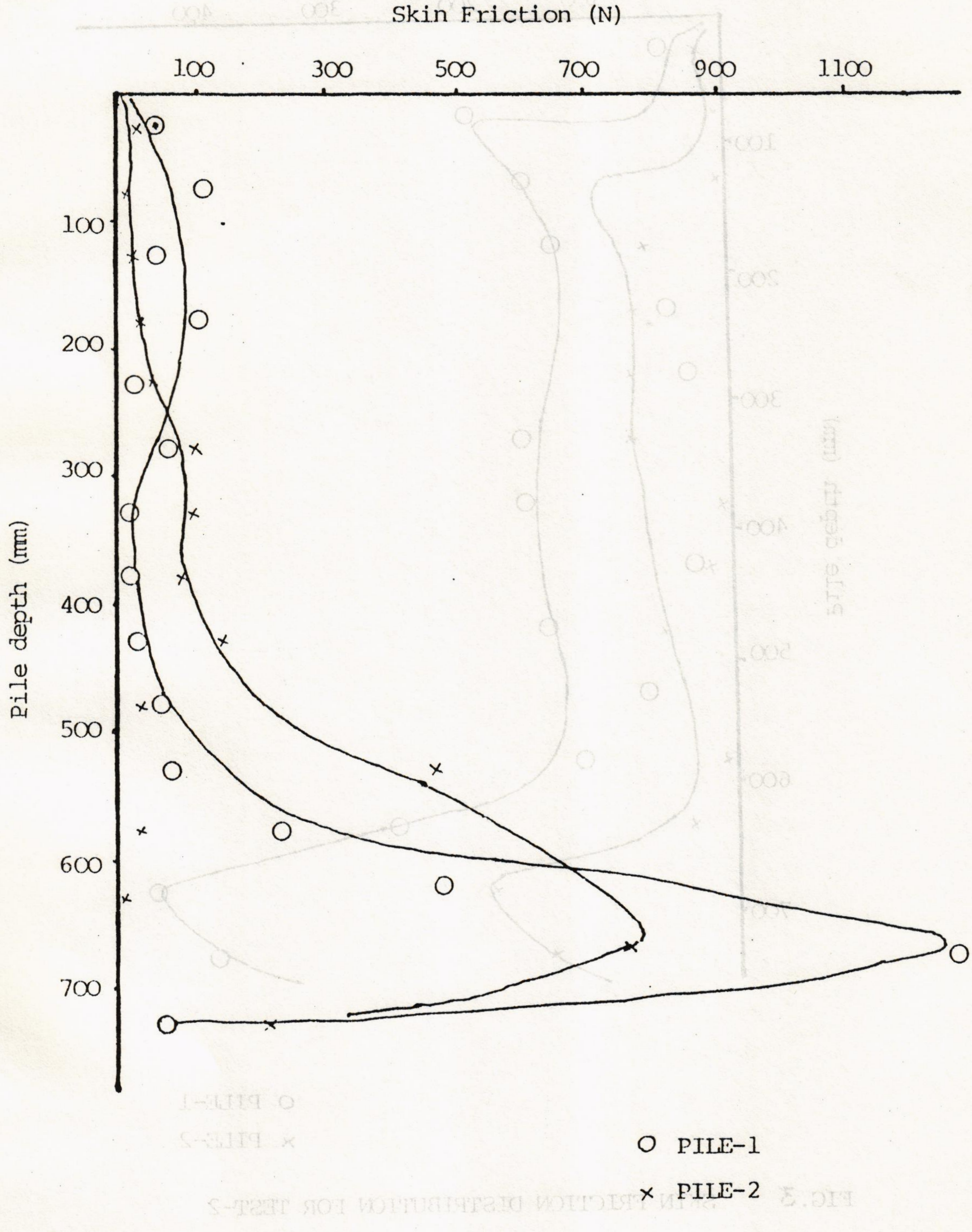

FIG. 2 SKIN FRICTION DISTRIBUTION FOR TEST-1

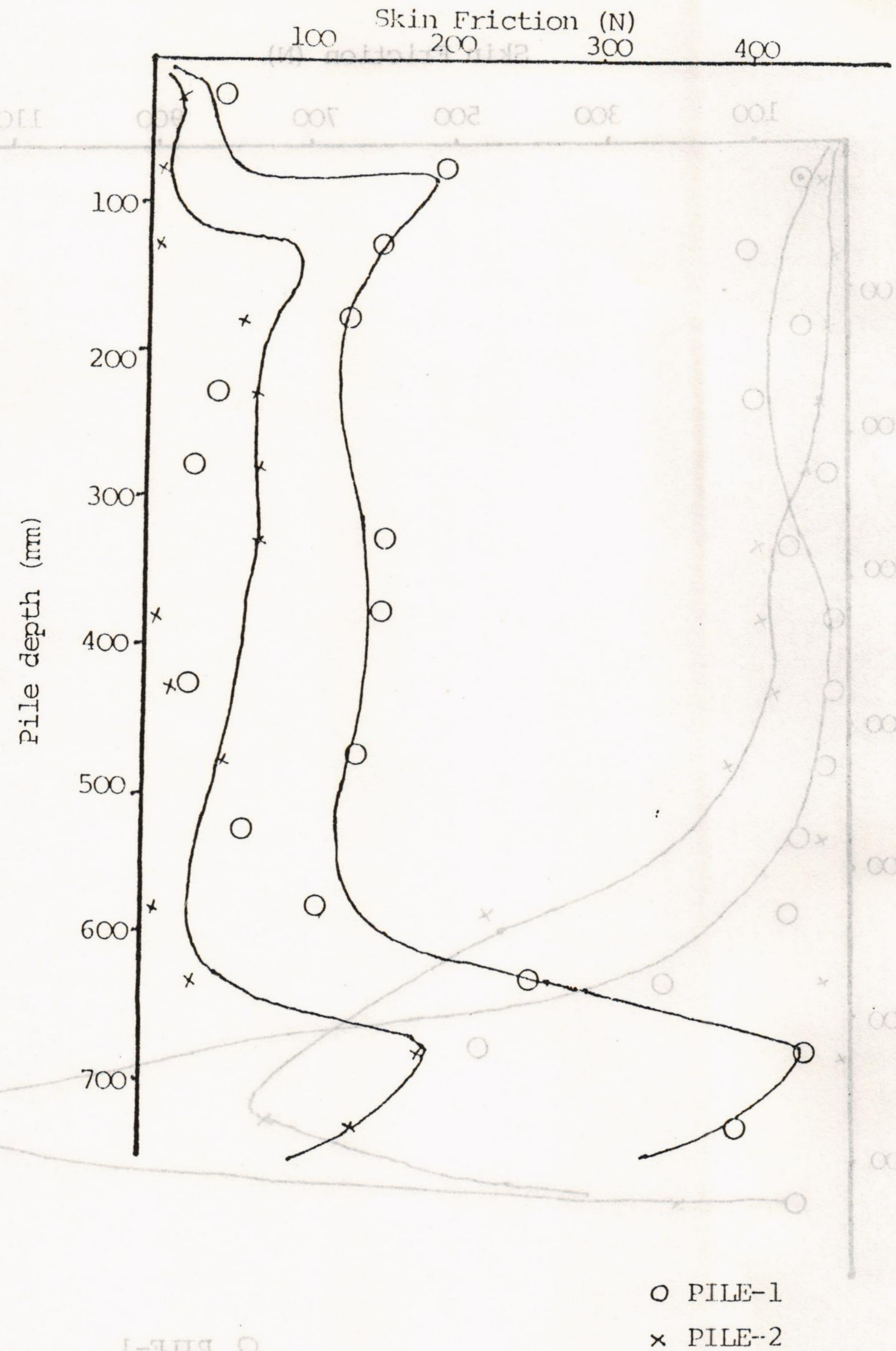

FIG. 3 SKIN FRICTION DISTRIBUTION FOR TEST-2

CONCLUSIONS:

1. The point resistance measured in the experimental work was found to be increasing with depth.

2. The distribution of skin friction loads is not linear. After increasing initially with depth, up a maximum at 2.5 pile diameters above the pile point, the skin friction value drops significantly with depth.

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PETROGRAPHY OF THE NEELUM GRANITE NEELUM VALLEY AZAD JAMMU AND KASHMIR

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ABSTRACT: Granitic rocks intruded into Tonal Formation occur in Neelum Valley near Neelum Village. 14 thin Sections of the granite were examined to describe the petrography of these rocks. Besides this basic minor bodies were also found intruded into the Neelum granite which are also described. Petrographic data support the field observations that these rocks are intrusive suite of magmatic rather than of a replacement origin.

INTRODUCTION

The Neelum granite takes its name from Neelum Village, in Neelum Valley, Azad Kashmir. The study area lies between longitude 73° 52 to 73° 56 E and latitude 34° 36 to 34° 40 N. The granitic body extends from east to west. The western part of the exposure could be studied while eastern part lies in Occupied Kashmir.

GENERAL GEOLOGY

Neelum granite is coarsely porphyritic to medium grained and extends westward towards Kaghan Watershed. Many hand specimens were collected out of which 14 thin sections were made to obtain data on texture and petrography.

The rocks of the Neelum granite occur typically as light grey to brownish grey. The fresh exposures of the rocks show whitish grey colour. However, close examination shows brownish black biotite specks in whitish grey background. At some places black tourmaline is also found in the granite.

In Mianwatch ridge area granitic rocks weather to bouldry outcrops. Boulders are as large as 5 to 7 metres in diameter. The over all rocks are coarse to medium grained. Xenoliths of variable sizes are found and exhibit blackish colour. The contact metamorphism have transformed Tonal Formation wall rocks and has developed hornfelses. Both Neelum and Jura granites are magmatic but faulting has eliminated evidences of thermal effects along certain contacts. The thermal effects are best preserved at the contact of Neelum granite with Tonal (Kundalshahi – Nagdar garnet mica schist) at Rampura where a contact aureaole shows the development of three grades of thermal metamorphism viz from schist to the chilled granite margin, biotite hornfels, andalusite hornfels and silliminite honrfels (Ghazanfar et al., 1983). The enormous quantity of heat required for contact metamorphism apparently came from the magma that has crystallized into the granitic body exposed today.

PETROGRAPHY

Neelum granite is porphyritic to medium grained. In thin sections it shows hypidiomorphic and granitoid texture. The largest crystals are potash feldspar which are comparatively fresh and perthitic microcline. The plagioclase is mostly albite or oligoclase. It is usually euhedral to subhedral. Zoning is visible in some of plagicolase crystals. The occurrence of plagioclase is interesting. The fresh albite often occurs as inclusions in the microcline. This suggests that the albite remained mobile later that the microcline. The quartz is usually anhedral and occur from interstial to patches and as large crystals. The percentage range of minerals and their mode of occurrence is as follow: –

K – feldspar It is present as microcline and microperthite. These are the most common varities of potash feldspar. It sometimes also occur as inclusions in plagioclase. In some thin sections potash feldspar shows inclusions of biotite and muscovite. It ranges from 16% to 34% in the rocks.

Plagioclase : It is in the form of euhedral, to subhedral crystals exhibiting carlsbad and albite twining. It shows in some cases zoning and exhibit dust like inclusions. Inclusions of biotite and muscovite and also common in plagioclase. In some specimens cores of plagioclase crystals are altered intensely, whereas rims are relatively fresh. Alteration product is usually sericite and kaolinite. Myrmekitic texture is also found. Its composition lies within oligoclase to albite range. It forms 12% to 23% of the rocks.

Quartz; It generally occurs in the form of allotrio-

TABLE 1

Petrographic Composition of Neelum Granite

Thin Section No.	Quartz	K-feldspar	Plagio-clase	Biotite	Muscovite	Sericite	Ore	Sphene	Epidote	Garnet
K-1	43	20	17	8	9	2	—	1	—	—
K-3	49	18	12	11	8	2	—	—	—	—
K-4	34	32	13	11	6	3	1	—	—	—
K-5	40	29	16	7	5	2	1		—	—
K-6	48	17	19	11	3	2	—	—	—	—
K-7	45	31	12	6	2	4	—	—	—	—
K-8	43	16	22	12	6	1	—	—	—	—
K-13	39	27	15	10	7	1	1	—	—	
K-15	41	30	12	8	6	1	1	1	—	—
K-19	46	24	15	10	4	1	—		1	—
K-28	44	33	12	6	3	1	—		—	—
K-29	39	34	14	8	2	—	2	1	—	—
K-30	47	24	16	8	4	—	1	—		
K-37	43	20	23	4	8	—	—	1	1	—

morphic with interlocking margins. It also occur as large crystals. Sometimes it is mosaic and locally granulated. Quartz also occur as inclusions in potash feldspar. It varies from 34% to 49%.

Biotite: Biotite is ubiquitious in these rocks. It is variable in colour and pleochroism. Reddish brown biotite is common, generally dispersed in the rocks and sometimes in the form of aggregates. Ore inclusions in biotite are very common. Biotite flakes are rich in pleochroic haloes, probably around tiny zircon crystals. Minor chloritization can be seen around the margin of biotite flakes. Biotite occurs independently as well as inter-grown with muscovite. Its amounts vary from 4% to 12%.

Muscovite: It occurs in association with biotite. It various from 2% to 9% Accessory Minerals: Opaque ore, sericite, epidote and garnet are accessory minerals.

BASIC MINOR BODIES

The doleritic bodies are found intruded into the Neelum granite as well as in metasediments. However, samples were collected from basic intrusions present in granite. Three thin sections were made to study these rocks under petrographic microscope. Petrographically, the dolerite bodies are pyroxene-plagioclase rocks. Sometimes olivine crystals are found. Ophitic texture is commonly developed.

On the basis of study of thin sections of dolerite rocks under petrographic microscope the important aspects of minerals are described below.

Plagioclase: It varies from 45% to 52% while its composition ranges from An 44 to An 64. The plagioclase exhibits carlsbad and albite twining. It also shows laths of variable sizes. Zoning is sometimes visible. Dust like alteration product is very common in the centre of the plagioclase crystals.

Pyroxene: The pyroxene minerals make up 33% to 35% of these rocks. At margin pyroxene crystals alter to hornblende.

Olivine: It is found upto 6% in the dolerite rocks. It is usually fractured. It is subhedral to anhedral. Ore minerals are associated with olivine.

Biotite: Brown biotite occur upto 2% to 3% in these rocks. It is pleochroic in shades of brown and green.

Ore Mineral: Blck ilmenite is found dispersed in these rocks. Sometimes it is associated with pyroxene and sometimes exhibits association with altered plagioclase. It makes 2% to 3% of the rocks.

CONCLUSIONS

Evidences are present to prove that the granitic rocks crystalised from a granitic melt and not a product of granitization. Granitic body has sharp and clear contacts with the metasediments of Tonal Formation. The zone of contact metamorphism is another line of evidence that indicates predominantly magmatic origin for the Neelum granite. Tourmaline occurrence was found in the metamorphosed wall rocks is interesting. Although it is not a contact metamorphic mineral. Its formation whether from the reconstitution of boron from nearby pelitic psammatic rocks or from boron introduced from the granitic melt, is another indication of thermal environment compatible magmatic origin for the granitic rocks. The concept that granitic body was intruded to its present position as magmatic melt of dominantly fluid material is based on regional consideration and on local evidence.

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COMPUTERS AND ITS APPLICATION IN GEOLOGY

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INTRODUCTION

Since early times, people have looked for more efficient ways to obtain and process information. The need for more effective information processing toll became especially essential after world War-II. At that time, it seemed very likely that every organization, government, commercial or soical would eventually be overwhelmed by paper work.

Data processing, the modern name for paper work, means collection, processing and distribution of facts and figures to achieve a desired result. The equipments and procedures by which the result is achieved form a data processing system vary according to the needs of various organizations.

HISTORICAL BACKGROUND

The efforts leading to today's computers began many years ago. As early as in 1612 an 18 year old Frenchman, Blaise Pascal, developed a machanical adding machine with rotating gears that contained teeth representing the digits 0 through 9.

Extending the principle of the adding machine, Gottfried leibnitz, a German Mathematician, devised a calculating machine that multiplied with repeated addition and divided with repeated subtraction. This machine was demonstrated for the first time in 1694.

In 1880 the US Bureau of census employed Herman Hollerith to develop a machanical method of performing a massive data tabulation task for the processing of census data. He developed a device that coded population data as punched holes in cards. The data that had been recorded in this way was then read or sensed by another machinical device. Until world War-II, data was processed either manually or mechanically. The War, which had such dramatic effects on lives throughout the World, also created an urgent need for a new data processing method.

In the United States first large scale computing device was developed in the University of Pennsylvania between 1939 and 1946, by ENIAC (Electronic Numerical Integrator and Calculator). It was a 30 ton, 1500 square feet machine. However, in one day it could perform electronic calculations equivalent to 300 days of manual calculations. Thus the Electronic Digital Computer was born. The main feature of this computer was that the switching and control functions were handled by vacuum tubes. As a group they are called first generation computers. In the late 1950s these components were replaced by tiny and more reliable solid state transistors. The change-over to transistors created what is frequently referred to as second generation of computers. New technological advances miniaturized and refined various Components of second generation computers. Solid logic technology was applied to computer circuitry to create third generation computers. In some of these computers as many as 664 transistors, diodes and other components equivalent to 64 complete circuits were placed on a single silicon chip of the size of less than the eighth of an inch square. Circuits produced in this manner were known as integrated circuits or IC's. The change to third generation equipment began in 1963-64 but the major transition occured in 1965 when IBM (International Busines Machines) began to install its system/360 family of computers. These computers have been highly successful and many are still in use. The fourth generation of computers promises to offer still greater input, output storage and processing capabilities. The fourth generation of computers saw the introduction of the monolithic storage devices, improved and further miniaturized integrated logic circuits and the consturction of an actual laser memory for the NASA (National Aeronautics and Space Administration). Predictions have been made that with laser storage, we will soon be able to store over 50 billion characters in the sapce occupied by a postage stamp.

In the late 1970's computers began employing a revolutionary storage device, magnetic bubble memory. Bubble memory may be thought of as a negatively magneitized cylindrical magnetic field or bubble less than 3 micrometer in diameter moving in a positively magnetized film of magnetic garnet material. The presence of a bubble represents a binary 1 and the absence of a bubble represents a binary 0.

More important are the advancements that have occurred with respect to the software or programme available with these computers. Great strides have been and are being made in the areas of high level use of oriented programming languages, multi-programming and multi-processing techniques, data communications, distributed processing system and operating system.

MINI'S VS MICRO'S.

With the recent developments in the computers, two terms such as minicomputers and micro computers are frequently used. Most of the people are not very clear about these terms. Mini computers perform the basic arithmetic and logic functions and support some of the programming languages used with large computer systems but are physically smaller, less expensive, and are generally limited in their storage capability. The smaller or mini-computer systems are ideally suited for processing task not requiring access to large volumes of stored data. The micro computer was first introduced in the mid 1970's. The basis of the micro computer is the microprocessor, a silicon chip containing the necessary circuitry to perform arithmetic/logic operation and to control input/output operations. The micro processor is a very complex electronic circuit. It consists of thousands of transistors squeezed on a tiny chip of sililcon that is often little more than 3-4 millimeter square. The chip is then packed as a single integrated circut containing approximately 40 leads or contacts. By adding Input/Output devices and a memory to the micro processor, a micro-computer is formed.

Early micro computers offered a limited processing potential and even more limited choice of input/output devices. Today, however, these devices have grown in size and processing capabilities and support a wide range of input/output devices.

TYPES OF COMPUTERS

Modern computers are of two general types; Analog and Digital. A third type, the Hybrid computer, is a combination of these two. Analog computer operates by manipulating a continuously varying electrical signals. They are designed to duplicate in the same way as an Analog does i.e. the action of sometime varying phenomenon. Through the use of a wide variety of circuits and electronic netweork and input signle to an analog computer can be mainipulated in almost any desired fashion producing an output which has a functional relation to the original signal. Analog computers are not composed of logical circuits as are Digital computers. They are built of modules each of which has a specific function such as amplification integration, Summation and so on. Programming or preparation of the operational instructionsfor the computer consist of patching together modules in the desired sequence. Output from an analog computer is often in the form of a continuously varying Electrical Signal usually displayed on an oscilloscope or as a chart recording. Analog computers have been widely used by Hydrogeologists to study the flow of ground water or by Petroleum Engineers to predict reservior behaviour. However, their ability to solve general problems is limited.

Digital Computers, on the other hand, are those computers in which discrete representation of a data is mainly used. DAta is represented in the form of digits. The memory consists of tiny electromagnetic elements called the bits which are capable of accepting and storing electrical impulses by reversals in thin direction of magnetism laced through the bits in an intricate network of wires which carries electrical impulses. An electrical pulse travelling through a bit will cause magnetic polarization in a certain direction. A pulse of opposite sign will cause the bit to reverse polarization. Bit is acronym for binary digits because the two states of a core elements can represent one number in binary or base-two arithmetic.

PARTS OF COMPUTER

A computer consists of three parts: the central processing unit (CPU), the main memory, and the peripherals including control unit.

The CPU directs the activities of the computer by interpreting a set of instructions called the operations code, or opcodes for short. These instructions are loacted in the main memory. The memory is also used for the storage of data. The CPU communicates with the user through such peripherals as the console, the printer, the disk and so on. There are several electrical lines which are used to connect the CPU to memory and to the peripherals. These lines are collectively known as the buss or bus.

The CPU contains a set of registers which are internal locations used for data storage and manipulation. One of these is a special register called the accumulator. It receives the results of certain CPU Operations. The CPU will also have a status register to indicate the nature of a previous operation, e.g. whether the result is zero or negative or positive. It will also indicate whether a carry or a borrow occured during the operations.

Additional registers are used for auxiliary storage. They may contain general information or a number that is about to be added to the accumulator. Alternately a register may contain a number that refers to an address in the main memory. The value is called a memory pointer in this case. A special portion of memory may be set aside for storing data. This area is called a stack. A special register called the stack pointer refers to this region. Another register, the programme counter tells the CPU where to find the next instruction in memory.

The processing in the digital computers are carried out by means of pre-established sequence of instructions executed automatically by the computer. Digital computers are based on logical circuit. Electrical pulses can move through circuitary at a speed of light i.e. 186,000 MPS. The shortest the route, the pulse must travel, the quicker the processing and the bigger the problem that can be solved. Logic chips containing as many as 704 complete circuits and memory chips providing for storage of up to 64,000 bits of data have been developed. As more logic or memory circuits are placed on a single chip, the cost per circuit decreases. This makes it economically feasible to use more circuits therby increasing computing power in a much smaller piece of equipment at such a lower price.

Computer can be used for quite a few reasons, including, i) time factor i.e. to save time and efforts, ii) accuracy i.e. the use of information in ways that could be virtually impossible without the aid of computers.

COMPUTER APPLICATIONS

Two types of computing, business and scientific may be distinguished. Although the computing machines may be the same for both, the philosophy behind the two types is different. In business computing, relatively simple arithmetic and algebraic operations are applied to usually large volumes of data. Typically the data are processed periodically, perhaps daily, monthly, quarterly, or yearly to perform such functions as informing management, preparing bills for customers, keeping accounts and making out pay checks. Once set up, procedures are followed for as long as possible. The people involved wish to have their monthly bill on the same form and to compare them year after year on the same basis.

In scientific computing, on the other hand, complex mathematical operations are usually performed on data. They may or may not be voluminous. Usually a particular circulation is made only one or a few times. Even when a procedure is done repeatedly, as for guiding satellites, it is often modified after each use in order to encompass the previous result.

Electronic computer works on either real or simulated data.

By simulation, the fictitious data can be obtained and manipulated to investigate natural process. The procedure is the same as applied in clay-Cake and other physical – model experiments and the result suggests possible natural processes rather than uniquely specifying a single process. Simulation may also provide insight and suggest new field measurement of new field area that may yield more information through a designed experiment.

COMPUTER PROGRAMMING

There are several types of programming languages and translators available with the computers regardless of the type. The languages are broadly classified into problem oriented or high level languages such as COBOL, RPG, PLI for business applications, and Fortran and Basic for scientific applications, where machine oriented or low level language includes Assembler or Basic Assembly Language. For complex scientific formulas the Fortran (Formula translation) is ideally suited. The basic (Beginer's all purpose symbolic instruction code) language has an advantage for its utility both in business and scientific applications. Most of the micro computers are having a compiler known as C-Basic or compiler basic. A Geologist concerned with digital computing is well advised to invest his time to learn to write simple programmes and to communicate more effectively with the programmer. Complicated programming may be left to a professional programmer.

DATA ACQUISTION AND STORAGE

The acquistion, storage and retrieval of data consist of the collection, keeping it either permanently or temporarily and using the data in time. The close attention of the geologist interested in the analysis of the data is required.

Data may be recorded in either the field or laboratory. Most field recording is done on paper. The data recorded on paper must be processed into a machine in a readable form. Their collection should be arranged in a manner suitable for transfer to machine readable format.

The second method of field recording is mark sensing or optical scanning in which data are read optically. The third method of collection of field data is by the device named porta punch, in which holes are made in pre-perforated cards with a special punch.

Data collected by Seismic and other geophysical surveys including those in field lab mounted on truck may be digitized directly on cards or on magnetic tape for machine input. Rock analysis whether made chemically by X-ray flourecence or by any other mothod and crystallographic data can be digitized. A coordinate reader which resembles a drafting machine or a pantograph is also useful. If the machine readable records are not made initially, they must be produced from the original data. The other form of data recording is through magnetic tape. It has the advantage that mistakes can be corrected during verification but it is rather expensive and is less flexible than Hollerith Punched Cards.

DATA STORAGE

In organizing data storage, the main factors are the amount of data involved and question of how often and how fast the data must be recovered from storage, the kind of qeuipment available, and the use to be made of data after recovery.

Data are frequently stored on Hollerith Cards. The upper limit for one data file is 20,000 cards. The magnetic tape can be used if the size of Data file is large enough. However, magnetic tapes are more difficult to manipulate than cards because the data are arranged lineraly. Another drawback is that the tapes get erased accidently.

Two additional methods of storage are the disc file and the data cell. Both have the advantage that large amount of data can be stored and quickly retrieved. As disc files are expensive, they have been used primarily to maintain large files used frequently. However, if a disc file is available in a Computer System, voluminous scientific data, such as sedimentary petrographical data from a large basin or basalt analysis of the world, might well be stored on a disc and put into the disc file periodically for updating.

COMPUTING STRATEGY

No doubt, computer is our nation's most humble servant. We should not forget that computer can manipulate the data for which it is programmed. Unless the investigator has a clear purpose or purposes in mind, nothing good will result from computing.

The first principle is to establish tentative objectives.

(i) Perhaps species in two fossils population are to be compared.

(ii) Ore reserves are to be calculated faster and more accurately.

(iii) Differenentiation in a batholith is to be studied by examining rock types.

Preliminary computing should be done after same of the data have been collected or simulated. The preliminary computing serves as guide-perhaps to obtain additional data but certainly for testing the procedure to be used for the final data analysis. In geology, one or a few outcrops or formations may be sampled before the study is extended to the entire area of interest.

EARTH SCIENTIST AND COMPUTERS

The application fo Computer techniques to solve problems in geology has become vital. Many of these applications were thought of just erations a few years ago. Besides, the accuracy and high, there are other considerations. They include the availability of programmes, the reducibility of the data to numeric form and above all, the storage and retrieval facilities. If it is necessary to develop a programme it can be very lengthy, laborious and expensive. If the huge volume of complicated data is not involved, it would be desirable to obtain result manually. Fortunately, however, programmes are available from many sources and many may be adopted for a particular use (Merriam 1965). Now-a-days with the availability of low cost micro computers, there are many software companies present in the market, providing with pre written software package for commercial and scientific application users.

The first earth scientists to use computers were geophyscists and geotechnical engineers interested in accurate statistics. They had been using slide rules, mechnical methods and techniques in sedimentology and mineralogy. The paleontologists work with the probability of fossils instrata and the hydrologists with engineering aspects. Large quantities of data were handled and techniques were needed in manipulating them. It is very well understood that computers have only been commercially available for about 18 years. Their utilization by geologists is very recent. Geology entered the computer age with a publication in a geology journal of a IBM 650 Programme by Krumbion and Sloss (1958). In 1963, US Geological Survey published its first computer contribution series. The first book in a series on "Computer Applications in the Earth Science" was published by Plenum Publi Corp in the same year.

The wide variety of application of computer in geology covers the very important aspect of plotting the mas directly through computers. This is accomplished through careful selection of a wide range of plotters available as output devices in the market. One can select black and white or any other colour plotter, depending upon the requirement. As stated before, with the availability of pre written software packages in the market, one can use computer as a vital tool. A common package name "MAPLE" (is Mapping from Aerial Photographs and land area Evaluation) has greatly enhanced the production of these maps. MAPLE, which is mainly written in Fortran (formula translation) a computer language mainly used for manipulating scientific data. This package can be implemented on any suitable micro computer. This system, however, is available only from G.F. Marshall computers map data in digital form directly from the plotting instrument, transforms the data into national Grid Coordinator and stores it on minifloppy diskette on a Z80 based micro computer running under CP/M Operating System. This data may be used without any further ediling to draw a map on a flat hel plotter or to be merged with data from other models or from other sources such as digitising tables scanned to identify potential ambiguities, edited on the DVU (Visual Display Unit) Screen. It is used to draw a filed surveryor's draft may and to identify polygons auto-matically and to calculate their areas and finally draw a finished map with certain features fleshed out as smoothed double lines.

The "Mapple" system was successfully used by Forestory commission of Great Britian. In order to manage the woodlands effectively the commission required accurate maps showing the type of trees growing, the year of planting and the areas of each compartment of woodland. This mapping has until recently been used in traditional serial photography and photogrametric techniques producing an air plot which is then overlaid into an ordance Survey sheet base. Areas have been calculated by using planimeter.

The digitised data once entered into the system is held for a block of land. A block may equate to a map sheet or to an administrative area as required. Further the system not only caputers data but also transfers the data in the shape of pencil drawings survey and final maps. There are other Software packages such as SAS for statistical methods and Graphics available as an aid to Earth Scientists. The package available can be equally useful for plotting the frequency distribution, drawing a scatter diagram, probability plots on normal or lognormal probability graph, to calculate standard summary statistics (mean, Std devisation), Co-efficient of Variations, summarization in one-two or three dimensional cells.

It is interesting to note that for 150 years geologists have been collecting data and the geology is known by its nature, a historical and observational science. Early applications were mainly analytical. Next, was a stage of collecting data in machinable form for use in predicative techniques utilizing methods developed and well tested in other disciplines Simulation followed and results were evaluated in 1970'. Simulation may also provide insight and suggest new field measurements or new field areas that any yield more information through designed experiments. The work done by Harbargh and Merriam (1968) has attained a considerable repute in this connection.

COMPUTER IN GEOSTATISTICS

The application of computer in the discipline of statistical geology in Fortran and Basic language is available. A geologist working with statistical analysis having knowledge of Fortran or Basic can develop his own programme to solve his problem on his micro computer. The computer programmes written in Fortran language to solve the problems in parametric or now parametric statistics is available in "Manual of Fortran Computer programme for statistics". A Geologist working on Computer and in the field of geostatistics should understand that no one manual is available so far that can solve the particular problem. It is, however, in their best interest to spend a few weeks to learn the programming technique in Basic or Fortran language. The knowledge of programming language will facilitate them to develop the skills which are essential for "real world" use of statistical tool. In addition, the programme package available can easily be adapted to what-ever types of computer equipments a geologist encounters during his professional career.

Let us consider the following example how a geochemist can benefit from a computer by making use of the basic language.

In a geochemical analysis, it is a common practice to run a series of determinations or replicates on a single sample. If five or more values for Chromium in part per million are obtained by a Spectrographic analysis of a Sample of Shale to calculate the mean and standard deviation of replicates of Cr-Content a programme in Basic language is as follow :

```
10  REM AFZAAL.
20  REM AVG AND STD DEV OF REPLICATE
    IN CR (PPM).
30  REM N IS NO OF REPLICATE.
40  READ N
50  REM AVERAGE IS CALCULATED BELOW.
60  LET S = O
70  FOR I = 1 TO N
80  REM X IS CR (PPM).
90  READ X
100 LET S = S + X
110 NEXT I
120 LET A = S/N
125 REM STANDARD DEVIATION CALCULA-
    TED BELOW.
130 RESTORE
140 READ N
150 LET S = O
155 FOR I = 1 TO N
160 READ X
165 LET S = S + (X – A) ** 2.
```

```
170  NEXT I
175  LET S1 = SQR (S/N – 1)
180  PRINT "THE AVERAGE IS" ; A
190  PRINT "THE STANDARD DEVIATION IS",
     S1
900  DATA 1,205
910  DATA 2,255
920  DATA 3,195
930  DATA 4,220
940  DATA 5,235
999  END

READY  RUN OUTPUT WILL BE. THE AVERAGE IS
       222 THE STANDARD DEVIATION IS 23.88.
```

USE OF COMPUTER IN OIL INDUSTRY

The use of Computer has entered petroleum Exploration over a wide front. Both in geophysical and geologic applications, it has become a rapidly growing field. There is a vast amount of detailed data, both past and current, in any actively expored region, and one of the principal use is in the fast retrieval of these data. A specific kind of data can often be plotted directly on maps saving the geologist much time in assembling and recording the information. Anomalies that do not show up on ordinary contouring may show up in these maps and give the location of areas favourable for exploration.

One of the Unique application of the use of Computer in oil industry is to calculate Surge pressure (by W.R. Mattews). Surge Pressure is a major concern in well control. Running dirll pipe into a fluid filled hole can increase well bore pressure. These excessive surge pressures are frequently responsible for initiating lost circulation or formation damage. In developing the programme for its calculation several parameters are used.

Fluid movement can be either laminar or turbulent. Pressure losses caused by both laminar and turbulent flows are calculated & the larger of the two is used in determining equivalent circulating densities.

The equivalent circulating density is larger at the bit when the bit is above the casing seat and larger at the casing seat, when the bit is below the casing seat.

The programme requires a minimul amount of in put data, mud density plastic viscosity and yield point at the surface length and OD of the drill collars, drill pipe OD, casing Seat depth, bit depth, holdsize and velocity of the drill string at its run in the hole. For the programme to function properly the input data must be entered in a present sequence.

As an example, suppose at the Surface the mud density is 15 1b/gal plastic viscosity is 26 CP, and yield point is 8 Ib/100 Sq. Ft. Assume the drill Collars total equal to 300 Ft having OD of 7 in. Casing Seat depth is 9,000 ft. and bit size is 9/7/8 inch. What is the equivalent circulating density (ECD) at the casing seat and bit when the bit is at 8,000, 9,000 ft.

After in putting the necessary data with the bit at 8,000 ft; the floowing output data would appear :-

160 VDS (downward velocity, ft/MIN).
15.0276l216 (at the bit).
8000. Bit.
15.0245492 ECD (at the casing seat).
9000. Depth.
By changing bit depth to 9,000 ft a new set of output data will appear.
160. VDS.
15.02454592 ECD
9000 Bit.
15.02455492 ECD
9000. Depth.

Another example where computer can be useful is the rate of penetration analysis to analyze Bit record to increase penetration rates. (Hawkes, 1985). The ROP analysis is designed to provide insight into blance between Mechnical Energy (WR) and its bit hydraulic horsepower (BH HP) used to drill the well. The goal to maximize ROP without driving the equipment harder than necessary will result in reduced efficiency.

Furuther, the Computers and the use of statistical methods can be as beneficial as information retriveval system for already documented information and current field data.

- Analysis of individual project forms more of an overall corporate point of view.
- Increased Corporate Planning and Control, Particularly in optimum location, capacities, & number of facilities, resource evaluation market forecast, trend analysis, resource acquisition and capital allocation.
- Production Planning and Scheduling.
- Allocation of equipments, men and material.
- Process simulation and modeling.
- Process optimization by linear programming and other operation research techniques.
- In exploration including development, analysis of

prospect data geophysical, geochemical and drilling ore reserve calculation.

Past developments will have bearing on future events. Developments are too rapid and users are highly dependent on development in the computer industry and other disciplines for advancement of methods and ideas. Experts are working to change the computer from fantastically fast calculating machines to a device that mimcs, human thought process. Giving machines the capability to reason, to make judgement and even to as diagnosing lung diseases, locating mineral deposits and deciding where to drill for oil. Cognitive system Inc, in New Have, Connecticut, has already installed a test System at one Oil Company enabling its field Geologists to use natural language to obtain information from the Computer.

With the advent of 'Information revolution' more and more sophisticated hardware and Softwere concepts are replacing the old ones. However, Geologists must keep in mind their objectives, the problem defination and a proper system including problem solving techniques to get the maximum productivity and utility of Computers as a result oriented tool.

ACKNOWLEDGEMENT

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THE CONCEPT OF UNCONFORMITY IN THE GEOLOGICAL RECORD

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ABSTRACT: The stratigraphic concept of the resisdual deposit – the laterite is believed to form basis for recognition of the Paleocene succession of the Kohat-Potwar-Hazara province of northern Pakistan and thus enables to decipher the presence or absence of the Hangu Formation, the oldest formation of the Paleocene.

INTRODUCTION

An unconformity is a geological event which symbolizes a gap in the geological record of Earth's history. It is an event of interruption in the continuity of recording the geological history of the Earth. This event is well documented among the sedimentary r ›cks in a variety of ways.

Conventionally, an unconformity is defined as a surface of erosion or non non-deposition. In the event of erosion, it implies that what was already deposited and preserved was partly or wholly removed, thus creating a discontinuity in the geological record. In case of non-deposition the process of deposition is checked and creates a break in the geological record.

Recognition of unconformity (removal of geological record by erosion or a halt in the geological record by virtue of non-deposition) and its stratigraphic implication is the subject of discussion in this review.

DISCUSSION

When an unconformity is interpreted as a surface of erosion, it means that the eroded sediments from the pre-existing topography are laid down in areas of deposition. This depositional process produces fragments of rocks of varying size, say, from small pebbles to big boulders the fragments may be angular or rounded, depending on the distance of transport from the source and, moreover, the deposit may be homogeneous or heterogeneous. These clastic deposits overlying the eroded surface of the underlying rocks are termed the "Basal Conglomerate".

The term "Basal Conglomerate" refers to the basal position of these sediments to the overlying new cycle of deposition and demonstrates an interruption or end of the previous sedimentary cycle of deposition. Actually, the "Basal Conglomerate" marks the beginning of a new era of deposition.

In northern Pakistan, The Tobra Formation in the Salt Range and the Tanakki Boulder Bed in Hazara are examples of "Basal Conglomerate" because the Tobra Formation occupies basal position to the Nilawan Group, while the Tanakki Boulder Bed has a basal position to the Abbottabad Formation.

When an unconformity is recognised as a surface of non-deposition, it is marked by what is termed as residual deposits. The residual deposits are defined as those left in place as a result of the intensive chemical weathering. The basic philosophy about the genesis of residual deposits is that an area of low relief is exposed to prolonged intensive chemical weathering for the formation of residual deposits and that the erosional factor is almost negligible. Well known examples of residual deposits are laterite, china clay and bauxite (see figure 2). These residual deposits have a similar stratigraphic position as is the case of the "Basal Conglomerate" implying that these occupy basal position to the overlying new sedimentary cycle of deposition and merit stratigraphic terminology. In northern Pakistan i.e. Hazara, Kala Chitta and Salt Range, the Cretaceous – Tertiary boundary is marked by the residual deposit commonly known as laterite forming the base of the Paleocene succession (see Correction Table, figure 3)

Following the fundamental principles of stratigraphy, it can be argued that the stratigraphic applicaton of the residual deposits shall enable us to identify the lithostratigraphic units of the Paleocene succession of the Kohat-Potwar-Hazara province in norhtern Pakistan. It shall provide a logical platform to advocate for or against the presence or absence of the oldest formation of the Paleocene succession in the entire area. To be more exact, it will be with reference to the Hangu Formation whose type locality is situated in the Samana Range near the township of Hangu in the Kohat District (see Correction Map, figure 1).

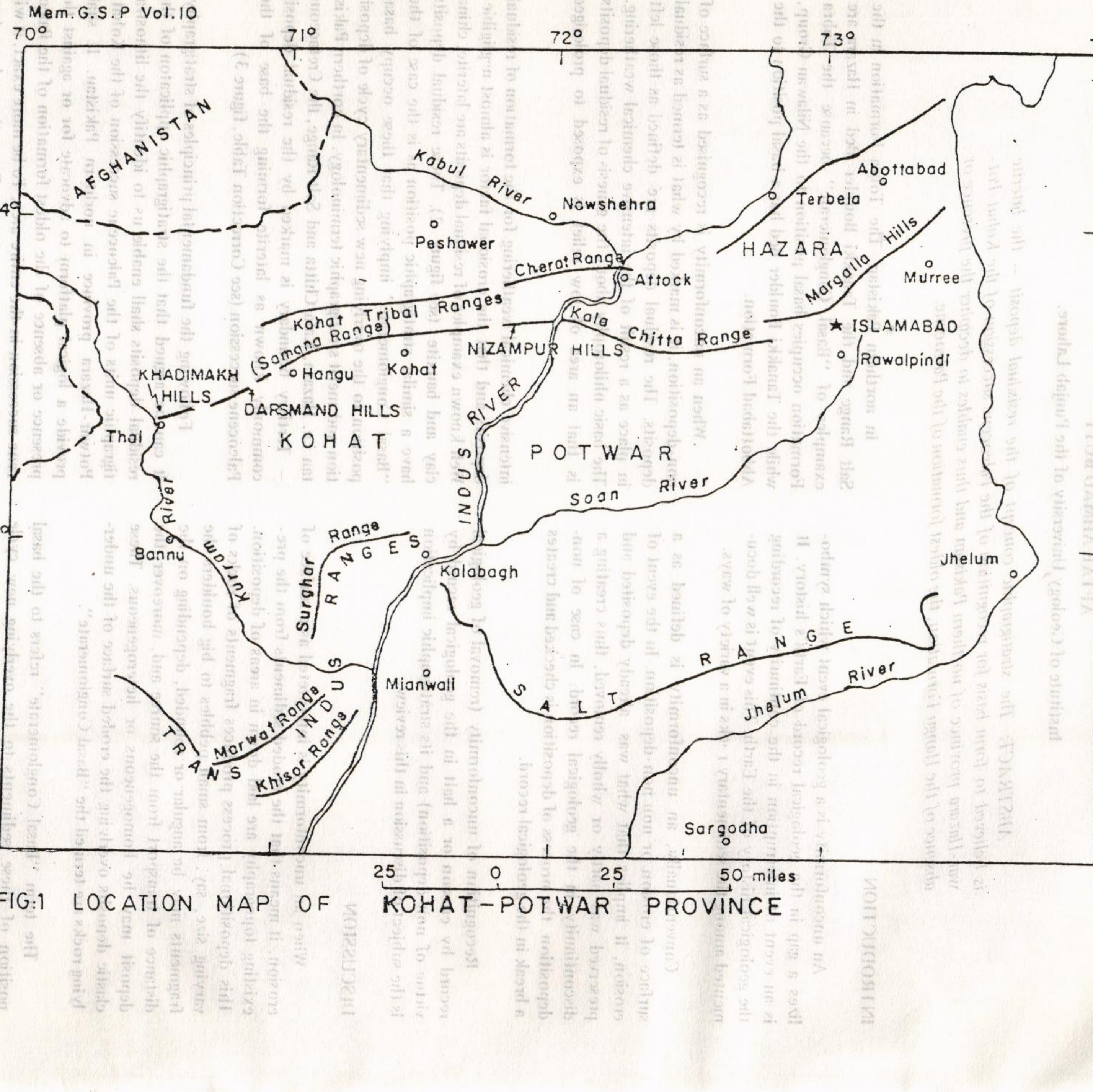

FIG.1 LOCATION MAP OF KOHAT-POTWAR PROVINCE

STRATIGRAPHIC SETTING OF THE PALEOCENE

Three formations constitute the Palecone succession of the Kohat-Potwar-Hazara province. These are the Hangu Formation, the Lockhart Limestone and the Patala Formation (Report stratigraphic Committee of Pakistan, 1974).

The Salt Range offers a classical locality for exposing a distinctly threefold division of the Paleocone formerly known as the Dhak Pass Beds, the Khairabad Limestone and the Patala Shale (Davies & Pinfold, 1937). These formations have distinct lithological characters and sufficient paleontological control for age evaluation. One of the best and easily accessible localities to examine these stratigraphic units in that of the Nammal Gorge near Musa Khel in the Mianwali District. Here, the Dhak Pass Beds are marked at their base, by a distinct laterite deposit. In other words, he laterite occupies the basal position to the Paleocene sequence – the beginning of new cycle of deposition.

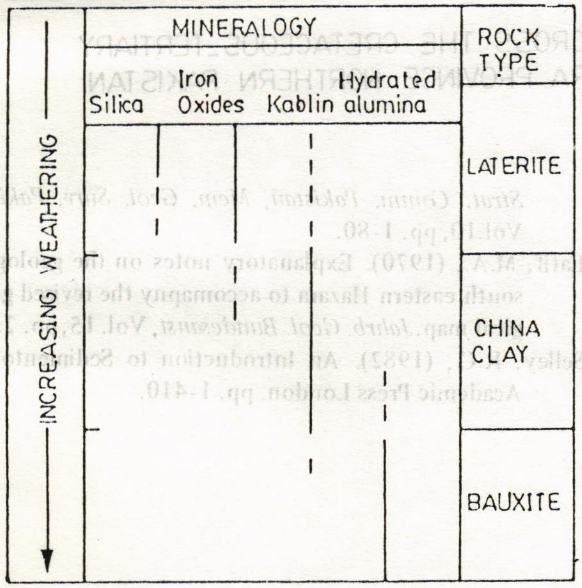

FIG.2 Diagram to show the composition of the residual deposits formed by intensive chemical weathering (from selley, 1982).

Comparison of the lithostratigraphic units of the Salt Range with those of the Kala Chitta Range and the Hazara region shows that the laterite deposit is present immediately at the base of the Lockhat Limestone in the latter localities, thereby indicating the absence of the Hangu Formation in these areas (see Correlation Table figure 3).

ROLE OF UNCONFORMITY IN HYDROCARBON EXPLORATION

When a sandstone is uplifted and submitted to weathering, the development of secondary porosity beneath a potential unconformity is caused by the phase termed epidiagenesis. This involves the creation of secondary porosity by the process of leaching of the cement and unstable detrital grains.

The geological setting of the Lumshiwal Sandstone seems favourable for the epidiagenetic changes to develop the reservoir characteristics for this formation beneath the potential Cretaceous Unconformity. Unfortunately this geological setting does not exist in the petroliferous Potwar and therefore ranking of this formation as a target for petroleum prospecting is precluded.

CONCLUSIONS

The stratigraphic concept of the residual deposits must form basis to decipher the presence or absence of a lithostratigraphic unit in the geological record. It is unequivocal and compares with the concept of "Basal conglomerate".

The application of this concept leads to conclude the absence of the Hangu Formation in the Hazara District and the Kalal Chitta Range.

The residual deposits merit stratigraphic terminology for having uniformity in the stratigraphic practice and to follow more logical approach towards stratigraphic synthesis.

The time gap along the K-T boundary in the Samana Range is of lesser magnitude in contrast to Hazara, Kala Chitta and Potwar region.

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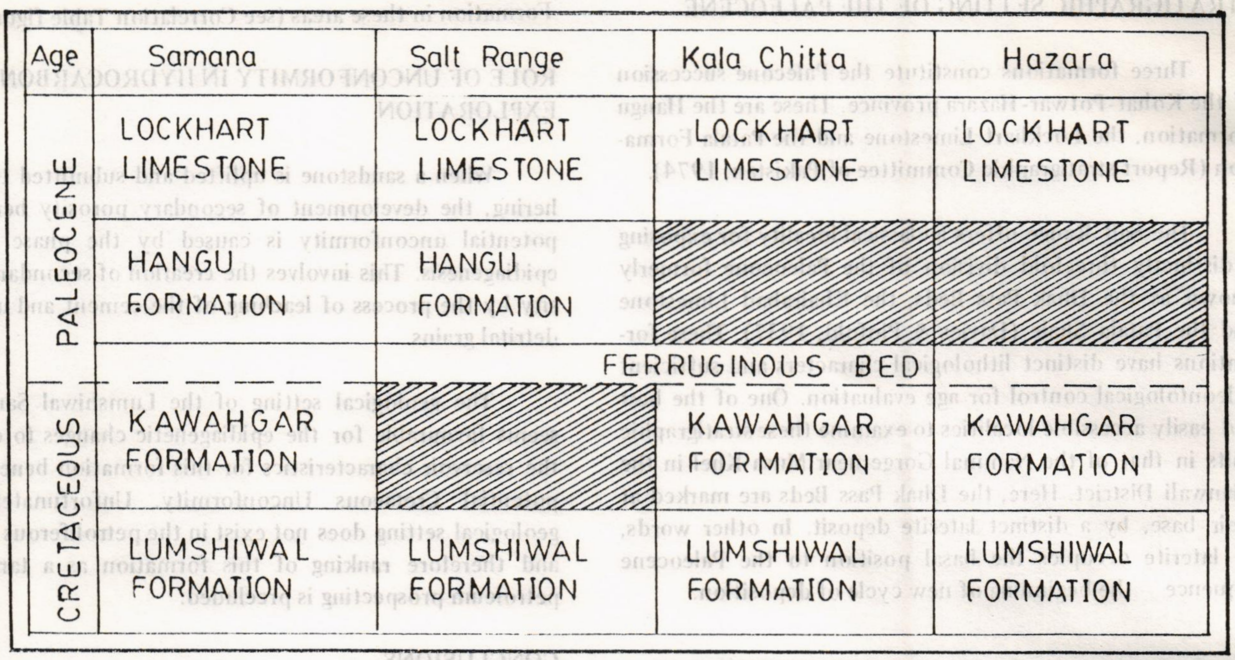

FIG:3 CORRELATION OF THE SUCCESSION ACROSS THE CRETACEOUS_TERTIARY BOUNDARY OF KOHAT_POTWAR_HAZARA PROVINCE NORTHERN PAKISTAN

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THE SCOPE OF GEOCHEMICAL PROSPECTION FOR MINERAL EXPLORATION IN AZAD JAMMU AND KASHMIR

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ABSTRACT: – The area constituting terriroty of Azad Jammu and Kashmir forms a part of the Great Himalayas, characterised by very high and inaccessible mountains. The accessible portions of these are covered by thick vegetational cover and colluvium, due to which, prospection for minerals by traditional techniques has not been very fruitful. This paper is an attempt to highlight the importance of geochemical prospection for the mineral exploration of the area and as such a brief description of various methods being employed in geochemical prospection have also been discussed. Possibility of future application of each method is also discussed.

INTRODUCTION

According to Siegel (1974), geochemistry is study of various physical chemical principals that influence and control fractionation, migration, and distribution of chemical elements in various lithological units of earth crust. These geochemical principals are being used extensively in exploration of natural resources and solving earth problems. Geochemical prospection is the practical application of chemical and biological principals to explore mineral deposits as well as hydrocarbons. The methods used in such prospections are direct and in most of the cases have given positive results. Where these are applied in conjunction with the geological and geophysical exploration techniques, successful results have been achieved.

Almost all mineral discoveries upto the IInd World War took place in areas where lithological units were exposed. All the areas which had vegetative or alluvial cover were mostly ignored for mineral prospection. However, at present geochemical prospection is considered to be the only direct approach to the problems of mineral exploration in such areas.

Advances in geological and chemical knowledge of the earth initiated the beginning of geochemical prospection. Georgius Agricola (1546) was the first geoscientist who gave references in his papers to the use of spring and natural waters, in prospecting for vein-type deposits. Early Chinese and European writers have given interesting references about the ability of certain plants to indicate mineral deposits.

The techniques of geochemical prospection were first used by Russian Geoscientists in period 1930 to 1932. Hydrogeochemical and pedogeochemical prspection methods were used by them extensively for exploration of Au, Cu, Pb, and Sn. After 1940, these methods were used in U.S.A., Canada and Scandenavian countries. Biogeochemical prospection techniques were first used by Sweden in 1936.

Rapid development in geochemical prospection started in 20th century as result of the following:

1. Identification of nature of primary and secondary dispersion halos associated with mineral deposits.

2. Development of accurate and rapid analytical methods, e.g. spectrographic and various specific sensitive colorometric reagents like dithizone.

3. Development of atomic absorption spectroscopy, which permits rapid and accurate analysis of rocks, soils, water and biological materials.

4. Introduction of statistical methods in geochemistry permitted a better evaluation of the background values and threshold values of the elements determined in the surveys.

GEOCHEMICAL PROSPECTION METHODS

The earth's crust consists of rocks, soils, natural waters and gases. Each of this material can be used for geochemical prospection. Accordingly, the methods fall under names, lithogeochemical (rocks), pedogeochemical (soil), hydrogeochemical (natural waters), biogeochemical (living organism) and atmogeochemical (gases). Each method is discussed briefly as follows:

Lithogeochemical Methods: Broadly speaking these methods are based on the analysis of rock or some particular mineral in rocks. The methods are used to outline geochemical province, where lithological units contain higher values of certain elements than normal values. The general thought behind this type of work is that these provinces may have concentration of some particular elements in belts or zones which can be called metallogenic province. After this identification, detailed local work is carried out to outline primary dispersion halos which are associated with various types of mineral deposits.

The effectiveness of this type of prospection depends upon many factors, especially the frequency of rock outcrops and type of deposits in the area. To be precise the rock-types have to the identified precisely and geochemical maps for each of the rock-type are prepared. Identification of geochemical province is an important phase in this prospection. This is how certain granitic intrusives containing higher concentration of tin and tungstn are identified. Similarly, certain basic intrusives which have high values of nickel and chromium may contain economic deposits of Ni and Cr. Likewise carbonate rocks with abnormally high concentration of lead and zinc may contain lead-zinc deposit. The relationship of geochemical provinces and associated deposits can also be extended to various types of rocks like copper bearing basalts, etc. To sum up, if value of some elements or elements in certain types of rocks are higher than normal in an area, there are bright chances that these rocks contain a deposit of that element.

Lithogeochemical surveys have not been given full attention which they deserve for prospection of mineral deposits, despite the fact that they have direct application to explore even concealed mineral deposit. Considerable research is required on these methods so that these can be placed on good footings for practical geochemical prospection.

Pedogeochemical Methods: Analysis of residual soil is the most extensively used geochemical technique for mineral exploration. This type of survey has been found very useful in areas where lithological units do not crop out and are under deep residual cover.

Generally, chemical composition of residual soil in an area reflects primary material which has undergone series of quantitative changes by pedogenetic processes. Therefore, soil cover of a parent mineralized rock shall exhibit some type of chemical pattern resulting from the weathering of that rock. Thus by these surveys, belts or zones having mineral potential are delineated and by detailed methods in conjunction with geological and geophysical work, mineral deposit or oil and gas in the area is pin pointed. In general B-horizon of the soil is used, but deep drilling and sampling near bed rock has been employed in many areas, where overburden is transported. In areas which are covered by glacial overburden, deep drilling methods for sampling have resulted in many mineral discoveries.

The sampling is done on regular grid pattern. Normally, 20 to 50 gram of sample is taken for analysis. Geochemical maps are prepared and data obtained is then interpretted to decipher the nature of anamoly.

Hydrogeochemical Prospection Method: These methods are successively being used for locating mineral deposits in various climatic conditions. These methods envisage analysis of natural waters, their precipitates and stream sediments. These are most effective and extensively used in analysis of stream sediments, because, of low cost. These methods rely on the fact that weathering products tend to be channelled into the surface drianage system, either in solutions or in the active stream sediments. Therefore, stream sediments can be regarded as nature's closest approximation to composite sample of the rock and soil upstream from the sampling point. Analysis of these sediments and their interpretation lead to discovery of mineral deposit. However, one has to take into account the effects of weathering and other secondary factors that may tend to modify the relationship between the composition of the stream sediment and the rocks and soil from which it has been derived.

Natural water analysis, especially stream waters, has not been used very successfully due to fluctuations with rainful and season. Nevertheless, these surveys in Canada have proved to be very effective. Due to advances in new analysis techniques, it is expected that this type of survey will be very successful for locating mineral deposits in future.

Analysis of underground water systems in over burden and rocks have not received much attention. However, efforts are being made to use this medium for exploration of concealed mineral deposit.

Many natural springs deposit their soluble contents at their orificies. These precipitates invariably reflects the presence of various elements in a geological terrain. Recent surveys indicated that presence of elements in precipitates at orifice indicate the presence of particular mineral deposit in the area. Few established indicator precipitates include manganese, limonite, carbonates and silica. The analysis and subsequent plotting of these on drianage may sometime clearly indicate belt or zones of mineralization.

Biogeochemical Prospection Methods: Principle involved in this type of prospection include systematic sampling and analysis of trees and shrubs etc. for trace elements. Goldschmidt in 1930 observed that humus of forest soil in some cases contains abnormally high values of various trace elements. He concluded that plants in that area responsible for the formation of humus must also contain high values of respective elements. This idea led to biogeochemical investigations for minerals.

Biogeochemical methods employ several bases for their effective utilization. In some cases trace element contents of trees and vegetation are used for outlining secondary dispersion halos in soil and overburden, while in other toxic effects or an overabundance of trace elements in the soil, which cause visible physiological effects in vegetation, is studied in detail. Another method uses the fact that certain plants grow only in zones where trace elements such as zinc, copper etc. are present in higher concentration.

Thus presence of such trees/vegetation in an area indicate a zone having extraordinary concentration of respective minerals. Another biogeochemical method is based on fact that bacteria and other organism grow profusely where hydrocarbons and other substances are concentrated in the rocks, soils or overburden.

Surveys based on indicator plants have successively been used in unglaciated area. Much work on indicator plants have been done by Cannon et al in U.S Geological Survey (Cannon, 1957). In glaciated regions exploration by this method have not been proved very successful.

Prospection based on the trace element contents of vegetation did not receive much attention. It was due to the fact that the pedogeochemical and stream sediment methods have proven so effective that these methods were not given preference. However, recently these methods have proved very successful in areas where very thick soil cover overlie concealed mineral deposits. In 1971, Chaffee and Hessin made an evaluation of various classes of geochemical samples that could be used in search of hidden copper, molybdenium, prophyry mineralization in the pediments of southern Arizona. This exploration resulted in discovering a cobalt-molybdenum deposit. They concluded that sampling of plants with deep penetrating roots could be very useful in the exploration of hidden area covered by thick alluvium.

Very little research work on microbiological techniques has been carried out on soil and rocks, so as to utilize mixroflora and fauna in search of mineral deposits. Numerous studies have indicated that various specific type of becteria flourish in sites where sulphides and sulphates are in abundance. This fact could be utilized in prospection for sulphide deposits.

Atomogeochemical Methods:– A few chemical elements being very volatile emit gases in atmosphere. These gases migrate to considerable distances from their focus of accumulation, thus they make board and extensive haloas. Mineral prospection by the analysis of gases is termed as Atomogeochemical prospection.

Principal elements which form dispersion holoas are:

Br, Cl, F,

Rn, SO_2, CO_2, H_2S,

Hg & I,

Atomogeochemical prospection have found considerable application in petroleum prospection as well as for mineral deposits. It has been observed that hydrocarbons are associated with a variety of mineral deposits including massive sulphide ores, lead-zinc ores in carbonate rocks and copper and nickle ores, analysis of these hydrocarbons in soils and rocks may aid in locating these deposits. Similarly SO_2, H_2S and other gases may be liberated during the oxidation of sulphides, therefore analysis of these gases may be utilized in locating such deposits.

Analysis of radon in soils and rocks has effectively been used for exploration of uranium deposits. Recently, this method was introduced in Canada. They found that streams and creeks with higher radon concentration generally outline prospective uranium areas or reconnaissance basis.

More volatile elements like Hg and As have found wide usage in soils, stream sediments and biogeochemical surveys as indicator elements for Au, Ag, and various sulphide deposits in may parts of the world. Iodine has been found as suitable indicator for certain Cu deposits, as it forms extensive haloas.

THE FUTURE OF GEOCHEMISTRY IN MINERAL EXPLORATION

Geochemistry is serving mankind not only in exploring natural resources but in agriculture and in public health. The application of geochemical principals in these fields have given extraordinary results due to which this subject has received special attention in recent years and research activities in this subject have increased many folds. Keeping in view the achievements so far made in mineral exploration by using geochemical principals and intensive research being carried out, it can be very safely predicted that this branch of earth science would be the most effective tool in future mineral exploration programmes.

Hydrogeochemical prospection will receive special attention and application of related methods will help in delineating the metalogenic provinces. Due to continuous research on these methods, it is hoped that new techniques will be developed and more positive results would be achieved.

Pedogeochemical prospection will remain most suitable technique for mineral exploration in areas, where rocks do not crop out on surface and are covered by thick alluvium. Biogeochemical prospection, especially, botanogeochemical methods will aid to this type of surveys. These methods will continue till area of mineral potential will be delineated.

Primary desperision haloas associated with known ore deposits will get special attention and more research will be carried out to establish its nature and mode of occurrence, etc. Dispersion haloas shall be mapped during geological mapping, alongwith alteration patterns. Regional geochemical mapping shall be carried out alongwith regional geological mapping. It will help to find indications of new ore deposits together with basic informations for use in deciphering the geological history of a region. To sum up geochemical prospection will be the most important tool for mineral exploration in future.

SCOPE OF MINERAL EXPLORATION IN AZAD JAMMU AND KASHMIR BY GEOCHEMICAL EXPLORATION TECHNIQUES

The area of the Sate of Azad Jammu and Kashmir constitutes a part of the Great Himalayas, and is famours for its inaccessibility, highly rugged mountainous terrain and a thick vegetational cover upto snow line. All these factors cause major hindrence in mineral exploration activities by using traditional exploration techniques. Lower reaches of the Neelum Valley, which is the most promising area for minerals in the State, are covered with thick vegetational and colluvial cover, due to which lithological units are not exposed. Due to these factors no major breakthrough by mineral exploring agencies has so far been made. Few nonmetalic minerals have been located in this part of the State, which are also confined to higher altitudes, where neither working season is enough nor infrastructures are available. Due to these factors these mineral deposits are also classified as uneconomical.

In order to achieve some positive results, geochemical methods have to be applied in conjunction with other geological methods. In the past few years, only a small part of the most promising areas of District Muzaffarabad and Poonch has been partially explored, by various mineral exploration agencies. As such major part of this area is still unexplored. Keeping in view previous geological work, this promising area should be divided into two major zones. (1) Virgin Areas and (2) Partially explored areas.

EXPLORATION IN VIRGIN AREAS

The area of the State which are still virgin, comprises of a part of District Muzaffarabad and Poonch, where igneous and metamorphic rocks are present. Since, this area is inaccessible and covered with vegetational cover therefore, it is imperative to first establish overall potential of the area and metallogenic zones may be delineated. Hydrogeochemical prospection would be most appropriate technique to start with. Sedimenth of all the major nalas of the areas have to be collected, starting from their point of confluence with major streams/rivers. Sampling has to be carried out at an appropriate interval, keeping in view geology of the area and length of the nalas. For more accuracy precision and check, duplicate sampling should also be undertaken. The analysis results of the sediment area of respective stream/nala. The compilation of the geochemical results of all nals will delineate metallogenic zones/belts.

After the delineation of metallogenic zones/areas, detailed geochemical exploration techniques may be used. Since, major part of promising area is covered with thick vegetation, therefore, pedogeochemical prospection technique would be most appropriate. Since soil cover in this area vary very much in thickness, therefore, before soil sampling, most appropriate soil horizon had to be identified. Soil sampling has to be carried out on grid pattern. Interpretation of analysis results will pin point ore in area.

Lower reaches of the most promising areas of the State are covered by various specific plant/species. Forest Department of the State has defined the areas having specific plant species. As such, biogeochemical prospection techniques would be of great help in mineral exploration of this area. From the data available with the Forest Department presence of various established indicator plants can be identified and by detailed exploration mineral deposits, if present, in the area could be pin pointed.

GEOCHEMICAL PRESPECTION OF PARTIALLY EXPLORED AREAS

Occurrences of various economic minerals have been established in various parts of the State. These include semiprecious and precious gemstones, sulphide minerals and other non-mettalic minerals. To establish their presence in same lithological unit in adjoining area, lithogeochemical prospection would be most appropriate technique. This technique is successfully being used, to find lead-zinc mineralization exposed in Manjhoter area, in adjoining areas.

Salkhala marble is exposed in upper reaches of Neelum Valley and contains sulphide mineralization at various places. This marble emits H_2S on hammering. A systematic lithogeochemical sampling and analysis of it on interpretation may help to identify/locate sulphide minerals rich zones in the area.

Disseminated malachite showing have been seen in the belt of about 20 miles in the Punjal Volcanics, exposed along the Main Boundery Fault at number of places from Reshian, Nauseri to Manjhoter. A systematic lithogeochemical sampling of the Panjal Volcanics and subsequent analysis for trace elements would delineate behavious and position of this zone in the area, which would help to locate it subsequently.

Two major granitic bodies are present in Jura and Keran areas of Neelum Valley. Analysis of muscovite in the rocks may help to locate tin deposits, if present in the area.

Besides these specific techniques, this area has to be explored with pedogeochemical and biogeochemical and other mineral exploration techniques.

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COMMENTS "ON SOME NEW EARLY JURASSIC MIOSPORES FROM DATTA FORMATION, WESTERN SALT RANGE PAKISTAN".

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It was interesting to see the above titled paper. Just by going through the abstract and looking at the plates of the newly erected species of miospores I got the impression that the authors are very found of erecting new species.

The reason for this may be lack of literature available to the authors, lack of comprehension of descriptive terminologies, and a critical eye to compare the grains with illustrations.

It was painful to read the descriptions of miospores. The test is full of mistakes which include typographic, descriptive, spelling and even references are wrongly cited.

Identification even at generic level is incorrect e.g. *Triquitrites, Matonisporites, Cingulatisporites,* etc. what to talk of species level.

Citation of reference is incorrect e.g. p.46, under *Triquitrites meharbanicus.* In reference it is quoted that Balme (1970) has described genus *Triquitrisporites* where as Balme 1970 has described a genus *Triquitrites,* p.332. The authors have consistently used the word *Triquitrisporites.*

Procedure for naming of new species does not follow the set rules of Botanical Nomenclature. Very seldomly names are erected after persons but the authors have named nine species after the author himself.

As a rule if a species is named after a person, that person should be a well known scientist in the field. Where as none of these persons is a palynologist.

Using the names of established formations (older/ younger) like[1] Nammal, Warcha and Tobra for naming Jurassic miospore is not desirable.

References metnioned in the text are not listed in biblography.

I am sorry to state that this paper instead of contributing to Pakistan palynology has created a confusion by publishing unnecessary and incorrect, wrongly identified miospore.

I shall urge the editorial board to get every paper thoroughly reviewed by specialists of the subject in the country or from outside before they are accepted for publication.

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DETAILED GRAVITY SURVEY OF GILGIT VALLEY, NORTHERN AREAS, PAKISTAN.

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ABSTRACT:– The gravity prospecting technique of Geophysics was applied to delineate the sub-surface geology of Gilgit Valley, Northern Pakistan. A network of gravity profiles were spread over an area of about 25 square kms. as it was a detailed gravity survey, therefore, the profile interval and station interval was kept 600 and 100 meters respectively. All the 18 profiles were decorated with 256 gravity station.

In order to get gravity values of all the station, the Master Worden Gravimeter Model-111 No. 955 with scale constant 0.0902/ scale division was used. For geodetic survey a Russian Transit Theodolite No. T.T, 5 and Pualin Micro-Altimeter M-2 was used.

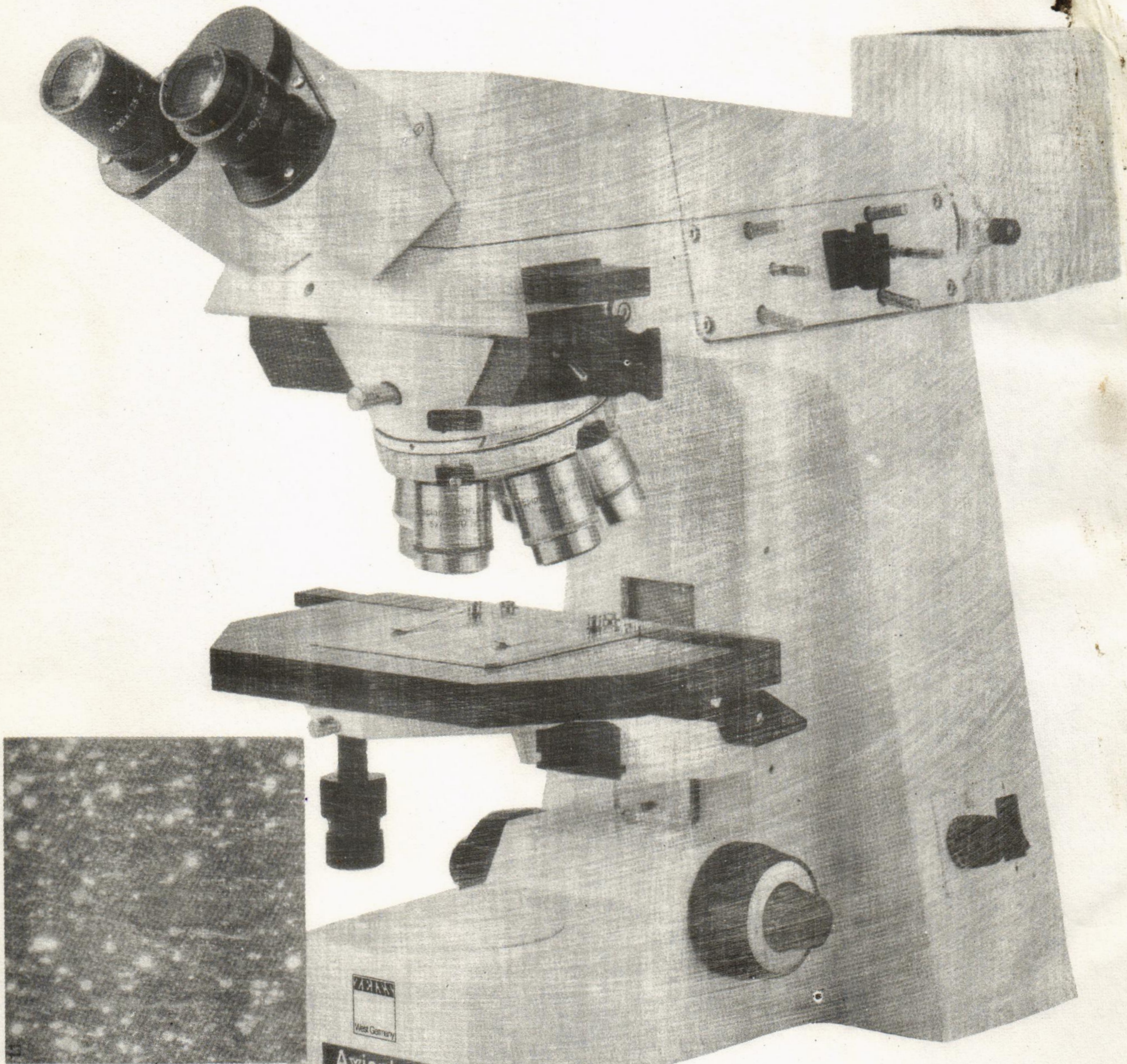
The main gate of Marcopolo Inn (Gilgit Town) was selected as the main-base station. No auxilary based station was established, because the area was small therefore all the profiles were linked to the main based station.

The scale of the maps was taken to be 1: 15840. The contour interval of the Bouguer anomaly map, the Residual anomaly map (after Griffins 1949), the regional anomaly map (after Griffins) and the second derivative anomaly map was 0.5 mgals and 500 x 10^{-15} C.G.S. units respectively.

Since the regional anomaly map showed heavy regional effects therefore the Bouguer anomaly map was not taken into account, hence all the interpretations were made by considering the residual anomaly map. An attempt was also made to give a detailed description of each anomaly very carefully to make the anomalies more sharp, the second derivative anomaly map after Elkins was also prepared.

The various graphical curves, developed by the intersections of six positive and two negative anomalies on resideal map indicated that there occurs a major granitic complex in which younger acidic intrusions could be the source of gravity low towards agency hospital and Karga while more basic dykes could be the source of gravity highs identified towards commissioner house, Airport and Jutial Area.

To find the relation of anomalous bodies with host rock and other geological informations, two general cross-sections along AB and A'B' were also drawn on the residual anomaly map. The anomalies have been found to be vertical rod (vertical cylinder) type with the estimated depth of all these anomalies as 10.0 kilometer. The thickness of the alluvium increases from west to East 10.0 feet per mile (down stream).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The authors are solely responsible for the facts and opinions stated in their papers and the correctness of the references.

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References should be arranged as follows:

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