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CRYSTALLINE GRAPHITE DEPOSITS OF AGRA-SILAIPATTI AREA MALAKAND AGENCY, NWFP, PAKISTAN

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ABSTRACT:– The crystalline graphite occurs in Agra-Silai Patti area at a distance of 32 to 40 Km by truckable road from Dargai railway station. The graphite is a part of the pelitic-psammitic rocks of the area. Important graphite bearing rocks occur in Silai-Patti, Haspur South, Haspur North, Agra and Rang Dheri localities. The thickness varies from about 5m to 52 and the deposits extend intermittently over a length of 8 Km.

The petrographic study showed that graphite had predominent grain size upto 0.25 mm. While flakes more than 0.5 to 1 mm were rare. The crystalline graphite contents in the rock are 19.32, 18.32, 21.70 and 17.53% on average in the localities mentioned above.

The dominant gangue minerals in the rock are quartz ($\bar{X}$ = 31.8 to 40.79), muscovite ($\bar{X}$=-23.01 to 35.83), goethite/limonite/haematite ($\bar{X}$=7.43 to 9.57), boehmite ($\bar{X}$=1.19 to 4.10) and minor andalusite, pyrite, feldspar, clay, magnetite, epidote, chlorite, tremolite, sillimanite etc. The Ore microscopy and X-ray studies confirm the presence of crystalline graphite.

Chemically the graphitic rocks contain graphitic carbon (X=14.99 to 17.82), amorphous carbon ($\bar{X}$= 1.41 to 1.80), SiO_2 ($\bar{X}$=50.78 to 54.15), Al_2O_3 ($\bar{X}$=12.48 to 14.13), Fe_2O_3 ($\bar{X}$=7.20 to 7.39), FeO ($\bar{X}$=0.60 to 0.87), MgO ($\bar{X}$=1.27 to 2.02), CaO ($\bar{X}$=0.29 to 1.13), Na_2O ($\bar{X}$= 0.63 to 0.81), K_2O ($\bar{X}$=2.43 to 3.08), H_2O ($\bar{X}$=0.99 to 1.22).

Textural relations suggest that graphite may be released as particles passing about 70 BBS mesh. This limits the recovery of flakes of appropriate size which would have otherwise produced flakes in appreciable quantities. However, optimum liberation of graphite was found to be between 200 to 250 BSS mesh for achieving better flotation.

Reserves of inferred category are 16.10 million tonnes which include 2.94 million tonnes of indicated category.

INTRODUCTION

The graphite bearing area lies about 40 km west of Dargai railway station in toposheet No. 38 N/10 of Survey of Pakistan in Malakand Agency. Dargai is connected with Peshawar via Nowshera by 105 Km of Metalled road.

The graphite bearing area of Malakand and the surrounding geological set up is most probably a part of the external flank of an anticlinorium. It is composed of metamorphics of possibly Precambrian age. The pelitic-psammitic, calcareous and quartzitic rocks are possibly of Cambrian age. The area is cut by a number of granitic and pegmatite intrustions (Wadia, 1953; Sokolov and Shah, 1966; and Chaudhry et al., 1976) and also by carbonatite rocks (Ashraf and Chaudhry 1977).

The graphite under study is found occuring in the uppermost zone of pelitic-psammitic rocks which are overlain by pelitic garnet grade rocks. These pelitic rocks are in turn overlain by calcareous rocks.(Fig. 1)

At most places and near graphite-schists the calcareous-quartzitic portion of this unit has changed over to para-amphibolite showing mild to strong stages of its development.

The quartzitic band of white colour about 16 m thick, occurring below the graphite-schists was used as a marker bed trending almost N-S, dipping E, from Inzergai to Haspur South, Block-C, but near Silai Patti village it changes its trend suddenly to NW-SE, dipping NW. This indicates a huge fold in this area. At the core of the fold the rocks are highly crushed and fractured and the graphite-schist at the nose of the fold in both Silai Patti and Block-C-II areas is much sheared.

GRAPHITE DEPOSITS

Graphite occurs in the garnet grade metamorphic schists of pelitic-psammitic nature. It occurs in the form of sheets, lenses and streaks. The area containing graphite forms the western part of the Malakand Metamorphic Complex. It has been traced for about (9000m) between Inzergai Kandao and Silai Patti. Both the graphite bed and the country metamorphic rocks trend almost NNE-SSW, and dip at 45° 60^{0} E and SE. Occasionally the graphite beds have steep to almost vertical dips (Fig-1). The bed is highly sheared, faulted and folded at many places; thickness varies considerably from 0.6 - 45 m.

The graphite deposits present in the Western Malakand Area are discussed locality-wise in the following paragraphs:-

Silai Patti: This area lies between the coordinates 688525 (Survey of Pakistan Sheet No. 38 N/10) and extends for 1460 m from Silai Patti westward to the River Swat. Silai Patti is 14Kmto the west of Kot. More than two beds run continuously in pelitic-psammitic schists for a length of about 180 m. There are five beds of graphite-schist 4.5 to 5.1 m thick in an area 304 m wide, while four beds of graphite-schists run parallel for 486 m. The trend is NW-SE and dips range from 40^{0}- 60^{0} SW.

The graphite-schist often contains thin intercalations of mica or quartz schists, and pegmatite which on thickening split the graphite-schist bed into several thinner beds. The quartzite and quartz-schists lie to the northeast of the area. To the southwest, the graphite in association with pelitic-psammitic schist has contact with calcareous schists, which form a very huge body.

The quality of graphite is quite good and the graphitic content appears to be approximately 20%.

Haspur South: This area lies between coordinates 715565 and 692526 (Survey of Pakistan Sheet No. 38 N/10) and is considered to be one of the most promising areas. The graphite-schist is about 3768 m long and varies in thickness from 9 to 45m.

Haspur South area has been divided into three blocks A, B & C on the basis of its large extent and variable structural features.

Block A from coordinates 715565 – 707553

Block B from coordinates 707553 – 704546

Block C from coordinates 704546 – 692526

Block 'C': This block extends upto Kot-Bajaur Road near Silai Patti and lies at the southern end of Block 'B'. Though it extends intermittently for a distance of 1670 m, the workable graphite-schist is present only in about 1200 m, the rest of the outcrop being covered under alluvium is very thin or absent.

At the northern extremity of this block (near village Jhandai) the graphite bed is covered by about 15 to 22 m thick alluvium for about 300 m. Wherever graphite-schist is exposed, it branches into four beds ranging in thickness from 1.2 to 7.6 m. These beds are again covered by alluvium and when they reappear after 30 m, three beds, varying in thickness from 1.2 to 24 m are seen to run parallel to each other. The main bed 25 m thick continues for a distance of 425 m thinning out towards SW while the other two pinch out. Another bed 9m thick was seen to the west of the main bed for a distance of 121.4 m but pinches out like others to form a 9 m thick bed near Silai Patti Kandao. After continuing for about 304 m southwards this bed also thins out and merges into the host schist. After a distance of 150 m two horizons of graphite-schist are noted, separated by 116 m wide barren rock. The upper horizon has a contact with a thick pegmatite body.

Upto the road at the southern end of Block 'C' for a distance of 185 m the graphite-schist is sheared, it pinches away and peters out and is overlain at places by alluvium.

The graphite-schist is associated with psammitic schist, which has a contact with calcareous schists to the east while the quartzites and quartz-schist lie to the west, trending NE-SW and dipping steeply towards SE.

The quality of graphite-schist is the same as in the other areas. The graphite content is estimated to range bet-

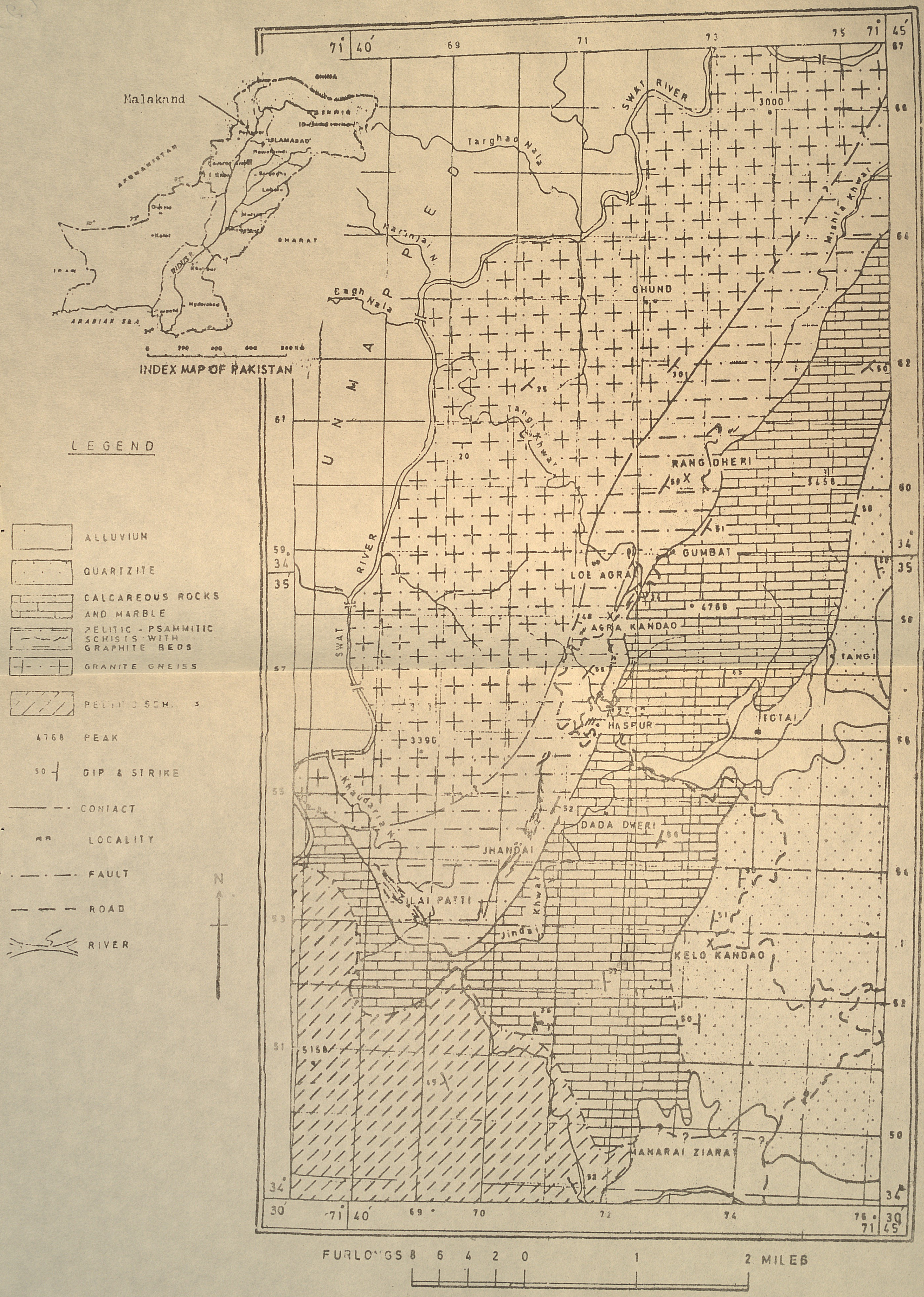

Fig: 1 GEOLOGICAL MAP OF SILAI PATTI - HASPUR AREA SHOWING GRAPHITE DEPOSITS.

ween 15–18%. Both the graphite flakes and mica impart schistosity to the rock. The oxidation of the iron oxides in the graphite-schist is more prominent at some places.

Block 'B': This block contains the thickest graphitic bed, ranging from 18 to 45 m. It extends for a length of about 760 m. It is structurally a very simple block, having steep dips (70^o to 90^o), though local variations in dip and strike are observed. A pegmatite dyke splits this bed into two, and at the contact muscovite upto 3 mm in size is found in graphite. The trend of the graphitic rocks is NE-SW. The intricate folding is intense (Fig. 2) at places within the bed of graphite schist changing the trend of the rocks locally. A few local faults are also present. The country rocks are quartz-schist and para-amphibolites. The former have contacts with graphite-schist, which are usually thin bedded and consist of quartz, mica, graphite, and limonite. The graphite is of good quality and gives shining lustre and soils the fingers. Near the southern limit of this block an intercalation of thick mica-schist again splits the graphite-schist into two beds.

At the southern end of Block 'B', the graphite beds are covered with thick alluvium. About 93 m from this point are two thick beds, in which one main bed is about 45 m thick. Further southwest, the thickness decreases to about 25 m. Thin beds also continue along the same direction of the thick bed. These thin beds at places decrease in thickness and also pinch out but reappear again near Silai Patti Kandao.

The graphite schist is of good quality and has a graphite content upto 20%.

Block 'A': This block extends for about a length of 1338m and is structurally the most disturbed (folded and faulted) block. The bed frequently pinches and branches out. The thickness of the bed is variable but does not exceed 18 m. An average thickness of 10.5 m has been estimated. The graphite is overlain by alluvium at three different places. At the northern end of the block the maximum length of the outcrop thus concealed is 365 m. The graphite exposed above the alluvium is highly sheared and has separated into 3 or 4 branches showing great variations in trend at many places.

The quality of graphite is good, being of phanerocrystalline type. As estimated in the field, the graphite-schist contains about 15-20% graphite, rest of the minerals are muscovite, quartz and limonite. Quite sizeable acid pegmatites are intruded in graphite-schist of this block.

Haspur North : This deposit lies north of the road (717566) and extends upto Agra Kandao for about a length of 1500 m. The graphite-schist occurs in this area with a variable thickness of about 1.5 to 12 m in the garnet grade pelitic-psammitic-schists. The graphite-schist is generally brownish red. Due to incompetent nature of graphite, intricate folding (Fig. 3) has occured at many places. General strike is almost NNE-SSW, and dip is towards SE, but there are local variations. Amount of dip also changes from almost 15° to vertical. It pinches and branches at some places. Being of phanerocrystalline nature the quality of graphite persists throughout the bed. The thin lenticular, lensoid and tabular intercalations in the graphite schists are of calcareous, argillaceous and quartzitic material. The intercalations of quartz-schists become quite thick (upto 0.9 m)

Agra North : This area lies to the north of Agra Kandao, starting from the coordinates 716582 and extending for about 900 m upto the coordinates 723690.

Two to four graphite beds of widely variable thickness, ranging from 0.3 to 15 m at some places, run almost parallel to each other. This variation is also due to the intense shearing which the incompetent beds have undergone.

Two faults running E-W and N-S, have been observed in the area. The E-W fault with a displacement of 7.5 m occurs about 65 m north of Agra Kandao and the N-s fault with a displacement of about 12 m runs about 100 m north of this fault. The main bed over 240 m long is from 6 to 7.5 m thick except at the northern end, where its thickness increases to 15 m, but soon the bed pinches out and is covered by the alluvium.

The graphite-schist lies within the pelitic-psammitic schists with sharp but sheared contact. The bed is silver grey to black in colour and is soft to medium hard. The intercalations of schists (graphitic as well as quartzitic) have been noted forming 0.3 to 0.6 m thick bands within the graphite-schist. The trend of the graphite-schist and the country rock is N10^oE to 35^oE and the dip varies from 40^o SE to 75^o SE.

Rang Dheri : This area lies about north of Agra North area and starts from coordinates 730600 (Survey of Pakistan Sheet 38 N/10) extending for 840 m upto coordinate 737606.

In this area the graphite bed occurs with an average thickness of about 9 to 10.5 m. It is folded and faulted, and at the low angle folds its outcrop is 60 m wide at two places. One of these outcrops is traversed by the Agra-Kolangi Road, which exposes a clear section. The other is to the west of this road, where besides folding, the bed is faulted from the main outcrop, with this the width of the

Fig. 2 Intricate folding in graphite Haspur South block 'B'.

Fig.3 Microfolding shown by clayey bands in Haspur North. graphite.

outcrop is increased very much. At a distance of about 102 m from the northern end and Range Dheri deposit, the graphite bed is thrown to the south by reverse fault, with a throw of about 60 m where graphite has sheared and pinched away. Beyond that the graphite-schist is faulted and the alluvium and the excavated material from the road has hidden most of the geology.

The shearing in graphite-schist beyond its limits, both towards north and south, is much pronounced. There the thickness is only 0.9 m.

The graphite-schist is thinly bedded, soft to medium hard and silver grey to black in colour and occurs between pelitic-psammitic schists. The yellow and brown iron oxide form coating along bedding and joint planes. The trend of the graphite bed and the country rocks is NE-SW and the dip is usually above 50^{0} SE and even horizontal.

The quality of graphite is similar as found in other areas, except along the shear zones, where percentage of the soft graphite material appears to be more. The intercalations of quartz-schist and carbonate veins are present.

Inzergai : The area extends from Inzergai Kandao to Hardial Kandao. North of Rang Dheri thin beds of graphite-schist, branching into 5-7 cm thick beds continue to crop out along the road. At Inzergai these beds are in contact with marble. The graphite is amorphous and gives black lustre. This amorphous graphite bed extends upto Hardial Kandao. Pinching and bulging of the beds is the main characteristic feature in this area. The beds are mostly sheared with graphitic carbon giving dull shining lustre. The material is generally hard, compact and massive, while at some places, particularly near the sheared zones, some soft beds are also present.

At Hardial Kandao the graphite-schist is 6 to 12 m thick, but it has dull black colour. Between Kolangi and Hardial Kandao, it is reddish black in colour due to iron staining, and occurs in contact with the pelitic schists. Impurities of mica, iron oxides, quartz and calcite veins can be seen. Local folds and faults are present, the general trend being NE-SW with variable dips to SE.

PETROGRAPHY

The Malakand graphitic schists are a part of pelitic-psammitic rocks of possibly Cambrian age. Since the graphitic schists mostly do not contain chlorite, so they may continue to retain their mineralogy through biotite and garnet grades of regional metamorphism. However, they are interbedded with rocks which contain both biotite and garnet. So they may be regarded as falling in the garnet grade. Andalusite appears in some samples. This mineral occurs in the thermal aureoles of the big pegamatite and granitic dykes which cut the schists.

The graphitic schists at the surface have undergone alteration due to weathering. Pyrite has mostly been altered to goethite/limonite. Some haematite also occurs. The acidic solutions produced during alteration have attacked the rock and produced clay as well as aluminium hydroxides from aluminium bearing silicates. Due to this alteration the zone of weathering has been extensively but irregularly traversed by goethite/limonite, clay and boehmite introducing an element of heterogeneity.

A total of sixty nine graphite bearing rocks were studied from the Malakand area. Twenty from Haspur North, twenty three from Haspur South, nine from Silai Patti, six from Agra North, six from Rang Dheri and five from Inzergai. The original rocks are fairly heterogeneous. They contain veins and streaks of boehmite, goethite/limonite, haematite, clay and quartz. Moreover, graphite itself is not necessarily uniformly distributed. However, efforts were made to cut the sections along areas which were more or less representative. The sections were cut mostly oblique to the schistosity. In the following account petrography of the area is given:

Grain size determination was carried out of the graphite and the gangue minerals (quartz, muscoviete/biotite, goethit limonite/haematit). It was found that bout 90 percent of graphite has grain size from 0.03 to 0.10 mm while 10% grains are coarser from 0.10 to 0.20 mm and occasionally at places the grains are upto 0.50 mm in size. Amongst the gangue muscovite/biotite have about 45 to 80% grains in the range of 0.03 to 0.20 mm and rest have size from 0.2 to 1 mm. Quartz is mostly 0.03 to 0.2 mm and occasional grains are upto 0.67 mm. Goethite/limonite/haematite occur mostly as aggregates of 0.02 to 0.2 mm while some are coarser upto 0.73 mm.

Graphite is present as aggregates and fine individual flakes. It is mostly crystalline. Most of the samples show metallic lustre in reflected light. At places it forms stringers. Graphite shows intergrowth with muscovite.

Muscovite is present as fine flakes and their aggregates. Alongwith graphite it marks the schistosity.

Quartz is present as anhedra. At places it forms bands and patches. Mostly it has rounded anhedral grains.

Goethite/limonite/haematite occur as aggregates and veins and at places form specks.

Boehmite is found only in 19 samples and occurs as small veins and aggregates. At places it shows crenulations. Out of 19 samples 10 samples of Haspur south contain boehmite.

Andalusite is present as anhedral grains.

Pyrite occurs as aggregates of fine material. It is black and opaque. It is associated mostly with Graphite.

Accessory minerals are mostly albite, microcline, clay, magnetite, carbonates, epidote, chlorite, tremolite and silliminite. These minerals are not ubiquitous rather they occur accasionally in the graphitic rocks. Table-1 can be consulted for their presence in these rocks.

ORE MICROSCOPY

Forty eight samples of graphite bearing rocks from the Malakand area were also studied under the reflected light. Eight of the samples were taken from Haspur North, eighteen from Haspur South, eight from Silai Patti, eleven from Agra North, and three from Inzergai. Modal composition is given in the section of Petrography therefore only relevent optics, textural relations and phase identifications have been discribed.

Graphite occurs as fine grains (0.01 to 0.13 mm), flakes (0.14 to 0.40 mm) as well as irregular aggregates. Its colour is greyish white to grey in reflected light. Its anisotropy is strong yellow. Graphite is predominantly crystalline but a very small amount is amorphous looking. Graphite may occur as inclusions within muscovite. Birefringence is strong. Reflectivity is 7 to 15%. It shows strong straw yellow anisotorpy.

Goethite/limonite occur as fine grains (0.03 to 0.20 mm) and colloform aggregates (0.20 to 0.73mm). Their colour under the reflected light is gray with a bluish tinge. Internal reflections are yellow brown to brown. They occur as streaks, veins, grains and irregular aggregates.

Haematite occurs as a subordinate phase. It is mostly associated with pyrite and goethite/limonite.

Pyrite is present as small anhedra (0.03 to 1.0 mm) grains randomly distributed and also occur as traces and relics. Its colour is whitish yellow. Birefringence is nil.

CHEMISTRY

Seventy six samples of the graphite schist from the Malakand area were chemically analysed for SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, H_2O-, H_2O+, Amorphous C and Graphitic C.

Eleven samples were taken from Silai Patti, twenty six from Haspur South, nineteen from Haspur North, seventeen from Agra North, and Rang Dheri and three from Inzergai. All the samples were analysed for graphite.

Silai Patti: Elven samples of graphite bearing schists from Silai contain 14.35 to 22.15% (W/W) graphitic carbon. There is an almost continuous range of variation between the two extreme values mentioned above.

Amorphous carbon is present as a subordinate phase. It ranges from 0.73 - 2.32% *W/W). The graphitic carbon is therefore predominent.

The contents of Fe_2O_3 range from 5.86 to 9.48%, of FeO from 0.35 to 1.54%, of SiO_2 from 46.88 to 54.62%, of Al_2O_3 from 11.0 to 15.48%, of Na_2O from 0.08 to 1.02 in ten samples and 2.39% in one sample (SPT-77-FS-56) and of K_2O from 1.52 - 2.93%.

For mean values and standard deviations of the chemical composition of graphite schist Table - 2 can be consulted.

The chemical composition of these rocks show that they are rocks of pelitic composition having rather large amounts of graphite and significant amounts of iron.

Haspur South: Twenty six samples of graphite bearing schists from Haspur South were analysed.

For field mapping Haspur South was divided into three blcoks, namely Blocks A, B and C. But the results of the chemical analysis show that there is no significant difference in their chemistry. Therefore in order to avoid unnecessary repetition the blocks are being described as one population.

They contain 10.34 to 21.01% (W/W) graphitic carbon. There is an almost continuous range of variation between the two extreme values mentioned above.

Amorphous carbon is present as a subordinate phase in all, but in one sample it ranges from 0.44 to 2.64% (W/W). The graphitic carbon is therefore predominant.

The contents of Fe_2O_3 range from 5.69% to 8.71%, of FeO from 0.22 to 1.37%, of SiO_2 from 47.99 to 59.55%, Na_2O from 0.23 to 2.10% and of K_2O from 1.66 to 3.95%. Al_2O_3 ranges from 9.09 to 16.55% in twenty five samples while one sample HPS-77-29 contains 19.00% Al_2O_3.

For mean values and standard deviations of chemical composition of graphite schist table-2 can be consulted.

The chemical composition of these rocks show that they are rocks of pelitic composition having rather large amounts of graphite and significant amounts of iron.

Haspur North: Nineteen samples of graphite bearing schists from Haspur North were chemically analysed.

Seventeen samples contain from 11.69 to 21.00% (W/W) graphitic carbon. There is an almost continuous range of variation between the two extreme values mentioned above. Two samples i.e. HPN-77-FSA-21, 25 contain 7.75 to 3.78% (W/W), graphitic carbon respectively.

Amorphous carbon is present as a subordinate phase. It ranges from 0.50 to 3.78% (W/W). The graphitic carbon is, therefore, predominant.

The contents of Fe_2O_3 in eighteen out of nineteen samples show a range of variation from 4.16 to 10.57%. Only one sample i.e. HPN-FSA-22 contains 15.28% Fe_2O_3.

The contents of FeO range from 0.18 to 2.70%, of SiO_2 from 47.55 to 61.79%, and of Al_2O_3 from 9.71 to 15.22%. Na_2O range from 0.10 1.02% in sixteen samples and from 1.69 to 2.16% in three samples.

The contents of K_2O range from 1.88 to 4.20% in eighteen samples while one sample (HPN-77-ASSM-10) contains 6.55% K_2O.

For mean values & standard deviations table - 2 can be consulted.

The chemical composition of these rocks show that they are rocks of pilitic composition having rather large amounts of iron.

Agra: Seventeen samples of graphite bearing schists from Agra were chemically analysed.

They contain from 15.22 to 22.58% (W/W) graphitic carbon. There is an almost continuous range of variation between the two extreme values mentioned above.

Amorphous carbon is present as a subordinate phase. It ranges from 0.93 to 1.96% (W/W). The graphitic carbon is therefore, predominant.

The contents of Fe_2O_3 range from 5.94 to 9.42% in sixteen samples while in one sample (AGN-770FM-63) it is 4.32% only.

The contents of FeO range from 0.24 to 1.88%, of SiO_2 from 44.41 to 57.50%, of Al_2O_3 from 10.10 to 17-30%, of Na_2O from 0.31 to 1.05%, and of K_2O from 1.86 to 3.82%.

For mean values & standard deviations table-2 can be consulted.

The chemical compositions of these rocks show that they are rocks of pelitic composition having rather large amounts of graphite and significant amounts of iron.

Inzergai: Three samples of graphite bearing schists from Inzergai were chemically analysed.

Two samples (INZ-77-S-1 and INZ-77-S-3) contain graphitic carbon 3.74% and 4.50% (W/W) respectively. Sample INZ-77-S-5 contains 9.74% (W/W) graphitic carbon.

Amorphous carbon is present as a subordinate phase. It ranges from 0.10 to 1.04% (W.W). The graphitic carbon is therefore, predominant.

The contents of Fe_2O_3 range from 1.42 to 2.04 in two samples, (INZ-77-S-I, and INZ-77-S-5) respectively. In sample INZ-77-S-3 its amount is 7.06%.

The contents of FeO range from 0.18 to 0.47%, of SiO_2 from 62.33 to 68.12%, of Al_2O_3 from 14.00 to 16.02%, of Na_2O from 0.36 to 2.50%, and of K_2O varies from 3.75 to 4.64%.

The chemical composition of these rocks shows that they are rocks of pelitic composition having rather large amounts of graphitic carbon than amorphous carbon and significant amounts of iron.

X-RAY ANALYSIS

X-Ray analysis of nine graphite bearing samples were done. Radiation used was CuK_α= 1.54 Å, voltage 35 KV, current 18 mA and the exposure time was six hours. The dÅ spaces were measured and the X-ray intensities were estimated visually. The analysis of the diffraction pattern show that:

1. Graphite gives relatively strong lines at 3.35, 1.68 and 1.54
2. Amorphous carbon shows a line falling between 2.03 to 2.05. Because of small amount of this carbon 1.26 and 1.08 lines cannot be distinguished. X-ray analysis therefore suggests the presence of small amounts of amorphous carbon in the samples.
3. Quartz is present in significant amounts in all the samples. The sample SPT Silai Patti and HPS-Block B show low quartz while sample Block A shows somewhat higher amount of quartz. The 3.34 line of quartz overlaps with 3.35 of graphite.
4. Weak mica and goethite/haematite patterns are also indicated.

In addition to graphitic carbon variable amounts of quartz, mica, iron oxides and amorphous carbon is present.

CONCLUSIONS OF PETROGRAPHIC AND CHEMICAL RESULTS.

Petrographic: The Petrographic and ore microscipic studies show these rocks are mostly fine grained graphite mica schists. They have well developed schistosity and are mostly from lepidoblastic to sub-lepidoblastic. In some cases they are poikilitic. Graphite occurs mostly as fine-grains. More than 90% grains are below 0.25 mm. Flakes more than I mm or even 0.5 mm are rare. The reflected light studies show that it is predominantly crystalline. Since it is fine grained, therefore most of it may not be suitable for crucibles etc. Graphite mostly occurs as independent grains. But it also occurs as intergrowths and as inclusions in other minerals specially muscovite. So crushing to 70 mesh and below may be necessary.

The reflected light studies show that goethite is by far the most predominant iron oxide mineral. Haematite and limonite are subordinate. Pyrite mostly occurs as relics. The iron oxide minerals occur mostly as veins, streaks and other irregular aggregates.

Petrographic studies show that overall muscovite and quartz are roughly equally abundant. They are followed by graphite and iron oxide minerals.

It is concluded from the foregoing studies that the rocks from the areas discussed above are fine grained graphite mica schists which contain economic percentages of

TABLE – I

MINERAL COMPOSITION OF GRAPHITE

	Sillai Patti		Haspur South		Haspur Narth		Agra		Inzergai	
	SPT-77		HPS-77		HPN-77		RND-77		INZ-77	
	$\bar{X}$	S.D	$\bar{X}$	S.D	$\bar{X}$	S.D	$\bar{X}$	S.D	$\bar{X}$	S.D
Graphite	19.32	4.45	18.32	5.92	21.70	8.90	17.53	4.83	17.72	3.71
Quartz	34.41	6.78	40.79	14.27	31.80	9.74	34.02	5.43	39.48	2.31
Muscovite	27.64	11.71	23.01	13.78	25.00	10.29	35.83	6.23	37.56	3.61
Goethite/ Limonite Haematite.	9.57	4.98	9.48	8.47	7.91	4.86	7.43	4.66	39.94	2.04
Boehmite	1.24	1.72	1.52	2.65	4.10	6.00	1.19	1.70	–	–
Andalusite	0.89	1.29	0.32	0.67	0.28	0.76	1.03	3.40	–	–
Pyrite	0.64	0.67	0.01	0.06	0.16	0.36	0.34	0.45	0.05	1.00
Albite	0.56	0.83	–	–	1.53	3.22	0.16	0.55	0.02	0.04
K-feldspar	–	–	0.62	1.59	0.75	1.97	–	–	–	–
Clay	5.40	4.70	5.13	5.33	6.58	5.44	1.94	2.19	0.06	1.02
Magnetite	0.17	0.33	0.01	0.06	–	–	0.25	0.60	–	–
Carbonates	–	–	–	–	–	–	0.16	0.55	–	–
Epidote	–	–	0.13	0.61	0.01	0.44	–	–	–	–
Chlorite	0.22	0.63	–	–	–	–	–	–	–	–
Tremolite	0.–		0.07	0.25	0.06	0.26	–	–	–	–
Silliminite	–	–	0.13	0.61	–	–	–	–	–	–
	N = 9		N = 23		N = 20		N = 12		N = 5	

$\bar{X}$ = Mean Values
S.D = Standard Deviations
N = Numbers

graphite. Amorphous carbon is subordinate. Textural relations suggest that graphite may be released below 70 mesh and that at fine levels high recovery of the mineral is possible. However it may not yield appreciable quantities of the flake graphite. The above are strongly recommended for the relevant work.

Chemical: **The chemical studies show that the samples from Haspur North, Haspur South, Agra North, Silai Patti and Rang Dheri contain apparently economic percentages of graphitic carbon. The contents of amorphous carbon are consistantly low. The contents of iron oxides are also significant. The bulk chemistry shows these rocks to be graphite bearing pelites, which are rather rich in iron.**

TABLE –2

CHEMICAL COMPOSITION OF MALAKAND GRAPHITE

	Sillai Patti		Haspur South		Haspur North		Agra		Inzergai	
	SPT – 77		HPS – 77		HPN – 77		AGN & RND–77		INZ – 77	
	$\overline{X}$	S.D	$\overline{X}$	S.D	$\overline{X}$	S.D	$\overline{X}$	S.D	$\overline{X}$	S.D
Graphitic Carbon	17.17	2.09	14.99	2.24	15.00	3.87	17.82	2.10	5.99	2.67
Ammorphous Carbon.	1.50	0.43	1.41	0.66	1.80	0.72	1.44	0.30	0.44	0.42
SiO_2	52.18	2.14	54.15	2.58	53.98	4.08	50.78	3.48	65.50	2.39
TiO_2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Al_2O_3	12.48	1.33	12.73	2.21	12.52	1.48	14.13	1.83	15.04	0.83
Fe_2O_3	7.29	0.44	7.23	0.80	7.20	2.51	7.39	1.23	3.51	2.53
FeO	0.81	0.38	0.67	0.34	0.87	0.68	0.60	0.37	0.30	0.12
Mn O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mg O	1.86	0.93	2.02	1.04	1.53	0.99	1.27	0.43	2.23	0.59
Ca O	0.68	0.60	0.88	1.11	0.61	1.13	0.29	0.41	0.0	0.0
Na_2O	0.63	0.62	0.81	0.48	0.73	0.55	0.70	0.19	1.49	0.88
K_2O	2.43	0.41	2.67	0.51	3.08	0.98	3.06	0.57	4.27	0.38
P_2O_5	0.03	0.08	0.10	0.15	0.09	0.09	0.02	0.04	0.0	0.0
H_2O^-	1.07	0.52	0.78	0.42	0.73	0.64	0.79	0.48	0.33	0.09
H_2O^+	1.22	0.32	1.00	0.44	0.99	0.33	1.15	0.25	1.06	0.08
I/L	0.38	0.17	0.48	0.25	0.81	0.83	0.52	0.19	0.11	0.02
	N = 11		N = 26		N = 19		N = 17		N = 3	

$\overline{X}$ = Mean Values
S.D = Standard Deviations
N = Numbers

TABLE – 3

X - RAY ANALYSIS

SPT-77-SM-45		HPS-77-S-35		HPN-77-FS-15		Salai Patti		Block - A	
dÅ	I	dÅ	I	dÅ	I	dÅ	I	dÅ	I
–	–	–	–	–	–	8.04	10	–	–
–	–	–	–	5.06	1	–	–	–	–
–	–	–	–	4.48	3	–	–	4.49	1
4.25	30	4.25	20	4.24	10	–	–	4.28	3
3.35	100	3.35	100	3.36	100	3.36	100	3.36	100
–	–	–	–	3.18	3	3.18	1	–	–
–	–	–	–	2.99	2	2.98	1	–	–
–	–	–	–	2.87	1	–	–	–	–
–	–	–	–	2.81	1	–	–	–	–
2.57	6	2.56	1	2.59	10	–	–	–	–
2.46	10	2.46	5	2.46	10	2.46	5	–	–
–	–	–	–	2.39	1	–	–	–	–
2.28	10	2.28	1	2.27	10	–	–	–	–
2.25	8	–	–	2.25	2	–	–	–	–
2.13	10	2.13	1	2.13	15	2.13	10	2.13	5
–	–	2.04	3	2.04	2	2.03	30	2.04	15
1.99	3	2.00	3	1.99	15	–	–	1.98	1
1.82	25	1.81	30	1.81	1	1	1.82	1.82	2
–	–	1.77	30	–	–	–	–	–	–
1.67	10	1.67	5	1.67	15	1.68	40	1.68	30
–	–	–	–	1.64	5	–	–	1.66	1
–	–	–	–	1.60	1	1.54	5	–	–
1.54	20	1.54	10	1.54	25	1.38	2	1.54	10
–	–	–	–	1.51	1	1.23	10	–	–
1.46	2	–	–	1.45	5	1.15	10	1.38	8
1.38	25	1.38	10	1.37	20	–	–	1.23	20
1.20	2	–	–	–	–	–	–	1.16	20
1.18	1	–	–	–	–	–	–	1.12	5
–	–	–	–	–	–	–	–		

TABLE 3 (Contd..)

X – RAY ANALYSIS

Block C		Rang Dheri		HPS. Block B		Agra North	
dÅ	I	dÅ	I	dÅ	I	dÅ	I
4.24	30	4.25	25	–	–	4.26	20
3.36	100	3.35	100	–	–	3.36	100
–	–	–	–	–	–	3.03	1
–	–	2.57	2	–	–	–	–
2.46	5	2.46	5	3.36	100	2.46	5
2.29	2	2.28	5	–	–	2.28	5
2.25	1	–	–	–	–	2.25	2
2.14	20	2.13	10	–	–	2.13	10
2.08	5	–	–	–	–	2.08	3
2.03	40	2.03	30	–	–	2.03	30
1.98	1	1.99	1	–	–	1.98	1
1.82	10	–	–	–	–	1.82	10
1.68	50	1.68	40	–	–	1.68	50
1.54	10	1.54	25	–	–	1.54	10
1.37	5	1.37	10	–	–	1.37	10
1.23	10	1.23	15	2.04	5	1.23	10
–	–	1.20	1	–	–	–	–
–	–	1.18	1	–	–	–	–
1.16	10	1.15	10	–	–	1.15	10
–	–	–	–	1.68	10	1.11	5

REFERENCES

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

Chaudhry, M.N., Ashraf, M., Hussain, S.S. & Iqbal, M., (1976). Geology and Petrology of Malakand and a part of Dir (toposheet 38 N/14). *Geol. Bull. Punjab Univ.*, No. 12, No. 17–40.

Sokolov, B.A., & Shah, S.H.A., (1966). Major tectonic features of Pakistan, Part I Western Province. *Sci. Ind.*, Vol. 4, No. 3, pp. 176–199.

Wadia, D.N., (1953). Geology of India. Macmillan & Co. London. 3rd Ed.

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PETROLOGY OF MURREE FORMATION OF POONCH DISTRICT, AZAD KASHMIR

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Abstract:– A detailed petrographic, chemical and spectrochemical study of Murree Formation from Poonch Distt. of Azad Jammu and Kashmir is being presented for the first time. This study includes petrographic analysis of 22 sandstones, 31 shales and 13 limestones; chemical analysis of 23 sandstones, 6 shales and 13 limestones ;chemical analysis of 23 sandstones, 6 shales and 3 limestones and spectrochemical analyses of 10 sandstones, 8 shales and 4 limestones.

A comparison of the Murree Formation and Siwaliks of Poonch is presented to show similarities between the two. It is shown that the two have been derived from the same source.

The view held so far (following Wadia, 1928) that the Murree Formation has been derived from Dharwar and Cuddapah rocks of Peninsular India is despelled. Instead, it is clearly shown that the Murree Formation like the Siwaliks (Chaudhry and Ashraf, 1981) have been derived from the rising Himalayas.

In Poonch area it is shown that the lower Murree Formation are marine, while the middle and upper Murrees are of continental origin with local lacustrine conditions.

INTRODUCTION

Most of the area studied is composed of Murrees. The Murree Formation occupies a broad belt striking NE-SW. and occurs in western and northwestern Poonch district. Table-1 G gives a general sequence of rocks in Poonch Distt. and shows the position of Muree Formation (Fig. 1)

GEOLOGY

The formation is composed of a series of alternating sandstones and shales with subordinate marls and limestones. The Upper Murree sandstones are medium to coarse grained. They contain mica or mica like clay minerals. These sandstones are rather soft. They are light yellowish grey to light brown in colour

Lower Murree sandstones are fine to medium grained (generally). They are red to purple in colour but grey colour may also be seen. The Upper Murree sandstones may contain plant fossils.

The Upper Murree shales are red, purple, buff, brown and green. They may contain plant fossils. The Lower Murree shales are light coloured, brown grey and buff. They contain calcite veins and are devoid of fossils.

The marls and limestone bands and beds occur in the Lower Murrees. Their colours are cream and light grey to dark grey. One limestone bed exposed in Bassan Nala near Hallan Shamali is fossiliferous and contains formanifera. This bed is 20 to 50 feet thick. The fossils are most proprobably of Oligocene age.

In the following the three main lithologic types i.e. sandstones, shales and calcareous rocks will be described separately.

PETROGRAPHY

Sandstones

Although Upper and Lower Murree sandstones have been distinguished in the field on the basis of grain size, mica content and colour, the petrographic studies show that the sandstones are similar as regards their mineralogy. The Upper Murree sandstones at many places may contain more mica than the Lower Murree sandstones.

Lower Murree sandstone may also contain higher amount of iron oxide minerals but the Upper Murree sandstones are not devoid of the same minerals. The mica minerals also occur in Lower Murree sandstones, they are however, finer grained. There are no hard and fast mineralogical distinctions between the Upper Murree and the Lower Murree sandstones. Because of similar mineralogy and also the common provenance, the Upper and Lower Murree sandstones will be described as parts of a single petrographic entity. The sandstones show a rather uneven distribution of constituent minerals even within the limits of a hand specimen.

Some Murree sandstones are fine grained but most of them are medium to coarse grained. The grains are mostly of quartz, rock-fragments, feldspar and mica.

The grains are mostly subangular to subrounded. The finer grained sandstones contain numerous rounded grains.

The matrix is composed of clay, sericite, small grains as described above, and accessory minerals. The cement/binding matter is calcareous, ferruginous, argillaceous and siliceous.

The results of the Murree Sandstones alongwith their averages and standard deviations (of the individual constituents) are given in Table - 1.

In the following is given the description of the mineral constituents.

Quartz: It ($\bar{X}$ = 30.45, SD = 10.04), occurs as medium to coarse grains. The grains are subangulr to subrounded. Rounded quartz grains, in medium to coarse grained sandstones constitute a small proportion of the rock. However, in finer grained sandstones, rounded quartz grains are more common. Quartz grains often show strain twinning and undulose extinction. For chertry rock fragment $\bar{X}$ = 8.27, SD = 3.06 and for quartzitic rock fragments $\bar{X}$ = 1.77 SD = 2.00.

Rock Fragments: The unstable rock fragment ($\bar{X}$ = 7.25. SD = 4.58) are mostly medium to coarse grained and are angular to subangular. Subrounded grains are subordinate. The rock fragments are phyllitic carbonate (described with carbonate) shaly, cherty, quartzitic and volcanic. The volcanic fragments are acid to intermediate in composition.

K-feldspar: It ($\bar{X}$ = 3.86, SD = 3.76) mostly occurs as medium to coarse grained angular to subrounded grains. But subangular grains are predominant in most samples. Both microcline and orthoclase have been found. It shows varying degrees of alteration to clay and sericite.

Plagioclase/Albite: They ($\bar{X}$ = 3;11. SD = 1;69) occur as elongate and subangular grains. Many grains are subprismatic to prismatic in outline. They may also show alteration to clay and sericite.

Haematite/Limonite: They ($\bar{X}$ = 4.55, SD = 3.53) occur as grains, amorphous looking aggregates, stains and as diffused streaks as irregular veinlets. The two minerals are intimately associated. In non-incident reflected light they show from yellowish brown to brown colours. Occasionally orange stains suggest that some goethite may also be present.

Magnetite: ($\bar{X}$ -= 0.39, SD = 0.65) This mineral occurs as small subhedral to anhedral grains which show alteration to limonite. Magnetite itself is black and opaque. It occurs in 8 samples only and ranges from 0.5 to 2.0%, and shows steel grey colour in reflected light.

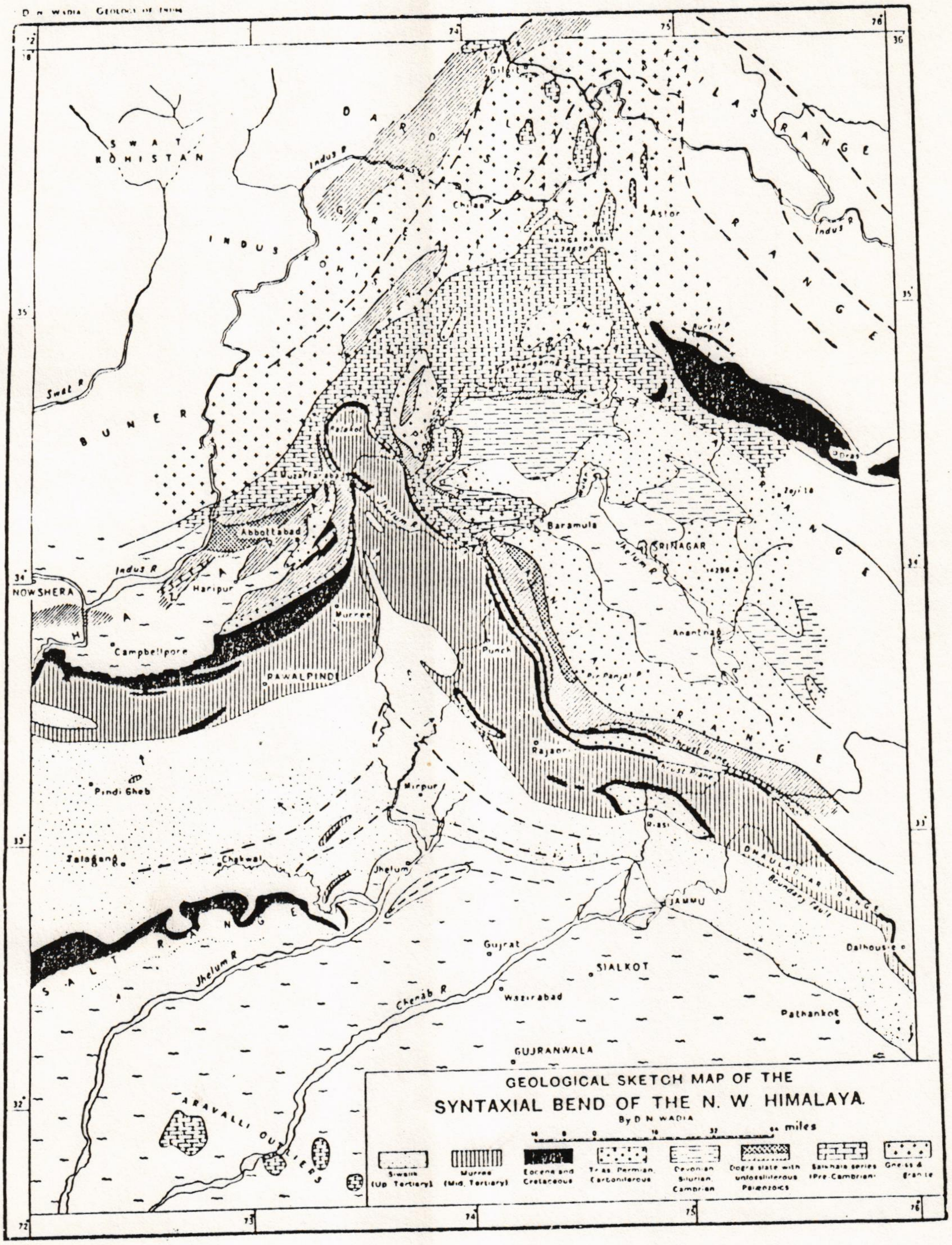
Calcite/Dolomite: They ($\bar{X}$ = 25.25, SD = 11.94) are important and essential constituents of sandstones. They constitute the predominent part of the cement. They are fine to coarse grained and occur as grains as well as rock fragments.

Muscovite/Sericite: They ($\bar{X}$ = 4.48, SD = 2.98) often occur associated. Sericite is fine grained whereas muscovite is generally fine to medium grained. Some muscovite should be considered as grains. The rest of the muscovite is a part of the matrix. Sericite along with clay also occurs as an alteration product of the feldspars.

Clay: It ($\bar{X}$ = 7.32, SD = 3.53) occurs as small specks, fine microcrystalline to cryptocrystalline minerals and as irregular aggregates. It may also occur as an alteration product of feldspars. It is an important constituent of the matrix.

Tourmaline: It occurs as small grains in a few samples. It is pale yellowish green and strongly pleochroic. It is schrolite. It occurs in two samples only and in them, it is 0.5% and 1.0%.

Pyrite: It occurs as subhedral to eumorphic grains. It has


GEOLOGICAL SKETCH MAP OF THE
SYNTAXIAL BEND OF THE N. W. HIMALAYA.
By D N WADIA
miles
Siwalik (Up. Tertiary)
Murree (Mid. Tertiary)
Eocene and Cretaceous
Trias. Permian, Carboniferous
Devonian Silurian Cambrian
Dogra slate with unfossiliferous Palæozoics
Salkhala series (Pre-Cambrian)
Gneiss & Granite
SWAT KOHISTAN
INDUS KOHISTAN
DARDISTAN
GREAT HIMALAYA
BUNER
NOWSHERA
Campbellpore
RAWALPINDI
Abbottabad
Haripur
Murree
Baramula
SRINAGAR
Anantnag
Punch
Rajaori
Pindi Gheb
Chakwal
Jhelum
Mirpur
JAMMU
Gujrat
SIALKOT
Wazirabad
GUJRANWALA
Pathankot
Dalhousie
Astor
Gilgit
Chilas
Indus R
Swat R
Jhelum R
Chenab R
SALT RANGE
ARAVALLI OUTLIERS

Table–1 G.

STRATIGRAPHIC SEQUENCE OF KOTLI AND POONCH AREAS

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

most probably formed in situ and indicates local reducing conditions. It occurs in four samples only and in them, it ranges from 0.5 to 1.0%.

Carbonaceous Matter: It occurs as small specks, amorphous looking matter and irregular bits.

It occurs in two samples only and is 1.0% in each case.

Epidote: It occurs as small angular to subangular grains. It is colourless to light green. The study of interference colours and birefringence shows that both zoisite as well as clinozoisite are present.

It occurs in three samples only and in them it ranges from 0.5 to 1.0%.

Garnet: It occurs as angular and light pink grains. It occurs only in one sample and its amount in it is 1.0%. For other minerals (rare accessories) Table –1 may be seen.

Shales

Murree shales constitute an important part of the Murree Formation. They alternate with Murree sandstones. They are of buff, red, purple, grey and green colours.

The Upper Murree shales are reu, purple, buff, brown and green. They may contain plant fossils. The Lower Murree shales are lighter coloured, brown, grey and buff. Petrographic studies however, show no clear cut distinction between the Upper Murree shales and the Lower Murree shales. The two will therefore be described as one greup. The results are given in the table 2.
The shales are fine grained, unequigranuler and are poorly to moderately compact. The clay is very fine grained and often microcrystalline to cryptocrystalline. Quatz is mostly fine grained but some medium grains also occur,. Some of the calcite is recrystallised and medium to coarse grained while most of it is fine grained. The quartz rich shales are mottled.

Clay. It ($\bar{X}$=56.47,S.D.=16.94) (Table 2) is mostly the predominant mineral of the rook. It is fine grained and generally microcrystalline to eryptocrystalline. The optical study shows it to mostly belong to the illite group. It is admixed with very fine grained muscovite. Some kaolinite and smectite group minerals are also present. These shales show fairly wide variation in clay percentage.

Quartz: It ($\bar{X}$= 16.00, S.D. = 8.90) is an important constituent of shales. It occurs mostly as fine grains but some medium grains also occur. It is predominantly detrital. Some authigenic grains with diffused and ragged outlines also occur. At some places quartz grains may form thin streaks.

Calcite/Dolomite: ($\bar{X}$ = 18.42, S.D = 12.48) Both petrographic and chemical study shows that the predominant and often the only carbonate mineral is calcite. They occur either as very fine grained, often microcrystalline to as medium to coarse grains containing inclusions of clay, quartz and iron oxides etc. As can be seen from the parameters the carbonates are highly variable in amount.

Haematite/Limonite: They ($\bar{X}$ = 4.16, S.D. = 2.59) occur intimately associated and impart red, purple and brown shades to the shales. They occur mostly disseminated. However, they may also form streaks, irregular aggregates and veinlets. Haematite may also occur as distinct grains. In reflected light they show from brown to blood red colours.

Mica: Both ($\bar{X}$ = 1.74, S.D. = 3.29) muscovite as well as sericite occur. They occur from fine to medium flakes. The flakes may often be aligned parallel to the lamination planes. The amount of mica is however, highly variable. Finer grained mica, specially sericite is intimately admixed with clay.

Chlorite: It ($\bar{X}$ = 1.02, S.D. = 1.74) is an accessory mineral. It may or may not be present. It occurs as small light of medium green flakes which show from slight to moderate pleochroism. Its interference colours may either be anomalous or normal (occasionally). It is generally closely associated with mica minerals.

Chert/Chalcedony: It is mostly lacking (it is present only in four samples out of a total of thirty one samples). Where present it occurs as an accessory mineral. However, in one sample (PHS-77-AH-124) its amount is 20.0% and it becomes an essential mineral. It appears to have been precipitated during or just after compaction. It shows mostly subradial structure, although some pepper and salt patterns can also be seen.

Albite: It occurs in only three samples. It forms small grains showing poorly developed twinning.

Magnetite: It ($\bar{X}$ = 0.34, S.D. = 0.70) occurs in only eight samples. It occurs as anhedral grains showing alternation to limonite.

Organic Matter: It ($\bar{X}$ = 0.50, S.D. = 0.81) occurs in eleven out of a total of thirty one samples studied. It occurs as tiny bits and amorphous looking blackish matter with a dull lustre and greenish to greyish brown colours in reflected light.

Pyrite: It occurs in six out of thrity one samples. It varies from 0.5 to 2.0%. It occurs as small subhedral to anhedral grains which appear to have formed in situ and under local reducing conditions.

Calcareous Bed and Bands

The calcareous bed and bands are grey, dark grey and greenish in colour. They are compact and often show well developed bedding. At some places they appear seminodular. They are interbedded with Murree shales of greenish grey colour. They range from almost pure limestone to marls. The results are given in Table - 3.

These rocks are mainly fine grained. They may however, contain medium to coarse grained recrystallized veins and patches of calcite. Some of the rocks are fossiliferous and contain formaniferal fossils. The quartz rich beds/bands give a mottled look.

Calcite: It ($\overline{X}$ = 69.85, S.D. = 14.61) is predominant mineral of the rock. It is generally fine grained and from microcrystalline to cryptocrystalline. It also occurs as small and randomly distributed and coarser grained patches and veins.

It also occurs as foramniferal fossil shells. The amount of calcite varies widely.

Clay: It ($\overline{X}$ = 4.92, S.D. = 4.66) occurs as extremely fine grained mostly intimately admixed with calcite

Quartz. It ($\overline{X}$ = 5.50, S.D. = 10. 75) occurs as small subangular to subrounded grains. It is mostly classtic and often shows undulose extinction. Some quartz however, appears to be authigenic in origin. This quartz occurs as small grains with diffused outlines. As can be seen from the table, the amount of quartz is highly variable.

Haematite/limonite. They ($\overline{X}$-5.12, S.D. = 5,02) are ubiquitous accessory to minor minerals. However, in some samples they assume the status of an essential mineral. They occur as small grains, amorphous looking aggregates, specks, stains, streaks and veinlets, in oblique reflected light they show from yellowish brown to blood red colour.

Muscovite/sericite. They mostly ($\overline{X}$ = 1.85, S.D. = 2.35) occur as tiny flakes which are often intimately associated with clay. However, some medium grained flakes also occur

Chalcedony. It ($\overline{X}$ =0.58, S.D. = 0.91) occurs in four samples only and in them it varies from 1.5 to 2.0%. It occurs as small areas showing radial as well as salt and pepper structure.

Garnet. It occurs as small angular grains of light pink colour. It occurs in only two samples and is 0.5% and 2.0%. It is clearly a detrital mineral.

Magnetite. Small subhedral to anhedral magnetite grains occur in one sample only. It is black and opaque but shows marginal alternation to haematite/limonite. In reflected light magnetite shows a steel black colour.

Pyrite. It occurs only in one sample where its amount is 5.0% (PHS-77-F-137.A). Pyrite occurs as subhedral to eumorphic grains. They appear to have formed in situ (authigenic).

Albite/plagioclase. It occurs in three samples only and in them, it ranges from 1.0 to 2.0%. It occurs as small authigenic grains with irregular outlines.

Chlorite. It ($\overline{X}$=0.54, S.D. = 1.03) occurs as small green to light green flakes which show slight to moderate pleochroism. They show anomalous interference colours.

Biotite. Two samples contain biotite (1.0% each). It is greenish brown and moderately pleochroic. It occurs as small flakes.

Tourmaline. Only one sample contains tourmaline (0.5%). It occurs as small grains. It belongs to the variety schrolte

Rock fragments. Only two samples contain rock fragments (3.0%) and 2.%). The fragments are calcareous, argillaceous and cherty.

K-feldspar. Only one sample (PLJ - 77HN-178) contains this mineral. It occurs as small clastic grains which show slight alteration to clay/sericite.

CHEMISTRY

Sandstones. Twenty three samples of Murree sandstones were chemically analysed. The results of the chemical analysis alongwith averages and standard deviations of the individual constituents are given in Table - 4.

The $\overline{X}$ for SiO_2 is 55.43 and S.D is 10.67, the $\overline{X}$ for CaO is 14.20 and S.D is 6.35, the $\overline{X}$ for I/L (mostly CO_2) is 13.86 and S.D is 5.21, the $\overline{X}$ for Al_2O_3 is 8.61 and S.D is 2.03, the $\overline{X}$ for Fe_2O_3 is 3.95 and S.D is 1.09, the $\overline{X}$ for MgO is 1.90 and S.D is 1.06, the $\overline{X}$ for K_2O is 1.12 and S.D is 0.51 and $\overline{X}$ for Na_2O is 0.63 and S.D is 0.25

The chemical results confirm the petrographic results. These are basically calcareous sandstones carrying variable amounts of clay/mica, unstable rock fragments and iron minerals.

Shale: Six samples of Murree shales were analysed. The results alongwith the averages and standard deviations of the individual constituents are given in Table - 5.

The $\bar{X}$ for SiO_2 is 53.66 and S.D = 7.67, the $\bar{X}$ for Al_2O_3 is 14.35 and S.D = 4.67, $\bar{X}$ for Fe_2O_3 is 8.75 and S.D = 2.09, $\bar{X}$ for CaO is 6.73 and S.D = 4.67, $\bar{X}$ for MagO is 3.24 and S.D = 1.36 and $\bar{X}$ for I/L is 10.56 and S.D = 4.51. The averages for Na_2O and K_2O are 0.51 and 1.67 and their standard deviations are 0.39 and 0.90.

Limestone Three samples of Murree limestones were analysed chemically. The results are given in Table - 6. In keeping with their petrographic variation they show rather wide variation in their chemical composition.

The contents of SiO_2 range from 4.99 to 34.61%, that of CaO from 21.96 to 47.68%, that of I/L from 20.20 to 39.06%, that of Al_2O_3 from 3.15 to 10.18%, Fe_2O_3 from 3.15 to 7.24% and that of MgO from 1.86 to 2.37%. Since they contain clay and mica minerals (also some contain feldspar) they show significant, though small, alkali content. The contents of Na_2O vary from 0.10 to 0.74% whereas the contents of K_2O range from 0.27 to as high as 1.98%.

The chemical composition shows that they are on the whole impure limestones which are to varying degrees siliceous/arenaceous and argillaceous/micaceous.

SPECTROCHEMISTRY

Sandstones: Ten samples were analysed by spectrochemical methods (Table–7) for V, Y, SC, Cu, Cr, ZrO_2, Ni-Co, Pb and Ba. The results are given in Table - 7. The contents of V range from 0.01% (in seven samples) to 0.002% (in three samples) Mo occurs in four samples only. In three samples it is 5 ppm while in one sample it is 10 ppm. The contents of Yare 5 ppm in four samples and 10 ppm in six samples. The contents of Sc range from I ppm to 5 ppm giving $\bar{X}$ = 2.80 and S.D. = 1.55. The contents of Cu range from I ppm to 5 ppm in eight samples while it is lacking in two samples. It gives $\bar{X}$ = 2.50% and S.D 2.22. The content of Cr are less than 0.01% in nine samples and 0.01% in one sample. The contents of ZrO_2 range from 0.01% to 0.08% giving an average of 0.03 and a standard deviation of 0.02.

The results do not show anomalies and do not suggest mineralization of the kind.

Shales. Eight samples of Murree shales were analysed by spectrochemical methods. The results are given in Table-8.

The V content ranges from 0.01 (in seven samples) to 0 005% (in one sample), the content of Mo is 5 ppm in five samples and in three samples less than 5 ppm. The contents of Y ranges from 5 ppm to 20 ppm (one sample is barren), the content of Sc in six samples ranges from 10 ppm to 30 ppm (it is absent in two samples), the content of Cu ranges from 5 ppm in six samples while in two samples it is less than 5 ppm, the content of La is 50 ppm in six samples and 100 ppm in one sample (being absent in one sample) the content of Ni-Co is 15 ppm in seven samples (being absent in one sample) and the content of Pb is 50 ppm in three samples while in three samples it is 50 ppm.

The contents of La are interesting.

Limestone: Four samples of limestones of Poonch were analysed by spectrochemical methods. The results are given in Table - 9.

The contents of ZrO_2 range from 0.012 to 0.025%, those of V range from 0.008 to 0.01%, those of Mo from O to 15 ppm, those of Y are 10 ppm in all the samples, those of Sc range from 2 ppm to 5 ppm, those of Cu range from 2 ppm to 5 ppm, those of Cr range from less than 0.01 to 0.01% those of Ni-Co range from less than 10 ppm to 10 ppm, those of Pb are less than 50 ppm, those of Ba range from 0.03 to 0.08%. La is absent in two samples whereas in the other two samples it is 10 ppm.

ORIGIN

In the following is considered briefly the origin of Murree Formation, based on the field observations and laboratory studies.

The Murree rocks are composed predominantly of purple to reddish borwn coloured interbedded sandstones and shales. At places brownish grey to greenish grey sandstones are found. In the lower parts of Murrees, marls and argillaceous limestones are also observed.

The rock fragments in the Murrees are of phyllites, carbonate, chert, quartzite and volcanics. The Murree rocks contain accessory to minor amounts of iron oxides and mostly contain significant quantities of clay.

The lower Murrees in view of their lithology and presence of marine fossils (Nummilites) of Oligolene (?) may be considered of marine origin whereas the upper and middle parts are considered to be of continental origin. These parts contain terrestrial plant fossils.

Deposition of these sediments (lower part) has taken place in shallow waters because the current ripple marks and cross bedding are the evidence of shallow water deposition. The sediments (middle and upper part) were mostly deposited in continental environments. This fact is proved by the presence of teresstrial plant fossils (in Potwar) and terrestrial mammalian remains and absence of marine fossils. But still the topography could be very undulating and local lacustrine conditions of depositions could have developed.

Wadia (1928) after studying the lithology of Murrees concluded that they were not derived from Himalayan high lands which were rising at that time, but from iron bearing Dharwar and Cuddapah rocks of Peninsular high lands. We shall comment on this observation below.

Huge thickness of sediments and interbedded shales, sandstones, and claystones are the characteristics of deposits formed under rapid conditions of subsidence and deposition in the basin. This shows nearness of the source area to the site of deposition. Coarse grained nature and the presence of unstable minerals and rock fragments in sandstones also reveal that transportation of the detritial material has taken place because of nearness of the source rock.

In the foregoing pages, a fairly detailed geological petrographic, chemical and spectrochemical study of the sandstones, shales and limestones of the Murree Formation has been presented. Of particular interest, from a petrogentic point of view, are the Murree Sandstones. They contain abundant rock fragments, which throw light on the nature of parent rocks from which the sediments of Murree Formation have been derived.

The Siwalik sandstones associated with these rocks from Poonch have also been studied (Ashraf and Chaudhry 1984) in detail. The provenance of these Siwalik sandstones has also been discussed in the following, a comparison of the sandstones of Murree formation and Siwaliks will be attempted, to show the community of origin of these rocks. Although a detailed petrographic, chemical and spectrochemical study of shales and carbonate rocks of Murree Formation has also been presented in the foregoing pages, they will not be commented upon further for the sake of being brief since the evidence presented by sandstone is outstanding.

Table–10– sets out averages and standard deviations of petrographic constituent comparisions of sandstones of Murree Formation and Siwaliks of Poonch. A comparison of the two sandstones shows a remarkable qualitative similarity in the petrographic compositions of the Murree and Siwalik sandstones. In addition to comparable mineral constituents, both groups contain carbonate, phyllitic, volcanic, quartzitic and shaley (fireclay etc.?) rock fragments. The volcanic rock fragments, in both cases are acid to intermediate in composition. Even the amounts of the two main constituents i.e. quartz and carbonates are very close to each other. The general petrographic resemblance is indeed remarkable.

Table–11–presents a comparison of averages and standard devitations of chemical compositions of Murree and Siwalik sandstones of Poonch. The general similarities and closeness of the chemical compositions is once again striking. However Siwaliks do contain somewhat higher Na_2O and MgO. This is because of the more sodic nature of feldspars and higher quantities of dolomitic matter in the Siwalik sandstones.

Table-12 presents a comparison of spectrochemical trace element compositions (V, Mo, Y, Sc, Cu, Cr, ZrO_2, Ni-Co, Pb and Ba) of Murree and Siwalik sandstones of Poonch. Once again the two sandstones have similar and comparable trace elements.

The above comparisons clearly point towards a community of origin for the Murree and Siwalik sandstones of Poonch.

The source rocks for the Siwaliks of Poonch and Kotli have already been discussed by Ashraf and Chaudhry (1984) and Chaudhry and Ashraf (1980 and 1981).

It is now suggested that the Murree Formation has its origin in the rising Himalayas. The carbonate and cherty rock fragments were derived from cherty limestones and dolomites. The phyllitic and possibly schistose rock fragments come from the low grade metapelites (belonging to the green schist facies of regional metamorphism). The volcanic rock fragments were derived from the acid to intermediate volcanics (at least partly from the arc zone, Ghazanfar & Chaudhry, 1984). The quartzitic fragments come from the meta-arenites. In short the Murree Formation rocks were derived from three groups.

1. Carbonate, pelites and quartzites.

2. Greenschist facies metamorphites which were mainly metapelites possibly with some associated quartzites.

3. Volcanic/volcanogenic rocks including acid to intermediate volcanics of arc type.

Such rocks represent the upper parts of the rising low grade metamorphites, sediments and volcanic/volcanogenic sediments of the rapidly rising Himalayas.

The Purana group, from which Wadia (1928) derives

TABLE – 1

Petrographic Composition of Murree Sandstones

Samples Nos.	PPI-77-FS-130	PPI-77-FS-131	PPI-77-FS132 A	PHP-77-FS-144	PHP-77-FS-146	PLD-77-FH-147	PLD-77-FH-149	PLD-77-FH-150,	PLD-77-FH-151	PHS-77-FH 152 A	PSI-77-F-153	PSS-77-F-154
Localities	Plangi	Plangi	Plangi	Haji pir	Haji Pir	Lusdanna	Lusdanna	Lusdanna	Halan Shamali	Sheikh-Sauli	Halan Janubi	Sauli School
Coordinates	103832	103832	102830	116941	135928	078930	063928	048933	048933	200897	175877	180869
Quartz	23.0	20.0	32.0	39.0	38.0	37.0	20.0	15.0	40.0	33.0	44.0	30.0
Calcite*	39.0	40.0	26.0	22.0	22.0	17.0	34.0	31.0	–	15.0	12.0	13.0
Rock fragments	6.0	8.0	7.0	7.0	4.0	8.0	17.0	8.0	20.0	–	5.0	8.0
Cherty rock-fragments	4.0	5.0	3.0	5.0	3.0	4.0	–	2.0	–	7.0	3.0	6.0
Quartzitic rock fragments	3.0	4.0	3.0	2.0	3.0	6.0	–	4.0	–	–	–	4.0
Clay	5.0	–	5.0	5.0	10.0	5.0	4.0	5.0	–	13.0	9.5	5.0
K-feldspar	4.0	5.0	4.0	2.0	2.0	3.0	6.0	15.0	–	7.0	–	5.0
Plagioclase/ Albite	3.0	–	2.0	2.0	5.0	4.0	2.0	4.0	1.0	6.0	3.0	5.0
Muscovite/ Sericite	3.0	4.0	4.0	2.5	1.5	5.0	3.0	4.0	–	3.5	14.0	5.0
Biotite	1.0	2.5	–	–	–	–	2.0	–	–	0.5	–	–
Chlorite	4.0	5.0	4.0	4.0	0.5	1.0	1.0	3.0	–	0.5	3.0	5.0
Haematite/ Limonite	1.5	3.0	5.5	3.0	4.5	3.0	4.0	2.5	19.0	6.0	1.5	5.0
Magnetite	–	–	–	0.5	0.5	–	–	1.5	–	0.5	–	2.0
Chert/Chalcedony	2.5	3.0	4.0	5.0	5.0	6.0	6.0	2.0	20.0	8.0	5.0	7.0
Epidote	1.0	–	–	–	–	–	1.0	–	–	–	–	–
Pyrite	–	0.5	0.5	–	–	1.0	–	–	–	–	–	–
Pyroxene	–	–	–	–	–	–	–	2.0	–	–	–	–
Garnet	–	–	–	1.0	–	–	–	–	–	–	–	–
Carbonaceous material	–	–	–	–	1.0	–	–	–	–	–	–	–
Tourmaline	–	–	–	–	–	–	–	1.0	–	–	–	–
Glauconite	–	–	–	–	–	–	–	–	–	–	–	–

*Carbonate fragments.

TABLE – 1 (Contd.)

Sample Nos	PPI-77-HN-177	PAP-77-HN-181	PBD-77-MHN-186	PBD-77-MHN-188	PBD-77-MHN-189	PJA-77-H-194	PJT-77-H-194	PKA-77-H-197	·PDT-77-MHN-206	PDT-77-MHN-213	MHN-214	
Localities	Parati	Abbaspur	Bagh (Dhuli)	Bagh (Dhuli)	Bagh (Dhuli)	Jandala	Jaluth	Kohala	Dhirkot	Dhirkot		
Coordinates	314835	728811	945900	905890	881922	698924	732885	561049	584048	584048	X̄	S.D
Quartz	52.0	38.0	28.0	37.0	32.0	28.0	24.0	20.0	10.0	30.0	30.45	10.04
Calcite	–	25.0	22.0	27.0	30.0	30.0	35.0	37.5	38.0	40.0	25.25	11.94
Rock fragments	–	8.0	7.0	8.0	3.0	4.0	6.0	11.0	9.0	5.25	7.25	4.58
Cherty rock fragments	–	4.0	4.0	3.0	4.0	6.0	4.0	6.0	–	4.0	3.50	2.06
Quartzite rock fragments	–	–	5.0	–	–	–	3.0	2.0	–	–	1.77	2.0
Clay	25.0	3.0	10.0	9.0	8.0	14.0	8.5	5.0	7.0	5.0	7.32	5.32
K-feldspar	2.0	–	5.0	–	5.0	6.0	2.0	1.0	11.0	–	3.86	3.76
Plagioclase/ Albite	3.0	3.0	5.5	4.0	5.0	4.0	3.0	1.0	3.0	–	3.11	1.69
Muscovite/ Sericite	5.0	7.0	2.0	3.0	6.0	2.0	2.0	8.0	6.0	8.0	4.48	2.98
Biotite	–	3.0	–	–	3.0	–	2.0	–	–	–	0.64	1.08
Chlorite	4.0	2.0	0.5	–	–	–	1.0	2.0	3.0	1.0	2.02	1.74
Haematite/ Limonite	7.0	3.5	4.0	4.0	4.0	4.0	6.0	2.0	4.0	3.0	4.55	3.53
Magnetite	2.0	0.5	–	–	–	–	–	1.0	–	–	0.39	0.65
Chert/Chalcedony	–	2.5	6.0	5.0	–	2.0	2.0	3.0	7.0	4.0	4.77	4.04
Epidote	–	–	–	–	–	–	0.5	–	–	–	0.11	0.31
Pyrite	–	–	–	–	–	–	0.5	–	–	–	0.11	0.26
Pyroxene	–	–	–	–	–	–	–	–	2.0	–	–	–
Garnet	–	–	–	–	–	–	–	–	–	–	–	–
Carbonaceous material	–	–	1.0	–	–	–	–	–	–	–	–	
Tourmaline	–	–	–	–	–	–	0.5	–	–	–	–	
Glauconite	–	0.5	–	–	–	–	–	–	–	–	–	

TABLE – 2

Petrographic Composition of Murree Shales

Sample Nos.	PHS-77-AH-126	PRK-77-MHN-179	PRK-77-MHN-180	PKA-77-MHN-201	PPI-77-FS-134	PHP-77-FS-141	PHP-77-FS-143	PML-77-MFW-161	PTA-77-HN-166	PRK-77-HN-171	PPI-77-HN-174
Localities	Halan-Shamali	Rawala-kot	Rawala-kot	Kohala	Plangi Nala	Haji Pir	Haji Pir	Maili	Topa	Rawala-Kot	Pothi
Coordinates	078930	819806	819806	548073	200 ft. above the nala	119958	116941	212923	728814	819806	
Quartz	15.0	8.0	27.0	7.0	8.0	–	32.0	22.0	20.0	25.0	10.0
Clay/Sericite	70.0	74.0	56.0	72.0	64.0	69.0	35.0	43.0	36.0	25.0	38.0
Calcite	10.0	15.0	–	15.0	20.0	25.0	30.0	25.0	40.0	27.0	45.0
Haematitle/Limonite	2.0	3.0	8.0	6.0	8.0	2.0	2.0	8.0	4.0	10.0	2.0
Albite	–	–	–	–	–	–	–	–	–	–	–
Chlorite	2.0	–	1.0	–	–	2.0	–	–	–	0.5	5.0
Chert/chalcedony	–	–	–	–	–	–	–	3.0	–	–	–
Muscovite/Sericite	–	–	7.5	–	–	–	–	–	–	12.0	–
Magnetite	–	–	–	–	–	–	1.0	–	–	–	–
Carbonaceous material	1.0	–	–	–	–	1.0	–	–	–	0.5	–
K-feldspar	–	–	–	–	–	–	–	–	–	–	–
Pyrite	–	–	–	–	–	1.0	–	–	–	–	–
Glauconite	–	–	–	–	–	–	–	–	–	–	–
Rock feagments	–	–	–	–	–	–	–	–	–	–	–
Tourmaline	–	–	0.5	–	–	–	–	–	–	–	–

TABLE – 2 (contd..)

Sample Nos.	PHS-77-F-99	PHS-77-F-100	PHS-77 F-101	PHS-77-F-102	PHS-77-F-104	PHS-77-F-105	PHS-77 F-106	PHS-77-F-108	PHS-77-F-110	PHS-77-F-111	PHS-77 F-112
Localities	– Halan Shamali –										
Coordinates	172883	172883	172883	164888	164888	162891	162891	158896	158896	156900	154904
Quartz	2.0	20.0	18.0	20.0	10.0	15.0	5.0	12.0	12.0	20.0	20.0
Clay/Sericite	92.0	47.0	56.0	55.0	81.0	48.0	61.0	63.0	65.0	44.0	44.0
Calcite	1.0	25.0	20.0	20.0	3.0	30.0	30.0	20.0	7.0	25.0	30.0
Haematite/Limonite	2.5	3.0	1.0	3.0	1.5	7.0	3.0	5.0	6.0	6.0	4.0
Albite	–	–	–	–	–	–	–	–	–	–	–
Chlorite	–	2.0	1.0	1.0	1.0	–	–	–	2.0	1.0	–
Chert/Chalcedony	–	–	–	–	–	–	–	–	–	–	–
Muscovite/Sericite	2.0	–	1.0	–	0.5	–	–	–	7.0	1.0	–
Magnetite	0.5	–	–	–	–	–	–	–	1.0	3.0	–
Carbonaceous material	–	2.0	2.0	1.0	2.0	–	1.0	–	–	–	–
K-feldspar	–	–	–	–	–	–	–	–	–	–	–
Pyrite	–	–	1.0	–	1.0	–	–	–	–	–	2.0
Glauconite	–	1.0	–	–	–	–	–	–	–	–	–
Rock fragments	–	–	–	–	–	–	–	–	–	–	–
Tourmaline	–	–	–	–	–	–	–	–	–	–	–

TABLE – 2 (contd...)

Sample Nos.	PHS-77-AH-124	PKA-77-MHN-205	PHP-77-AFSH-66	PHP-77-AFSH-72	PHP-77-AFSH-74	PHS-77-F-90	PHS-77-F-92	PHS-77-F-96	PHS-77-F-98		
Localities	Halan-Shamali	Kohala	Haji Pir	Haji Pir	Haji Pir	Halan Shamali	Halan Shamali	Halan Shamali	Halan Shamali		
Coordinates	078930	561059	173955	173962	174965	172882	172882	172883	172882	$\bar{X}$	S.D.
Quartz	10.0	18.0	5.0	35.0	25.0	33.0	15.0	15.0	12.0	16.00	8.90
Clay/Sericite	65.00	44.0	91.0	47.0	58.0	30.0	70.5	40.0	67.0	56.47	16.94
Calcite	–	20.0	–	6.0	–	20.0	10.0	37.0	15.0	18.42	12.48
Haematite/Limonite	5.0	8.0	2.0	4.0	2.0	2.0	1.0	6.0	–	4.16	2.59
Albite	–	–	–	2.0	4.0	3.0	–	–	–	0.29	0.94
Chlorite	–	–	–	3.0	2.0	8.0	–	–	–	1.02	1.74
Chert/Chalcedony	20.0	–	2.0	–	–	–	–	–	1.0	0.84	3.62
Muscovite/Sericite	–	10.0	–	3.0	7.0	2.0	–	–	1.0	1.74	3.29
Magnetite	–	–	–	–	1.0	1.0	2.0	–	1.0	0.34	0.70
Carbonaceous material	–	–	–	–	1.0	–	1.0	–	3.0	0.50	0.81
K-feldspar	–	–	–	–	–	1.0	–	–	–	–	–
Pyrite	–	–	–	–	–	–	0.5	2.0	–	0.24	0.56
Glauconite	–	–	–	–	–	–	–	–	–	–	–
Rock fragments	–	–	–	–	–	–	–	–	–	–	–
Tourmaline	–	–	–	–	–	–	–	–	–	–	–

TABLE – 3

Petrographic Composition of Murree Limestones

Sample Nos.	PHS-77-F-136	PHS-77-F-137A	PHS-77-F-138	PHS-77-FS-148	PLJ-77-HN-178	PTA-77-MHN-183	PBN-77-MHN-190	PKA-77-MHN-208
Localities	Halan Shamali	Halan Shamali	Halan Shamali	Halan Shamali	Lunj	Topa	Bagh (Nawab)	Kohala
Coordinates	172883	172883	172883	063928	814835	728811	686967	566058
Quartz	3.0	5.0	20.0	15.0	13.0	35.0	29.0	27.0
Calcite	89.0	85.0	54.0	60.0	72.0	50.0	60.0	55.0
Clay	4.0	3.0	15.0	15.0	5.0	3.0	2.0	5.0
Plagioclase/albite	–	–	1.0	–	1.0	–	–	–
Muscovite/sericite	–	–	1.0	8.0	1.5	2.0	5.0	2.5
Biotite	–	–	–	–	1.0	–	–	1.0
Chlorite	–	–	3.0	–	–	–	1.0	2.5
Haematite/Limonite	4.0	0.5	2.0	2.0	2.0	10.0	3.0	6.0
Magnetite	–	–	–	–	–	–	–	–
Chert/Chalcedony	–	1.5	–	–	2.0	–	–	–
Pyrite	–	5.0	–	–	–	–	–	–
Garnet	2.0	–	–	–	0.5	–	–	–
Carbonaceous material	–	–	–	–	–	–	–	–
Tourmaline	–	–	–	–	–	–	–	–
Rock fragments	–	–	3.0	–	2.0	–	–	–
K–feldspar	–	–	–	–	1.0	–	–	–

TABLE – 3 (contd...)

Sample Nos.	PDT-77-MHN-211	PDT-77-MHN-218	PLA-77-FH-220	PRK-77-HN-172	PPG-77 HN-176		
Localities	Dhirkot	Dhirkot	Lusdanna	Rawala-kot.	Pak Gali	$\overline{X}$	S.D.
Coordinates	584048	632005	–	819806	805831		
Quartz	6.0	20.0	1.5	7.0	20.0	15.50	10.75
Calcite	73.0	70.0	94.0	85.0	61.0	69.85	14.61
Clay	4.0	–	2.0	3.0	3.0	4.92	4.66
Plagioclase/Albite	–	2.0	–	–	–	–	–
Muscovite/Sericite	–	2.0	–	2.0	–	1.85	2.35
Biotite	–	–	–	–	–	–	–
Chlorite	–	0.5	–	–	–	0.54	1.03
Haematite/Limonite	15.0	3.0	1.0	3.0	15.0	5.12	5.02
Magnetite	–	–	–	–	1.0	–	–
Chert/Chalcedony	2.0	2.0	–	–	–	0.58	0.91
Pyrite	–	–	–	–	–	–	–
Garnet	–	–	–	–	–	–	–
Carbonaceous material	–	–	1.5	–	–	–	–
Tourmaline	–	0.5	–	–	–	–	–
Rock fragments	–	–	–	–	–	–	–
K–feldspar	–	–	–	–	–	–	–

TABLE –4

Chemical Composition of Murree Sandstones

Sample Nos.	PPI-77-FS-130	PPI-77-FS-131	PPI-77-FS-132	PHP-77-FS-140	PHP-77-FS-144	PHP-77-FS-146	PLD-77-FH-147
Localities	Plangi	Plangi	Plangi	Haji Pir	Haji Pir	Haji Pir	Lusdanna
Coordinates	103832	103832	102830	116941	116941	135928	078930
SiO_2	43.53	38.14	63.17	64.87	60.37	61.30	64.40
TiO_2	0.00	0.00	0.10	TR	0.00	0.11	0.09
Al_2O_3	5.09	6.00	7.80	8.18	8.30	10.97	9.21
Fe_2O_3	1.68	3.25	2.26	4.02	4.11	4.33	2.96
MgO	1.09	3.82	0.91	1.90	1.43	2.54	0.90
CaO	26.06	25.62	12.66	9.12	12.51	8.04	10.11
Na_2O	0.34	0.20	0.65	0.50	0.91	0.96	0.77
K2O	0.61	1.50	0.97	1.25	0.68	1.23	1.03
I/L	21.66	22.00	11.19	9.45	11.09	9.79	9.79
Total	100.06	100.53	99.71	99.29	99.40	99.27	99.26

Analysis at: Engineers Combine Limited, Lahore.

Table – 4 (contd....)

SAmple Nos.	PLD-77-FH-144	PLD-77-FH-150	PSI-77-F-152	PHJ-77-F-153	PSS-77-F-154	PBD-77 MHN-188	PBD-77-MHN-189
Localities	Lusda-nna	Lusda-nna	Sheik Sauli	Halan Janubi	Sanli School	Bagh (Dhuli)	Bagh (Dhuli)
Coordinates	063928	048933	200897	175877	180869	905890	881922
SiO_2	44.85	49.51	74.53	72.21	69.51	54.01	47.75
TiO_2	0.26	TR	0.49	0.32	0.34	TR	0.32
Al_2O_3	7.30	6.43	10.50	10.05	10.16	8.00	12.01
Fe_2O_3	4.01	2.82	4.26	3.03	3.67	4.43	5.16
MgO	1.19	1.62	0.97	1.01	1.22	0.97	1.79
CaO	21.18	18.72	2.24	4.61	6.19	16.73	15.41
Na_2O	0.56	0.66	1.01	1.14	0.60	0.54	0.61
K_2O	1.50	1.77	2.10	1.59	1.51	0.89	1.05
I/L	19.45	18.69	3.89	5.91	6.52	14.72	15.75
Total	100.30	100.22	99.99	99.87	99.72	100.29	99.85

Analysis at : Engineers Combine Limited, Lahore.

TABLE – 4 (contd....)

Sample Nos.	PJA-77-H-194	PBI-77-H-195	PMB-77-H-196	PJT-77-H-197A	PPA-77-H-198	PKA-77-MHN-199	PKA-77-MHN-200	PKA-77-MHN-202	PKA-77-MHN-203		
Localities	Jandala	Bangai	Mang	Jaleeth	Patrata	Kohala	Kohala	Kohala	Kohala	$\overline{X}$	S.D.
Coordinates	698624	716899	735196	723885	779926	–	542080	548071	555066		
SiO_2	50.72	54.32	57.53	38.26	65.01	59.72	54.18	41.88	45.06	55.43	10.67
TiO_2	0.00	0.16	0.10	0.11	0.26	0.18	0.24	0.31	–	0.15	0.14
Al_2O_3	8.46	7.58	8.04	14.01	7.74	9.08	7.00	6.85	9.30	8.61	2.03
Fe_2O_3	4.70	4.29	3.99	6.37	3.84	6.28	3.26	4.20	3.95	3.95	1.09
MgO	1.30	1.64	1.89	3.98	1.58	2.92	1.91	2.45	4.70	1.90	1.06
CaO	17.12	14.71	13.24	15.65	9.70	8.99	16.31	22.07	19.64	14.20	6.35
Na_2O	0.54	0.88	0.64	0.51	0.70	0.70	0.37	0.71	0.08	0.63	0.25
K_2O	0.92	0.88	0.69	2.10	0.94	1.35	0.72	0.51	0.036	1.12	0.51
I/L	16.27	15.47	13.74	19.01	9.68	10.83	15.95	20.96	17.07	13.86	5.21
Total	100.03	99.83	99.86	100.00	99.45	100.05	99.94	99.94	100.16		

Analysis at : Engineers Combine Limited, Lahore.

TABLE – 5

Chemical Composition of Murree Shales

Sample Nos.	PHP-77-AFSH-72	PHP-77-AFSH-74	PHS-77-F-90	PHS-77-F-92	PTA-77-HN-166	PRK-77-HN-171	$\bar{X}$	S.D.
Localities	Haji Pir	Haji Pir	Halan Shamali	Halan Shamali	Topa	Rawala-kot		
Coordinates	173963	174965	172882	172882	728814	819806		
SiO_2	62.70	57.84	58.18	54.40	43.21	45.61	53.66	7.67
TiO_2	0.14	0.02	0.00	TR	0.36	0.32	0.14	0.16
Al_2O_3	16.71	17.89	5.26	16.01	16.56	13.67	14.35	4.67
Fe_2O3	8.00	10.84	11.39	9.12	6.95	6.20	8.75	2.09
MnO	0.00	TR	0.11	TR	–	N.D.	0.02	0.04
MgO	4.23	1.45	4.76	4.27	2.66	2.09	3.24	1.36
CaO	1.81	1.81	8.31	4.69	11.33	12.43	6.73	4.67
Na_2O	0.80	0.58	0.28	0.00	2.99	1.08	0.96	1.07
K_2O	1.14	3.01	1.49	2.23	0.39	1.74	1.67	0.90
P_2O_5	–	–	0.28	–	–	–	–	–
I/L	5.03	6.65	9.53	10.77	14.53	16.82	10.56	4.51
Total	99.99	100.00	99.31	99.49	99.36	99.96		

Analysis at: Engineers Combine Limited, Lahore.

TABLE – 6

Chemical Composition of Murree Limestones

Sample Nos.	PHS-77-F-136	PHS-77-F-137	PLD-77-FH-148
Localities	Halan Shamali	Halan Shamali	Lusdanna
Coordinates	172883	172883	063928
SiO_2	4.99	32.52	34.61
TiO_2	–	0.00	0.35
Al_2O_3	3.15	9.46	10.18
Fe_2O_3	3.15	3.99	7.24
MnO	–	–	–
MgO	2.25	2.37	1.86
CaO	47.68	26.98	21.96
Na_2O	0.10	0.37	0.74
K_2O	0.27	0.88	1.98
I/L	39.06	22.98	20.20
Total	100.65	99.55	99.12

Analysis at : Engineers Combine Limted, Lahore.

TABLE – 7

Spectrochemical Composition of Murree Sandstones

Sample Nos.		PAPK-77-HN-181	PTA-77-MHN-182	PTA-77-MHN-183	PTA-77-MHN-184	PTA-77-MHN-185	PBD-77-MHN-186	PBD-77-MHN-187	PKA-77-MHN-206	PKA-77-MHN-207	PKA-77-MHN-208		
Localities		Abbaspur	Topa	Topa	Topa	Topa	Bagh (Dhuli)	Bagh Dhuli)	Kohala	Kohala	Kohala		
Coordinates		035787	728810	728810	728810	728810	945900	905890	561059	565059	566058	$\bar{X}$	S.D.
V	%	.01	0.01	0.01	0.01	0.01	0.01	0.01	0.002	0.002	0.002		
Mo	ppm	–	–	–	–	–	10	–	5.0	5.0	5.0		
Y	ppm	10	5	10	5	5	5	10	10	10	10		
Sc	ppm	5	5	5	2	2	2	1	2	2	2	2.80	1.55
Cu	ppm	5	–	5	1	5	1	–	1	2	5	2.50	2.22
Cr	%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
ZrO_2	%	0.025	0.014	0.025	0.014	0.014	0.015	0.014	0.012	0.012	0.012	0.02	0.01
Ni-Co	ppm	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10		
Pb	ppm	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50		
Ba	%	0.03	0.01	0.08	0.02	0.02	0.03	0.01	0.03	0.03	0.05	0.03	0.02

Analysis at : PINSTECH

TABLE – 8

Spectrochemical Composition of Murrees Shales

Sample Nos.		PHS-77-F-98	PHS-77-F-99	PHS-77-F-100	PHS-77-F-101	PHS-77-F-102	PHS-77 F-104	PHS-77-F-105	PHS-77-F-106		
Localities		Halam Shamali									
Coordinates		172883	172883	172883	172883	164888	164888	162891	162891	$\bar{X}$	S.D.
ZrO_2	%	0.007	0.014	0.014	0.014	0.04	0.002	0.014	0.02		
V	%	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.01	0.01	1.77
Mo	ppm	<5.0	<5	<5	5	5	5	5	5	7.50	5.35
Y	ppm	5	5	5	10	20	–	10	10	8.13	5.94
Sc	ppm	–	10.0	10	20	30	–	10	10	11.25	9.91
Cu	ppm	5.0	<5.0	H 5	5	5	5	5	5		
La	ppm	50	50	50	50	100	–	50	50	50.00	26.73
Cr		–	–	–	–	–	–	–	–	–	–
Ni-Co	ppm	15.0	15.0	15	15	15	–	15	15	10.63	6.23
Pb	ppm	<50	<50	<50	50	50	50	50	50		
Ba	–	–	–	–	–	–	–	–	–		

Analysis at: PINSTECH

TABLE – 9

Spectrochemical Analysis of Murree Limestones

Sample Nos.		PTA-77-MHN-183	PKA-77-MHN-208	PDT-77-MHN-211	PDT-77-MHN-218
Localities		Topa	Kohala	Dhirkot	Dhirkot
Coordinates		728810	566058	584048	651984
ZrO_2	%	0.025	0.012	0.02	0.014
V	%	0.01	0.002	0.01	0.008
Mo	ppm	–	5	15	5
Y	ppm	10	10	10	10
Sc	ppm	5	2	2	2
Cup	ppm	5	5	5	2
Cr	%	<0.01	<0.01	0.01	0.01
Ni-Co	ppm	10	<10	<10	<10
Pb	ppm	<50	<50	<50	<50
Ba	%	0.08	0.05	0.05	0.03
La	ppm	–	–	10	10

Analysis at : PINSTECH

TABLE – 10

Mineral and Rock Composition of Murree and Siwalik Sandstones.

	Murree Rocks		Siwalik Rocks	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Quartz	30.45	10.04	25.43	6.60
Calcite/Carbonate fragments.	25.25	11.94	29.57	6.30
Muscovite/Sericite	4.48	2.98	4.43	1.73
Clay	7.32	3.53	3.00	1.57
Chalcedony	–			–
K-feldspar	3.86	3.76	2.64	2.95
Chlorite	2.02	1.74	2.86	0.89
Albite/Plagioclase	3.11	1.69	2.07	1.69
Haematite/Limonite	4.55	3.53		
Magnetite	0.39	0.65	–	–
Tourmaline	0.10	–	1.32	0.87
Quartzitic rock fragments	1.77	2.0	3.42	1.79
Chert rock/chalcedony fragments	8.27	3.06	10.79	2.67
Other rock fragments	7.25	4.58	5.98	4.00
Pyrite	0.11	0.26	- tr	- tr
Epidote	0.11	0.31	0.64	1.15
Biotite	0.64	1.08	1.57	1.50
	N = 22		N = 14	

the Murree Formation is composed mainly of High grade gneisses and schists, ironstones, granites, syenites, dunites as well as volcanics, slates and phyllites and jaspers/cherts. The Murree rocks do contain phyllites, volcanics and cherts, but they do not contain fragments or minerals characteristic of high grade schists and gneisses. They also do not contain accessories characteristic of syenites and ultrabasics. If volcanics and phyllitic fragments survived transportation from Penensular India to areas like Poonch there is no reason why ironstone, syenitic, granitic and ultrabasic rock fragements could not have survived.

The fact of the matter is that had Murree sandstones been derived from the Cudapah and Dharwar of Peninsular India, rock fragments as well as unstable minerals would certainly have been eliminated. The sandstones would have become well sorted and mature. Only stable minerals and stable accessories would have survived.

It is therefore concluded that the Murree Formation

TABLE–11

A Comparison of the Chemical Composition of Murree Sandstones and Siwalik Sandstones of Poonch.

	Murree Sandstones		Siwalik Sandstones	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
SiO_2	55.43	10.67	49.85	7.22
TiO_2	0.15	0.14	0.14	0.19
Al_2O_3	8.61	2.03	8.77	2.52
Fe_2O_3	3.95	1.09	4.87	1.46
MgO	1.90	1.06	2.71	1.15
CaO	14.20	6.35	15.12	4.05
Na_2O	0.63	0.25	1.14	0.60
K_2O	1.12	0.51	1.42	0.40
I/L	13.86	5.21	15.63	4.27
	N = 23		N = 10	

TABLE–12

A Comparison of Spectrochemical Analysis of Murree and Siwalik Sandstones of Poonch

	Murree Sandstones	Siwalik Sandstones
V	0.002–0.01%	0.002 to 0.01%
Mo	0 to 10 ppm	5 to 20 ppm
Y	5 to 10 ppm	0 to 5 ppm
Sc	1 to 5 ppm	2 to 5 ppm
Cu	0 to 5 ppm	1 to 5 ppm
Cr	0.01 to 0.01%	0.01 to 0.01%
ZrO_2	0.012 to 0.025%	0.012 to 0.035
Ni/Co	10 ppm	10 ppm
Pb	50 ppm	50 ppm
Ba	0.01 to 0.08%	0.03 to 0.08%
	N = 10	N = 5

rocks were not derived from the Penensular India but were, as shown above, derived from the rising Himalayas.

The petrographic compositions (specially of the rock fragments) of sandstones shows that these rocks have been derived from cherty limestones/dolomites, low grade schists and phyllites of pelitic origin, acid to intermediate volcanics (of arc type) and volcanogenic sediments and quartzites.

Such rocks represented the upper parts of the rising low grade metamorphites and volcanic/volcanogenic sediments of the rapidly rising Himalayas.

REFERENCES

Ashraf, M. and Chaudhry, M.N., (1984). **Petrology of Siwalik rocks of Poonch area, Azad Jammu and Kashmir.** *Kashmir Journal Geol.* **Vol. 2, No. 1.**

Chaudhry, M. N., and Ashraf, M., (1980). **The Volcanic rocks of Poonch Distt. Azad Kashmir. Proc. Intern. Commit. Geodynamics, Grp-6, Mtg. Peshawa, Nov. 23-29, (1979):** *Spec. Issue. Geol. Bull. Univ. Peshawar,* **Vol. 13 P 121-128.**

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

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

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ON SOME NEW EARLY JURASSIC MIOSPORES FROM DATTA FORMATION WESTERN SALT RANGE, PAKISTAN

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ABSTRACT.– The present paper deals with the Palynological analysis of the rock samples belonging to Datta Formation of Western Salt Range, Pakistan. 21 samples yielded indentifiable microspores, only new species are systematically described. The palynoflora include 30 new species comprising 18 spore pollen genera, 16 belonging to trilete, I to monolete and 1 to bisaccate. All the assemblages are dominated by pteridophytic spores represented by triletes, where as bisaccates are rarely represented. The miospore assemblages are compared with other parts of the world.

INTRODUCTION

"Variegated shales" of earlier literature, now named Datta Formation is widely developed in the Western part of the Salt Range and in the Trans-Inuds Ranges Surghar, and Shaikh Budin Hills. The palynology of the Datta Formation is very meagre. Rock samples were first palynologically examined by Shah (1955), who reported a rich variety of microfossils which included several kinds of spores, both vesiculate and non vesiculate, few megaspore like bodies, fragments of wood, and several cuticular pieces. The microspores were mostly pteriodophytic and coniferous while cycadophytic pollen grains were rare. Among the large number of cuticules, considerable proportion was of Brachyphylum type, indicating that coniferales were strongly represented in the flora. The same samples were reinvestigated by Jain and Sah 1968 and 1969, who described some additional micro and megaspores which consisted of the following important Mesozoic genera viz *Todisporites, Matonisporites. Trigrisporites, Osmundacidites, Podocarpites* and *Classopollis.*

In 1980 the authors undertook a palaeobotanical expedition to collect samples for palynological investigation from Datta Formation in the Nammal gorge area. The formation is about 150m thick at Nammal gorge. In those parts of formation from where the present material has been collected, the formation consists of variegated (red, maroon, grey and white) sandstone, shale, siltstone and mudstone with irregularly distributed calareous dolomite, carbonaceous ferruginous glass sand and fireclay horizons.

MATERIAL AND METHODS

Sampling was made at different levels of stratigraphically measured sections. To avoid external contamination, the surface of rock shales in every case was dug to a depth of at a least two feet before sampling. Thereafter, the collected samples were immediately transferred into thick polythene bags, which were further placed in accordingly labelled and numbered cotton pouches.

Fifty grams of each sample were crushed to I mm size pieces. The crushed samples were subjected to bulk maceration in commercial nitric acid for four days for complete oxidation. After this, the residual material was washed by distilled water four times, allowing to settle six hours between each decantation. The completely neutralized material was then treated for one minute with 5% potassium hydroxide solution to get rid of humic acids. Material was then neutrailized by several decantations by distilled water. For staining fifteen drops of 2% aquas safranine solution were added to each of the 100 cc of completely macerated and neutrailized material. A drop of stained material from each sample was mounted in a drop of glycerine jelly by using No. 2, 10 mm square cover glasses, margins of cover glasses were sealed with enamel paint. Two hundred slides of each sample were prepared and thoroughly investigated. Photomicrographs were taken with x40 and x 100 objectives respectively with Leitz Ortholux Photomicrocamera, using ORWO Panchromatic

ASA 125, 35 mm film.

EXPRESSION OF FREQUENCIES.

The relative abundance of various miospore species were determined by counting 450–500 specimens in each slide. Relative frequencies of different specie's are ex pressed as follow:

Dominant	:	more than 25%
Abundant	:	more than 15% but less than 25%
Common	:	more than 10% but less than 15%
Rare	:	more than 5% but less than 10%
Very Rare	:	less than 5%

SYSTEMATIC PALYNOLOGY

Anteturma SPORITES H. Potonie, 1893
Turma TRILETES Reinsch emend. Dettmann, 1963
Suprasubturnam ACAVATITRILETES Dettmann, 1963
Subturma AZONOTRILETES Luber emened. Dettmann, 1963
Infraturma LAEVIGATI (Bannie and Kidson) Potonie 1956

Genus LEIOTRILETES Naumova ex Potonie and Kramp, 1954.

Type species: *Leiotriletes sphaerotriangulatus (Loose)* Potonie and Kremp. 1954.

Leiotriletes tolleratus n. sp.
Plate 1 Fig. 8

Holotype: Plate 1 Fig. 8 Slide No. P_{12} A/09/C4
Distribution: rare.
Dimensions: (30–specimens) Equatorial Diameter 55 (62 71/u.

Diagnosis: Miospore, trilete, amb concave triangular, angles flat to rounded, sides concave, polar view, anisopolar, "Y" radii prominently developed, contact area distinct, trilete suture open, arms traversing more than 3/4 of radial length, 23–20 u long, sharply tapering towards equatorial rim. Laesurae open throughout its entire length, 10 u apart in the middle, 5 u apart at tips, lips ± 3 u thick smooth and straight. Laesurae bordered by prominently thickened, clearly defined, raised exinal bands, running almost parallel to it on the prox imal face. Exine laevigate to infra granulate, ± 2 u thick, showing corresponding dark and light patches due to variations in its thickness. Exine forming a dark thick, continuous to discontinuous band of variable thickness, strictly confined to distal equatorial rim. Interradial distal surface laevigate to chagrenate.

Remarks and Comparision.– It is separated from all the species assignable to the genus *Leiotriletes* Naumova) Potonie and Kremp 1954, by well marked raised lips around commissure, representing contact area. It is distinguished from *Phyllothecotriletes rotundus Streel* (1964) figs. 2–3 by its clear cut triangular contour and length of laesurae. While genus *Cyathedites* Couper (1953) P. 27 is distinguished by the absence of dark lips (raised), which is a characteristic feature of the present sporomorph. Although dark unraised lips have been included in the description of *Cyathedits australis* Couper 1953 is Tralau and Artursson (1972) fig. 2 B.

Derivation of Name;– Tolleratus in Latin meaning raised refering to raised labra.

Probable Affinites.–Filicinean.

Slide No. P_{12}A/09/C4.

Leiotriletes naumovaensis n. sp.

Plate 1 Fig. 7

Holotype.	Plate 1 Fig. 7 Slide P_{12}A/9/Cl.
Distribution:	frequent.
Dimensions:	(48-specimens) Equatorial Diameter. 41 (51) 58 u.

Diagnosis.– Miospore, trilete, amb strongly triangular, angles sharply pointed to rounded, sides straight to sharply convex, sometimes with a sharp depression in the center with bulged sides, polar view, anisopolar, tetrad scar strongly developed, contact area corresponds to entire prox imal face. Laesurae closed 20–22 u long, ex tending almost to equator. Commissure bounded by a dark and well defined straight to sinuous ± 3 u wide lips with smooth margins with a tendency of slightly becoming broader before joining the equatorial rim. Exine laevigate to intragranulose, with dark and light areas indicating variations in ex ine thickness, especially along the radial and hemisphere occasionally associated with one or two dark bands, running across the spore just above the center, connecting the two interradial faces.

Remarks and Comparison.– Leiotriletes triviates Naumova (1953) Pl. 45. Fig. 14, is similar in all respects, ex cept the size range, which is 25–30 u, while the f4mm Pakistan specimen is 41 (51) 58 u in size, with well defined labra in contrast to the above mentioned species.

Derivation of Name: After Naumova of USSR.

Probable Afinites: Filicinean.

Slide No: $P_{12}A/9/CI$.

Genus Gleichenidites (Ross) Delcourt and Sprumount.
Type species: (Gleichenidites sinonicus Ross 1949.

Gleicheniidites perforatus n. sp.

Plate 2 Fig. 2

Holotype : Plate 2 Fig. 2 Slide $P_7S/8$ Lower.

Distribution : frequent

Dimensions : (25-specimens) Equatorial Diameter 62 (68) 80 u.

Diagnosis.– Miospore, trilete, anisopolar, amb broadly triangular, angles rounded, sides straight to slightly convex, undulating, trilete suture distinct, contact area well defined, ornamented with closely packed granules. Laesurae closed, 3/4 spore radius, commissure protected by sharply defined ± 2 u high, ± 3 u, sinuous, translucent raised labra. Exine infra granulate to laevigate ± 3 u thick, more dark and thick at angles, forming broadly rounded rather supressed quriculate buldgings, which are further interconnected with each other, through the dark exine of interradial areas. The sides of triangular contact area uniformly decorated with foeveolae, arranged in one alignment. Foevelae 1 x 1.5 u in size. Torus differentiable into three distinct zones. The outer zone is 2 u wide, middle zone hyaline granulate, traceable upto the interadial region. The last and the final zone is represented by dark opaque, thickened exinal band, interconnecting the auriculate buldgings, running parallel to the rows of foveolae. Contact area corresponds to entire proximal face, where it is represented by a comparatively hyaline and more granular exine.

Remarks and Comparison.– *Gleichenidites perforatus* is distinguished from all the known species assignable to *Gleichenidites* in having perforations (Foeveolae) around the triangular contact area.

Probable Affinites: Gleichniaceae.

Slide No: $P_7S/8$ Lower.

Gleichenidites psilatus n. sp.

Plate 3 Fig. 10

Holotype: Plate 3 Fig. 10 Slide $P_7K/Bulk/one/C_3$.

Distribution: rare to very rare.

Dimensions: (19–specimens) Equatorial Diameter 24 (29) 31 u.

Diagnosis.– Miospore, trilete, amb subtriangular, angles rounded, sides straight to convex, polar view, anisopolar, laevigate to infragranulate, tetrad markings and contact area distinct, torate, with short plain field torus, laesurae closed, more than 3/4 radius, commissure thin and sinuous, ± 2 u wide, covered by thin raised labra. Triangular region dark around "Y" marking distinct.

Exine *b* 2 u thick, showing three prominent dark patches, very close to the laesurae in the interradial region, which represent torus. Remaining exine is less dark in colour. Contact area is indicated by more or less translscent exine around laesurae.

Remarks and Comparison.– *Cyathedites minor* couper (1953) Pl. 2, Fig. 13, P. 28 is apparently indentical, but differs in size and in the absence of torus. *Gleichendites* sp. Slsik (1968) Pl. 8, Figs. 6–7 is similar in gross morphology. Slsik catagorically compared his specimen with *Cyathedites minor*, also recorded by Hammen and Burger (1966) P. 176, 12, Slsik's species are significantly different, because they are lobate in contrast to the specimen under discussion. *Concavisporites complicatus* Thomson and Pflug (1953) P. 50, Pl. 1, Figs. 33–34. is separated by the morphology of torus.

Derivation of Name : After psilate exine.

Probable Affinites : Gleichniaceae.

Slide No: P_7L-Bank/one/C_3.

Gleicheniidites sublevare n. sp.

Plate 2. Fig. 1

Holotype: Plate Fig. 1 Slide No. $P_7/11$.

Distribution: Common.

Dimensions: (27-specimens) Equatorial Diameter 51 (56) 62 u.

Diagnosis.– Miospore, trilete, amb triangular, angles rounded, sides straight, polar view, anisopolar, torate, "Y" marking and contact area distinct. Lete open, arms of laesurae extending more than 3/4 of radial length, lips smooth to slightly curved, more wide in the center, sharply pointed towards the radial region Commissure bounded by thick labra, labra straight and 10 u wide, almost equals the length of laesurae. An additional thick dark band encircling the entire labrum represents full fold (Voll-Falten) torus. The edges of torus towards the peripheral end are blunt and rounded. Torus raised upto 6 u which is a distinctive feature.

Exine infragranulose, ± 2 u thick more dark within the radial region, whereas less dark and hyaline along the interradial margins.

Remarks and Comparison.– It resembles *Gleicheniidites voltfalteni* Pl. 21, Figs. 2–3 of the present work, with the only exception of the sides and extermites of the torus which are rounded and blunt in the present specimen.

Derivation of Name: Sublevare (Latin) meaning raised up, after raised torus.

Probable Affinites: Gleichniaceae.

Slide No: 24/291082/14.

Gleicheniidites megasenonicus n. sp.

Plate 2. Fig. 5.

Holotype: Plate 2 Fig. 5 Slide P_7-Bulk/4/C2.

Distribution: abundant.

Dimensions: (27-specimens) Equatorial Diameter 45 (55) 63 u.

Diagnosis.– Miospore, trilete, amb triangular to semilobate, angles rounded, sides concave occasionally associated with marginal folds restricted to interradial region, polar view, anisopolar, torate, "Y" markings distinct, contact area clearly defined represented by the formation of full fold torus. Laesurae extending almost to equator, commissure guarded by 3 u wide, 1 u high, clearly defined, raised sinuous labra. Extermites of laesurae slightly thickened and flattened (upto 5 u), becoming ariculate in appearance and ± 2 u thick, more thick in the interradial region along the equatorial periphery. Laesurae bordered by slightly thickened exinal bands representing narrow band torus, Granulate hyaline area between torus ridges and laesurae arms on the proximal face represent contact area.

Remarks and Comparison.– Concavisporites antweilorensis Thomson in Thomson and Pflug (1953) P. 50, Pl. 1, Fig. 43 is almost similar with the exception of the morophology of torus, the sides of the triangle are more sharply contracted forming a semilobate configuration. On the other hand *Gleicheniidites senonicus* Ross in Norris (1969) Pl. 107, Fig. 16 and 17 is identical in gross morphology, its correct morphographic comparison is difficult, because, Norris did not provide any description. Measurement of Norris figured specimen showed that its size ranges between 20–40 u, while Pakistani specimen touches the upper limits of the size range of this specimen.

Derivation of Name: After its significantly large size and resemblance to the species *G. sinonicus* Ross.

Probable Affinites: Gleicheniaceae.

Slide Nos: P_7 Bulk/4/C2, $P_1$2/03/C1, P_{12}A/C2, P_7 B-Left/6/C3, P_7/11, P_7 Bulk/4/C1.

Gleicheniidites torostriatus n. sp.

Plate 2 Fig. 3

Holotype: Plate 2 Fig. 3 Slide : P_7-Bulk/one/C1.

Distribution: common.

Dimensions: (26-specimens) Equatorial Diamenter 51 (57) 71 u.

Diagnosis.– Miospore, trilete, amb sub triangular, angles rounded, sides straight to concave, polar view, anisopolar, laevigate to granulate, tetrad marking and contact area distinct, torate, full fold torus present, torus ornamented with faintly developed radial bars. Laesurae closed, arms unequal, often extended upto the full length of spore radius, bounded by thick dark flat labra, gradually becoming more flat and wide towards the periphery, ending bluntly in the radial region, Torus represented by dark, crescentric exinal bands, originating from the angles and travelling at a short distance parallel to the laesurae.

Examine ± 1.5 u thick, laevigate to infragranulate, irregularly thickened, contact area represented by translucent exine in between the torus and laesurae.

Remarks and Comparison.– *Gleicheniidites senonicus* Ross 1949 in Playford (1971) Pl. 104, Fig. 12, has somewhat closer morphological relationship, except the size range. Playford's specimen is not fully described, but by measurements, his figured specimen showed ± 28 u size in diameter. The same species recorded by Elsik (1968) Pl. 18, Figs. 8–9 is again small size. The present species is distinct in having faintly developed radiating bars present around the edges of the torus, which is a characteristic feature, not recorded in any of the species assignable to *Gleicheniidites* so far.

Derivation of Name: Due to the presence of the radial bars (striations) around laesurae.

Probable Affinites: Gleichniaceae.

Slide No: P_7K-Bulk/one/C1.

Gleicheniidites volfaltenii n. sp.

Plate 3 Fig. 15

Holotype: Plate 3. Fig. 15 Slide P_7K-Bulk/one C6/.

Distribution: frequent.

Dimensions: (20 - specimens) Equatorial Diameter 50 (55) 61 u.

Diagnosis.– Miospore, trilete, amb triangular, angles rounded, sides slightly convex to straight. Polar view, anisopolar, torate, "Y" markings and contact area prominently visible, laesurae extending upto the entire radial length, joining the angles, closed, arms of laesurae unequal, 38 u to 40 u long. Commissure covered by a thick smooth raised labrum. 3 u thick at the point where the arms of laesurae originate, gradually becoming more wider towards the angles, never exceeding a width of 5 u.

Contact area represented by translucent exinal area present between the labra and torus. Full fold (Voll-Falten) type of torus present, proximal surface is faintly ornamented with sparsely distributed cones, occuring as a dark crescentric band completely encircling the laesurae arms. Exine ± 3 u thick, more dark and fine within the vicinity of angles, and along interradial area.

Remarks and Comparison.– Torus in the present sporomorph is of Voll-Falten type, and proximal surface is finely ornamented with cone•, sparsely distributed outside the torus, which are only discerniable upon careful L-O analysis under oil immersion. This very specimen is abundantly distributed in the Jurassic shales of Nammal Gorge. It has close similarities with ≽leicheniidites torostriatus Pl. 16, Fig. 2 (Vo. II) of the present work. It is differentiated from all other species by the absence of light coloured bars, along the torus, and presence of voltfalten type of torus.

Derivation of Name: After Full Fold (Volt-Falten) type of torus.

Probable Affinites: Gleichniaceae.

Slide No: P_7-Bulk/one/C5, P_7K-Bulk/one/C4.

Gleicheniidites torodecoratus n. sp.

Plate. 2 Fig. 4

Holotype: Plate. 2 Fig. 4 Slide: P_7K-Bulk/one/16

Distribution: rare.

Dimensions: (20-specimens) Equatorial Diameter 41 (48) 58 u.

Diagnosis:– Miospore, trilete, amb triangular, angles rounded, sides convex to straight, exhibiting slight undulations along the outer margin of equatorial rim, off polar view, anisopolar, trilete suture clearly defined, contact area distinct, laesurae closed, arms 21 to 25 u long, straight and smooth, extending upto the angles, some times crossing the equatorial rim and extended upto the distal hemisphere. Commissure bounded by low, flattened, clearly defined labra of more or less uniform thickness (± 2.5 u) sometimes one laesurae arm slightly thickened, than the remaining two. Exine of interradial and proximal surface relatively thin and hyaline.

Remarks and Comparison:– The sporomorph is distinguished from rest of the species described in this work, and elsewhere, due to the following reasons. Firstly, the ornamentation is faintly intragranulate, and secondly the torus is ornamented with sparsely distributed perforations and apicules.

Derivation of Name: After decorated torus.

Probable Affinites: Gleichniaceae.

Slide No: P_7K-Bulk/one/C6

Gleicheniidites foveolatus n.sp.

Plate. 3 Fig, 6

Holotype: Plate. 3 Fig. 6. Slide P_7K-Bulk/one/C5.

Distribution: frequent.

Dimensions: (31-specimens) Equatorial Diameter 62 (69) 80 u.

Diagnosis:– Miospore, trilete, amb triangular, angles rounded to slightly pointed, sides straight to slightly convex, anisopolar, "Y" radii and contact area distinct, trilete suture partly open, arms forming a small triangular vertex, arms of laesurae more than 3/4 spore radius commissure smooth, straight, protected by ± 3 u wide straight to sinuous translucent low labra. Labra accompanied by narrow band torus, bearing striated radial bands, inter-mixed with foeveolae. Exine ± 2 u thick, foveolate, exine of radial region extraordinarily dark and thick, imparting dark colour and appearing as equidimentional homogenous black patches at each angle. Exine of proximal pole and distal peripheral interradial region thin and hyaline, with sharply defined, comparatively coarser granulations. Granulations 0.5 to 1 u in diameter. Contact area represented by dark ex inal bands bordering or running parallel at a short distance above laesurae.

Remarks and Comparison:– *Gleicheniidites senonicus* Ross (1949) in Playford (1971) Pl. 104, Fig.12, *Gleicheniidites torostriatus* Plate 19, Fig. 1, 2,in the present work are differentiated by the absence of narrow band torus and partly open laesurae, forming a smaller triangular vertex. Also, it is differentiated on the basis of ornamentation of ex ine, which is foveolate.

Derivation of Name: After foveolate ex ine.

Probable Affinites: Gleichniaceae.

Slide No: P_7K-Bulk/one/05.

Genus Punctatisporites (Ibrahim) Poronie and Kremp 1954.

Type species: *Punctatisporites punctatus* Ibrahim 1933.

Punctatisporites nammlensis n. sp.

Plate. 3 Fig. 1

Holotype; Plate. 3 Fig. 1 Slide No. P_{12}A/14/Cl.
Distribution: rare.

Dimensions: (16-specimens) Equatorial Diameter 36 (42) 45 u.

Diagnosis:– Miospore, trilete, amb spatulate, originally sub-spherical, polar view, anisopolar, microgranulose to punctuate, tetrad scar prominent, contact area distinct, laesurae open along its entire length, ± 13 u long, and radius, ending sharply towards the peripheral region. Contact area represented by dark ex inal bands, associated with the lips of laesurae, Ex ine ± 2 u thick, irregularly ornamented with dark and light areas, ex hibiting corrosion pores of varying degrees, compressional folds absent.

Remarks and Comparison:– The diagnosis given for *Punctatisporites irrasus* Hacquebard 1957, in Hibbert and Lacey (1969) P 421, Pl. 78, Fig. 1, is identical, but differs greatly in size. *Punctatisporites punctatus* Ibrahim 1932 in Smith and Butterworth (1967) Pl. 1, Figs. 19–20 can be compared but again size and rough spore margins are the barrier *Punctatisporites priscus* Bharadwaj and Salujha 1965 in Foster (1975) P. 127, Pl. 1, Figs. 11-12 is separated by its widely size open triradiate marking.

Derivation of Name: After Nammal gorge Western Salt Range Pakistan.

Probable Affinites: Flicinean.

Slide No: P_{12}A/14/Cl.

Punctatisporites distinctus n.sp.

Plate 3 Fig. 12

Holotype: Plate 3 Fig. 12 Slide No. P_7K-Bulk/one/5.

Distribution: rare.

Dimensions: (32-specimens) Equatorial Diameter (67) 75 u.

Diagnosis:– Miospore, trilete, amb spherical, angles rounded sides straight to convex, polar view, anisopolar, granulose to punctate, "Y" scar and contact area distinct, laesurae 22 to 24 u long, closed, commissure thin and bounded by an ex traordinarily thick smooth and straight labra. Ex ine ± 2 u long, closed, commissure thin and bounded by an ex traordinarily thick smooth and straight labra. Ex ine ± 2 u thick, intrapunctate, irregularly ornamented, sometimes hyaline or transparent around labra indicating contact area. The ex ine of radial and interradial region more darker than the central hyaline portion, appearing in the form of a kark band of uniform thickness, especially, the ex ine of radial region is represented by deep black homogenous patches, which are in continuity, or are connected with the thick labra.

Remarks and Comparison:– Genus *Punctatisporites* (Ibrahim) Potonie and Kremp 1954 has the qualities to accept this sporomorph with the ex ception of distinct contact area which is somewhat hyaline and the spore is anisopolar. It is separated from all the species assignable to the genus *Punctatisporites* by its peculair ornamentational pattern of structural elements (Punctuations), which are comparatively larger around "Y" marking, while they are denser and closely packed towards the peripheral region forming demarcation between the prox imal contact area and rest of the spore.

Derivation of Name: After distinct contact area.

Probable Affinites: Filicinean.

Slide No: P_7K-Bulk/one/5.

Punctatisporites warchhaensis n. sp.

Plate 3 Fig. 2

Holotype: Plate 3 Fig. 2 Slide No. $SM_2BB/5$.

Distribution: frequent.

Diamensions: (34-specimens) Equatorial Diameter 74 (88) 102 u.

Diagnosis:– Moispore, trilete, oblique polar view, anisopolar, amb ± circular, "Y" marking distinct, laesurae 50-40 u long, ± 3 u wide, ± 4 u apart, arms of laesurae extending full length of spore radius, slightly crescentric in orientation. Commissure raised 2–3 u high, slightly radially divergent. Contact area indistinct, exine ± 1 u thick, laevigate to infragranulate, exhibiting differentially shaded areas, due to uneven thickness.

Remarks and Comparison:– The described specimen has similarities with the diagnosis given for *Leotriletes blairatholensis* Foster (1975), isolated from Blairthol, Lower Permian Coal Measures of Central Queensland, Australia, Fosters Fig. 1 and 2 (Pl. 1) are not justifiable to be considered as laevigate. The Pakistani spores isolated so far are almost circular in outline, exine being devoid of any clear cut ornamentation, thus the described specimen is more closely comparable with the diagnosis given for *Punctatisporites punctatus* (Ibrahim) Potonie and Kremp 1954, but it differs slightly in ornamentation. It may have certain similarities with *Punctatisporites gretensis* Blame and Hennely (1956), from the Lower Permian of Australia. A similar specimen was also described by Foster (1975), giving an equatorial diameter of 63(70) 100 u, but his figured specimen show relatively wider labra in relation to the present specimen. Although, the described specimen fall into the dimensions given for *Punctatisporites fungosus* Blame (1970), but is separated by the thickness of its exine, and arms of laesurae, which are of equal length.

Derivation of Name: After the village of Warchha, Western Salt Range, Pakistan.

Probable Affinites: Filicinean.

Slide No. $SM_2BB/5$.

Genus Concavisporites (Pflug) Delcourt and Sprumont 1955.

Type of species: Concavisporites rugulatus Pflug in Thomson and Pflug 1953.

Concavisporites auriculatus n. sp.

Plate 3 Fig. 8

Holotype: Plate 3 Fig. 8 Slide No. P_7-Bulk/5/C2.

Distribution: rare.

Dimensions: (16-specimens) Equatorial Diameter 3 35 (41) 49 u.

Diagnosis:– Miospore, trilete, amb triangular, torate, angles flat, ends slightly elevated, forming triaugular buldgings, polar view, anisopolar, auriculate, "Y" marking clearly defined, contact area distinct, laesurae arms ± 18 u, more than ½ radius, ending abruptly, commissure guarded by 2–3 u thick, ±2 u high, raised, sinuous, sometimes twisted, clearly defined labra. Labra forming a thick nodular structure at the point of origin of trilete suture. Full fold torus present. Exine 2–3 u thick, relatively thick and dark around entire equatorial rim, showing dark and thick peculiar straight bands present at the base of each angle interconnecting inter radial margins opposite to each other. Exine in the immediate vicinity of laesurae arms relatively thin and translucent, contact area represented by dark crescentric exinal bands running almost parallel to "Y" radii on the proximal face. Auriculae 5–7 u high, 10–12 u broad at base. Distal interradial margins undulating, with smooth edges, due to differentially thickened exinal bands.

Remarks and Comparison:– *Concavisporites juriensis* Blame, in Norris (1969) Pl. 102, Figs, 6–7, is more or less identical in its gross morphology and measures about ± 20–30 u (calculated from Norris's figured specimen), although complete description of which was not available. Thomson and Pflug (1953) have described eight species of the genus, out of which *Convavisporites obtusangulus* (Potonie) Pl. 1, Figs, 35–42, P. 50, is somewhat comparable, with the exception of full fold torus and well defined auriculae, which are absent in their sporomorph. *Concavisporites crassus* Venkatachala, Kar and Raza (1969) described from the Upper Jurrassic of Kutch (India) is again dissimilar in many respects.

Derivation of Name: After auriculate thickenings at the angles.

Probable Affinites: Not known probably Filicinean.

Slide No: P_7-Bulk/5/C2.

Genus Divisisporites Thomson and Pflug 1953.

Type species: *Divisisporites divisus* Pflug in Thomson and Pflug 1953. Pl. 1, Fig. 59.

Divisisporites balmensis n. sp.

Plate 1 Fig. 9

Holotype: Plate 1 Fig. 9 Slide No. P_7K-Bulk/one/3.
Distribution: frequent.

Dimensions: (34-specimens) Equatorial Diameter 41 (48) 62 u.

Diagnosis:– Amb triangular, angles broadly rounded, sides straight to concave, with undulations of varying degrees, polar view, anisopolar, "Y" marking distinct, contact area well defined, laesurae closed, arms extending upto the equatorial rim. Arms of laesure ± u long, 3 u wide in the center, gradually expanding, bifurcating, and becoming flat within the vicinity of radial region before joining the equatorial rim. Commissure protected by low to slightly raised smooth edged sinuous labra. Exine ± 2 u thick, more thick and dark on distal surface, along the interradial equatorial margins and species. Interradial exine of distal pole sometimes exhibiting faintly developed longitudi-nally placed, weak exinal fold or undulations compareable to rugulae. Strongly to weakly developed dark excentric bands on the proximal face, running almost parallel to laesurae represent torus. Torus attributable to short plane field type of torus. Weakly developed compressional folds associated with interradial equatorial periphery were also found in some cases.

Remarks and Comparison:– *Divisisporites nammlensis* Jain and Sah (1968) P. 127, Pl. 1, Figs. 3–4 has certain similarities with the present described sporomorph, but it differs in size range, and also due to the presence of short plane field torus and distinct labrum, which extends along the "Y" marking upto the equator. Also the ray ends are bifurcated which are rather blunt and ill defined. D. ovalis Sah and Jain 1965 in Jain and Sah (1968) is small sized as compared to the Pakistani specimen. *Divisisporites* species described by Norris (1969) Pl. 102, Fig. 17, is clearly differentiated by its comparatively thicker exine. All the species described by Thomson and Pflug (1953) are either different in size range or other morphographic features, such as ornamentational pattern of exine and morophology of "Y" marking.

Derivation of Name: After B. E. Balme of University of Brisbane Western Australia.

Probable Affinites: Filicinean.

Slide No: P_7K-Bulk/one/C3, P_7-Left/6/C5.

Infraturma Apiculati (Bennie and Kidston) Potonie 1956 Subinfraturma Granulati Bybova and Jachowicz 1957.

Genus Cadiospora (Kosanke) Venkatachala and Bharadwaj 1964.

Type species: *Cadiospora magna* Kosanke 1950.

Cadiospora granulatus n. sp.

Plate 3 Fig. 9

Holotype: Plate 3 Fig. 9 Slide No. P_7B-Left/06/03.

Distribution: frequent.

Dimensions: (20-specimens) Equatorial Diameter 59 (67) 77 u.

Diagnosis:– Miospore, trilete, anisopolar, amb triangular, angles broadly rounded to narrow rounded. Proximal surface rather flat trilete rays distinctly visible, contact area discemiable, laesurae closed, arms of laesurace ± 31 u long, extending more than 3/4 spore radius, sometimes touching equator, commissure bordered by ± 2 u wide straight to sinuous slightly raised labra, connected with arculae curvaturae like band above equator. Contact area represented by hyaline exine around "Y" marking, which demarcates contact area. Exine ± 2 u.thick, infragranulate comparatively thickened at the angles forming arculate like structures, and comparatively darkened in the radial interradial peripheral region, associated with relatively small and thinly populated granules of variable dimensions.

Remarks and Comparison.– *Cadiospora megna* Kosanke (1950) P. 50, Pl. 16, Fig. 1, isolated from the Pennsylvanian coals of Illinois, has somewhat nearest comparison, as far as gross morphology is concerned, but is significantly larger in size as compared to the specimen under discussion. While discussing the morphology of *Cadiospora magna* Kosanke has stated on page 50: "The apex of the rays (trilete apperture) is open or closed, the rays devoid as the terminus of the rays and interradially becomes the arcuate ridge, the spore coat is minutely punctate to finally granlose and measure 6–8 u in thickness". In the present sporomorph the exine is relatively thinner as compared to Kosanke's species.

Butterworth and Williams (1954) has expressed their views about the ornamentation and other morphographic features of the British species *C. sphaera* on P. 76, by saying that "the distal surface is laevigate, but subsequent examination of British specimen shows that the exine to be densly granulate", for this reason, they suggested that there is no basis to recognise *C. sphaera* as a separate species.

The specimen under discussion can easily be differenciated from all the known species assignable to the genus

Cadiospora Kosanke (1950), in having well developed arcuate ridges like structures and infragranulate exine.

Derivation of Name:	After infragranulate spordoerm.
Probable Affinites:	Not known.
Slide No:	P78-Left/6/3.
	Infratuma Murornati Potonie and Kremp 1954.
	Genus Convulutispora Hoffmeister, Staplin, and Malloy 1955.
Type species:	Convoltispora florida Hoffmeister, Staplin and Malloy 1955.
	Plate 1 Fig. 4.
Holotype:	Plate 1 Fig. 4 Slide: P12A/14/C2.
Distribution:	frequent.
Dimensions:	(38-specimens) Equatorial Diameter 41 (48) 56. u.

Diagnosis.– Miospore, trilete, amb rounded triangular, polar view, anisopolar, "Y" marking distinct, contact area not detectable, laesurae closed, arms of trilete marking ± 19 u long, almost reaching equator, commissure protected by 2–3 u thick, 2 u high, slightly wavy, smooth edged labra, sometimes tips of laesurae dialated and flattened before joining the equatorial rim Exine interareticulate slightly curvimurate, muri well defined, 2–3 u thick, 2 u 'high, forming irregular meshes, with a tendency of forming larger lumina on the distal radial and interradial region, on proximal hemisphere. Lumina 8–10 u long, 4–6 u broad, Exine along equatorial rim more thickened and darkened associated with frequent undulations.

Remarks and Comparison.– It is separated from all the known species assignable to the Genus *Convolutispora* by its curvimurate exine, with a tendency of forming larger lumina on the distal radial and interradial region on proximal hemisphere, and also by the tips of laesurae which becomes dilated and flattened before joining equator. The members of the genus *Convolutispora* Hoffmeister, Staplin and Malloy 1955 were not even recorded by Balme (1970) or Jain and Sah (1968) from the Paleozoic or Mesozoic sediments of the Salt Range.

Derivation of Name	:	After distinct muri.
Probable Affinites	:	Filicinean.
Slide No	:	P_{12}A/14/CI

	Infraturma Muromati Potonie and Kremp 1954.
	Genus Microeticulatisporites (Knox) Potonie and Kremp non sensu Bharadwaj.
Type species:	*Microteticulatisporites Lacunosus* (Ibrahim) Knox 1950.
	Microreticulatisporites emphaniatus n. sp.
	Plate 1 Fig. 5
Holotype:	Plate 1 Fig. 5 Slide No. P_{12}A/12/C3.
Distribution:	frequent.
Dimensions:	(17-specimens) Equatorial Diameter 50 (51) 55 u.

Diagnosis.– Miospore, trilete, amb rounded triangular, polar view, anisopolar, contact area detectable, "Y" marking clearly defined, reticulate, laesurae closed, arms ± 23 u long, always reaching equator, ending abruptly, commissure bordered by irregularly thick, sinuous, low to raised labra where thickness varies from 2 u to 4 u, labra being thickest in the center at the point of origin og "Y" marking. Margins of labra not clearly defined. Exine 3–6 u thick intrareticulate, composed of irregular compact to loosely arranged Muri, encircling differentially shaped and spaced lumina. Muri curvimurate, radially oriented, straight to highly branched, 2–5 u thick, muri enclosing vermiculate lumina of variable dimensions, 5–10 u long, 2–4 u wide.

Muri more closely fitted on proximal face, especially within the vicinity of point of origin of trilete arms, where they are so densly packed that lumina are hardly visible, or totally absent. Muri terminating beyond equatorial periphery, projecting radially as small rodlets (2–3 u long ± 3 u wide) from the entire equatorial rim in optical section. At some places the bases of such rodlets fused forming a dark, smooth, continuous to discontinuous, equatorially thickened band.

Remarks and Comparison.– *Microreticulatisporites bharadwajii* Pl. 30, Figs. 2, 3, 4, of the present work is comparable with the described specimen, with the exception of the curvimurate muri, which are oriented and projects radially. It can be separated from all the known species assignable to the genus *Microreticulatisporites* by its radially oriented curvimurate muri, a feature, which can be compared with the radially arranged apicules in *Emphamisporites decoratus* Allen (1965).

Derivation of Name: After curvimurate muri, a feature also possessed by the spores belonging to the genus *Emphanisporites?*

Probable Affinites: Sphenophyllales? Hepaticae.

Slide No: $P_{12}A/12/C3$.

Microreticulatisporites bharadwajii n. sp.

Plate 1 Fig. 6

Holotype: Plate 1 Fig. 6 Slide P_7B-Left/6/C2.

Distribution: rare.

Dimensions: (26-specimens) Equatorial Duanebter 43 (46) 58 u.

Diagnosis.– Miospore, trilete, amb rounded triangular to subspherical, polar view, anisopolar equatorially thickened, "Y" radii not always detectable, faintly orweakly developed contact area corresponds to entire proximal face, laesurae arms ± 20 u long, travelling upto equator, slightly or considerably dilated and flattened before joining equatorial periphery. Commissure guarded by straight labra possessing notched margin, labra ± 2 wide, 1–2 u high, more wide and thickened at tips, Exine 3–5 u thick, reticulate, reticulations not homogenous, muri straight to slightly arched, enclosing regular to irregular lumina of variable dimensions, muri 2–4 u thick, lumina 2–4 u long, 2–5 u wide, becoming more broad to elongated along distal equatorial region, lumina highly reduced or absent along radial region, replaced by tightly packed muri, giving rise to darkened and thickened exinal patches, in that area.

Tips of muri rounded to sharply pointed, projecting radially beyond equator, exine equatorially thickened, periphery notched.

Remarks and Comparison.– *Microreticulatisporites diatretus* Norris (1969) PP. 589, Pl. 105, Figs. 12–15, appears to be similar in gross morphology, including size range, but can be differentiated because of lacunae and muri of different sizes. Genus *Microreticulatisporites* has not so far been recorded from Jurassic deposits of Pakistan (cf. Balme 1970, Jain and Sah 1968). Six different species of the genus have been mentioned in Smith and Butterworth (1967) all of which are different.

Derivation of Name: After D. C. Bharadwaj of Birbal Shahni Institute of Paleobotany Lucknow (India).

Probable Affinites: Sphenophyllales? Hepaticae.

Slide No: P_7B-Left/06/C2, P_7K-Bulk/1/C3, $P_{12}A/12/C1$.

Genus Foveosporites Balme 1957.

Type species: *Foveosporites canalis* Balme 1957.

Foveosporites distinctus

Foveosporites distinctus n. sp.

Plate 3 Fig. 5

Holotype: Plate 3 Fig. 5 Slide No. P_7K-Bulk/One/C3.

Distribution; rare.

Dimensions: (20-specimens) Equatorial Diameter 40 (39) 38 u.

Subturma Zonotriletes Waltz 1935.

Infraturma Auriculati (Schoph) Dettmann 1963.

Genus Triquitrites (Wilson and Coe) Potonie and Kremp 1954.

Type species: *Triquitrites arculatus* Wilson and Coew 1940.

Triquitrites meharbanicus n. sp.

Plate 3 Fig. 4

Holotype: Plate 3 Fig. 4 Slide: P_7 K-Bulk/one/C2.

Distribution: frequent.

Dimensions: (20-specimens) Equatorial Diameter 61 (67) 81 u.

Diagnosis.– Miospore, trilete, amb triangular, angles broadly rounded to slightly pointed in some cases, margins wavy, polar view, anisopolar, trilete suture and contact area marked by comparatively thin and translucent exine bordering laesurae. Laesurae open, arms of laesuae ± 26 u long, extending more than ¾ spore radius, lips smooth, straight upto 4 u wide, ± 1 u high, exine intragranulate to foveolate on proximal surface, foveolae differently shaped and variable in size, ± 3 u thick, Exine of radial region relatively thickened and darkened, slightly bulged, forming broadly rounded auriculate structures of more or less equal dimensions at the angles. Auriculae are interconnected with dark coloured exinous band.

Remarks and Comparison.– Balme (1970) has described three species of the Genus *Triquitrisporites* which are totally different from the specimen under discussion. Presenting his views he says: –

> "*Triquitrisporites* ranges from the Touranaisian, but are most abundant in West-phalian deposits in which some species are stratigraphically important, since the review by Sullivan 'Neves was prepared, additional species of *Triquitrisporites* have been discribed by Ouyang (1962) from Lungtan series in South China, the age of these deposits is in dispute but they have been regarded as Permian, even late Permian. Ouyang drew attenion to the noteable similarities between his assemblage and those from the Upper Westphalian of Europe and his palylonogical evidence points towards a late Carboniferous rather than late Permian, *Triquitrisporites* has rarely been recorded from sediments younger than Stephanian".

Pakistani spores are undoubtedly auriculate, somewhat triangular, with convex to plane sides, and, moreover, the auriculae has a tendency to protrude, a feature which is detectable only upon careful L-O analysis under oil immersion. On the other hand, Balme's (1970) species are somewhat lobate in appearance, several species of the genus Camptotriletes described by Naumova (1953) may have some superficial resemblance, but they are not comparable due to the differences in their ornamentational pattern of exine. T. *protensus* Kosanke (1950) P. 40, Pl. 8., Fig. 2 and T. tribullatus (Ibrahim) in Schopf Wilson and Bentall (1944) P. 47 are different as far as their size range is concerned. They are rather small in size, and also differs in the morphology of arcuate ridges. The auriculae in the specimen under discussion are not sharply bludgeing and are further interconnected with each other through fine exinous demarcations. Ornamentation consists of variously distributed and oriented foveolae, which is also its most outstanding distinctive feature. Genus *Tripartites* Shemel 1950 cannot be compared because spores belonging to this genus are although ariculate, but are quite different in having somewhat spatulate or trilobed amb. Probably it is the first time that Genus *Triquitries* Wilson and Goe is being reported from the Jurassic strata of Pakistan.

Derivation of Name: After Meharban Ali Khan of Rampur, U.P. India.

Probable Affinites: Filicinean.

Slide No: P_7K-Bulk/one/C2.

Genus matonisporites (Couper) Dattmann 1963.

Type species: Not known.

Matonisporites infragranulatus **n. sp.**

Plate 2 Fig. 6.

Holotype: Plate 2 Fig. 6 Slide No. P_7B-Left/6/C5

Distribution: rare.

Dimensions: (16-specimens) Equatorial Diameter 41 (52) 72 u.

Diagnosis.– Miospore, trilete, amb triangular, angles rounded, concex to straight, polar view, anisopolar, "Y" marking and contact area distinct, torate, laesurae 11 u long, arms of laesurae open, lips smooth, extending ½ of the radial length, curved and sharply tappering towards the equatorial rim. Commissure guarded by 10m thick labra, torus distinct, short plain field type of torus present outside the labrum. Exine 2.5 u thick, laevigate to infragranulate. Radial exine more darker than interradial exine, which is light in colour.

Remarks and Comparison.– *Cyathedites autralus* Couper (1953) P. 27, Pl. 2, Fig. 12, is apparently indentical (including size range), but the Pakistani specimen is clearly differentiated by possessing well developed torus. Matonisporites granulatus Kimyai 1968 in Kimyai (1974) Pl. 1, Fig. 3, has closest comparison including size range, shape and external morphology, but differs slightly in ornamentational pattern of the exine.

Derivation of Name: After infragramularexine.

Probable Affinites: Matoniaceae.

Slide No: P_7B-Left/6/C5, P_7K-Bulk/one/C4.

Matonisporites hafizensis

Plate 3 Fig. 13

Holotype:	**Plate e Fig. 13 Slide P_7-Bulk/one/ C2.**
Distribution:	**rare.**
Dimensions:	**(21-specimens) Equatorial Diameter 52 (53) 55 u.**

Diagnosis.— Miospore, trilete, amb straight triangular, angles rounded, sides sometimes slightly convex, polar view, anisopolar, "Y" suture and contact area clearly defined, contact area distinct, trilete arms ± 20 u long, commissure protected by ± 2 u thick, slightly raised, sinuous, smooth edged labra. Exine thickness variable, exine on proximal face within the vicinity of trilete marking laevigate to granulate, exine of distal radial and interradial region granulate, grana uniformly distributed ± 0.5 u in diameter. Exine comparatively thick and dark, exhibiting no structural details and appearing like ± 12 u thick equatorial collar. Small portion of exine of distal interradial region along equatorial periphery is laevigate. Exine 1.5 u thick.

Remarks and Comparison.— *Matonisporites impensus* Hedlund 1966 P. 13, Pl. 2, Fig. 1, can easily be differentiated on the basis of its amb, which is ± circular, where as the specimen under discussion is triangular in outline. *Matonisporites* sp. A. Romans (1975) Pl. 4, Fig. 9, and *Matonisporites crassiangulatus* Balme) level Cartte 1964, in Tralau (1971), and the other specimens described as new species in the present work are again significantly dissimilar in gross morphology, including over all contour and morphology of exine.

Derivation of Name:	**After Hafiz M. Ilyas of the Deptt. of Botany, University of the Punjab, Lahore. (Pkistan).**
Probable Affinites:	**Matoniaceae.**
Slide Nos:	**P_7-Bulk/1/C2, P_7-Bulk/1/C3.**

Genus Zosterosporites Kosanke 1973.

Type species:	***Zosterosporites triangulatus* Kosanke 1973.**
Type species:	***Zosterosporites triangulatus* Kosanke 1973.**

***Zosterosporites ashfaqii* n. sp.**

Plate 1 Fig. 1

Holotype:	**Plate 1 Fig. 1 Slide: P_7-Bulk/5/ C1.**
Distribution:	**very rare.**
Dimensions:	**(18-specimens) Equatorial Diameter 35 (38) 45 u.**

Diagnosis.— Miospore, trilete, amb concave triangular, angles flat to bulbous, sides concave, with carrying degrees of undulations, polar view, anisopolar, "Y" degrees of undulations, polar view, anisopolar, "Y" marking clearly defined, contact area corresponds to entire proximal face, laesurae closed, arms extending almost to equator, commissure guarded by ± 3 u wide, ± wide, ± 2 u high, raised, slightly sinuous well defined labra. Exine ± 2 u thick, laevigate to infragranulate, comparatively thickened and darker in the radial and interradial region along the distal pole, exine within the vicinity of trilete marking on the proximal face laevigate, exhibiting different shades due to variations in thickness, compression folds common, normally restricted to the equatorial species and interradial region.

Remarks and Comparison.— The monotypic species Zostersporites triangularis Kosanke (1973) Pl. 1, Holotype No. 1, and 2, paratypes 3–6, is almost similar except the size range, which is 35–34 u based on 29 specimens, whereas the size range of Pakistani specimen is 35(38) 45 u. The sporomorph under discussion is further differentiated from *Zosterosporites triangularis* Kosanke (1973) in having infragranulate exine, and sinuous labra with bulbous extermites, these features are absent in Kosanke's species.

Derivation of Name:	**After the name of Ashafq Ahmad, Director, Central Urdu Board, Lahore, Pakistan.**
Probable Affinites:	**Pteridophytic.**
Slide No.	**P_7-Bulk/5/C1.**

***Infratuma Cingulati* (Potonie and Klaus) Dettmann**
Genus *Cingulatisporites* Thomson, in Thomson and Pflug 1953.

Type species:	***Cingulatisporites levispeciosus* Thomson in Thomson and Pflug 1953.**

***Cingulatisporites abbasii* n. sp.**

Plate 1 Fig. 3

Holotype:	**Plate 1 Fig. 3. Slide: P_7K-Bulk/one-3.**

Distributions: frequent.

Dimensions: (28-specimens) Equatorial Diameter 41 (48) 58 u.

Diagnosis.— Miospore, trilete, amb triangular, angles rounded, sides straight, cingulate, polar view, anisopolar, "Y" marking and contact area prominently visible, laesurae open, arms of laesurae extending more than ¾ of radial length, sometimes reaching the equatorial rim. Lips smooth to very slightly sinuous. Lips ± 14 u apart in the center In most of the specimens the so called labral flaps were pushed apart and folded back. Exine ± 3 u thick, showing radially placed light bands within the vicinity of interradial region, the undulations can be compared with rugulae. In some of the specimens this feature appeared to be a regular feature, but in most of the cases it was less numerous and even entirely absent.

Remarks and Comparison.— *Cingulatisporites levispeciosus* Pflug, in Thomson and Pflug (1953) P. 58, Pl. 1, Fig. 16, is similar in size range, but can be easily differentiated on the basis of the morophology of cingulum. *Cingulatisporites persicus* Kimyai (1974) Pl. 1, Figs. 10-11 has nearest comparison, specifically Kimyai has not given he size range, and even the magnification (X 300) provided by him seems to be incorrect. The present writer has very carefully studied Kimysi's figured specimens (Plates 1 and 2), which showed a magnificant of + X 600. If this is accepted as correct, then Kimyai's specimens must have an estimated size of 65–68 u in maximequatorial diameter, which almost fits in the size range of the present sporomorph. Nevertheless, the Pakistani sporomorph under discussion is significantly different from Kimysi's species and other species assignable to *Cingulatisporites* due to its light and dark bars, appearing as radially placed alternate crests and throughs in the interradial region of the cingulum.

Derivation of Name: After Anis Ahmad Abbasi, Associate professor of Geomorphology, Department of Geography, Punjab University, Lahore (Pakistan).

Probable Affinites: Selaginallacene.
Slide No.: P_7K-Bulk/one/C3.

Suprasubturma Laminatitriletes Smith and Butterworth 1967

Subturma Zonolaminatitriletes Smith and Butterworth 1967

Infraturma Cingulati Smith and Butterworth 1967

Genus Densoisporites (Berry) Butterworth, Jansonius, Smith and Staplin 1964.

Type species: *Densoisporites convensis* **Berry 1937.**

Densoisporites tobraensis **n. sp.**

Plate 3 Fig. 7

Holotype: Plate 3 Fig. 7 Slide P_{12}A/12/C3.

Distribution: frequent.

Diensions: (18-specimens) Equatorial Diameter 30 (34) 42 u.

Diagnosis:— Miospore, trilete, amb triangular, polar view, aniospolar, "Y" marking prominent, contact area distinct. Laesurae open, lips smooth and straight, arms of laesurae extending more than ½ radius, gradually tapering towards the peripheral region. Commissure guarded by thick and dark labra.

Exine ± 3 u thick, intrapunctate, appearing as dark band around equator, which is distinguishable into two zones.

Remarks and Comparison:— It is separated from all the species assignable to *Densoisporites* by its peculiar dark exinal band around equator, which is further distinguishable into two zones.

Derivation of Name: After the village of Tobra Eastern Salt Range.

Probable Affinites: Selaginellaceae.
Slide No: P_{12}A/11/C3,P_{12}A/3/C1.

Genus Lycospora (Schopf, Wilson and Bental) Potonie and Kremp 1954.

Type species: *Lycospora micropapillata* **(Wilson and Coe) Schopf, Wilson and Bentall 1944.**

Lycospora retusoides **n. sp.**
Plate 3 Fig. 11

Holotype: Plate 3 Fig. 11, Slide: P_{12}A/A/13.

Distribution: rare to very rare.

Dimensions: (18-specimens) Equatorial Diameter 25 (27) 30 u.

Diagnosis:— Miospore, trilete, amb subtriangular, angles rounded, sides slightly convez, polar view, anisopolar, cingulate, contact area distinct, tetrad marking distinct, arms of laesurae 7 to 8 u bounded by ± 3 u thick, and folded labra, one arm of which is always thrown into a thick fold, forming figure "S" type configuration. Cingulum 7 u thick, associated with alternate, long, thick dark and small, thin light, fine, radially placed bands of variable dimensions, exine ± 2 u thick, exhibits undulations at peripheral margins.

Remarks and Comparison:– *Vallatisporites microgalearis* Hibbert and Lacey (1969) Pl. 82, Figs. 4–5, P.433, has similar morphological features, except the size, which is too large as compared with the Pakistani specimen. There is clear bifurcation at the extermites of the laesurae, a feature, which can also distinguish this specimen from the genus *Densoisporites*. *Lycospora noctuins* Butterworth and Williams 1958 in Smith and Butterworth (1967) Pl. 20, Figs. 4–6, P. 248, is again dissimilar, as it lacks bifurcated tips of laesurae.

Derivation of Name: After bifurcated tips of laesurae.

Probable Affinites: Lycopodiales.

Slide No: $P_{12}A/13, P_7$-Bulk/14/C1.

Genus Radiizonates Staplin and Jansonius 1964.

Type species: *Radiizonates aligerens* (Knox) Staplin and Jansonius 1964.

Radiizonates akhlaqii n. sp.

Plate 1 Fig. 2

Holotype: Plate 1 Fig. 2 Slide : $P_{12}A/14/C2$.

Distribution: very rare.

Dimensions: (16-specimens) Equatorial Diameter 52 (58) 64. m.

Diagnosis:– Miospore, trilete, amb convex triangular, cingulate, faintly visible, contact area prominent, laesurae closed, sinuous, arms 28–34 u long, reaching upto the outer margin of zona. Commissure bounded by ± 2 u by 12–15 u thick corona, encircling entire spore radially. Shape of corona confirming overall spore amb. Pheripheral exine around entire equatorial rim thickened to form ≚ 2 u thick continuous, darkened exinal band, constituting the inner margin of zone. Exoexine from this dark exinal band, extended to form straight to curved, branched or unbranched diffused columns or rods, the tips of rods are fused to form outer zonal margin. Margin of zone wavy to notched, at some places appearing as oval to elliptical, beaded nodular thickenings at the tips of exoxinal extensions (rods or columns). Columns or rods comprising zona ≚ 2 u long, more thickened at tips, slightly extended Columns or rods of the distal hemisphere alternate with the columns or rods of proximal hemisphere. Central body laevigate, irregularly thickened with dark and light patches, giving an impression of verrucae. Contact area is represented by a relatively dark and thick exine on the proximal face.

Remarks and Comparison:– *Radiizonates difformis* (Kosanke) Staplin and Jansonius 1964 in Smith and Butterworth (1967), P. 264, is differentiated in having reticulate anastomosing ridges on the equatorial flange, whereas the Pakistani specimen in contrast to this has radially arranged columns or rods. While *Radiizonates* sp. cf. *Radiizonates difformis* (Kosanke) Staplin and Jansonius 1964, in Smith and Butterworth (1967), Pl. 21, Figs. 14–16 is similar in size, thickness of cingulum and formation of ridges, with the exception of the ornamentational pattern of the exine of central body. Geological age of the sporomorph under discussion might be a barrier in comparing it with any of known species of *Radiizonates*.

Derivation of Name: After Akhlaq Ahmad Bhutta of the Botany Department, Punjab University, Lahore (Pakistan), in recognition of his work in Palynology in Pakistan.

Probable Affinites: Not known.

Slide No: $P_{12}A/14/C2$.

Anteturma Pollenites Potonie 1931.

Turma Monoletes Ibrahim 1933

Suprasubturma Acavatomonoletes Dettmann 1963

Subturma Azonomonoletes Luber 1935

Infraturma Sculpatomonoleti Dyband Jack 1957

Type species: *Punctatosporites subspheroidus* n. sp.

Plate 3 Fig, 3

Holotype: Plate 3 Fig. 3 Slide : P_7B-Left/06/C5.

Distribution: abundant.

Dimensions: (108-specimens)

Total length = 31(39)59 u.
Total breadth - 26(34)55 u.

Diagnosis:– Miospore, monolete, bilateral amb oval, oblique polar view, anisopolar, monolete marking clearly defined, contact area distinguishable, lete extending more than ¾ equatorial axis, slightly curved, ≚28 u long, closed, often masked by a crescentric exinal or ray fold. Commissure protected by ≚2 u thick slightly sinuous labra, hardly visible due to the overlapping of exinal fold. Granulations more strongly developed on distal face within the vicinity of contact area, oriented in verrucae fashion. Puncta 0.5 u in diameter.

Remarks and Comparison:– *Punctatosporites* sp. cf. *Punctatosporites minutus* described by Balme (1970) Pl. 6, Figs. 1–3 is similar as far as the shape of the spore is concerned, but the size is quite smaller. *Marttisporites scabratus* Couper in Norris (1969) Pl. 109, Fig. 5, and 6 may be compared, but is again small sized. It is separated from all the known species assignable to the genus *Punctatosporites*, by its peculiar outline, clearly defined punctations, raised labra and larger size range.

Derivation of Name: After subspherically oriented oval amb.

Probable Affinites: Marsiliaceae.

Slide Nos: 01/C2, P

Slide Nos: P_7B-Left/06/C5,P_7B-Left/06/C1, P_7B-Left/01/C2,P_7-Bulk/01/C2, P_7-Bulk/01/C2.

Turma Saccites Erdtman 1947
Subturma Disaccites Cookson 1947
Infraturma Podocarpoiditi Potonie and Thomson and Thiergart 1950.

Genus Podocarpidites (Cookson) Potonie, 1958.

Type species: Not known.

Podocarpidites zafarensis n. sp.
Plate 3 Fig. 14

Holotype: Plate 3 Fig. 14. Slide : P_7K-Bulk/one/C6.

Distribution: very rare.

Dimensions: (18-specimens)

Total length = 66(69)75 u
Corpus diameter = 41(43)46 u
Marginal

Total length = 66(69)75 u.

Dimensions: 18-specimens)

Total length = 66(69)75 u
Corpus diameter = 41(43)46 u
Sacci height = 55(58) 62 u
Marginal crest: – 5 u.

Diagnosis:– Pollen grain, disaccate, haploxylonoid, corpus dark coloured, distinct, outline ≚ sub circular, exine of cappa intragranulate, dark, 4–5 u thick, relatively more thick around equatorial margin. Crista proximalis raised, sinuous, ± 5 u high. Cappula oval or fusiform, ± 13 u wide, exine of cappula slightly thinner than cappa, otherwise same. Saccihemispherical or semi rounded rectangular, laterally attached with slight distal inclination, exoexine of sacci ≚5 u thick, translucent intrareticulate to intragranulate, reticulations being ssupressed due to the destruction of bodering muri. Exine exhibiting prominently to faintly developed irregular cracks, sometimes giving an impression of pseudoreticulations, ornamentational elements fused at margin, forming ≚ 5 u thick, distinct, unevenly wide equatorial collar. Margins of sacci weakly notched, otherwise smooth or slightly undulating. Size of sacci 1/3 of corpus. Sacci unequal in size.

Remarks and Comparison:– *Podocarpidites sp. cf. P. novius* Sah and Jain 1965 described by Jain and Sah (1968) P. 131, Pl. 2, Figs. 47, 48, 52, is closely comparable. Jain and Sah (1968) did not provide definite size range, nor complete technical description of their species. The estimated size calculated from their figures seems to be 50–65 u in maximum breadth, saccus upto 40 x 20 u wide, and corpus diameter 30 u. Jain and Sah (1968) differentiated their specimens from the other known species of *Podocarpidites* by having wings of unequal sizes. This has however relationship with *Podocarpidites marwickii* Couper (1953) P. 36, Pl. 4, Fig. 39, isolated from the Lower Cretaceous sediments of Newzealand, but can easily be differentiated in having relatively small bladders and heavily thickened saccus exoexine.

Derivation of Name:

Derivation of Name: After A. H. Zafar, Botany Department, Govt. College, Lahore. (Pakistan).

Probable Affinites: Podocarpaecae.

Slide Nos: P_7K-Bulk/one/C6,P_{12}A/S9/C2.

DISCUSSIONS:

Jurassic palynological Assemblage of the Salt Range studied during the present investigation are significantly different from other parts of the world. This indicates that the phytogeographical aspects of Salt Range Flora, were quite different from their contemporary counterparts of the other parts of the world.

No significant qualitative or quantitative change in the distributional pattern of palynoflora was recorded, in the 110 feet thick composite section of the Datta Formation.

Present Jurassic palynomorph population is characterized by the high frequency of trilete and monolete spores, and more or less total extinction of bisaccate and monosaccate pollen grains. Of the trilete miospores, most of the species discovered are new, mainly dominated by "Gleicheniidites".

Index genera, which are indicators of Jurassic beds in the Salt Range area, as revealed by the present investigation are given below:–

Leitoriletes **Nammova ex Potonie and Kremp, 1954,** *Densoisporites* **(Berry) Butterworth, Jansonius, Smith and Stepline 1964,** *Lycospora* **(Schopf, Wilson and Bentall) Potonie and Kremp 1954,** *Knoxisporites* **(Potonie and Kremp) Neves and Playfored 1961,** *Micror ticulatisporites* **(Knox) Potonie and Kremp non sensu Bhdj,** *Codiospora* **(Kosanke)** *Venkatachala* **and Bhdj 1964,** *Cingulatisporites* **(Pflug) Delcourt and Sprumont 1953,** *Gleicheniidites* **(Ross) Delcourt and Sprumont,** *Zosterosporites* **Kosanke 1973,** *Radiizonates* **Staplin and Jansonius,** *Triquitrites* **(Wilson and Coe) Potonie and Kremp 1954,** *Cyathedites* **Couper 1953,** *Convolutispora* **Hoffmeister, Staplin, and Malloy 1955,** *Foveosporites* **Balme 1957,** *Dictyotriletes* **(Naumova) Smith and Butterworth,** *matonisporites* **(Couper) Dattmann 1963,** *Punctatisporites* **(Ibrahim) Potonie and Kremp 1954 and** *Divisisporites* **Thomson and Pflug 1953.**

Of the large number of miospores species studied during the present work, the following 30 new species have been circumscribed, which can also be used as index miospores for Datta Formation early. *Leitoriletes tolleratus L. naumovaensis, Punctatisporites distinctus, P. nammalensis, P. warchhaensis, Densoisporites tobraensis, Lycospora retusoidies, Microreticulatisporites emphaniatus, M. bharadwajii, Codiospora granulatus, Cingulatisporites abbasii, Concavisporites auriculatus, Gleicheniidites psiltus, G. megasinonicus, G. torostriatus, G. foveolatus, G. sublevarae, G. perforatus, G. voltfalteni, G. torodecoratus, Zosterosporites ashfaqii, Divisisporites balmensis, Matonisporites hafizensis, M. infragranulatus, Radizonates akhlaqii, Triquitrites maherbanensis, Convolutispora distinctus, Foveosporites distinctus, Punctatosporites subspheroidus and Pdodcarpites zafarensis.*

Podocarpites zafarensis **is the sole representative of bisaccate palynomorph in Datta Formation.**

Most of the Early Jurassic miosporal assemblage of India are characterised by the Predominane (50–80%) of pollen belonging to the genus *Glassopollis* **(cf. Jain and Sah, 1969 and Srivestava 1966), which is totally absent in the Salt Range Jurassic miofloral assemblages.**

The miofloral assemblages obtained from Barko and Sakrigalighast in the Rajmahal Hills, India, are predominated by the presence of large number of pteridophytic spores (upto 35 5), mostly belonging to the genera *Deltoidospora, Cythidites and Gleicheniidites* **(Maheshawri and Kumar 1979), in this respect assemblages can be equated with the presently described Pakistani Jurassic miospore population, the only exception being the sporadic occurrence of the first of the above mentioned genus in the Salt Range.**

Due to the absence of the two important miospore genera viz : *Gallialasporites and Arauceriacites,* **the Pakistani miosporal assemblages can easily be separated from palynofloral assemblages reported from India eg Kutch (cf. Venkatachala, Kar and Raza, 1969), Vemavaram (Kar and Sah, 1970), Rajmahal Hills (Sah and Jain, 1965), Lametaghat, Sehora and Hathnapur (Bharadwaj, Kumar and Singh, 1972), Bansa (Bharadwaj and Kumar 1975), Jabalpur group Hoshangabad (Masheshwari and Kumar 1979).**

Only one Bisaccate genus i.e. *Podocarpites* **is meagerly represented in the Datta Formation and due to this reason it may have certain relationship with Vemavarm and Upper Katrol and Bansa miofloras of India, where this genus is predominently recorded.**

Jurassic spores and pollen grains from Australia have been studied by Balme (1957). Out of many genera described by him, only two i.e. Cyathidites, and *Cingulatisporites,* **are found in the Salt Range, whereas most of the genera including the typical Jurassic** *Classopollis* **are totally extinct here.**

Jurassic miospore assemblages from Sweden (cf. Tralau 1967, Tralau and Arturssin 1971) resemble the Salt Range mioflora, because both these assemblages share some common elements, which are ; *Todisporites* **minor,** *Matonisporites crassiangulatus, and Cyathidites australis,* **apart from this the genera** *Concavisporites, Gleichenii-*

dites and Convolutispora, are also common.

This miofloral assemblages obtained from the Jurassic beds of Iran, due to predominence of trilete and monosulcate microspores, are the most closely comparable assemblages (cf. Kimyai 1974). Kimyai (1974) described and illustrated 27 miospores species belonging to 18 genera, of which, some are closely allied to those recovered recently from Salt Range. Common genera in both the investigations are *Cyathidites, Cingulatisporites, Matonisporites* and *Podocarpites.*

There is classopollis recorded by other workers from Early Jurassic is absent from Datta Formation.

Lycopodiumsporites and Gleicheniidites, which usually become fairly common after Middle Jurassic in other parts of the world are commonly to abundaently represented in these beds.

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REFERENCES

Allen, J.C., (1965). Lower and Middle Devonian spores of North and Central Vestspitzbergen : *Palaeontology,* vol. 8(4) : p. 687–748.

Balme, B. E.,(1957). Spores and Pollen grains from the Mesozoic of Western Australia : *Comm. Sci. Indust. Research Organiz. Australia, Coal Res. Sect.,* T. C. 25, 48 P.

Balme, B. E. (1970). Palynology of Permian and Triassic Strata in the Salt Range and Surghar Range, W. Pakistan. In Stratigraphic Boundry Problems : Permian and Triassic of West Pakistan. Edited by : Kummel, B. and Teichert C. *Univ. Kansas, Geol. Deptt, Sp. Pub.* vol. 4. PP. 305–453.

Balme, B. E. and Hennelly, J.P.F.,(1955). Bisaccate sporomorph from Australian Permian Coals. *Austral. Jour. Botany.* Vol. 3, p. 89–98.

Bharadwaj, D.C., and Kumar, P. (1975a). Palynostratigraphy of Mesozoic sediments from Macharar Nala, Basna, M.P., India, *Geophytology,* vol. 4 (2) 147–152.

Bharadwaj, D.C., Kumar, P., and Singh, H.P., (1972). Palynostratigraphy of Coal deposits in Jabalpur Stage, Upper Gondwana, India. *Paleobotanist,* vol. 19 (3), p. 225–247.

Butterworth M.A., and Williams, R. W., (1954). Descriptions of nine spores of small spores from the British Coal Measures. *Ann. Mag. Nat. Hist, vol.* 7. p. 753–64.

Couper, R.A., (1953). Upper Mesozoic and Cainozoic spores and pollan grains from New Zealand: Palaeont. *Bull. Geol. Survey New Zealand,* No. 22, 77 p.

Elsik. W.C., (1968). Palynology of a Paleocene Rockdale lignite, Milam Country, Texas. 1. Morophology and Taxonomy. *Pollen et. spores.* vol. 10(1), p.263–314.

Foster, C. B., (1975), Permian plant microfossils from the Blair Athol Coal Measures. Central Queensland, Australia. *Palaeontographica abt. B.* vol. 154(5–6), p. 121–171.

Fatmi, A. N., (1977). Mesozoic of Pakistan. Pakistan *Geol. Surv. Mem.* vol. 12.p. 29–56.

Hibbert, F. A., and Lacey, W.S., (1969). Miospores from the Lower Carboniferous Basement Beds in the Menai Straits Region of Caernarvonshire, Northwales. *Palaeontology,* vol. 12(3), p. 420–440.

Hammen, T.V.D., and Burger, D. (1966). Pollen flora and age of the Tokuta Formation (Guyana). *Leids Geol. M Med.,* vol. 38, p. 173–180.

Jain, K. P. and Sah, S. C. D., (1968). A Lower Jurassic Miospore Assemblage from the Variegated Shale, Nammal Gorge, Salt Range (West Pakistan). *Palaeobotanist,* vol. 17, p. 127–136.

Jain, K. Pond, Sah, S. C. D., (1969). A Lower Jurassic Miospore Assemblage from the Variegated Shale. Nammal Gorge, Salt Range (West Pakistan). *Palaeobotanist.* vol. 19(2). p. 103–117.

Kar, R. K., and Sah, S. C. D., (1970). Palynological investigation of Gondwana outcrop from Vemavaram with remarks on the age of the bed. *Palaeobotanist,* vol 18(2), p. 103–117.

Kimyai, A., (1974). Jurassic plant Microfossils from Iran. Symposium on stratigraphical palynology sp. Pub. No. 3. P. 1–7.

Kosanke, R. M., (1950). Pennsylvanian spores of Illionis and their use in Correlation : *Bull. Illinois. State Geol. Survey* vol. 74, p. 128 pp.

Kosanke, R. M., (1973). Palynological studies of the Coals of the Princes Reserve District in Northeastem Kentucky. *Unit. St. Geol. Surv. Proff. Paper 839.* p. 1–22.

Meheshwari, H. K., and Kumar P., (1979). A Jurassic Mioflora from the Jabalpur group exposed in Marand River near Morghat, Hoshangabad Distt. Madhya Pradesh. *Geophytology,* vol. 9(–2), p. 47–51.

Naumova, S. N., (1953). Spore Pollen complex of the Upper Devonian of the Russian Platform and their Stratigraphical Value. *Trav. Inst. Sci. Geol. Akad. Nauk. S. S. S. R,* vol. 143 (Geol. Ser. No. 60), p. 1–154 (In Russian).

Playford, G, (1971). Palynology of Lower cretaceous

(Swan River) strata of Saskatchewan and Maintoba *Palaeontology*, vol. 14(4), p. 533–565.

Romans, R. C., (1975). Palynology of some Upper Cretaceous Coals of Black Mesa, Asizona. *Pollen et spores* vol. XIII, No. 2, p. 274–329.

Sah, S. C. D., (1955). Plant microfossils from a Jurassic Shale of Salt Range, West Punjab (Pakistan) : *Palaeobotanist*, vol. 4. p. 60–67.

Sah, S. C. D. and Jain, K. P., (1965). Jurassic spores and Pollen grains from the Rajmahal Hills, Bihar. India: with a discussion on the age of the Rajmahal intertrappean beds. *Paleobotanist*, vol. 13(3), p. 264–290.

Schopf. J. M. Wilson, L. R. and Bentall, R., (1944). An annotated synopsis of paleozoic fossil spores and the definitional of generic groups: *Illinois Geol. Surv. Rept. Invert.*, No. 91.p.66.

Smith, A. H. V. and Butterworth, M. A., (1967). Miospores in the Coal seems of the carboniferous of great Britain. Palaeontological Association London. Special paper in *Palaeontology* No. 1., p. 324.

Srivastava. S. K., (1966). Jurassic microflora from Rajisthan India. *Micropalaeontology*, vol. 12 (1), p. 87-103.

Streel, M., (1964) Une association de spores due Givetien inferieur de la vesdre, a goe (Belgique). *Ann. Soc. Geol. De Belgique*, vol. 87(7), p.1–29.

Thomson, P. W., and Pflug, H., (1953). Pollen and sporen des Mittel - Europaischen Tertiars. *Palaeontographica ab. B.* vol. 94 (1-4), p. 1–38.

Tralau, H., (1967). Some Middle Jurassic Microspores of Souther Sweden. Geologislca Foreningens-i-Stockholm Forhand Lingar. vol. 89, p. 469–472.

Tralau, H. and Artursson, (1971). New Middle Jurassic pollen and spore Floras from Southers Sweden and the Ore Sund. *Grana*. vol. 12.p. 57–63.

Venkatachala, B. S. Kar, R. K. and Raza, S., (1969) B. Palynology of the Mesozoic sediments of Kutch, W. India–3. Morphological study and revision of the spore genus Trilobosporites Pant and Potonie, 1956. *Palaeobotanist*, vol. 17(2). p. 123–126.

EXPLANATION OF PLATES.

PLATE I.

1.	Zonotrisporites ashfaqii n. sp.	X 1000
2.	Radizonates akhlaqii n. sp.	X 1000
3.	Cingulatisporites abbasii n.sp.	X1000
4.	Convolutispora distinctus n. sp.	X 1000
5.	Microreticulatisporites emphaniatus n. sp.	X1000
6.	Microreticulatisporites bharadwajii n.sp.	X 1000
7.	Leiotriletes naumovaensis n.sp.	X 1000
8.	Leiotriletes tolleratus n. sp.	X 1000
9.	Divisisporites balmeinsis n. sp.	X 1000

PLATE II.

1.	Gleicheniidites sublevarae n. sp.	X 1000
2.	Gleicheniidites perforatus n. sp.	X 1000
3.	Gleicheniidites torostriatus n. sp.	X 1000
4.	Gleicheniidites torodecoratus n. sp.	X 1000
5.	Gleicheniidites megasinonicus n. sp.	X 1000
6.	Matonisporites infragranulatus n. sp.	X 1000

PLATE III.

1.	Punctatisporites nammalensis n.sp.	X 1000
2.	Punctatisporites warchhanesis n. sp.	X 4000
3.	Punctatosporites subspheroides n. sp.	X 1000
4.	Triquitrites meharbanicus n. sp.	X 400
5.	Foveosporites distinctus n. sp.	X 1000
6.	Gleicheniidites foveolatus n. sp.	X 400
7.	Densoisporites tobraensis n. sp.	X 1000
8.	Concavisporites auriculatus n. sp.	X 1000
9.	Cadiospora granulatus n. sp.	X 400
10.	Gleicheniidites psilatus n. sp.	X 1000
11.	Lycospora retusoides n. sp.	X 1000
12.	Punctatisporites distinctus n. sp.	X 400
13.	Matonisporites hafizensis n. sp.	X 400
14.	Podocarpites zafarensis n. sp.	X 4000
15.	Gleicheniidites voltfaltneii n. sp.	X 400

PLATE 1

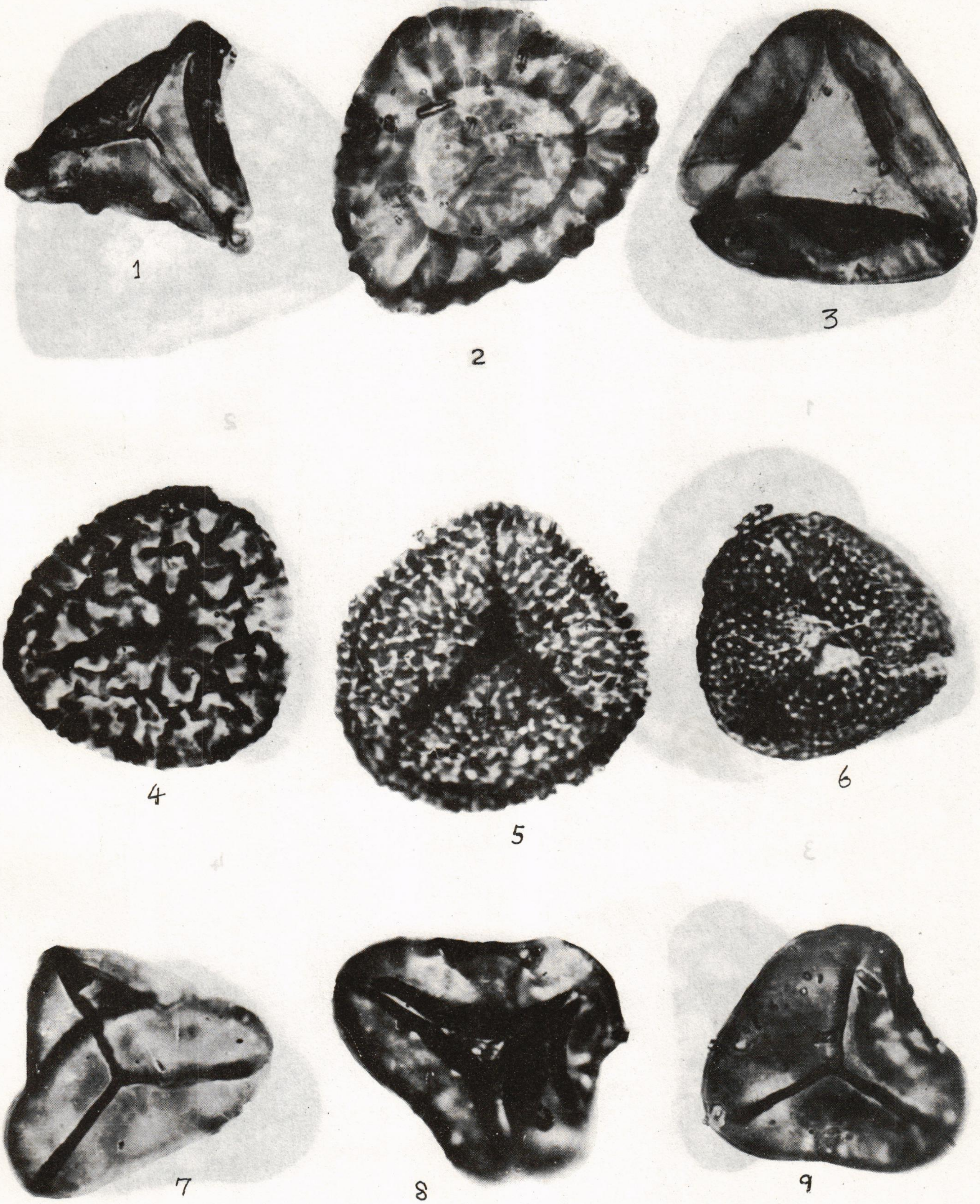

PLATE 2

1

2

3

4

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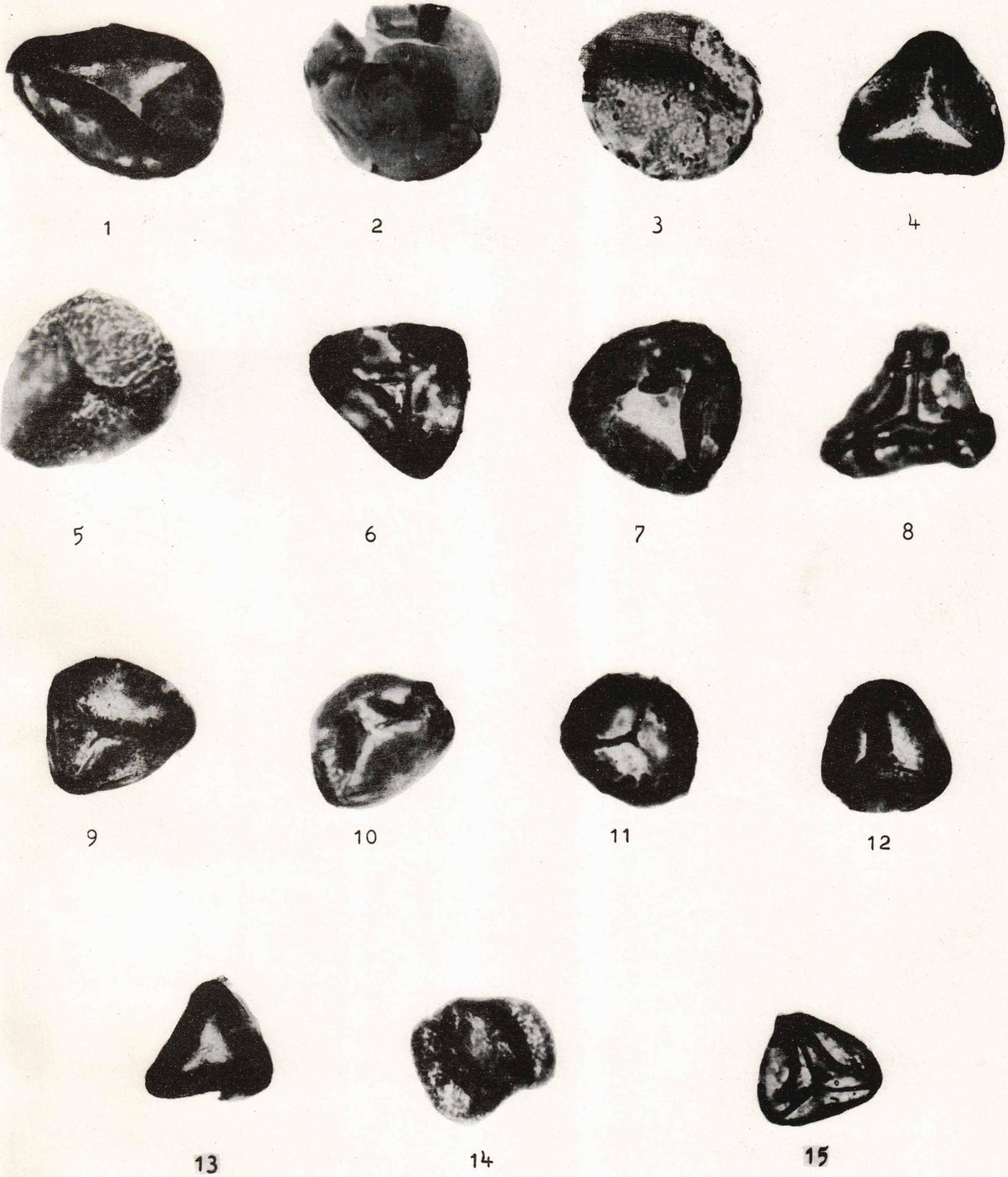
PLATE 3



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CHEMICAL EVIDENCE FOR DEDOLOMITIZATION

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ABSTRACT:– Dedolomitization textures can be recognized with the help of petrographic studies. Other evidences for the diagenetic process of dedolomitization can be obtained with the help of electron-probe analysis (Ca and Mg scans across dolomite crystals), and by combining volumetric estimates of the dolomite content and their Mg/Ca molar ratios.

INTRODUCTION

The investigation of diagenesis in carbonate rocks has progressed to a stage where, in addition to the process of dolomitization, overprint of dedolomitization are also being considered. Petrographic criteria for the recognition of dedolomites (the calcite which has replaced dolomite) are available in the literature (Khawaja, 1980, 1983).

This study based on data from the Ordovician Gordon Subgroup at Gunns Plains, N.W. Tasmania discusses the chemical evidences that can be used to demonstrate dedolomitization.

METHODS

Electron microprobe analyses were carried out on 5 samples using a JEOL JXA-50A scanning electron microprobe analyzer. EDAX spectra were used for analyses. absorption, fluorescene, ionization and back scattering were made with the aid of the incorporated computer programme TAS SUEDS. Back scattered electron images and X-ray distribuion maps were obtained on a tilt of 20° with current 3 x 10^{-9} amps and accelerated voltage 15 KV.

A Techtron AA-6 atomic absorption spectrophotometer was used to analyze Ca and Mg in the soluble carbonate fractions of 70 samples. It is essential that the peels/thin sections and solutions for chemical analyses be made from the same parts of the samples as the elemental concentration can vary even within a single sample. This can be observed in Table 1 which shows 10 analyses of 5 samples (2 analyses from adjacent parts of each samples)

A Phillips diffraction unit, which generated Ni filtered A_iK_a radiation was used for X-ray diffraction (XRD) analyses. Powdered samples chosen at random were smeared onto glass slides using non-diffracting grease. Scanning was done at a rate of 1^0, 2^0 per minute. Most of the dolomite peaks were observed at 2 0 = 30.92 and 30.90 giving "d" spacing of 2.89, which corresponds to ideal dolomites.

RESULTS AND DISCUSSION

It is widely accepted that the Mg present in ancient carbonate rocks is a measure of the dolomite content. Therefore, the replacement of dolomite by calcite (dedolomitization) should result in a loss of Mg. De Groot (1967) has experimentally demonstrated this removal of Mg ions from an ideal dolomite and precipitation of Mg-free calcite.

The loss of Mg can also be proven with the help of electron-probe analysis (Scholle, 1971, 78; Katz, 1971; Baenayake, 1975). Figs. 1 and 2 are the electron microprobe scans of two partly dedolomitized samples from the present study. The (a) portions in the figures show the secondary electron images and X-ray distribution maps of Mg whereas, (b) and (c) are the X-ray distribution maps of Mg and Ca respectively. The comparison in terms of Mg and Ca distribution and the reconstruction in Figs. 1 (d) and 2 (d) showing areas within the dolomite replaced by dedolomite (higher Ca with little or no Mg towards the margins of the crystals) clearly demonstrates centripetal dedolomitization.

Chemical evidence for dedolomitization can also be obtained from atomic absorption spectroscopy combined with petrographic observations. Petrographic separation of dolomite and dedolomite for purposes of volumetric estimation is difficult and leads to significant error estimates since the degree to which individual dolomite crystals are affected by dedolomitization is highly variable ranging from a small clot to a whole dedolomitized rhomb. Therefore, the occurrence of dedolomitization textures has been ignored in the visual and point count estimates of the dolomite content.

The estimated dolomite content (including dedolomite) in the studied samples, based on X-ray diffraction analyis, as has been mentioned previously is ideal dolomite (Fig. 3). The Mg/Ca molar ratio in an ideal dolomite is 1.

TABLE 1

ATOMIC ABSORPTION ANALYSES FROM DIFFERENT PARTS OF THE SAME SAMPLE

Sample No.	Mg	Ca
49156	1.56	33.22
	2.12	33.68
49294	0.86	36.94
	0.74	38.30
49303	0.73	36.71
	0.52	37.68
49309	1.03	37.17
	0.98	37.62
49322	1.18	30.59
	1.29	32.41

As can be observed in Fig. 4, the plotted samples (inspite of their being ideal dolomites) do not correspond to the ideal dolomite line thus implying dedolomitization. In other words, samples (ideal dolomites) with no included dedolomite, whatever their dolomite content, should plot on the line Mg/Ca = 1. Deviation of sample points from the ideal dolomite line is inferred to be due to the presence of variable amount of dedolomite in them.

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REFERENCES

Basnayake, S.B., (1975). Geochemistry and petrography of Ordovician Gordon Limestone, Mole Greek area. Thesis (B. Sc. Hons). Geol. Dept., Univ. Tasmania (unpublished).

Groot, K. de, (1967). Experimental dedolomitization. *Jour. Sed. Petrology*, V. 37, p. 1216-1220.

Katz, A., (1971). Zoned dolomite crystals. *Jour. Geology*, V. 79, p. 38-51.

Khawaja, A.A., (1983). A note on dedolomitization textures. *Jour. Engg. & Appl. Sci.*, v. 2, p. 101-103.

---------- (1980). Depositional and diagenetic environments of the Gordon Subgroup (Ordovician), gunns Plains, N.W. Tasmania. Thesis (Ph. D.) Geol. Dept., Univ. Tasmania (unpublished).

Scholle, P.A. (1978). Carbonate Rock constitutents, textures, cements, and Porosities. *Am. Assoc. Petrol Geol., Mem.* 27, p. 1 – 241.

---------- (1971). Diagenesis of deep-water carbonate turbidites, Upper Cretaceous Mount Antola Flysch, Northen Appenines, Italy. *Jour. Sed. Petrology*, V. 41, p. 251 – 260.

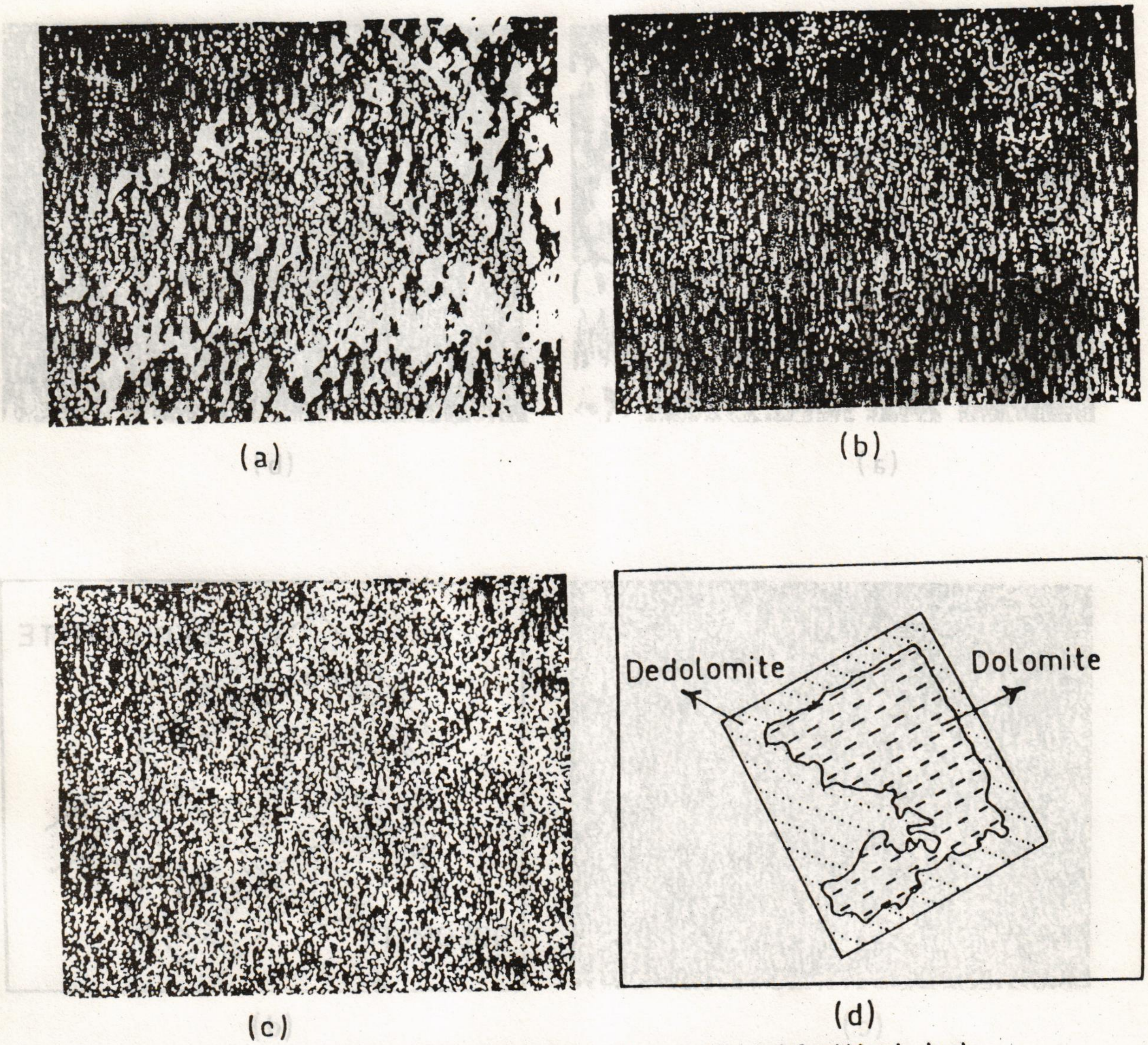

Fig. 1 . Electron microprobe scans of a partly dedolomitized rhomb of dolomite. (a) Back scattered electron image and X-Ray distribution map of Mg. (b) and (c) are X- Ray distribution maps of Mg and Ca respectively. (d) Reconstruction of the dolomite rhomb showing areas replaced by dedolomite. Intensity of individual patterns do not reflect absolute or relative abundances of elements. Sample 49043.

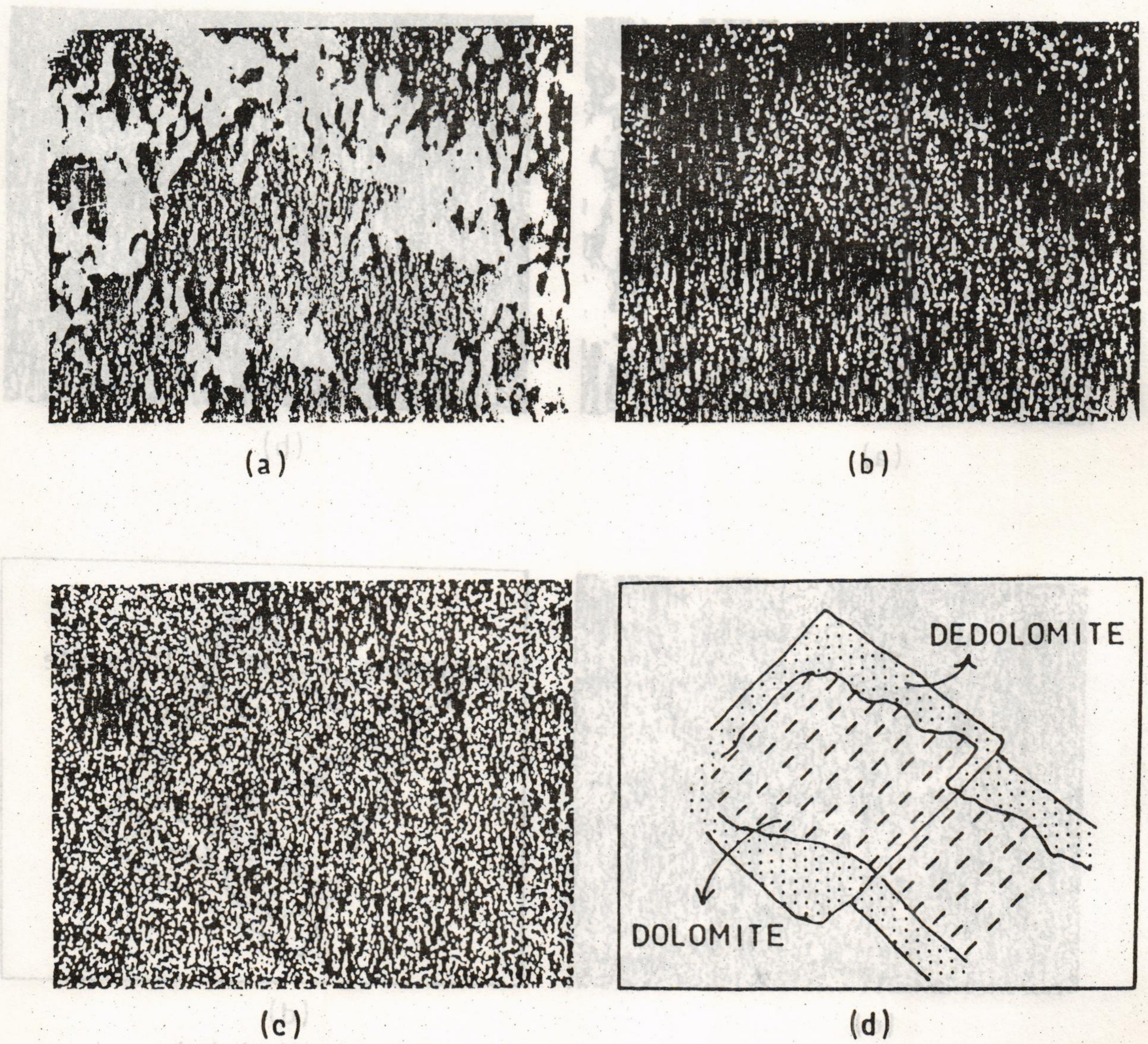

Fig. 2 . Electron microprobe scans of a partly dedolomitized rhomb of dolomite. (a) Back scattered electron image and X- Ray distribution map of Mg. (b) and (c) are X- Ray distribution maps of Mg and Ca respectively. (d) Reconstruction of the dolomite rhomb showing areas replaced by dedolomite due to centripetal dedolomitization. Intensity of individual patterns do not reflect absolute or relative abundances of elements. Sample 40077.

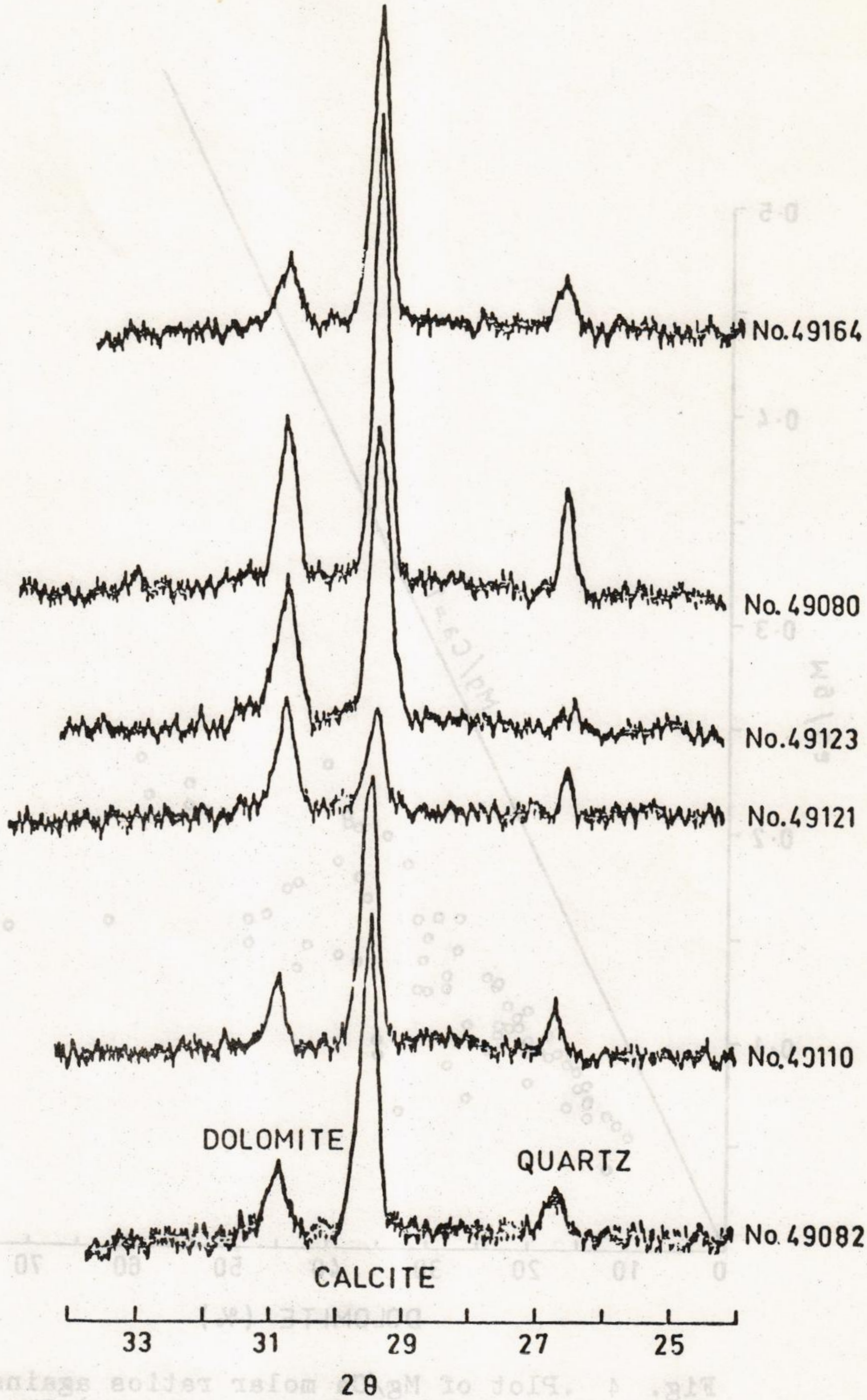

Fig.3. X-ray diffractograms showing the major peaks of dolomite, calcite and quartz.

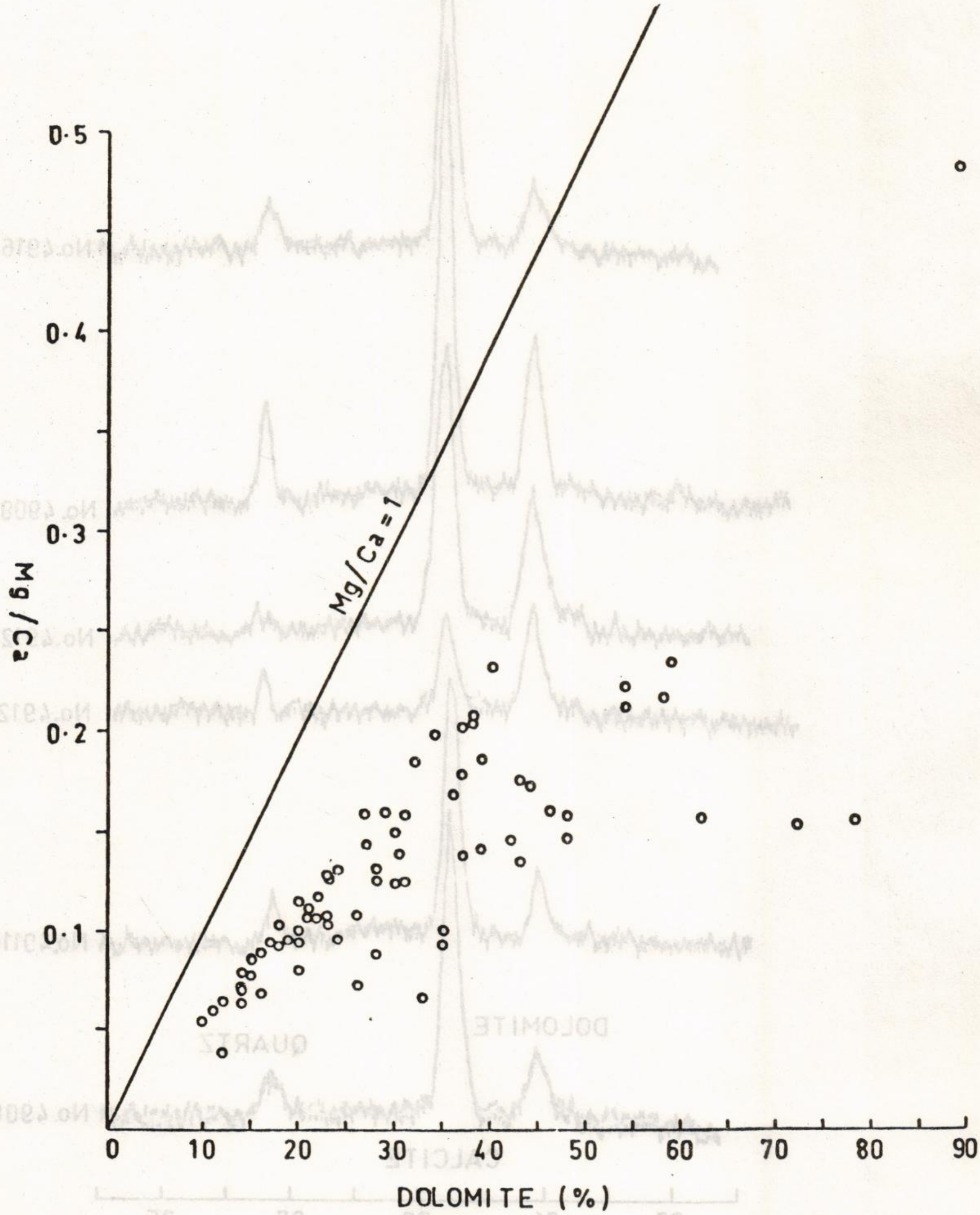

Fig. 4 .Plot of Mg/Ca molar ratios against the dolomite percent(volumetric estimate).The straight line(Mg/Ca=I) representing the ideal dolomite has been drawn taking e.g.Mg/Ca 0.5,0.3,0.2=50%,30% and 20% dolomite respectively.

GROUND WATER CHEMISTRY AND IRRIGATION WATER CRITERIA OF THE TAHLAB AQUIFER, BALUCHISTAN

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ABSTRACT.– The results of hydrogeological studies of the Tahlab Aquifer (North Western Baluchistan) are used to generate irrigation water criteria for this aquifer. The data was obtained from 15 boreholes, and consists of hydrochemical analyses for the major ionic composition. The concepts of hydrochemical facies alongwith a trilinear plot, form the basis for the interpretation of the composition and the potential relationship to irrigation deduced.

INTRODUCTION

Tahlab Valley is situated in the North Western part of Baluchistan, Pakistan (Figure-1). It is a major south easterly trending valley which drains into Hamaun-e-Mash-khel. The Tahlab Aquifer is composed of alluvial sands and gravels infilling the fault controlled Tahlab valley. The Aquifer extends along the valley for as much as 100 Kilometers. The width of the aquifer varies from five to ten kilometers of which more than two kilometers lies within Pakistan and the rest is in the territory of Iran.

During hydrogeological investigations 15 boreholes were drilled in the centre of the Tahlab valley. Maximum penetration of the boreholes were upto 300 meters, but no bedrock was encountered.

The aquifer is unconfined, but at some places the presence of silt and clay horizons make the aquifer partially confined. Boulton and Hantush type curve methods have been used to assess the aquifer characteristics.

Hydrochemical analyses of samples from different boreholes were used to study and interpret the aquifer's chemical characteristics.

Results of the hydrochemical analyses of three boreholes is given in tables 1,2 and 3. Ionic balance of each borehole was checked and all were within a range from 0.42% to 3.43% showing the results to be reliable.

WATER QUALITY

Ground water in the aquifer is alkaline and values of PH for boreholes SIP, S2P and S3P (Tables 1,2 & 3) range from 8.13 to 8.38. The total dissolved solids content of the ground water is high, generally varying from 1440 to 5840 mg/l (Table-4).

Electrical conductivity (EC) of the surface water samples range from 12000 to 17000 micromhos/cc, whereas EC for the wells range from 2200 to 6000 micromhos/cc.

Borehole TE 1, located in the down valley adjacent to the Swamps (Figure-1) has an anomalous value of 38000 micromhos/cc which may be due to the evaporative effects on stagnant water.

GRAPHIC REPRESENTATIONS OF CHEMICAL ANALYSES DATA OF TAHLAB GROUND WATER

For the graphic representation of hydrochemical data of Tahlab, modified form of Stiff pattern and Piper Trilinear diagram is used. (see figures - 2 and 3).

STIFF PATTERN DIAGRAM

For brevity sake the data from the boreholes SIP, S2P and S3P is shown in Figure-2. The ionic concentrations are expressed in milliequivalents per litre (EPM). As the width of Pattern (figure-2) is an approximate indication of total ionic content, it can be observed that it is nearly similar in all the bore holes of Tahlab Valley. The ground water is dominated by the sodium cations and by sulphate and chloride anions.

TRILINEAR PLOT

In figure - 3, cations are expressed as percentages of total cations in milliequivalents per litre (EPM), plot as a single point on the left triangle; while anions, similarly expressed as percentages of total anions, appear as a point in the right triangle. These points are then projected into the central diamond-shaped area parallel to the upper edges of the central area. All these points in the diamond-shaped area represent the total ionic distribution. These samples

Table – 1

Location S1P

Sampled by Zulfiqar

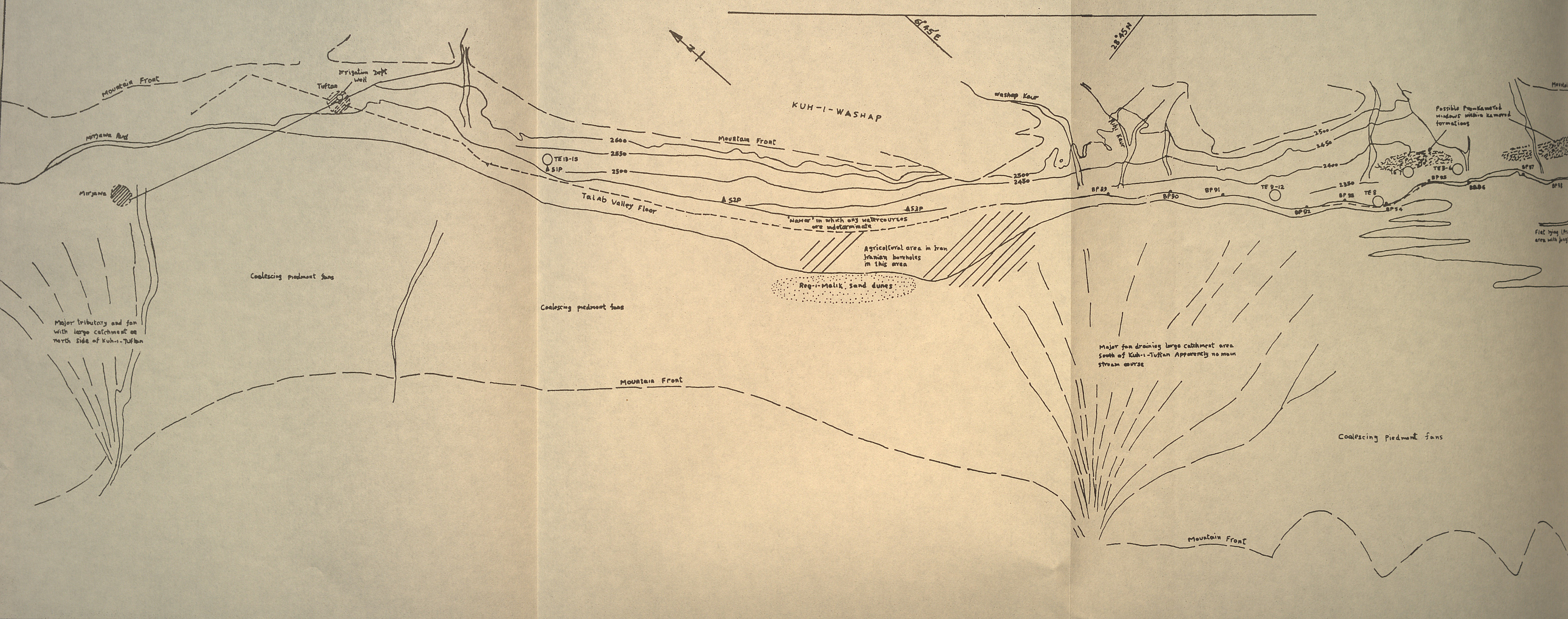
T.D.S. 2610

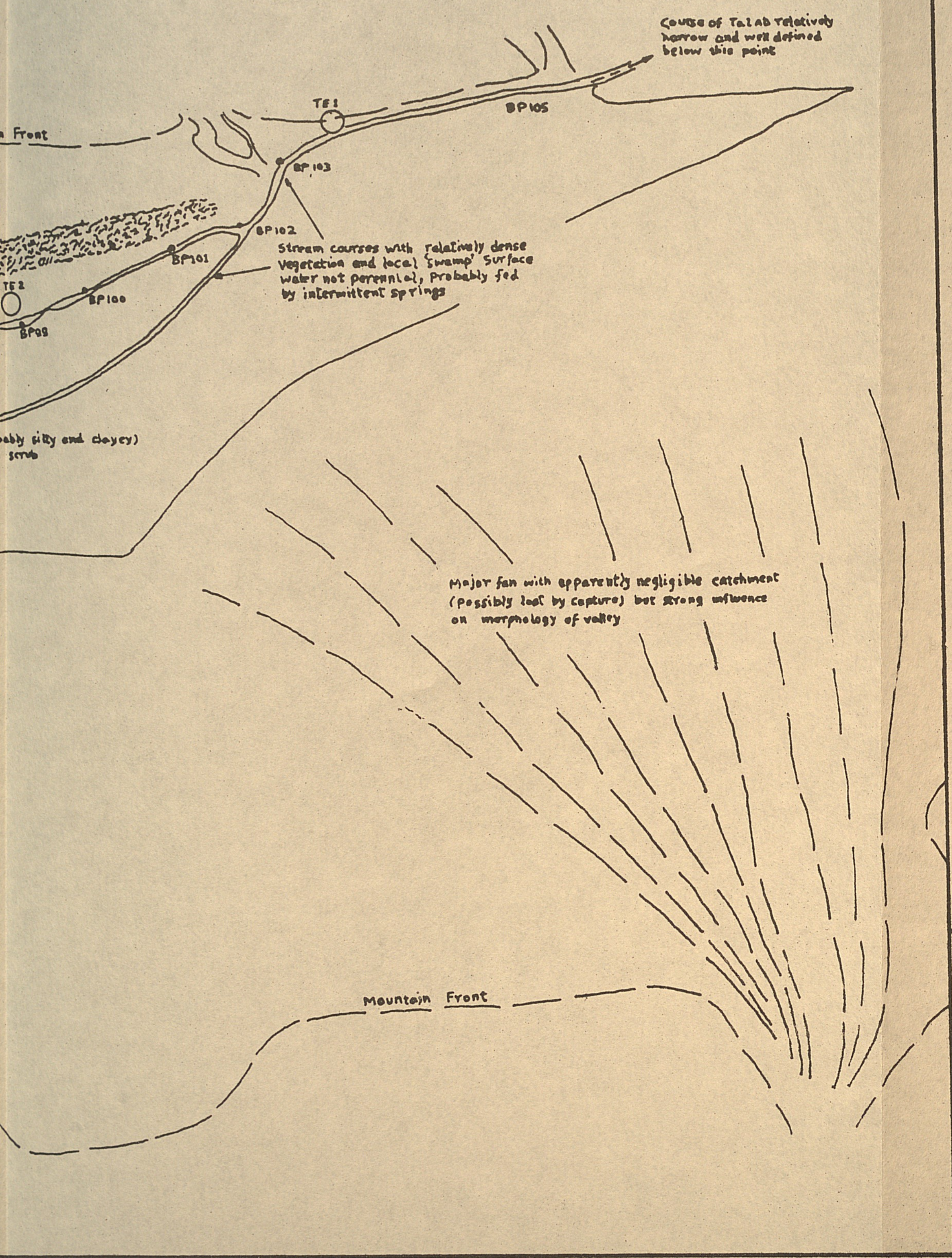
pH (laboratory) 8.38

CATIONS	mg l–1	meq l–1	% meq.	ANIONS	mg l–1	meq l–1	% meq.
Ca	84	4.19	10.38	CO_3	NIL	NIL	NIL
Mg	68	5.59	13.85	HCO_3	257	4.21	10.70
Na	690	30.01	74.37	Cl	699	19.72	50.13
K	22	0.56	1.39	SO_4	740	15.41	39.17
				NO_3	–	–	–
				F			
TOTALS		40.35				39.34	

Ion Balance = Cations – Anions meq l^{-1} = 1.01

$$\% \text{ Discrepancy} = \frac{\text{Ion Balance}}{\text{Cations + Anions}} \times 100 = 1.26$$


KUH-I-WASHAP
Mountain Front
Mirjawa Road
Tuftan
Irrigation Dept Well
Mirjawa
TE 13-15
S1P
2600
2550
2500
2450
2400
2350
S2P
S3P
Talab Valley Floor
'Nawar' in which any watercourses are indeterminate
Agricultural area in Iran
Iranian boreholes in this area
Reg-i-Malik sand dunes
Washap Kaur
Kuhi Kaur
61°45'E
28°45'N
N
BP89
BP90
BP91
TE 9-12
BP92
BP93
TE 8
BP94
BP95
TE3-6
BP96
BP97
Possible Pre-Kamerod windows within Kamerod formations
Coalescing piedmont fans
Major tributary and fan with large catchment on north side of Kuh-i-Tuftan
Major fan draining large catchment area South of Kuh-i-Tuftan Apparently no main stream course



K E Y

Pakistan/ Iran border

• BP95 Border Post (Pakistan)

▲ Pump test sites

Note

Approximate borehole locations plotted from 1 : 50,000 map

SCALE

0 1 2 3 4 5 6 kilometers

Scale 1:10,000

Figure : 1

SKETCH MAP OF UPER TALAB VALLEY

are well clustered indicating similar water quality.

HYDROCHEMICAL FACIES AND INTERPRETATION

Hydrochemical facies for the Tahlab Aquifer are shown in figure - 3. These represent distinct zones that have cation and anion concentrations describable within defined composition categories. In figure-3, the Trilinear plot is further subdivided as suggested by Morgan and Winner (1962).

The Ground water is dominated by sodium cations and by sulphate and chloride anions and it is clearly seen by the placement of cation and anion concentrations in the triangular area. All the projected points in the diamond-shaped area come close together which are indicative of total ionic concentrations.

Boreholes S1P and S2P can be regarded as the best quality producing wells in comparison to the rest of the wells. Projection of anion and cation concentrations of S1P and S2P in the diamond shaped area come a little away from the other projected points. Other projected points in the diamond shaped area are indicative of rather saline water which may be due to the presence of evaporite minerals, gypsum, anhydrite and halite within the aquifer skeleton.

It seems likely that these minerals are present in the recent alluvial sediments, and that the Chemistry of the waters is related to the solution of minerals within the aquifer. However, the equilibrium conditions for calcium and sulphate (gypsum) solution with sodium and chloride (halite) shows that groundwaters in the Tahlab are undersaturated with respect to gypsum or anhydrite. Furthermore, the relatively low calcium concentrations, in the presence of moderate bicarbonate, suggest that ion exchange mechanisms are operating in the aquifer with the replacement of sodium by calcium on the clay minerals within the sequence.

IRRIGATION WATER CRITERIA OF TAHLAB AQUIFER:

Sodium – Adsorption-Ratio (SAR):

Following the U.S. Department of Agriculture Salinity Laboratory (1954), Sodium-adsorption-ratio (SAR) of water can be expressed as

$$SAR = \frac{(Na^{+})}{\sqrt{\frac{(Ca^{+2}) + (Mg^{+2})}{2}}}$$

where Ion concentrations are expressed in milliequivalents per litre. SAR predicts reasonably well the degree to which irrigation water tends to enter into cation-exchange reactions in Soil. The hydrochemical data in milliequivalents per litre (EPM) of Tahlab aquifer is used to calculate the values of SAR for each borehole, and then plotted against the electrical conductivity values of the same boreholes. (see Table 4 and figure 4). Points falling off the diagram represent high value of salinity and SAR.

SAR	Quality classification of water for Irrigation
	WATER CLASS
10	Excellent
10 - 18	Good
18 - 26	Fair
26	Poor

Ground water is being used from the Tahlab Aquifer for the irrigation of trees, wheat, almond and alfalfa. SAR values suggest (see table 4) that water quality of the upper valley is better than the downside of the valley.

Sodium salinity hazard suggests that soil salinity problems are likely to be encountered by the cation exchange reactions. Cation exchange reaction reduces the permeability of soil and thus drainage takes place slowly but some plants can tolerate brackish water and following the rating of irrigation water for various crops, Tahlab ground water could be better utilised.

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REFERENCES

Back, W., and Hanshaw, B.B., (1965). Chemical Geohydrology *Adv. Hydrosci.*, 1, PP.49–109.

Freeze Ra and Cherry J.A., (1979). Groundwater

Poster, M.D., (1942). Chemistry of Groundwater in Hydrology P.P. 646-655, MCGRAW-Hill, New York.

Hem, J.D., (1970). Study and interpretation of the chemical characteristics of natural water. U.S. Geol. Surv. Water-supply paper 1973, PP 103-230.

Hill, R.A., (1940). Geochemical patterns in coachella valley Calif, *Trans. Amer. Geophys. Union* Vol. 21.

Mprgam Jones and M D. Eggboro (1981) Hydrochemistry of the Jurassic limestones in Gloucestershire Q JEG 14 P 25-39.

Morgan, C.O. and M.D. Winner, JR, (1962). Hydroche-

Table – 2

Location S2P

Sampled by Zulfiqar

T.D.S. 1662

pH (laboratory) 8.1

CATIONS	$mg\ l^{-1}$	$meq\ l^{-1}$	% meq.	ANIONS	$mg\ l^{-1}$	$meq\ l^{-1}$	% meq.
Ca	64	3.19	12.73	CO_3			
Mg	49	4.03	16.09	HCO_3	263	4.31	17.35
Na	400	17.4	69.46	Cl	349	9.85	39.65
K	17	0.43	1.72	SO_4	513	10.68	43.99
TOTALS		25.05				24.84	

Ion Balance = Cations – Anions $meq\ l^{-1}$ = 0.21

% Discrepancy = $\frac{\text{Ion Balance}}{\text{Cations + Anions}}$ x 100 = 0.42

Table – 3

Location S3P

Sampled by Zulfiqar

T.D.S. 2050

pH (laboratory) 8.2

CATIONS	$mg\ l^{-1}$	$meq\ l^{-1}$	% meq.	ANIONS	$mg\ l^{-1}$	$meq\ l^{-1}$	% meq.
Ca	84	4.19	13.88	CO_3	–	–	–
Mg	66	5.43	17.99	HCO_3	217	3.55	11.58
Na	460	20.01	66.28	Cl	490	13.82	45.09
K	22	0.56	1.85	SO_4	638	13.28	43.33
TOTALS		30.19				30.65	

Ion Balance = Cations – Anions $meq\ l^{-1}$ = 0.46

% Discrepancy = $\frac{\text{Ion Balance}}{\text{Cations + Anions}}$ x 100 = 0.76

mical facies in the 400 foot and 600 foot sands of the Baton rouge Area, Louisiana *U.S. Geol. Surv.* Prof. Paper 450-B PP B120-121.

Piper, A.M., (1944). A graphic procedure in the geochemical interpretation of water analyses. *Trans. Amer. Geophysical Union,* Vol. 25 PP. 914-928.

Todd, D.K., (1980). Groundwater Hydrology; 2nd Ed.

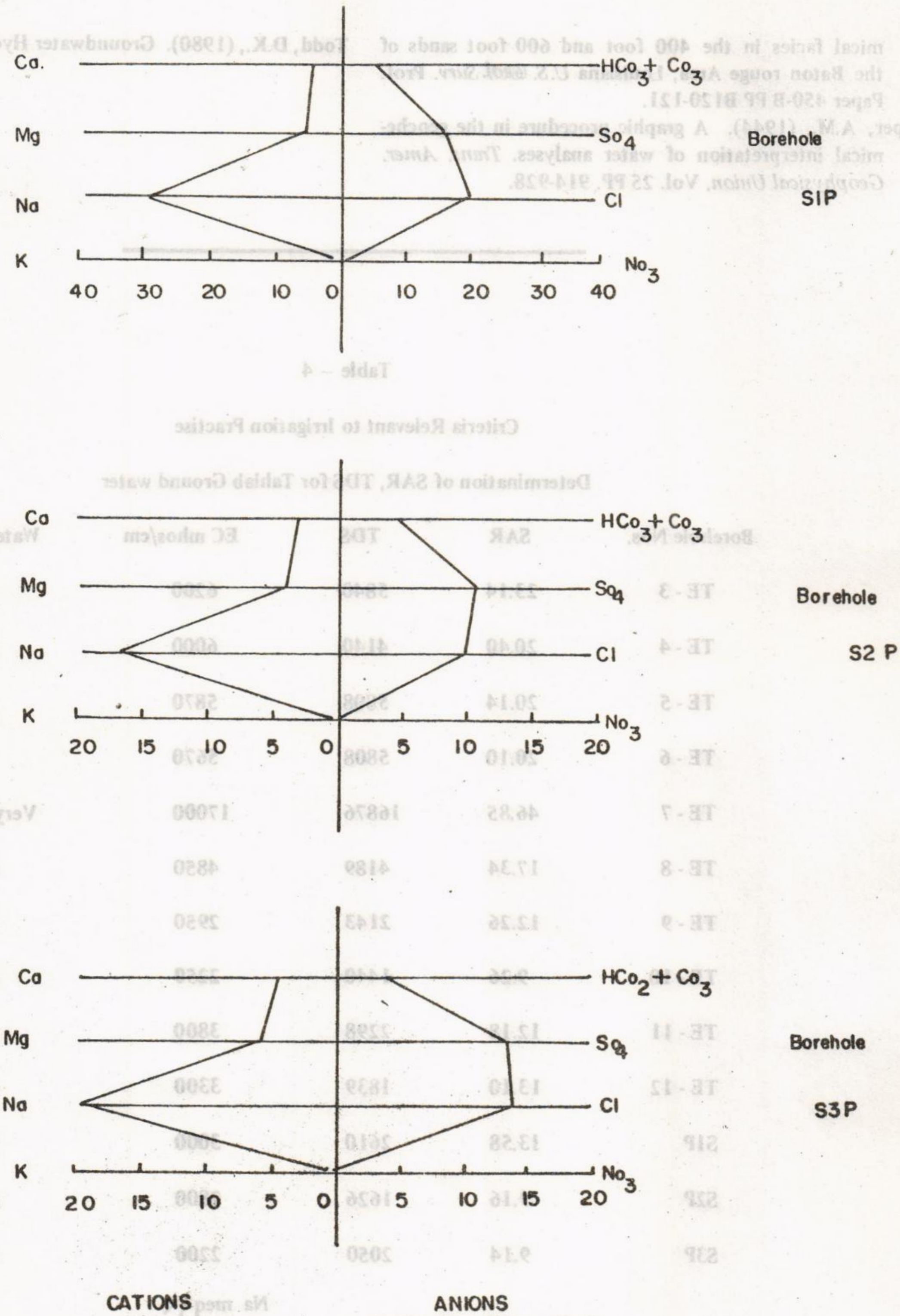
Table – 4

Criteria Relevant to Irrigation Practise

Determination of SAR, TDS for Tahlab Ground water

Borehole Nos.	SAR	TDS	EC mhos/cm	Water class
TE - 3	23.14	5840	6200	Fair
TE - 4	20.40	4140	6000	Fair
TE - 5	20.14	5808	5870	"
TE - 6	20.10	5808	5670	"
TE - 7	46.85	16876	17000	Very poor
TE - 8	17.34	4189	4850	Good
TE - 9	12.26	2143	2950	Good
TE - 10	9.26	1440	2250	Good
TE - 11	12.18	2298	3800	Good
TE - 12	13.10	1839	3300	Good
S1P	13.58	2610	3000	Good
S2P	9.16	1626	2800	Good
S3P	9.14	2050	2200	Good

$$\text{Sodium Adsorption Ratio} = \frac{\text{Na meq}\backslash\ell}{\sqrt{\frac{Ca + Mg}{2}}}$$



In

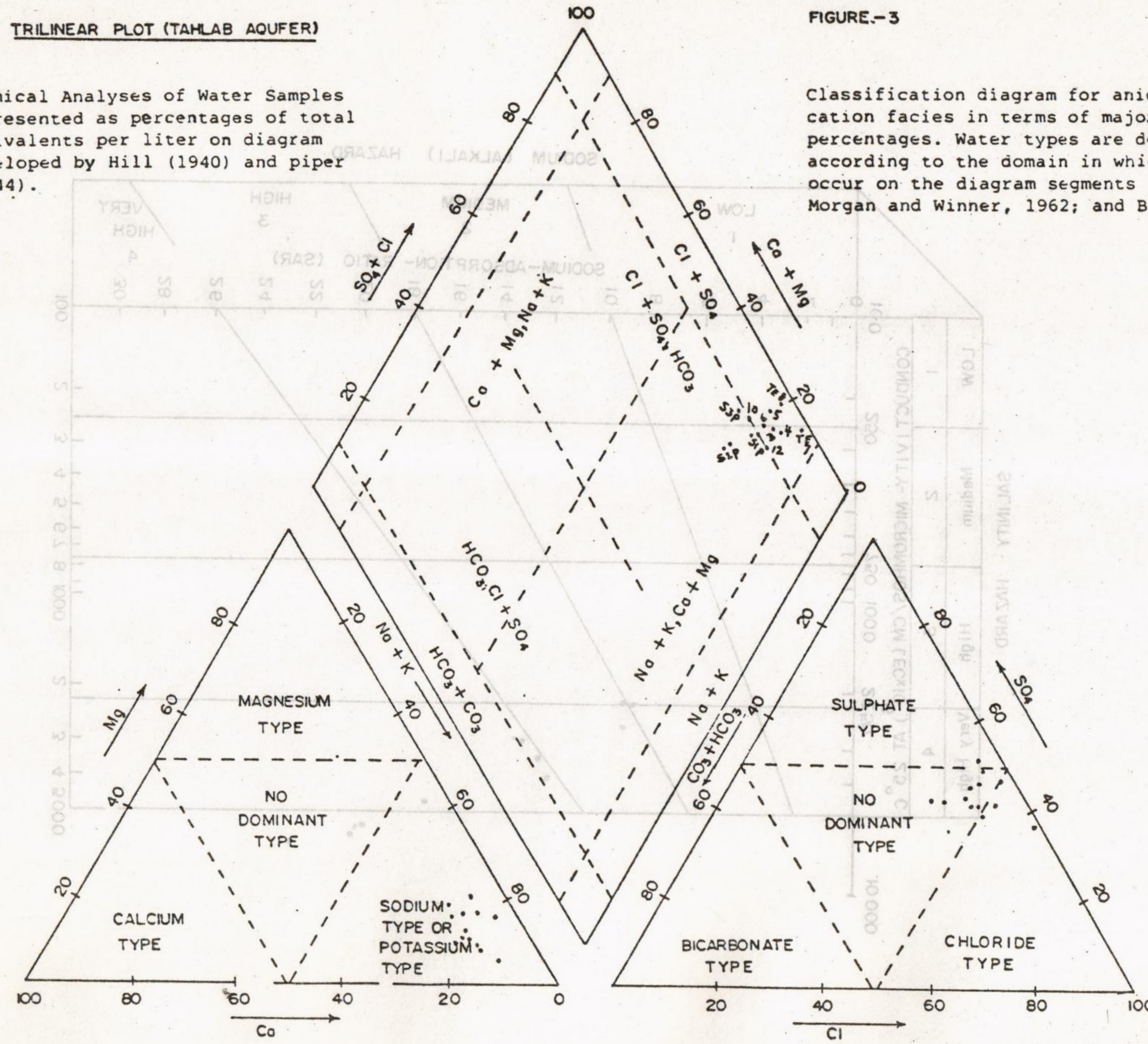
milliequivalents per litre (EPM)

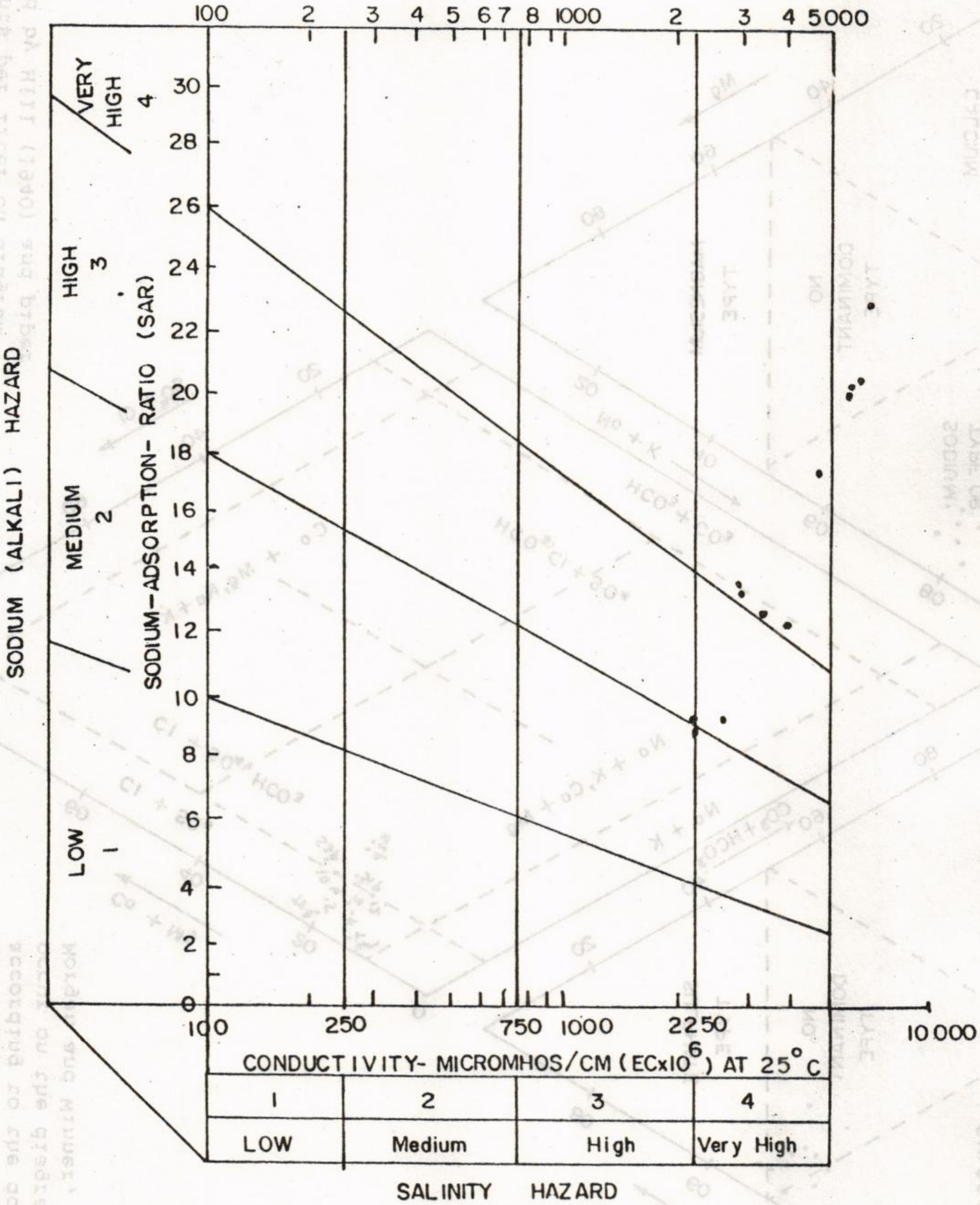
TRILINEAR PLOT (TAHLAB AQUFER)

FIGURE.-3

Chemical Analyses of Water Samples represented as percentages of total equivalents per liter on diagram developed by Hill (1940) and piper (1944).

Classification diagram for anion and cation facies in terms of major - iron percentages. Water types are designed according to the domain in which they occur on the diagram segments (after Morgan and Winner, 1962; and Back, 1966).




SODIUM (ALKALI) HAZARD
LOW 1
MEDIUM 2
HIGH 3
VERY HIGH 4
SODIUM-ADSORPTION-RATIO (SAR)
100 2 3 4 5 6 7 8 1000 2 3 4 5000
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
100 250 750 1000 2250 10000
CONDUCTIVITY- MICROMHOS/CM (ECx10^6) AT 25°C
1 2 3 4
LOW Medium High Very High
SALINITY HAZARD

FORMATION OF ESTUARINE BEDFORMS THROUGH HYDRAULIC CONDITIONS

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ABSTRACT:– Bedforms in esturaies form in response to complex variations in flow conditions. The sequence of bedforms formed under increasing strength of flow in the lower flow regime is: Linear ripples, lunatelinguoid ripples, sand waves, linear megaripples, scour megaripples, and planned-off megaripples. Bedforms formed under upper flow regime conditions are rare. Cross-bedding formed by bedform migration also change in form with change in flow conditions, from small scale-festoon, to planar, to large scale-festoon cross-bedding under increasing flow strength.

INTRODUCTION

Flume experimentation has shown that bedforms in alluvial channels change in response to variation in slope, depth, velocity, and other variables. Flow conditions were first divided into upper and lower flow regimes by Simons et al. (1961), and sequence of bedforms was described for increasing strength of flow (Table 1 and Fig. 1). A summary of data on Colorado State flume experiments can be found in Simons et al. (1961).

An interpretation of flow conditions in esturaies can be made by study of intertidal and subtidal bedforms. Harms and Fahnestock (1965) set the major precedent for interpretation of stream power and flow regime through analysis of bedforms in their study on the Rio Grande estuary.

Perhaps the main problem in projecting flume data to the field is the size of the flume in which the original experiment was done. A small flume does not allow a bedform to develop fully in its third dimension, with, and limited heights of sidewalls do not allow a large range of depth of flow. The most realistic simulation of real conditions has been at Colorado State University, in a large flume that measures 46m long by 25m wide and allows flow depths of as much as 0.6m. But even this large flume is not wide enough and does not have enough flow depth to develop fully what Simons and Richardson (1962) term "Bars" and what our Tay Estuary Research Group calls "Sand Waves" (Alizai, 1980).

BEDFORM TYPES

Both linear and lunate-linguoid ripples are found in the Tay Estuary (Figs 2 and 3). Harms (1969) shows that linear ripples develop in response to lower strengths of flow than do lunate-linguoid ripples. Liu (1957) indicates that at the beginning of bedload movement linear ripples form first and then break into a lunate-linguoid pattern almost at once. Most estuarine ripples are lunate-linguoid especially those associated with higher flow regime bedforms.

Most estuarine megaripples (= 0.6 to 7m) in the study area have a well developed scour pit in front of the slip face and hence are termed "scour megaripples". The bedforms that Simons and Richardson (1962) call dunes are scour megaripples in our classification. Dunes formed in smaller flumes tend to extend from sidewall to sidewall and are incomplete forms of a fully developed scour megaripples.

In the Scotish estuaries, sand waves (= 7m) exist in areas of deeper water and lower flow velocities than scour megaripples and thus form at lower Froude values. Sand waves tend to have straight to somewhat sinous crests with well developed lunate-linguoid ripples on their backs. Sand waves commonly have no pits in front of their slip faces but they do tend to develop shallow scour pits at times of higher velocity flow, for example during spring tides. Crests also tend to become more sinous in response to greater flow strengths.

With the above idea in mind, one can classify strengths of flow in the lower flow regime on the basis of three dimensional bedforms. Figures 4 and 5 present some data on strengths of flow versus large scale bedform type. Scour megaripples are formed under greater strengths of flow (Fr = .36) and sand waves under lower strengths (Fr = .22) but both under "dune" conditions in the sequences of Simons and others. Megaripples with linear crests occur in some localities under special flow conditions, but they are not common. They are interpreted as have formed during flow conditions intermediate between scour megaripples and sand waves. Transition bedforms are found in areas of

TABLE I.

CLASSIFICATION OF FLOW REGIME

(After Simons, Richardson and Nordin, 1965, p.36)

Flow Regime	Bed Form	Mode of Sediment Transport	Type of Roughness	Phase Relation between Bed & Water Surface
Lower Regime	Ripple Ripple on Dunes Dunes	Discrete Steps	Form Roughness Predominates	Out of Phase
Transition	Washed out Dunes		Variable	
Upper Regime	Plane Beds Antidunes Chutes & Pools	Continuous	Grain Roughness Predominates	In Phase

higher flow strengths, but upper-flow regime bedforms are rare in estuaries.

CROSS-BEDDING

Lunate-linguoid ripples from small-scale festoon cross-bedding; in a cut horizontal, to the bedding surface, throughs are found and these can be used as an idicator of current direction (Fig 6). Cross-bedding in linear ripples is poorly defined and interpretation is a problem.

Sand wave migration forms planar cross-bedding of greater amplitude than that generally formed by scour megaripples. However, this cross-bedding is extremely difficult to see in the field. Tentatively, then, "dune" cross-bedding type can be correlated wih flow regime in the following manner; with increasing strength of flow "dune" cross-bedding goes from planar to a combination of planar and festoon. At still greater strengths of flow, scour megaripples decease in wavelength and form concave slip faces. At this stage of flow (upper part of lower regime), well developed festoon cross-bedding is formed.

CONCLUSIONS

A sequence of bedforms and cross-bedding types can be correlated with increasing strength of flow. Harms and Fahnestock (1965, plate 1) give a general sequence of bedforms and cross-bedding formed with increase in flow regime. Figure 7 of this paper is a further refinement of that sequence for lower flow regime bedforms and cross-beddings. In addition estuarine depositional environments where the different bedforms occur are indicated in the summary diagram (Fig 7).

REFERENCES.

1. Alizai, S.A.K., (1980). Sediments in the intertidal zone of the upper Tay estuary. Ph.D. thesis (unpublished), University Dundee, Scotland, U.K.

2. Harms, J.C., and Fahnestock R.K., (1965). Stratification, bedforms, and flow phenomena (with an example from Rio Grande) in Middleton, G.V., eds. Primary Sedimentary Structures and their Hydrodynamics Interpretation. *Soc. Econ. Paleont. Mins. Spec. Publ.* Vol.12, P 84-115.

3. Liu, H.K., (1957). Mechanics of sediment ripple formation. *Jour. Hydraul. Div. Amer. Soc. Civil Eng. Proc.* Vol 83, No. HY2, P 1-23.

4. Simons, D.B., and Richardson, E.V., (1962). Resistance to flow in alluvial channels. *Am. Soc. Civl Eng. Trans.* Vol 127. P 927-1006.

5. Simons, D.B., Richardson, E.V. and Nordin, C.F., (1965). Sedimentary structures generated by flow in alluvial channels. In: Middleton, G.V. eds. Primary Sedimentary Structures and their Hydrodynamic Interpretation. *Soc. Econ. Paleont. Mins. Spec. Publ.* 12, P 34-54.

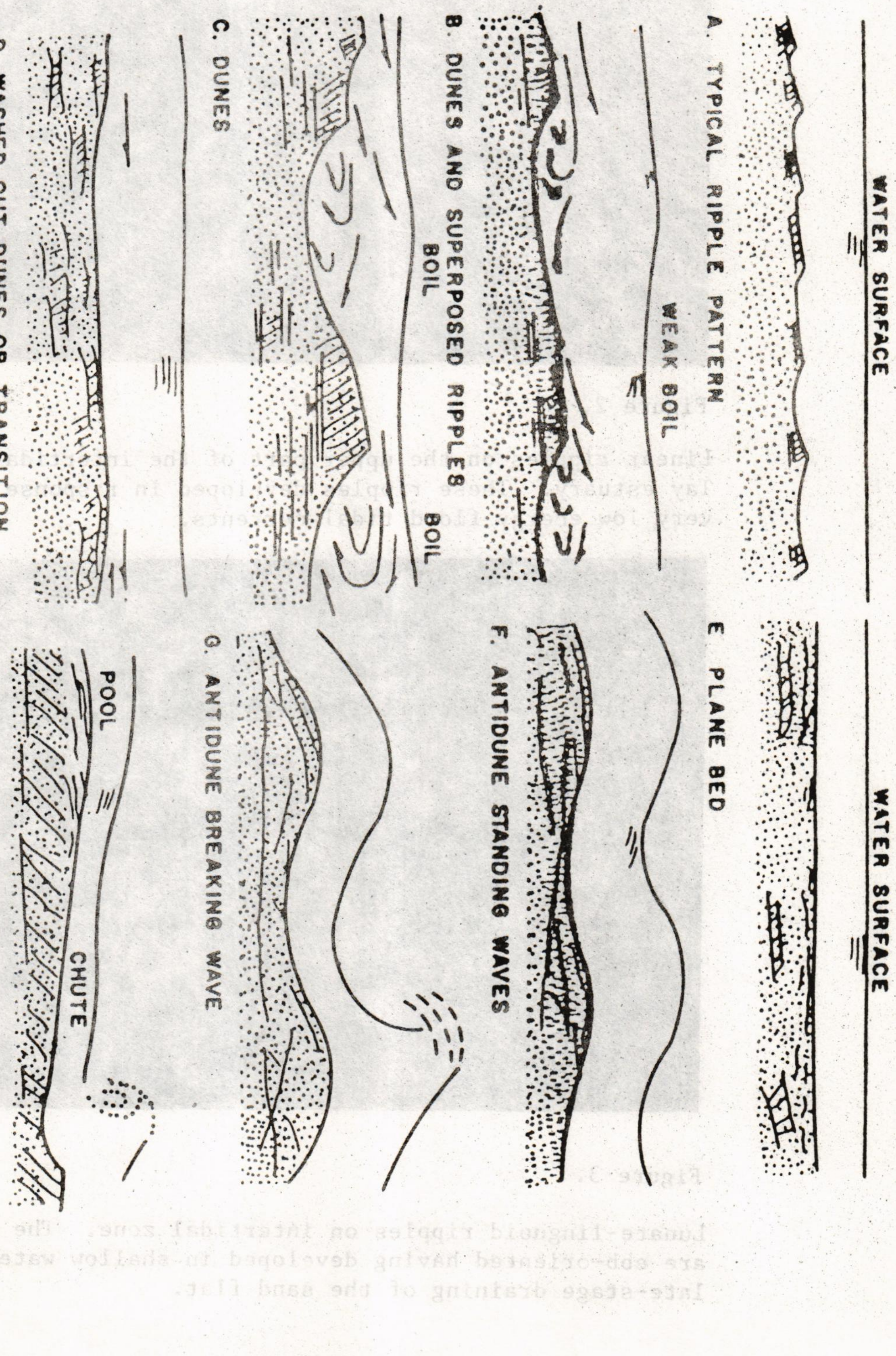

Figure 1. Sequence of bedforms with increased in flow regime conditions (after Simons and Richardson, 1962).

Figure 2.

Linear ripples on the upper part of the intertidal zone, Tay estuary. These ripples developed in response to very low energy flood tidal currents.

Figure 3.

Lunate-linguoid ripples on intertidal zone. The ripples are ebb-oriented having developed in shallow water during late-stage draining of the sand flat.

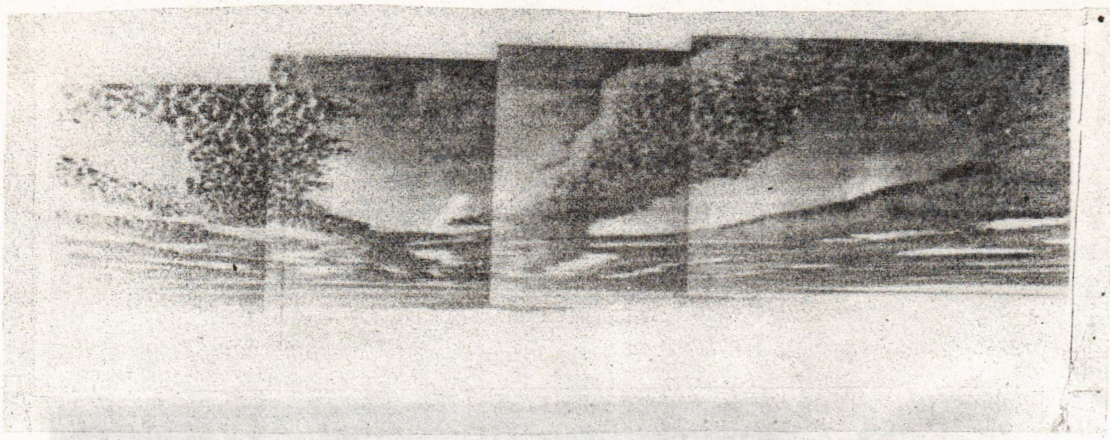

Figure 4.

Sandwaves on the intertidal zone, Tay estuary. The bedforms are flood oriented with wave length of 10 to 15m. Note the well developed lunate-linguoid ripples on the backs of the sand waves.

Figure 5.

Megaripples on the intertidal zone. The megaripples show an ebb orientation.

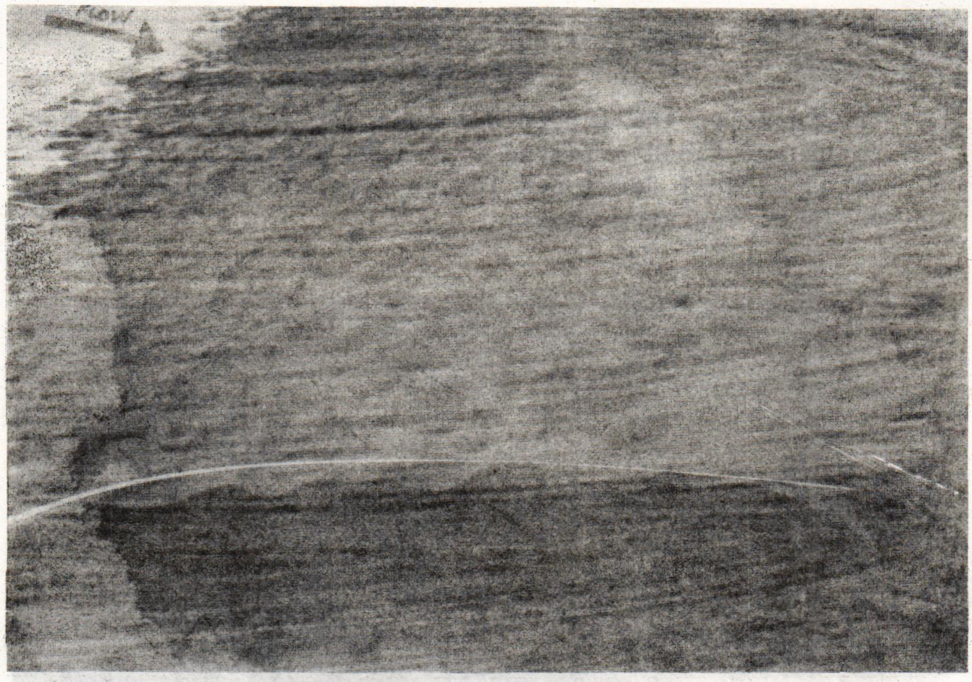

Figure 6. Small-scale festoon crossbedding formed by lunate-linguoid ripples (ebb oriented) on the inter-tidal zone.

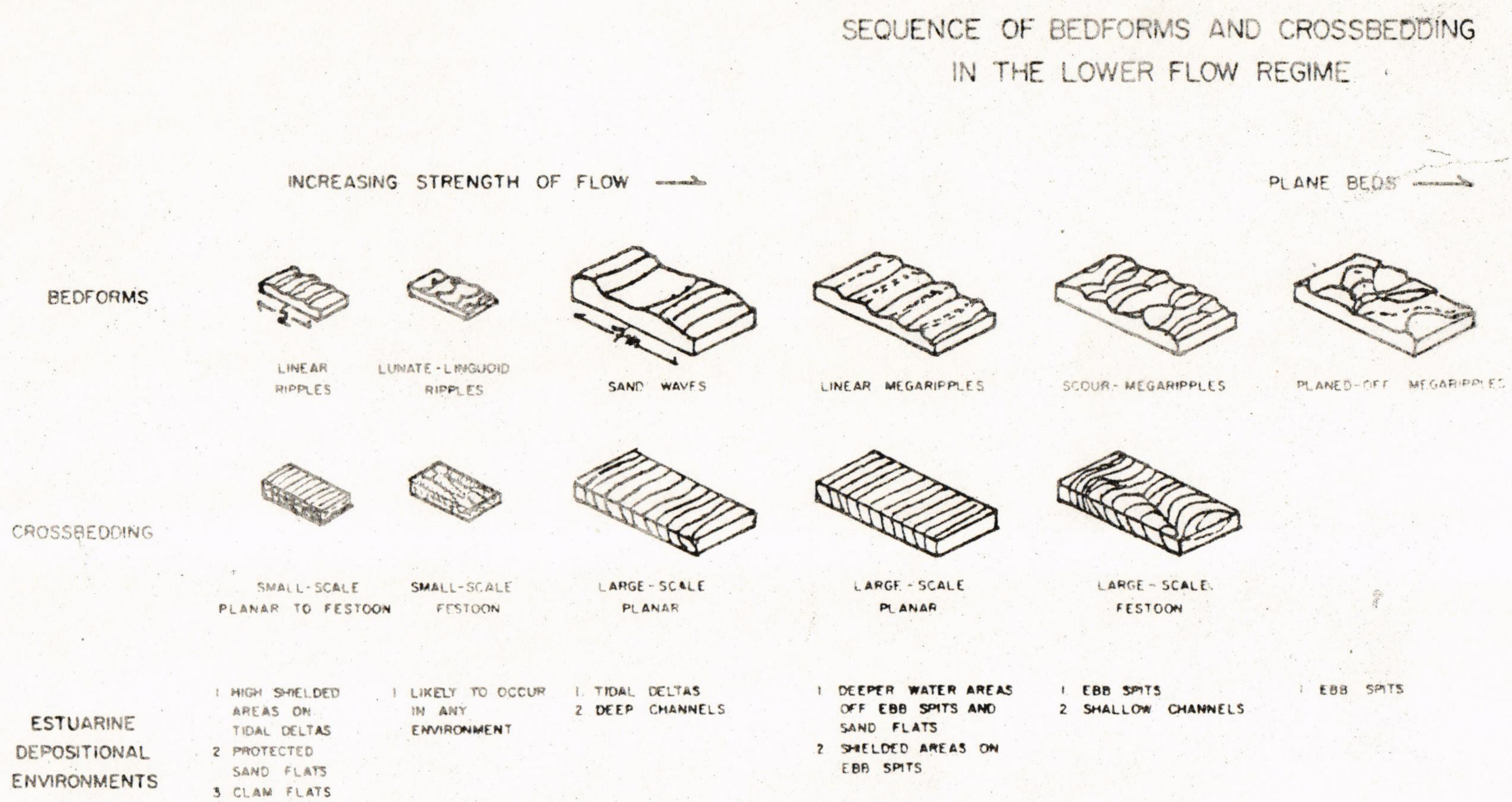

Figure 7. Sequence of bedforms and cross bedding with increasing strength of flow in the lower regime. Some depositional environments in the estuary where each bedform may occur are indicated.

GEOGRAPHICAL VARIATIONS IN THE UPPER DEVONIAN MIOSPORE ASSEMBLAGES

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ABSTRACT:– The Upper Devonian miospore assemblages that have been reported from western Europe, North America and North Africa are found to have a uniform composition and are referred to as the Multifurcata suite. The miospore species that are regarded to be ubiquitous to the Upper Devonian sediments of northern and southern hemispheres include Retispora lepidophyta, Vallatisporites vallatus var. hystricosus, Knoxisporites literatus, K. pristinus, Auroraspora micromanifesta and Punctatisporites solidus. While the Upper Devonian miospore species of Australia are identifiable with taxa recorded from northern and southern hemisphere sequences, some are clearly endemic to the Australian sediments. Of the latter Granulatisporites frustulentus, Convolutispora fromensis, Hymenozonotriletes scorpius, Diaphanospora riciniata and Leiozonotriletes laurelensis are particularly noteworthy. The first named miospore (Granulatisporites frustulentus) is the most abundant and persistent of the endemic forms of the Australian miospore assemblages reported from Australia are referred to as the Frustulentus suite in this study.

A correspondence between the North American miospore assemblages and those from other continents support the concept of an essential cosmopolitan floral elements. However, in detail there are some interregional differences.

INTRODUCTION

In the proceedings of the 17th Inter-University Geological Congress held in Queen Mary College (University of London) 17-19 December, 1969, several contributors discussed the concept of 'province' and offered definitions (see Middlemiss *et al.* 1971). Charig (in Middlemiss *et al.* p. 111) considers that province is an entirely arbitrary concept. Holland (in Middlemiss *et al.* p. 61) quotes from Darlington's well known book on 'Zoogeography' (Darlington 1957): "The great difficulty with faunal region is not philosophical but practical". Funnell (in. Middlemiss *et at.* p. 192) qoutes Valentine's definition of a province as simply a collection of communities associated in space and time. In the author's opinion the floral province should be recognized on the basis of several different forms of spores including endemic elements and it should have rather precise boundaries.

Sullivan (1965) established three floral provinces in Visean characterized by distinctive miospore associations. These are referred to as the *Monilospora* suite, the *Grandispora* suite, and the *Kazakhstan* suite. The *Monilospora* suite was established for the miospore assemblages described from western U.S.S.R., Spitsbergen and northern Canada. The miospore association in western Europe and U.S.A. had been termed the Grandispora suite and third Kazakhstan suite in the Kazakhastan area of central U.S.S.R.

Sullivan (1967) also distinguished two miospore suites from data accrued from the Tournaisian sediments, the *Vallatisporites* suite and the *Lophozonotriletes* suite. The former occurred in southeast Canada, U.S.A., western Europe, Australia and probably the Middle East. The miospore assemblages reported from Spitsbergen and western U.S.S.R. were called the *Lophozonotriletes* suits. Sullivan could not delimit the Tournaisian floral provinces geographically because of insufficient data from the strata of proved Tournaisian (Kinderhookian) age. He observed, however, that *Vallatisporites* and *Lophozonotriletes* suites occupy the same geographical position as the younger *Grandispora* and *Monilospora* suite respectively.

During the last few years attention has been concentrated on Devonian spores to differentiate them into provinces. It is difficult, as will be evident from Fig. 1. to differentiate the Upper Devonian microfloras on a global scale. This difficulty has also been noted by Rigby & Schopf (1969) who state that the Devonian microfloras seem to lack provinciality. Chaloner & Lacy (1973, pp. 273-274, text fig. 1) on macrofossils also reached a similar conclusion and postulated that it was only after the Late Carboniferous to Early Permian that distinctly geographically restricted segregation became evident. Bar & Riegel (1973) observed distinct phytogeographical segregations between Gondwanaland and Euramerica in the Middle Devonian, while the microfloras of the Upper Devonian and Lower Carboniferous were found rather uniform in composition. Richardson & McGregor (1977 M.S.) made an attempt of differentiating Devonian microfloras into provinces. They achieved the same result as proposed by Bar & Riegel (loc. cit.). Richardson & McGregor (loc. cit.) found a remarkable floristic similarities in the Lower, some differentiation in the Middle Devonian assemblages but again little microfloristic variation in the Upper Devonian.

It is worth mentioning that apart from microfloras, faunas also provided negative evidence concerning the provincialism in the Upper Devonian. House (in Middlemiss *et al.* p. 78) concludes "it happens that I am particularly interested in Deveonian ammonoides and there is little evidence of separation into province in the Devonian for them". Pointing to the possibility of provincialism in the lower Devonian, House (loc. cit. P.77) states" Provincial distributions in the early Devonian tend to be lost by the late Devonian". In the Eastern North America Oliver (1976) delineated distinct provincialism of rugose corals in the Early Devonian. He observed that percentage of endemic forms were decreased through the Middle Devonian to zero in the early Late Devonian. Bar & Riegel (1974) indicated that general tendency of the floristic evolution has been confirmed for macrofloras. In conclusion, it can be regarded that both faunas and floras show litter evidence for provinciality in the Upper Devonian.

RESULTS AND DISCUSSION

The miospore assemblages that have been reported from the Upper Devonian deposits of Canada, U.S.A., the British Isles, Belgium, poland and North Africa all have a more or less uniform composition. (For a detailed study the readers are referred to Ahmed (1978). In other words the miospore records from western Europe and North Africa mirror those of U.S.A. and Canada. The latter are distinguished by the presence of miospores with multfurcate processes, crassitudinous forms with distal murornate and/or verrucate sculptural features, laevigate pseudosaccate species and those miospores possessing 'banded' curvaturae. Typical forms are *Synorisporites flexuosus* and/or *S. variegatus* Ahmed 1978, *Aneurospora greggsii* and *A. incohata.* Apart from above mentioned elements, and excluding Australia and U.S.S.R., the presence of miospores possessing multifurcate spines seems to be cosmopolitan. Assemblages which fall in this category may be referred to as the *Multifurcata* suite because of the widespread and frequent occurrence of miospores with multifurcate spines.

The miospores assemblages recovered from the Soviet regions do not contain any additional species. In fact, these are characterized in a negative sense as they do not possess distinctive forms with multifurcate appendages and/or forms with 'banded' curvaturae such as *Aneurospora greggsii* and *A. incohata.* It is considered premature to attempt to define these assemblages in terms of a characteristic species. These, therefore, may conveniently be grouped together with those miospore assemblages revealed from Europe, North Africa and North America. Australian miospore assemblages do not contain any of the elements characteristic of the *Multifurcata* suite. In contrast these are distinguished by the profusely represented endemic form *Granulatisporites frustulentus* which has not been reported in any of the areas outside Australia, consequently these are referred to as the *Frustulentus* suite.

As most of the species mentioned above and listed in fig. 1. are unlimited in their spatial distribution the palaeogeographical picture is made indistinct. In consequence the evidence does not provide convincing palaeofloristic units. After depicting some floral similarities with the European and Canadian assemblages Playford (1976, p. 57) considered that there might be significant phytogeographical links between North African (Libyan and Algerian) and Australian miospore contents. Recently evidence has been accrued through palynological investigations conducted by Massa & Moreau-Benoit; the results of investigations into North African miospore assemblages signal that palynologically Australia is probably a distinct continent (see Fig.1). Because it is devoid of certain components which are omnipresent in the miospore records of the Upper Devonian strata in the areas lying within the northern hemisphere. However, a minority of indigenous elements in Australian sediments e.g. *G. frustulentus, C. fromensis and D. riciniata* (see Fig. 1) is hardly sufficient in the present state of knowledge to warrant the term province. Unless more data on the subject are accumulated, floral province is difficult to delineate.

Geographical and geological links between Africa and North and South America during Palaeozoic have been suggested by various workers. Bar & Riegel (1974) observed close palynological and lithological similarities between the two fragmental parts of ancient Gondwanaland, and therefore Maranhao basin of Brazil was considered as direct continuation of the Ghana coastal regions. On the other hand Streel (1974) remarked upon palynological affinities between North Africa and the Great Lakes region of eastern North America, and suggested probable geographical contiguity during the Upper Devonian.

	MIOSPORE SPECIES	U.S.A.	Canada	Ireland	England & Wales	Belgium	Poland	North Africa	USSR	Australia
Multifurcata suite	Miospores with multifurcate spines, Hystricosporites/Ancyrospora multifurcata.	■	■	■	■	■	●	■		
	Aneurospora greggsii	■	■	■		■	●	O		
	Aneurospora incohata	■	■	■	■	■	■	■		
	Synorisporites flexuosus	■	■	O	■	■		■	■	
	Auroraspora versabilis	■		O	■	■	■		■	
	Auroraspora commutata	■		■	■	O			■	
	Auroraspora poljessica	■		■	■	■			■	
	Auroraspora varia	■	■	O					■	
Ubiquitous species	Retispora lepidophyta	■	■	■	■	■	■	■	■	■
	Vallatisporites vallatus var. hystricosus	■	■	■	■	■	●	■	●	●
	Knoxisporites literatus	■	■	■	■	O	●	■	●	■
	Knoxisporites pristinus	■			●	■	●			■
	Auroraspora micromanifesta	■		■	■		●	■●	O	■
	Hystricosporites porrectus	■								■
	Pulvinispora depressa	■				■				■
	Punctatisporites solidus	■	●				■			O
Frustulentus suite	Granulatisporites frustulentus									■
	Apiculatisporis morbosis									■
	Convolutispora fromensis									■
	Camptotriletes balmei									■
	Cirratriradites impensus									■
	Hymenozonotriletes scorpius									■
	Diaphanospora riciniata									■
	Grandispora notensis									■
	Leiozonotriletes laurelensis									■
Miospores common to U.S.A. and Ireland	Calamospora liquida	■		■						
	Retusotriletes concretus	■		■						
	Retusotriletes sp.	■		●						
	Apiculiretusispora fructicosa	■		■						
	Pulvinispora quasilabrata	■		■						
	Geminospora lemurata	■		■						■
	Emphanisporites ?rotatus	■		■			●	■		
	Convolutispora vermiformis	■		■						
	Streelispora catinata	■		■						
	Synorisporites variegatus	■		■						
	Grandispora corunata	■		■						
	Retispora lepidophyta var. granda	■		■						
	Auroraspora torquata	■		■						
	Hystricosporites porcatus	■		■						

(Column group heading: OCCURRENCE)

■ Recorded from Upper Devonian ● Recorded from Lower Carboniferous O Dubious specific assignment.

Fig. 1. Regional comparison of selected Upper Devonian miospore species.

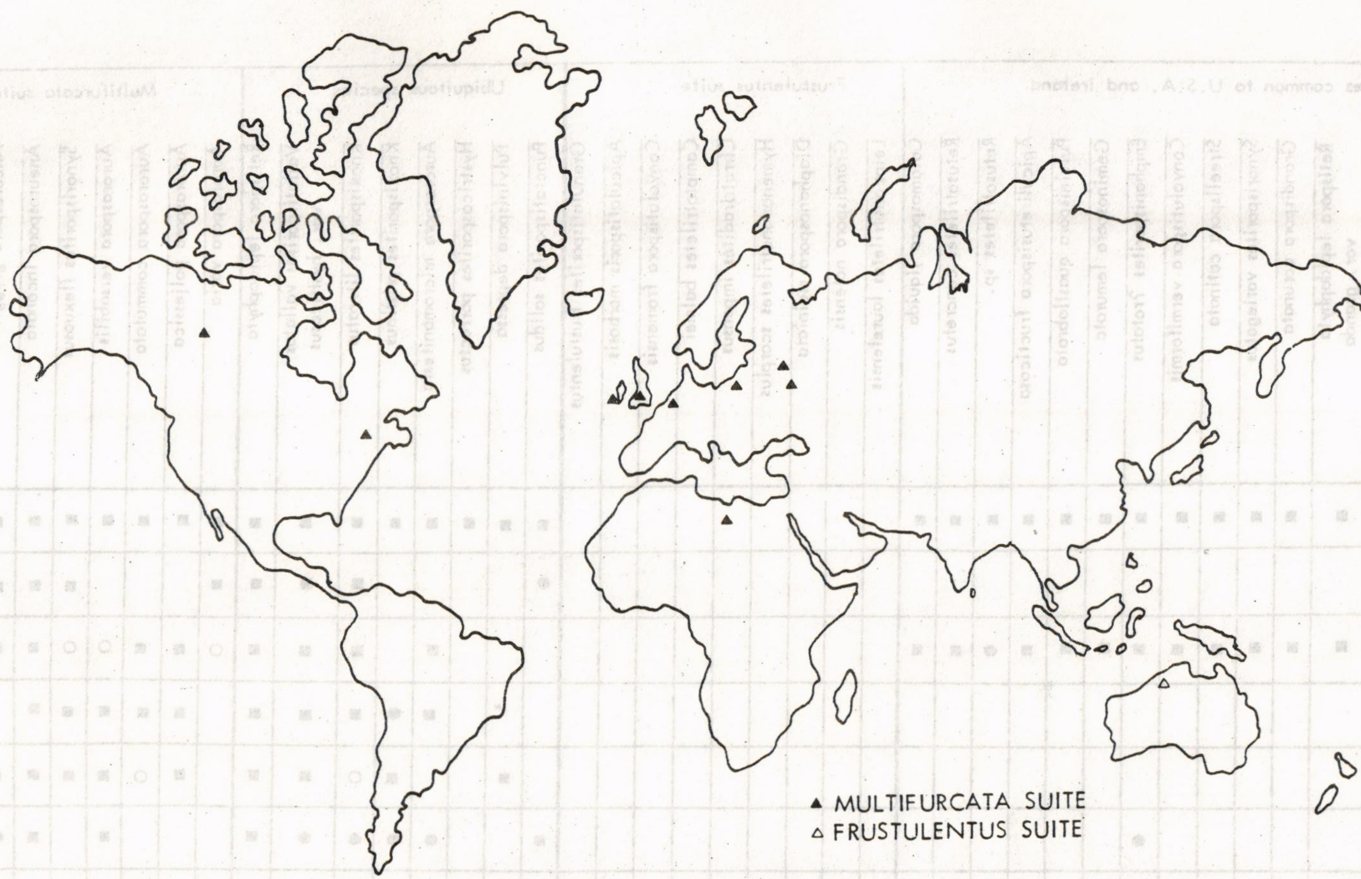

fig. 2 The distribution of the floral suites plotted on the present continent positions.

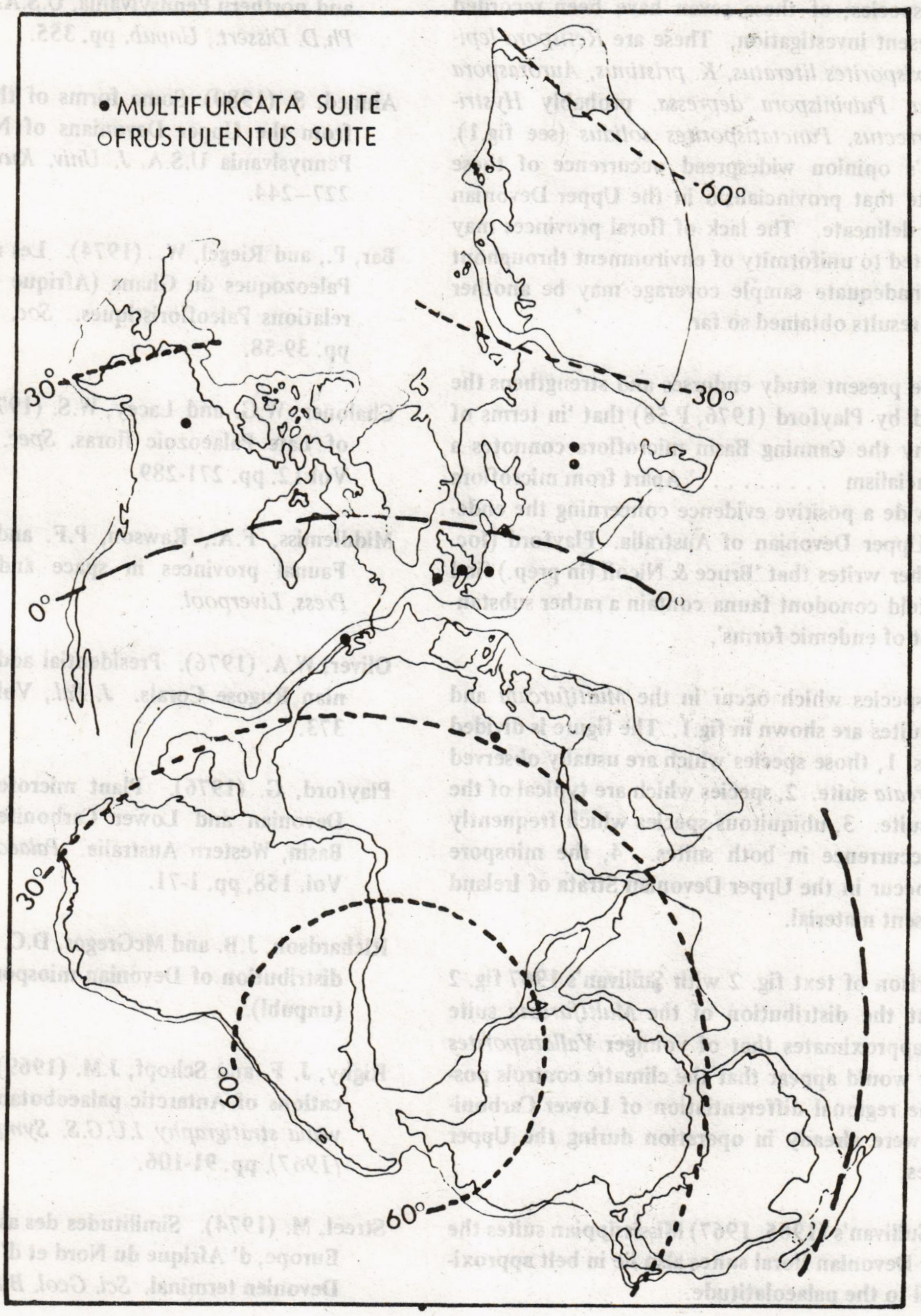

fig. 3. The distribution of the floral suites plotted on the pre-drift continent positions (Middle Devonian) suggested by McElhinney after Oliver 1976.

Playford (loc. cit.) went on to suggest that "the Canning Basin microflora connotes a definite provincialism". Streel (1974) also pointed to the possibility of provincialism in Australia. Australian (Famennian) sediments yielded 53 miospore species; of these seven have been recorded during the present investigation. These are *Retispora lepidophyta, Knoxisporites literatus, K. pristinus, Auroraspora micromanifesta, Pulvinispora depressa,* probably *Hystricosporites porrectus, Punctatisporites solidus* (see fig.1). In the writer's opinion widespread occurrence of these species indicate that provincialism in the Upper Devonian is difficult to delineate. The lack of floral provinces may also be attributed to uniformity of environment throughout the world. Inadequate sample coverage may be another reason for the results obtained so far.

Indeed the present study endorses and strengthens the view expressed by Playford (1976, P.58) that 'in terms of Phytogeography the Canning Basin microflora connotes a definite provincialism ....' Apart from microflora funa also provide a positive evidence concerning the endemism in the Upper Devonian of Australia. Playford (loc. cit. P.57) further writes that 'Bruce & Nicoll (in prep.) find that the Fairfield conodont fauna contain a rather substantial component of endemic forms'.

Selected species which occur in the *Multifurcata* and *Frustulentus* suites are shown in fig.1. The figure is divided into four parts. 1, those species which are usually observed in the *Multifurcata* suite. 2, species which are typical of the *Frustulentus* suite. 3, ubiquitous species which frequently make their occurrence in both suites. 4, the miospore forms which occur in the Upper Devonian Strata of Ireland and in the present material.

A comparison of text fig. 2 with Sullivan's 1967 fig. 2 will show that the distribution of the *Multifurcata* suite more or less approximates that of younger *Vallatisporites* suite. Thus it would appear that the climatic controls postulated for the regional differentiation of Lower Carboniferous floras were already in operation during the Upper Devonian times.

As with Sullivan's (1965, 1967) Mississippian suites the present Upper Devonian floral suites also lie in belt approximately parallel to the palaeolatitude.

Two of the problems arising from this study are, how such a cosmophlitan spore flora could exist whereas provinces apparently existed in the L ower Carboniferous, and secondly why there are some differences in the Australian Upper Devonian.

REFERENCES

Ahmed, S. (1978). Palynology and biostratigraphy of some Upper Devonian deposits of western New York State and northern Pennsylvania, U.S.A. *London University, Ph.D. Dissert., Unpub.* pp. 355.

Ahmed, S. (1980). Some forms of the genis *Anroraspora* from the Upper Devonians of New York State and Pennyslvania U.S.A. *J. Univ. Kuwait (Sci)*,Vol. 7, pp. 227–244.

Bar, P., and Riegel, W. (1974). Les microfloras des series Paleozoques du Ghana (Afrique Occidentale) et leurs relations Paleofloristiques. *Soc. Geol. Bull.*, Vol. 27, pp. 39-58.

Chaloner, W.G. and Lacey, W.S. (1973). The distribution of Late Palaeozoic floras. *Spec. pap. Palaeontology.* Vol.12. pp. 271-289.

Middlemiss, F.A., Rawson, P.F. and Newall, G. (1971). Faunal provinces in space and time. *Seel House Press, Liverpool.*

Oliver, W.A. (1976). Presidential address Biology of Devonian Rugose Corals. *J. Pal.*, Vol. 50, No. 3, pp. 365-373.

Playford, G. (1976). Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin, Western Australia. *Palaeontographica, Abt. B.*, Vol. 158, pp. 1-71.

Richardson, J.B. and McGregor, D.C. (1977). Geographical distribution of Devonian miospore floras. *I.C.P. India* (unpubl).

Righy, J. F. and Schopf, J.M. (1969). Stratigraphic implications of Antarctic palaeobotanic studies. In: *Gondwana stratigraphy I.U.G.S. Symposium, Buenos Aires (1967)*, pp. 91-106.

Streel, M. (1974). Similitudes des assemblages de spores d' Europe, d' Afrique du Nord et d'Amerique du Nord, au Devonien terminal. *Sci. Geol. Bull.*, vol. 27, pp. 25-38.

Sullivan, H.J. (1965). Palynological evidence concerning the regional differentiation of Upper MIssissippian Floras. *Pollen et Spores*, Vol. pp. 539-563.

Sullivan, H.J. (1967). Regional differences in Mississippian spore assemblages. *Rev. Palaeobot. Palyn.* Vol. 1. pp. 185-192.

EVIDENCE OF AN INCIPIENT PALAEOZOIC OCEAN IN KASHMIR, PAKISTAN

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ABSTRACT. The Himalayas are interpreted to have formed by continent–continent collision between Indo-Pak plate and Asia. This event has been dated to be Eocene. Prior to the collision however, tectonics of the passive northern margin of the Indian plate has rarely been examined although these older rocks constitute a significant part of the Himalayan region especially the southern Kohistan ranges of Yeats & Lawrance (1984).

Geochemistry of the Panjal volcanics is used to demonstrate that these represent an incipient ocean floor which lay between the Gondwanaland and Kashmir-Hazara microcontinent prior to the break-up of India from Gondwanaland.

INTRODUCTION

Most tectonic interpretations of the Himalayas consider the Indus suture zone (ISZ) as the northern edge of the Indian continent (Radhakarishan et al., 1984; Talent and Mawson, 1979; Dewey and Bird, 1970; Powell and Conaghan, 1973; Stoneley, 1975; Molnar and Toppannier, 1975). Sinha-Roy (1976) suggested that the central crystallines was a microcontinent and a basin developed south of this microcontinental mass. This interpretation was supported by Radkhakarishna *et al.,* (1975). However, in Pakistan, the distinction between the central crystalline axis/and other well-defined zones of the Indian Himalayas are not clear (Yeats and Lawrence 1984).

Volcanic rocks in general have particular characteristics which serve to indicate the tectonic regions of their eruption (Pearce and Cann, 1973; Pearce and Norry, 1979). A linear belt of basic volcanic rocks is exposed in Azad Kashmir along the Pir Panjal range and is bounded on both sides by thrust contact (Fig.1). Petrological-geochemical character of these volcanics is the subject of this study in order to define their tectonic environment.

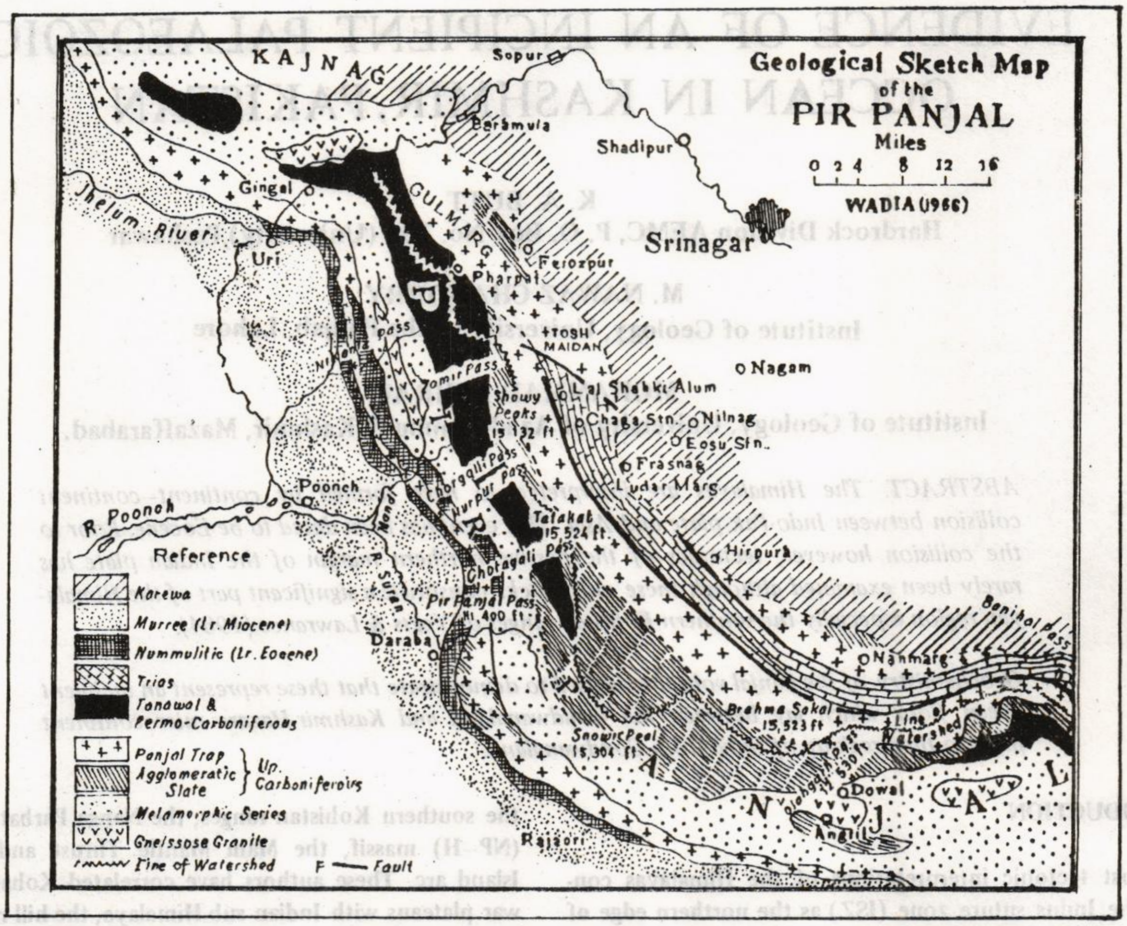
GEOLOGICAL SETTING

Yeats and Lawrence (1984) divided Pakistan Himalayas into the Indian foreland, the Salt Range, Potwar and Kohat plateaus, the Hill Ranges, the intermountain basins, the southern Kohistan ranges, the Nanga Parbat-Haramosh (NP–H) massif, the Main Mantle Thrust and Kohistan Island arc. These authors have correlated Kohat and Potwar plateaus with Indian sub-Himalaya, the hill ranges with the Lesser Himalayas and NP-H massif to higher Himalayas and have suggested the absence of Tethys Himalayas in Pakistan.

The Main Mantle Thrust is considered to be the northernmost end of the Indo-Pak plate. Ghazanfar and Chaudhry (1984) reported Palaeozoic ophiolite and Island arc sequence from Hazara-Kashmir syntaxis. The ophiolite sequence is represented by basic lavas of Panjal volcanics which show pillow structures (Ghazanfar and Chaudhry 1984) associated with marine sedimentry rocks and slices of ultrabasic rocks. On the basis of gradation of limestones interbedded with the volcanics and fossils recovered from intravolcanic sediments their age can be bracketed between Devonian and Triassic (Ghazanfar & Chaudhry 1984). A thick sequence of agglomeratic slates and volcanic breccias are associated with the volcanics, suggesting explosive volcanism. These volcanics vary in colour from dark to light green. They exhibit microporphyritic amygduloidal and vesicular textures. Vesicules are filled with zeolites, calcite chalcedony and quartz.

PETROGRAPHY

The Panjal volcanics are composed of basaltic lava



Fig–1. Geological sketch map of Pir Panjal Range (after Wadia 1966).

flows with associated tuffs, agglomeratic slates and volcanic ashes. These volcanics occur as inliers within the Paleocene rocks mostly along the foot of Pir Panjal range in upper Haveli tehsil. Fine grained green to grayish green volcanics show a sequence of lava flows at the base whereas tuffs and ashes are generally restricted to the top of the pile.

These rock have a typical aphanitic texture, microporphyritic to subporphyritic, vesicular to amygduloidal, some flows or parts of flows are amygduloidal with epidote or epidote/chlorite filling the vesicules. In others vesicules are filled with zeolites, calcite and chalcedony/quartz.

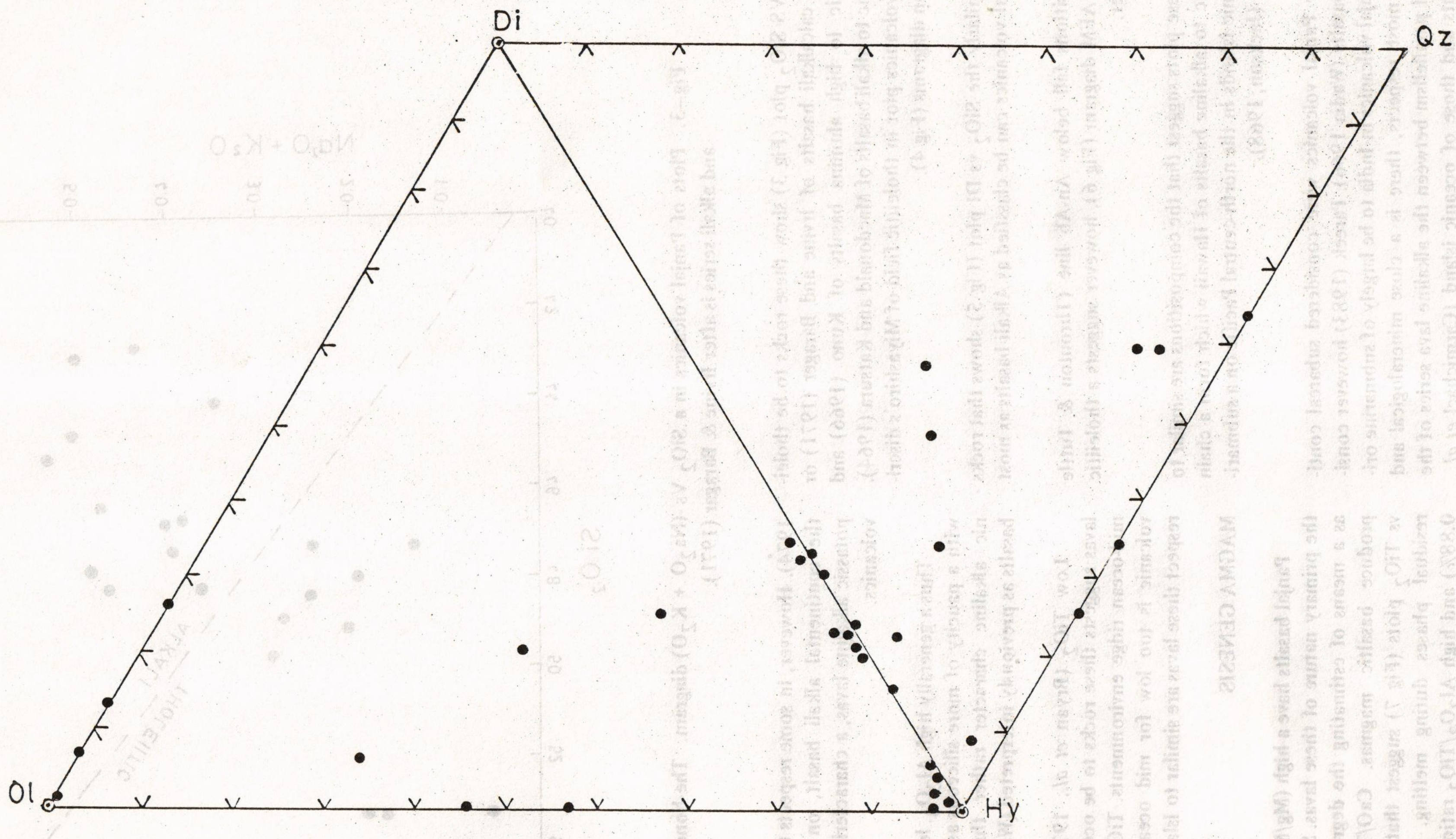
Plagioclase occurs as fine to medium subhedral to euhedral laths. Alteration to sericite, clays and epidote is common. Clinoyroxene is fine to medium-grained and subhedral. It shows extensive alteration to epidote, amphibole and chlorite. Minor constituents include anhedral quartz, magnetite and sphene. Chlorite, amphibole, epidote, calcite and sericite are the secondary minerals formed at the expense of plagioclase and or/pyroxene. Patches of devitrified flows were also observed.

The microphenocrysts of plagioclase and clinopyroxene and absence of olivine suggest these rocks to be tholeiites (Lurant et al., 1980).

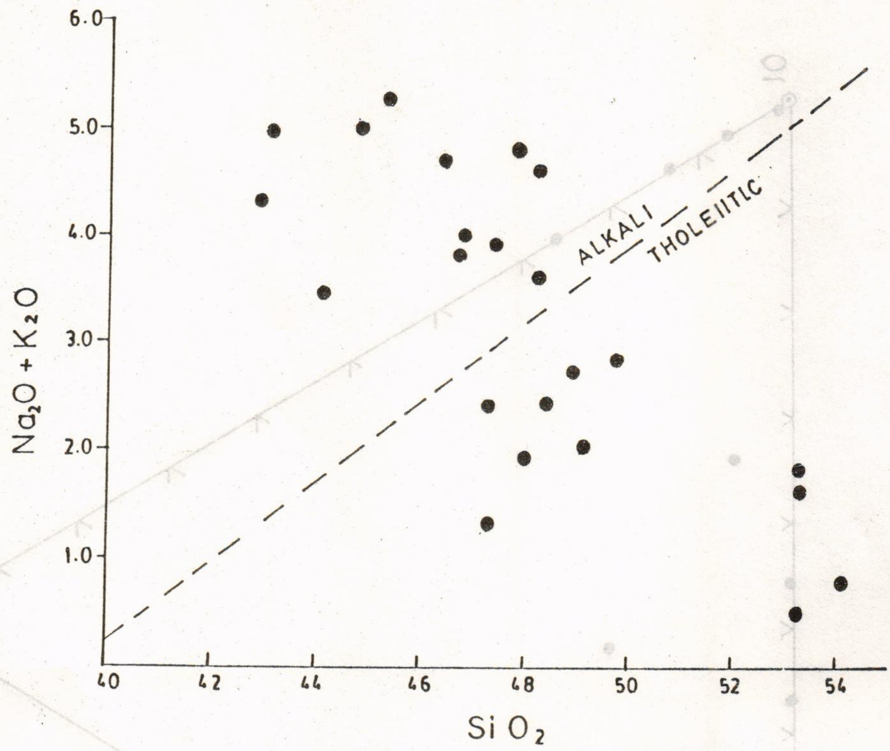
GEOCHEMISTRY

Twenty three selected samples were analysed for major elements by classical wet methods and spectrophotometry. Analytical data is presented in Table 1 whereas average analyses of the Panjal volcanics and of different tectonic regimes are given in Table 2.

The normative compositions of Panjal volcanic varies between olivine and quartz normative rocks with a predominance of normative hypersthene (Fig 2). SiO_2 variation (42. 89 - 54.1%) in these volcanic rocks suggests a basaltic to basaltic andesite composition. The Panjal volcanics have a higher Al_2O_3 and low TiO_2 content as compared to Deccan traps (Wadia, 1966) which represent the intra-plate basaltic volcanics of the Indian plate. Na enrichment during spilitization or hydrothermal alteration may cause these rocks to plot in the alkaline field. The (NaO_2+



Fig–2. Plots of relative proportions of normative 01, Hy, Di, and Qz in Panjal volcanics.



Fig–3. Plots of Panjal volcanics in a SiO_2 Vs (Na_2O + K_2O) diagram. The bondary between tholeiitic and alkali series is after Irvine & Baragar (1971).

K_2O) VS SiO_2 plot (Fig 3) show these rocks to be tholeiitic to calcalkali basalts of Irvine and Barager (1971) or tholeiitic to high alumina basalts of Kuno (1966) and tholeiitic to alkali basalts of Macdonald and Katsura (1964). Panjal volcanics plot in tholeiitic field of Miyashiro's discrimination diagrams (Fig 4).

Similarly the SiO_2 vs DI plot (Fig 5) shows that rocks of Panjal volcanics can be classfied as Alkali basalts as most

compositions fall below An-Ab line (Thronton & Tuttle 1960). AFM diagram (Fig 6), however suggests a tholeiitic character.

These plots suggest that the compositions are similar to tholeiitic to alkaline basalts of Hawaii which form a chain of oceanic islands in the north-central Pacific on a submarine ridge (Jackson, 1968).

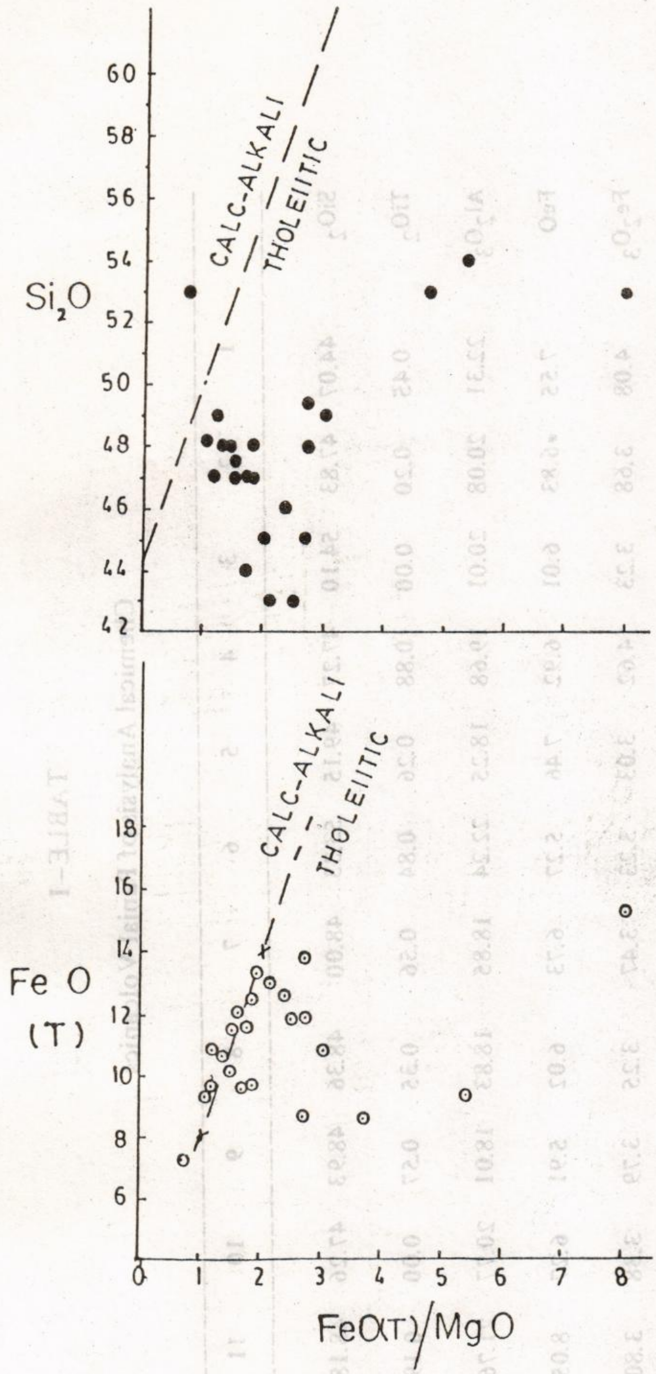
The Panjal volcanics were considered subareal continental basalts (Wadia 1966). Pareek (1983) however considred Panjal volcanics in India to be largely of submarine origin. In most respects, there is a close mineralogical and chemical parallelism between the alkaline lava series of the continents and those of oceanic island (Carmichacl *et al.*, 1974). However, in some respects there also are departures; the continental alkali basalt, on the whole, have more potassic alkaline lavas, a characteristic lacking in the Panjal volcanics.

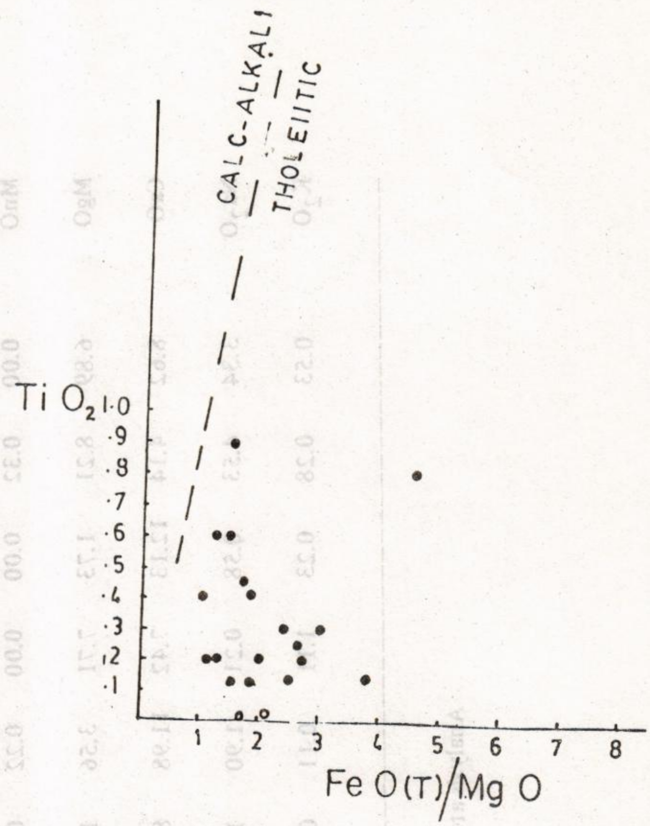
Thus a generally high Al_2O_3. low TiO_2 and a low K_2O, with a paucity of more siliceous associates, reflect an oceanic alkaline character rather than continental alkaline basalts as previously interpreted (Wadia 1966).

Low TiO_2 (Bryan *et al.*, 1976) content of pillowed lavas suggests these rocks to be ocean tholeiites erupted in mid-ocean ridge environments. TiO_2 content of the Panjal volcanic is too low for mid ocean ridge basalts. In this respect these lavas are similar to Island arc basalts.

MAGMA GENESIS

Panjal basalts have a high (Mg/Mg+ Fe) ratio, suggesting the primary nature of these lavas. Sun *et al.* (1979) used Ti as a means of estimating the degree of partial melting to produce basaltic magmas. CaO/TiO_2 and Al_2O_3/TiO_2 vs TiO_2 plots (Fig 7) suggest that Ca and Al are held in residual phases during melting. Low TiO_2 (Maximum 0.88%) and high Al_2O_3/TiO_2 ratio (always more than 22)





Fig–4. Plots of Panjal volcanics in terms of variation of (a) SiO_2 (b) FeO & (c) TiO_2 with increase of FeO/MgO and CA & TH fields shown are after Miyashiro's (1975)

of Panjal volcanics suggest that the volcanics owe their origin to a high degree of partial melting (Radhakrishna et al., 1984).

Partial melting (20–30%) of pyrolite yeilds basaltic magmas with high Mg numbers (Mg/Mg + Fe). The Panjal volcanics with a high Mg/Mg + Fe ratios are comparable to primary lavas but Mg content of these rocks is however on the lower side for similar rock compostions. This Mg depletion is suggestive of a strong olivine fractionation trend. A decrease in TiO_2 with fractionation index also supports a strong fractionation process operative in the evolution of these magmas (Fig 8). However, FeO shows an increasing trend with increasing fractionation, possibly indicating a removal of Mg due to olivine fractionation and a complimentary increase in FeO as a result (Fig 8). A slight increase in Al_2O_3 (Fig 9) reflects strong olivine fractionation resulting in a relative enrichment of felsic phase during evolution of Panjal volcanic basalts. Such a fractionation is again characteristic of oceanic basalts (Perfit *et al.,* 1980).

DISCUSSION

The northern limit of the Indian plate has been variously interpreted to be either Indus suture zone (Radhakrishna *et al.,* 1984; Dewy and Bird, 1970) or further north of ISZ as suggested by Crawford (1974). The Panjal volcanics lie much too south of the proposed northern limit of the

TABLE–I

Chemical Analysis of Panjal Volcanics

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	44.07	47.83	54.10	47.27	49.15	53.33	48.00	48.36	48.93	47.26	48.18	53.30
TiO_2	0.45	0.20	0.00	0.88	0.26	0.84	0.56	0.35	0.57	0.00	0.19	0.75
Al_2O_3	22.31	20.08	20.01	19.68	18.25	22.24	18.85	18.83	18.01	20.77	21.76	19.69
FeO	7.55	•6.83	6.01	6.92	7.46	5.27	6.73	6.02	5.91	6.27	8.05	4.52
Fe_2O_3	4.08	3.68	3.23	4.62	3.03	3.23	3.47	3.25	3.79	3.38	3.80	2.78
MnO	0.00	0.32	0.00	0.00	0.22	0.00	0.33	0.23	0.31	0.00	0.00	0.00
MgO	6.89	8.21	1.73	7.71	3.56	1.81	7.40	8.81	8.02	5.67	4.35	9.77
CaO	8.62	4.14	12.13	7.42	11.98	8.86	10.80	10.80	9.87	9.84	7.81	5.83
Na_2O	3.34	4.53	0.58	0.21	1.90	1.70	1.62	2.19	2.45	1.74	3.17	1.23
K_2O	0.53	0.28	0.23	1.11	0.11	0.14	0.29	0.18	0.23	0.60	0.42	0.35

Analysis at: Engineers Combine Ltd. Lahore.

TABLE – 1 (Contd)

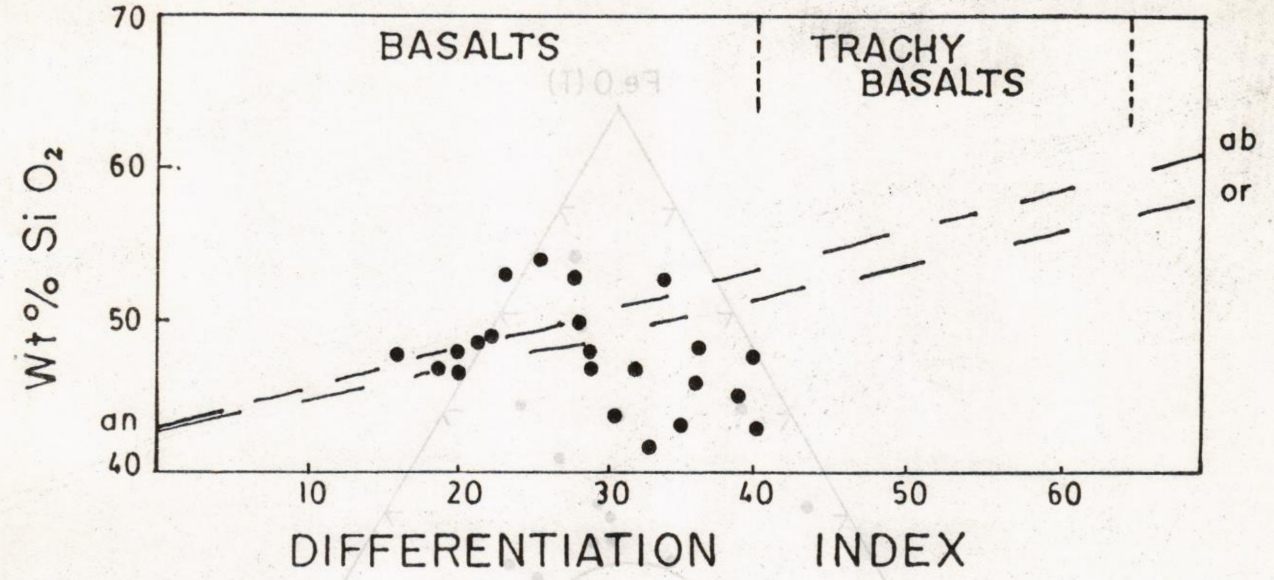
	13	14	15	16	17	18	19	20	21	22	23
SiO_2	46.72	49.57	47.37	53.24	48.17	43.14	46.83	46.37	44.84	45.37	42.89
TiO_2	0.21	0.15	0.16	0.06	0.13	0.00	0.18	0.31	0.24	0.18	0.14
Al_2O_3	19.53	21.91	16.28	13.39	22.26	23.31	19.35	18.05	17.46	20.60	24.82
FeO	7.88	3.50	7.84	10.68	6.06	9.09	6.94	8.22	9.02	8.29	7.09
Fe_2O_3	3.65	3.00	4.23	4.58	3.56	3.90	3.74	4.44	4.86	5.31	4.73
MnO	0.14	0.06	0.18	0.16	0.07	0.00	0.33	0.32	0.00	0.06	0.00
MgO	6.98	3.11	7.81	1.91	5.44	6.13	8.76	5.30	5.21	7.00	4.81
CaO	7.01	11.63	8.12	11.05	5.87	5.90	7.80	6.71	7.91	4.25	8.03
Na_2O	3.70	2.70	2.25	0.46	3.23	4.44	3.60	2.98	3.71	4.97	3.90
K_2O	0.09	0.12	1.69	0.00	1.42	0.49	0.37	1.75	1.25	6.18	0.36

Analysis at: Engineers Combine Ltd., Lahore.

AVERAGE COMPOSITION OF PANJAL VOLCANICS AND THOSE OF DIFFERENT TECTONIC REGIMES

Components	Panjal X	Volcanics S.D.	Ridge thole-iites	Arc tho-leiites	Continental rift tho-leiites	Island thole-iites	Oceanic alkali basalts	Continental rift alkali basalts.	CA basalts
		1	2	3	4	5	6	7	8
SiO_2	48.14	3.07	49.80	51.10	50.30	49.40	47.40	47.80	48.10
TiO_2	0.30	0.25	1.50	0.83	2.20	2.50	2.90	2.20	0.73
Al_2O_3	19.88	2.55	16.00	16.10	14.30	13.90	18.00	15.30	18.33
Fe_2O_3	3.84	0.66							2.07
FeO	7.05	1.57	10.00	11.80	13.50	12.40	10.60	12.40	5.04
MgO	5.93	2.47	7.50	5.10	5.90	8.40	4.80	7.00	5.04
CaO	8.36	2.28	11.20	10.80	9.70	10.30	8.70	9.00	10.50
Na_2O	2.63	1.30	2.75	1.96	2.50	2.13	3.99	2.85	1.88
K_2O	0.79	0.52	0.14	0.40	0.66	0.38	1.66	1.31	1.56
MnO	0.12	0.13							

(1) Average composition of Panjal volcanics.
(2–7) after Condie (1976)
(8) after Barbieri et al. (1976).



Fig–5. Plots of SiO_2 VS differientation Index. Also shown is the Thoronton & Tuttle saturation lines an–or and an–ab which separate the field of understurated rock (below) from that of saturated rocks (above).

Indian plate. Geochemical evidence presented herein suggests an oceanic origin of these basalts.

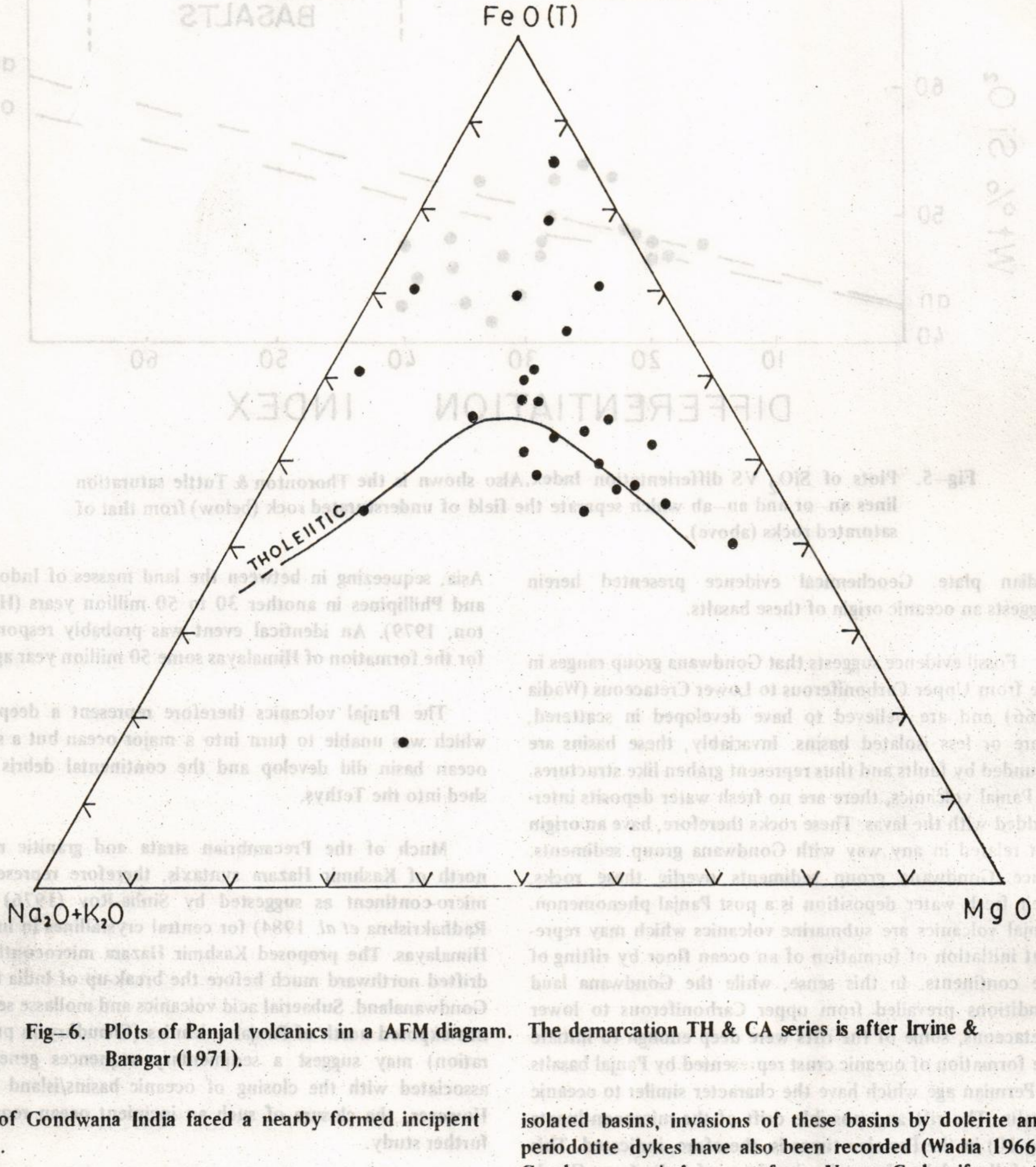
Fossil evidence suggests that Gondwana group ranges in age from Upper Carboniferous to Lower Cretaceous (Wadia 1966) and are believed to have developed in scattered, more or less isolated basins. Invariably, these basins are bounded by faults and thus represent graben like structures. In Panjal volcanics, there are no fresh water deposits interbedded with the lavas. These rocks therefore, have an origin not related in any way with Gondwana group sediments. Since Gondwana group sediments overlie these rocks, their fresh water deposition is a post Panjal phenomenon. Panjal volcanics are submarine volcanics which may represent initiation of formation of an ocean floor by rifting of the continents. In this sense, while the Gondwana land conditions prevailed from upper Carboniferous to lower Cretaceous, some of the rifts were deep enough to initiate the formation of oceanic crust represented by Panjal basalts of Permian age which have the character similer to oceanic basalts. The rift and possible drift of the microcontinents (Fig 10) in the Permian times is, therefore, indicated. This was followed by the major break-up of India from Gondwanaland. Thus, initial break-up of the continent before the major event is indicated.

Similar rifting of the northern margin of the Australian continent has been demonstrated by (Pigram and Panggebean, 1984). This similarity becomes all the more significant if we consider that Australia is likely to collide with Asia, sequeezing in between the land masses of Indonesia and Phillipines in another 30 to 50 million years (Hamilton, 1979). An identical event was probably responsible for the formation of Himalayas some 50 million year ago.

The Panjal volcanics therefore represent a deep rift which was unable to turn into a major ocean but a small ocean basin did develop and the continental debris was shed into the Tethys.

Much of the Precambrian strata and granitic rocks north of Kashmir Hazara syntaxis, therefore represent a micro-continent as suggested by Sinha-Roy (1976) and Radhakrishna *et al.* 1984) for central crystallines in Indian Himalayas. The proposed Kashmir Hazara microcontinent drifted northward much before the break-up of India from Gondwanaland. Subaerial acid volcanics and mollasse sequence exposed north of Panjal volcanics (Chaudhry in preparation) may suggest a sedimentary sequences generally associated with the closing of oceanic basins/island arcs. However, the closure of such an incipient ocean requires further study.

Geochemistry of Panjal volcanics presented herein suggests that they represent an ocean crust of alkaline to tholeiitic basaltic compoistion. The existance of Gondwana sediments north of Panjal thrust (Fig 1) suggests the rifting of a microcontinent during Permian, the age of Panjal volcanics. Thus, as a consequence of development of an ocean floor as evidence by these volcanics the northern

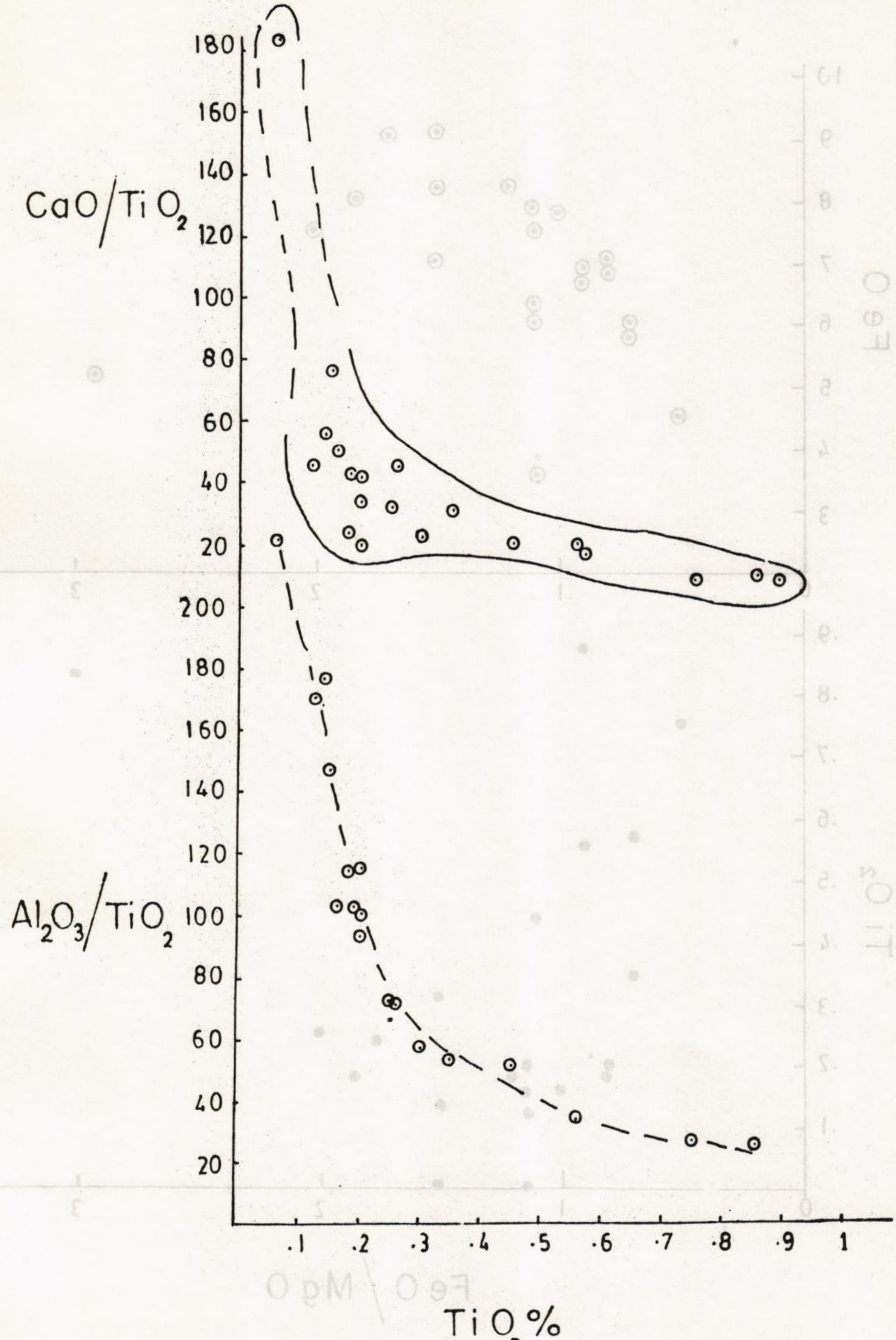


Fig–6. Plots of Panjal volcanics in a AFM diagram. The demarcation TH & CA series is after Irvine & Baragar (1971).

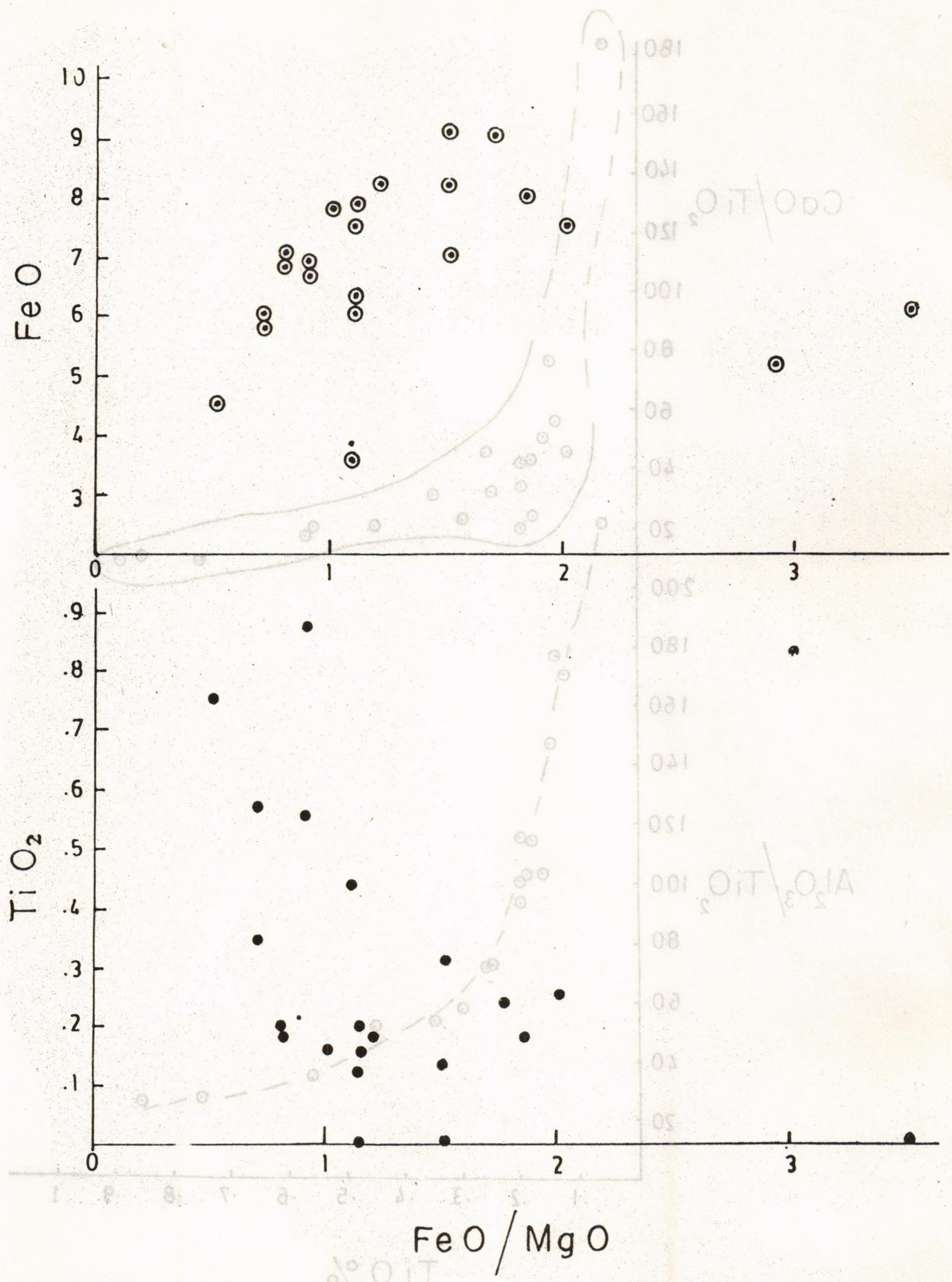
edge of Gondwana India faced a nearby formed incipient ocean.

Northward flight of India followed in late Cretaceous which could have caused collision of Kashmir - Hazara microcontinent with India but the mechanism of closure of such an incipient ocean remains to be studied.

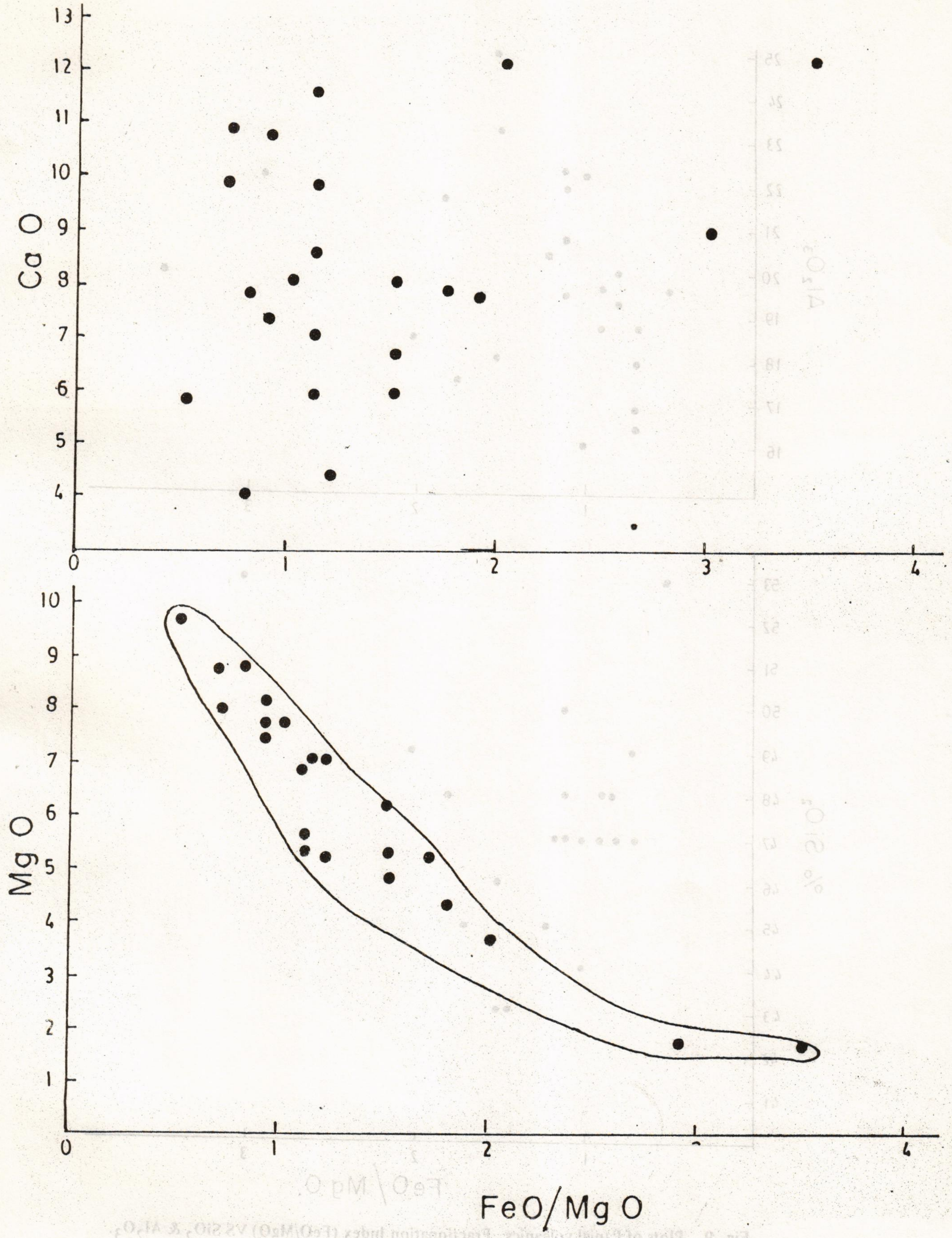
While in many parts of the region Gondwana group of land origin are recorded to have developed land deposits in isolated basins, invasions of these basins by dolerite and periodotite dykes have also been recorded (Wadia 1966). Gondwana period ranges from Upper Carboniferous to Lower Cretaceous. Some of the Gondwana rifts developed into oceanic crust of which Panjal is an example which possibly represents an incipient ocean floor during Permian. This incipient ocean records a Permian "shattering" of pangea since its major break-up is considered to be Triassic (Haq 1984).

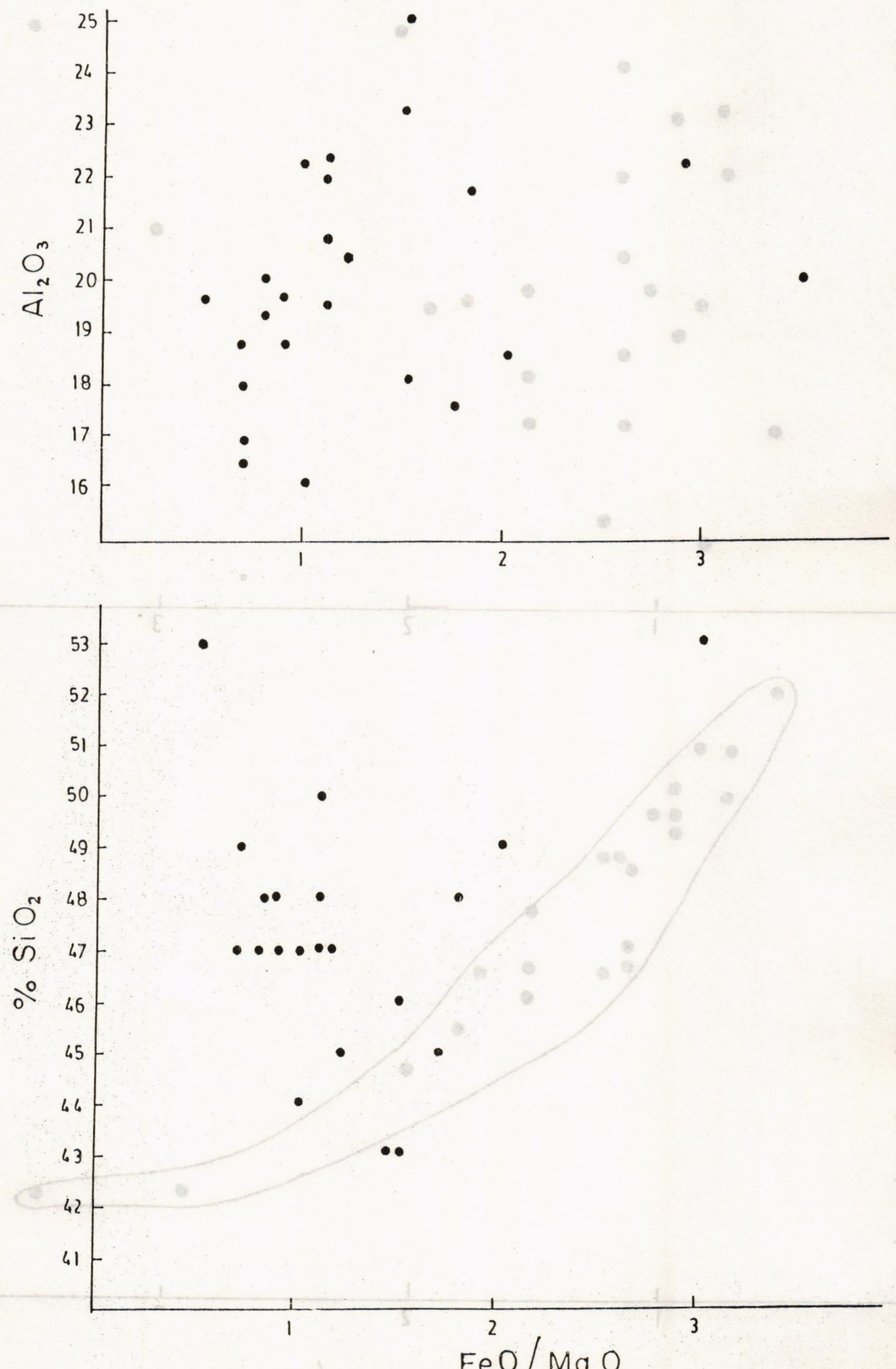


Fig–7. Plots of Panjal volcanics in TiO_2 VS CaO/TiO_2 and Al_2O_3/TiO_2 variation diagrams.

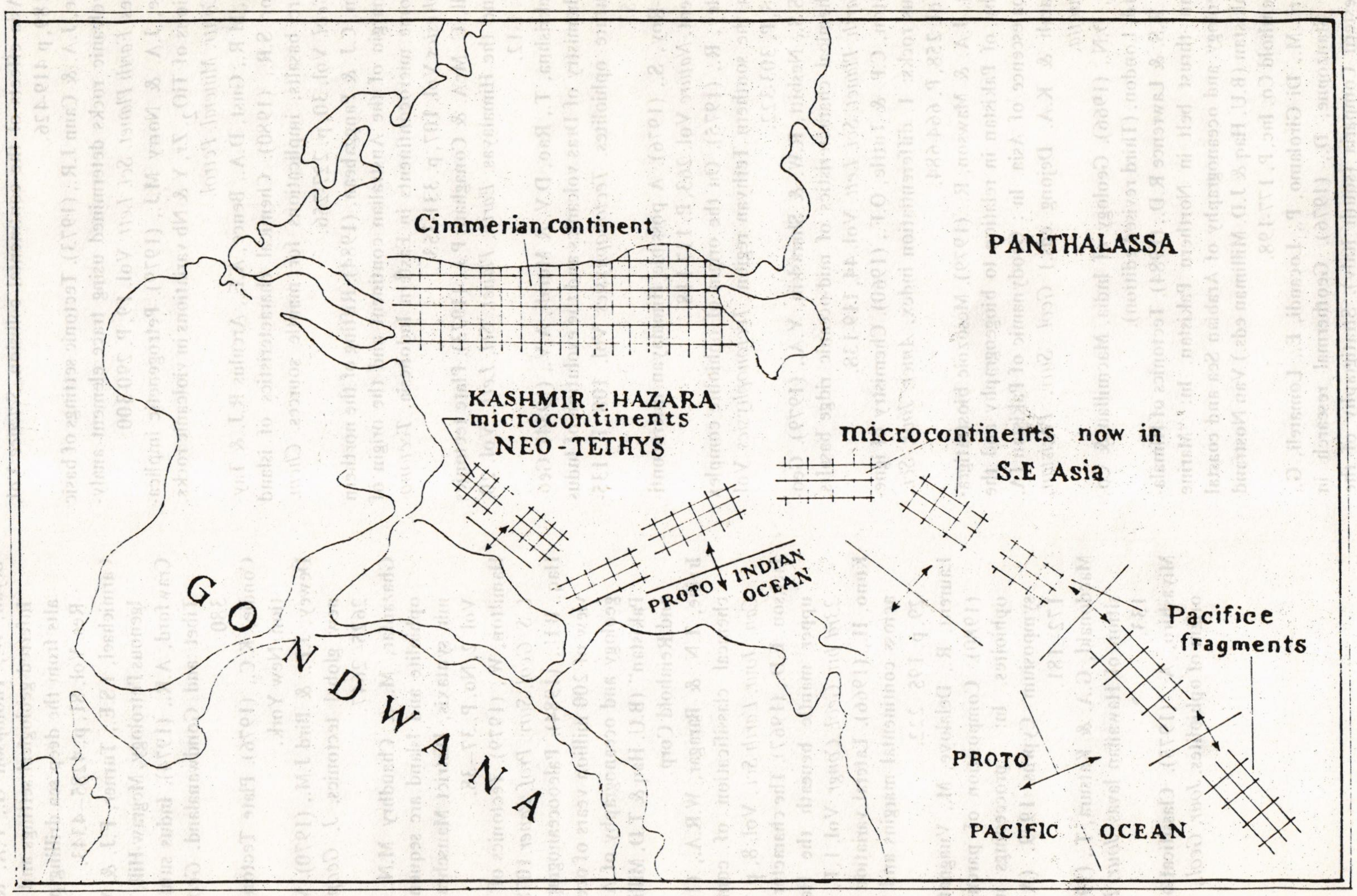


Fig–8. Plots of Panjal volcanics: Fractionation Index (FeO/MgO) VS TiO_2, FeO, MgO & CaO.


Ca O
Mg O
FeO/Mg O



Fig–9. Plots of Panjal volcanics. Fractionation Index (FeO/MgO) VS SiO_2 & Al_2O_3.



Fig–10. Initial rifting of Gondwanaland and formation of microcontinent modified after Pigram and Panggabean (1984).

REFERENCES

Molnar, P. & Tappooiner, P., (1975). Cenozoic tectonics of Asia effects of the continental collision. *Science* Vol. 189, p 419-426.

Pearce, J.A. & Cann J.R., (1973). Tectonic settings of basic volcanic rocks determined using trace element analyses. *Earth Planet. Sci. Lett.* Vol. 19, P. 290-300.

Pearce, J.A. & Norry M.J., (1979). Petrogenetic implications of TiO_2, Zr, Y & Nb variations in violcanic rocks. *Contr. Mineral. Petrol.*

Perfit, M.R., Gust, D.A., Bence, A.E., Arculus R.J. & Taylor S.R., (1980). Chemical characteristics of island arc basalts, implications for mantle sources. *Chem. Geol.* Vol. 30, p. 227-256.

Pigram, C.J. & Panggabean, (1984). Rifting of the northern margin of the Australian continent and the origin of some microcontinents in Eastern Indonesia. *Tectonophysics* Vol. 107, p. 331-353.

Powell, C. McA. & Conaghan, P.J., (1973). Plate tectonics and the Himalayas. *Earth. Planet. Sci. Lett.*, Vol. 20, p. 1-12.

Radhakrishna, T., Rao, D.V. & Murali, A.V., (1984). Geochemistry of Dras volcanics and the evolution of Indus suture ophiolites. *Tectonophysics* Vol. 108, P. 135-153.

SInha-Roy, S., (1976). A possible Himalayan microcontinent. *Nature* Vol. 263, P. 117-118.

Stoneley, R., (1975). On the origin of ophiolite complex in the southern Tethyan region. *Tectonophysics* Vol. 25, P. 303-322.

Sun. S.S., Nesbitt, R.W. & Sharaskin, Y.A., (1979). Geochemical characteristics of mid-oceanic ridge basalts. *Earth. Planet. Sci. Lett.* Vol. 44, 119-138.

Thornton, C.P. & Tuttle, O.F., (1960). Chemistry of igneous rocks: 1. differentiation index. *Amer. Jour. Sci.*, Vol. 258, P. 664-684.

Talent, J.A. & Mawson, R., (1979). Mesozoic biostratigraphy of Pakistan in relation to biogeography and the coalescence of Asia. In : Geodynamic of Pakistan (A. Farah & K.A. Dejong eds.) *Geol. Surv. Pakistan, Quetta.*

Wadia, D.N., (1966). Geology of India. Macmillan & Co. Ltd, London. (Third revised edition).

Yeats, R.S. & Lawrence R.D., (1984). Tectonics of Himalayan thrust belt in Northern Pakistan. In: "Marine geology and oceanography of Arabian Sea and coastal Pakistan (B.U. Haq & J.D. Milliman eds.) Van Nostrand Reinhold Co. Inc, P. 177-198.

Barbieri, M., Di Girolamo, P., Locandi, E., Lomareli, G., & Stanzopne, D., (1976). Geothermal research in western Comparia (south Italy). Stratigraphy of the parete 2 explorations well and new data on volcanic sequence. *Proc. Int. Congr. Int. Assoc. Hydrol. Sci., Athens.*

Bryan, W., Thompson G., F.A. & Dickey J.S., (1976). Inferred geological settings and differentiation in bassalts from the deep sea drilling project. *Jour. Geophys.* Res. Vol. 81, p. 4285–4343.

Carmichael, I.S.E., Turner, F.J. & Verhoogen, J., (1974). Igenous Petrology. Mcgraw-Hill, New York.

Crawford, A.R., (1974), Indus suture line, the Himalayas, Tibet and Gondwanaland. *Geol. Mag.*, Vol. P. 367-380.

Condie, K.C., (1976). Plate Tectonics and Crustal Evolution. New York.

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

Ghazanfar, M. & Chaudhry M.N., (1984). A Paleozoic ophiolite and Island arc sequence of Hazara - Kashmir syntaxis, District Mansehra. *Kashmir Jour. Geol.* Vol. 2, No. P. 37–38.

Hamilton, W., (1979). Tectonics of the Indonesian region. *U. S. Geol. Surv. Prof. Paper* 1078.

Haq, B.U., (1984). Paleooceanography. A synoptic overview of 200 million years of ocean history. In "Marine geology and oceanography of Arabian Sea and coastal Pakistan" (B.U. Haq & T.D. Milliman eds). Van Nostraand Reinhold Corp.

Irvine, T.N. & Baragar, W.R.A., (1971). A guide to the chemcal classification of common volcanic rocks. *Can. Jour. Earth Sci.*, Vol. 8, p. 523–525.

Jackson, E.D., (1967). The character of the lower crust and upper mantle beneath the Hawaiian Islands. Proc. *23rd Int. Geol. Congr.* Vol. 1, P. 131–150.

Kuno, H., (1966). Lateral variation of basalt magma type across continental margins and island arcs. Bull., Vol. 29, p. 195 -222.

Laurent, R., Delaloye, M., Vuagnat, M. & Wagner J. J., (1980). Composition of parental basalt magmas in ophioites. In: proceedings international ophiolite symposium Cyprus 1979. (A Panayiotou ed.), p. 172–181.

Macdonald, G.A. & Katsura, T., (1964). Chemical composition of Hawaiian lavas. *Jour. Petrol.*, Vol. 5, P. 82–133.

Miyashiro, A., (1975). Classification, characteristics and origin of ophiolites. *Jour. Geol.*, Vol. 83, P. 249–281.

A THIRD SUTURE IN NORTHWEST HIMALYA

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ABSTRACT.– The MKT and MMT are two sutures so far identified in NW Himalayas and Northern Area. In the region of Kaghan and Neelum Valleys the Main Boundary Thrust (MBT) constitutes an older Upper Palaeozoic Punjal Suture. The Panjal Volcanics-Agglomeratic Slate–Tanol sequence in this area may together mark the opening and closure of a basin developed on a rifted continental margin possibly associated with an arc. Stratigraphy along the MBT points to the existence of an Upper Palaeozoic Panjal Sea in the area of Northwest Himalaya separating the Indian Mainland from its rifted tectonic slice, the Kashmir Hazara Continental Slice.

INTRODUCTION

It is now recognized that the tectonic framework of Northwest Himalaya is different from the eastward part like the Kamaon Himalaya. The central Himalaya were the first to be investigated and a tectonic model was presented (Powell and Conaghan, 1973; Le Fort, 1975; Mattauer 1975; Powell, 1979) for the area based on doubling or tripling of the crust. So far as the Northwest Himalaya are concerned Wadia's work (1928, 1931) remained the dominant work until the beginning of sixties. Research work by various Pakistani institutions and organizations has gradually increased its pace since then and the advent of the theory of plate tectonics gave it a new spurt after the mid-seventies.

TWO SUTURES RECOGNIZED IN NORTHWEST HIMALAYA

A tectonic model for Northwest Himalayas was first clearly put forward by Tahirkheli et al. (1979) and Bard et al. (1979). This model later developed by the authors is based on the presence of an island arc, the Kohistan and Ladakh island Arc, sandwiched between the Asian and the Indian plates in the region of Northwest Himalaya. This island arc sequence is shown to be bound by two sutures represented by the MKT in the north and the MMT in the south. Chaudhry et al. (1983, 1984) have shown that the actual situation in the field is more complicated and the whole mass between the two sutures MKT and MMT can in no way be termed a simple island arc sequence. Not only according to these latter writers there are more than one island arcs but also there is a vast oceanic lithosphere trapped within the so-called Kohistan Island Arc complex of Tahirkheli et al. (1979). Furthermore according to Chaudhry et al. (1984) aiChaudhry, Ghazanfar & Ashraf (1983) subduction along the MMT proceeded southwards under the Indian continental mass and not northwards as postulated by Tahirkheli and Bard (op. cit). It should, however, be mentioned that the field investigations in Ladakh, Kohistan and Karakorams are still of a very reconnaissance and preliminary type and as more work is carried out on the ground the tectonic picture will continue to be clarified.

Along the MKT, the northern suture, greenstones and shreds of ultrabasics have so far been reported along more than one belts (Chaudhry et al., 1984). Along the MMT, the southern suture, ultrabasics and blue-schist (Shams, 1979) have been reported. The stratigraphy along these two sutures is being worked out but according to available data both these sutures are considered to time around Cretaceous. Eastwards these two sutures are believed to merge in the Indus-Tsangpo suture between the Tethyan Himalayas and the Tibetan Himalayas.

NATURE OF THE MAIN BOUNDARY THRUST (MBT)

According to the tectonic model built for central Himalaya, Powell and Conaghan, 1973, le Fort, 1975 Mattauer, 1975, Powell, 1979) after the intial continental collision between India and Asia the Indian plate broke along the Main Central Thrust (MCT) and started to thrust under its own broken wedge doubling the thickness of the crust under the Tethyan Himalayas and giving birth to granites now forming the Central Crystalline Axis (CCA) of the Himalayas. It is also believed that underthrusting of the Indian lithosphere along the MCT came to an end in Miocene times about 15 million years ago. At about this time the Indian sheild developed a second fracture the Main Boundary Thrust (MBT) along which underthrusting was resumed which had come to an end along the north located

MCT. The extent of this underthrusting along this new fracture the MBT has, however, been debated, for one, because of the absence of granites as evidence the underthrusting along MCT.

TECTONIC RELATION BETWEEN CENTRAL AND NORTHWEST HIMALAYAS.

As the geology in Northwest Himalayas began to be known and various tectonic zones named, there has been a strong tendency to extend the divisions of Himalayas and the tectonic zones as worked out in central and eastern Himalayas laterally westwards into the area of Pakistan. More recently, however, it has been realized that the situation in Northwest Himalaya or the northern Pakistan Himalayas is more complicated because of the presence of more than one sutures and more than one island arc sequences. (Chaudhry, et al. 1984). Furthermore the tectonic framework is complicated by arcuate bends of strike and syntaxes.

STRATIGRAPHY ALONG THE MBT IN KAGHAN

The stratigraphic sequence between Paras and Jared in the Kaghan (Fig.1) Valley is as follows: –

	Muree Formation
Tertiary	Lockhart Formation
	Hangu Formation
Mesozoic	Samana Suk Formation
	Panjal Series
Palaeozoic	Agglomeratic Slate Series
	Tanol Formation
Cambrian	Kaghan Formation
Precambrian	Sharda Group (Salkhala Formation)

The Tertiary and the Mesozoic sequence is sedimentary unmetamorphosed but the Palaeozoic and older rocks are metamorphosed. The two sequences, however, are juxtaposed by major thrusting. From the standpoint of tectonic history it is the Palaeozoic sequence comprising the Panjal volcanics, the Agglomeratic Slate and the Tanols which is the most interesting and informative and it is necessary to discuss their nature in some detail.

THE NATURE OF TANOL FORMATION

A sequence of psammatic and pelitic schists and quartzites underlies the Agglomeratic Slates. In Kaghan these normally have a faulted contact with the Agglomeratic Slates. However, where not faulted they appear to have a gradational contact (Middlemiss, 1911; Wadia, 1931; Coulson, 1928; Ghazanfar and Chaudhry, 1984.)

The age of Tanols is controversial. The age evidence in Hazara is conflicting. Because they underlie Abbotabad Formation of Cambrian age (Latif, 1970, 1972; Rushton, 1973) they have been considered Late Precambrian along with Hazara Slates. Others have, however, reported Siluro-Devonian fossils from carbonates intimately associated with Tanols of Swabi Tarbela area (Martin et al. 1962; Davies and Riaz Ahmad, 1963; Stauffer, 1968). The evidence from Kashmir is more consistently in favour of Devonian and Carboniferous (Wadia, 1931; Gupta, 1975; Fuchs and Gupta, 1978). To us it appears there are two so-called Tanols, one which belongs to Kashmir facies and the other of Hazara affinities. However, the problem requires more investigation.

Wadia (1975)* describes the Tanols (Tanawals) associated with Agglomeratic Slate-Panjal Sequence as follows: ". . . . .Occur in a number of fold-faulted, disturbed longitudinal basins, one to four miles across the strike". He writes further,". . . .but beyond suggesting that the Tanawals bridge the gap between these Slate Series and the Permo-Carboniferous no definite age can at present be ascribed to this group. It is possible that the lower part of the Tanawals may be coeval with so old a formation as the Muth Series. In the Poonch Pir Panjal, these rocks show a clear lateral passage into Agglomeratic Slate Series of Upper Carboniferous age. The whole group is entirely devoid of fossils." Continuing further he says, "From the nature of their occurrence in disconnected isolated basins, away from the wide sedimentary terrains, and their barren nature it is conjectured that the Jaunsars and Tanawals are a continental system of mid-Palaeozoic deposits laid down in depressions of the Hazara Kashmir land mass."

We have quoted Wadia to bring forth his description of the depositional character of Tanols between Kaghan and Jammu, viz.,

1) occurrence in disconnected isolated basins,

2) "they bridge the gap between Slate Series and Permo-Carboniferous,"

3) " In the Poonch. . . .show a clear lateral passage into Agglomeratic Slate Series of Upper Carboniferous age"

4) their barren nature

5) they "are a continental system of mid - Palaeozoic deposits laid down in depression of the Hazara Kashmir land mass.

The Tanols might, therefore, represent a time when the mid-Palaeozoic land mass of Kashmir-Hazara (now indicated by a general unconformity) was developing disconnected basins representing the beginning of a phase of continental rifting which later led to the development of an incipient sea.

THE NATURE OF AGGLOMERATIC SLATES

The Agglomeratic Slates (Middlemiss 1910, Wadia 1931, Calkin et al. 1975) in the Kaghan Valley is a Volcanogenic, possibly in part arc -derived metasedimentary sequence (Ghazanfar and Chaudhry, 1984). It is interbedded with arenaceous and argillaceous material and graphitic material. Bossart et al. (1984) have called it the Chushal Formation in the Kaghan Valley consisting of tillites, conglomerates and graphitic schists. The tillites being composed of slates, limestone, gneisses and tourmaline pegmatites in a shaly matrix. According to Bossart, et al., (1984) no sign of volcanic material was identified. Near Nauseri in Neelum Valley, however, undoubtful volcanic rocks are present at this horizon. Such evidence has also been furnished by Wadia (1931) and Calkin et al., (1975).

The age of this formation is, according to the work of Bion and Middlemiss (1928) and Wadia (1931 , 1961) Carboniferous to Permian.

The Lower part of the Agglomeratic Slate sequence appears to be gradational with the Tanol Formation at places (Ghazanfar and Chaudhry, 1984).

The agglomeratic slate sequence is a complex one containing volcanic, volcanogenic sedimentary, continental, glacial and marine facies, in many ways similar to the cratonic rift assemblages. They were thus perhaps a marker of a developing rift in which the sea had already ingressed at many places.

Age and Stratigraphic Position of the Agglomeratic Slates:

Age and Stratigraphic Position of the Agglomeratic Slates: Regarding the age of Panjal Series, in which he includes both the Agglomeratic Slates and the Panjal Traps Wadia (1975) writes, "The Panjal volcanic series commences from varying horizons. From the Muscovian, Uralian or even Permian, in different localities and extends in its upper limit, likewise, to the Lower Permian in some places and the Upper Trias in others. Both the lower and upper limits are generally precisely dated with intercalation with known fossiliferous horizons."

More specifically about the Agglomeratic Slates he writes ". . . . . at a few localities several interesting suites of fossils have been discovered which are identical with forms entombed in the underlying Fenestella series. . . " (Upper Carboniferous).

Again he writes, "The presence of Lower Gondwana plants in beds immediately overlying the volcanics favours the inference that the slate-conglomerate is a glacial deposit corresponding to the Talchir boulder-beds." Talchir boulder bed is considered Upper Carboniferous.

He further writes, "The Agglomeratic Slates of Nagmarg and Bren contain Lower Gondwana plants, associated with a series of sandstones and shales containing a marine brachiopod fauna and Eurydesma. This horizon corresponds with the Eurydesma horizon of the Salt Range productus Series". Eurydesma beds of Salt Range are considered Upper Carboniferous (Uralian).

THE PANJAL SERIES

In the Kaghan Valley the Panjal Series comprises a thick metamorphosed volcanic sedimentary sequence of greenstones and marbles/limestones. The volcanics are predominantly metabasalts, greenish to greenish grey with dark green porphyroblasts of chlorite and patches of epidote and at places amygdules filled with quartz, chlorite and at times agate. A relic pillow structure is found at places. The associated marbles/limestone are generally characterised by apparently gradational contacts. There are three main bands of these fine grained crystalline marbles/limestones named as the Ling band the Bhunja (after the locality now named Faridabad) band and the Shinu band (Ghazanfar and Chaudhry 1984). There has been a lot of confusion regarding the stratigraphic position of these bands. Wadia (1928, 1961) and Calkin et al. (1975) considered at least one band the northernmost, Shinu band, as the Abbotabad Formation. The other two bands were considered possibly Triassic and the equivalent of Samana Suk Limestone. Wadia (1961) and Ghazanfar and Chaudhry (1984) have shown, however, that these bands are an integral part of the Panjal sequence and may date Permian to Triassic. Wadia (1931) had also noted the gradual passage of these limestones with the Panjal lavas. All the three bands are definitely different both from Abbotabad Formation and Samana Suk Formation. These three marble limestone bands in fact belong to an entirely different facies and tectonic set-up.

The Panjal volcanics are predominantly basic flows with tholeiitic to alkaline affinites. The andesitic compositions are rare. The basic flows appear to be associated with minor altered ultrabasic.

Oceanic Nature of Panjal Volcanics: Wadia (1931) considered the Panjal lavas subaerial "The volcanic or pyroclastic theory is in keeping with the vast succession of sub-aerial lava flows–Panjal Traps –which overly the Agglomeratic Slates. . . ." Later (1961), he wrote ", There are no fresh-water sedimentary intercalations of the nature of "inter-trappean" beds, but in the body of the traps there are found considerable thicknesses of intertrappean marine fossiliferous limestones. . . . .These limestones are obviously fossiliferous and show a gradual passage into ash-beds and traps above and below. . . "Wadia estimated the thickness of the traps at 2000 to 2500 meters.

Observations in Kaghan valley agree in main with his description which, however, has been quoted because it relates to the entire extent of the Panjal volcanics a lot of which are inaccessible now to workers in Pakistan.

Now Wadia's description regarding the absence of freshwater deposits from entire length and thickness of the Panjal volcanics and the presence of interbedded marine fossiliferous sequences casts a doubt on his interpretation of the flows as sub-aerial when this stratigraphic evidence in combined with the presence of relic pillow structures in Kaghan Valley and the oceanic, tholeiitic to alkaline affinites (Chaudhry and Ghazanfar under preparation) of the flows the case for sub -oceanic nature of the Panjal volcanics is further strengthened.

A study of chemistry, norm and mode (Chaudhry and Ghazanfar, under preparation) show that the calc-alkaline series are generally unimportant in the Panjal greenstones. On the other hand the marine basalts of tholeiitic as well as alkaline affinites are closely associated. Spilitic lavas including pillow lavas are common (and at places are even predominant) associates of the tholeiites and alkaline basalts. Rare potash rich varieties associated with spilites are also met with at places.

Apart from the agglomeratic slates there are later diorites, epidiorite norites, gabbros and rhyolites and andesites (Wadia, 1931). Rare lamprophyres and keratophyres appear to be earlier facies associates of agglomeratic slates. But field relations are obscure and need to be worked out in detail.

Age of Panjal Lavas: Regarding the age of Panjal lavas Wadia (1975*) writes, ". . . in the body of these traps there are found considerable thickness of inter-trappean marine fossiliferous limestones of Permian (Sirban), and Lower and Middle Trias age. These limestones are obviously fossiliferous and show a gradual passage into ash-beds and traps above and below. . . ." Again, "The upper limit of the Panjal lava-flows in Vihi is clearly defined by the directly overlying plant-bearing beds of Lower Gondwana facies, which in turn are immediately succeeded by marine Permian rocks. In other cases, however, the flows have been found to extend to a much higher horizon, as far as the Upper Triassic, a few flows being found locally interbedded with limestone of that age. In general the Panjal Volcanics ceased their eruptive activity in the Permian. These subaerial volcanic eruptions, therefore, bridge over the gap which is usually perceived at the base of the Permian in all other parts of India."

THE SEDIMENTARY SEQUENCE

We have above described a part of the stratigraphy along MBT as revealed in Kaghan Valley between Paras and Jared Valley.

Here the metamorphosed rocks are, however, juxtaposed against a sedimentary sequence towards the continental side or what is here known as the core of the syntaxis. In the core of the syntaxis this sequence is dominated by the Murrees. Along the fault, however, preserved patches of older sedimentary rocks, foraminiferal limestone, calcarenites, claystone and oolitic limestones are present, - a sequence comparable to Lockhart, Hangu and Samana Suk formations in Southern Hazara.

REINTERPRETATION OF MBT AS A SUTURE IN KAGHAN AND AZAD KASHMIR.

The above stratigraphic description indicates that the Palaeozoic sequence of Kaghan belongs to an entirely different facies of rocks distinct from that of South Hazara.

Furthermore it is clear from the description of Agglomeratic Slates and Panjal Volcanics that the two collectively represent rift-ophiolite-island arc sequence with the Panjal representing in Kaghan submarine basaltic flows with tholeiitic to alkaline affinites (Ghazanfar and Chaudhry 1984, Butt, Chaudhry, Ashraf 1985, this volume).

Thus, generally speaking, we have older metamorphosed rocks north of MBT and younger sedimentary rocks south of it (in Kaghan area near Paras it is the east and west of a limb of Hazara-Kashmir Syntaxis Fig 1. & Fig . 2). The MBT in Kaghan and Neelum Valley, Azad Kashmir , has, therefore, acted as a suture along which representatives of a Palaeozoic incipient ocean floor, the Panjal volcanics, and an associated rift - arc sequence, the Agglomeratic Slate, have been thrust southwards on to the rocks of continental marginal affinites or a miogeosynclinal sequence.

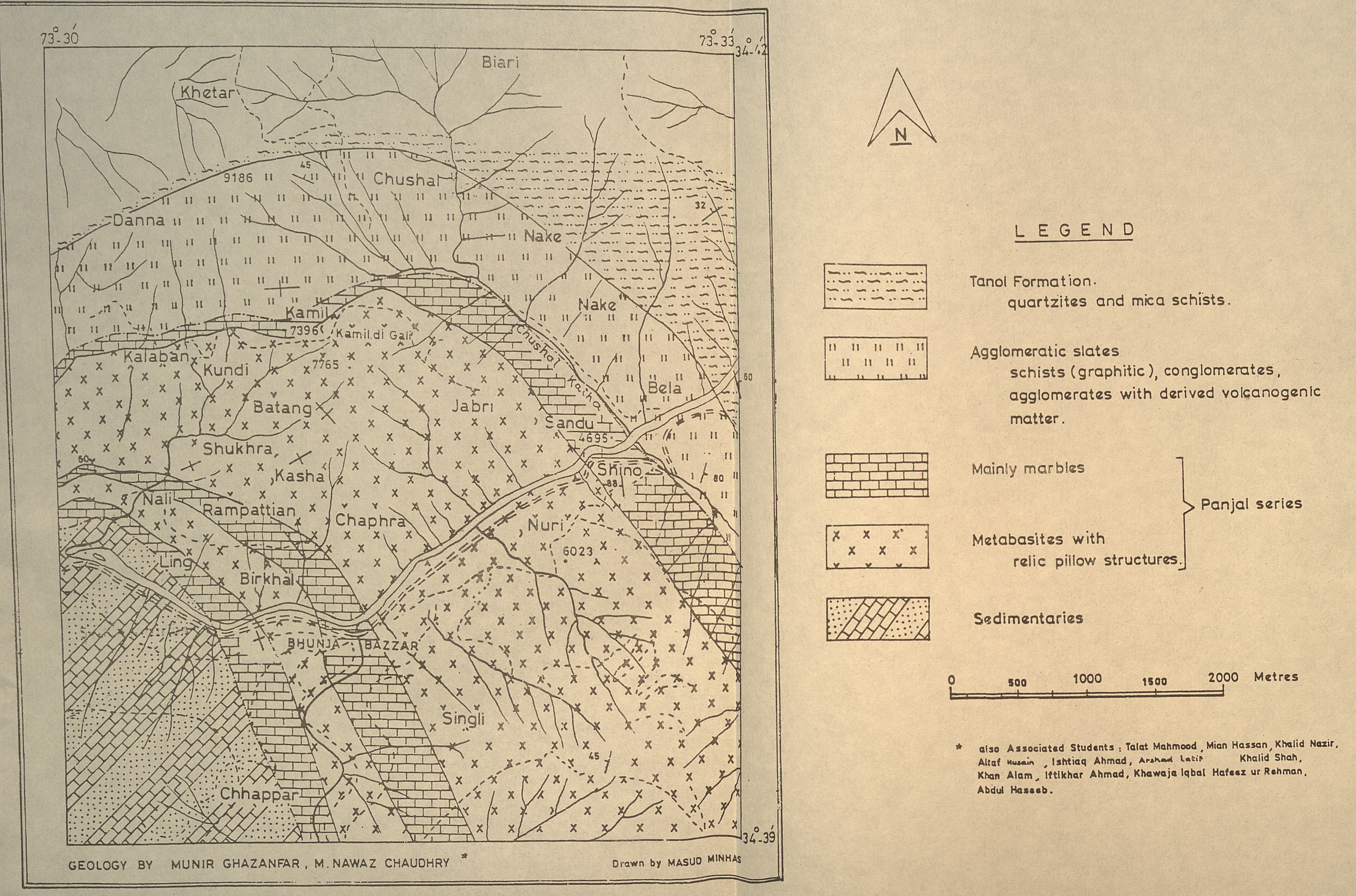


Fig. 1 GEOLOGICAL MAP of MALKANDI-SHINO AREA KAGHAN VALLEY

THE PANJAL SEA AND THE KASHMIR HAZARA CONTINENTAL SLICE.

Now if the Panjal Series and the Agglomeratic Slate Series represent rift-ophiolite-arc sequence then the 50 to more than 200 km. wide strip of rocks to the north that is between the MBT and the MMT is a continental slice.(Fig 2) This continental slice occurs now to the north of Peshawar, Abbotabad, Malkandi in Kaghan Valley, Nauseri in Neelum Valley and Poonch, Azad Kashmir (Butt, Chaudhry and Ashraf, 1985 this volume) have already referred to the presence of some microcontinent and Ghazanfar and Chaudhry (1984) and Butt, Chaudhry, Ashraf (1985) have referred to the presence of a Palaeozoic ocean which we suggest may be called the Panjal Sea. It is likely that the Palaeozoic Panjal Sea was short-lived, shallow and norrow. It probably opened in the middle Palaeozoic and closed in Early Mesozoic. The Kashmir-Hazara Continental Slice may well have been part of the Indian continental lithosphere prior to the opening of the Panjal Sea. The slice was, however accreted to its mother once again. The MBT zone has a dual nature. On the one hand it represents a Pala–eozoic suture the Panjal Suture marking the closure of Pala-eozoic rift sea, the Panjal Sea leading to the accretion of a continental slice, the Kashmir-Hazara Continental Slice with India. On the other hand more recent thrusting has also taken place along the MBT. The extent of the Panjal Suture, however, needs further investigation.

CONCLUSION

The Main Boundary Thrust (MBT) Zone in Kaghan, Balakot and Azad Kashmir constitutes a Palaeozoic suture representing the remnants of a Palaeozoic sea. This shallow ocean represented an ingress of sea into a mid-Palaeozoic rifted continental margin which then closed probably through the process of a north directed subduction. Later south directed thrusting has occurred along the MBT zone concealing the older rocks of Indian shelf affinity and juxtaposing the Panjal Series against much younger rocks of Indian margins. Some of the historical and petrogenetic complications of the sequence are also due to the fact that a varied tectonic phenomena are closely associated in a narrow time and space framework.

REFERENCES

Bard, J.P., Maluski, H. Matte, Ph., and Proust F., (1980). The Kohistan Sequence: Crust and mantle of an obducted island arc., *Int. Committee on Geodynamics Group* 6, pp. 87-94.

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

Butt, K.A., Chaudhry, M.N., Ashraf, M., (1985). Evidence of an Incipient Palaeozoic Ocean in Kashmir, Pakistan, *Kashmir Jour. Geol.* Vol. 3

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

Chaudhry, M.N., Ghazanfar, M., Ashraf, M., & Hussain S.S. (1984). Geology of the Shewa-Dir-Yasin Area and its Plate Tectonic Interpretation. *Kashmir Jour. Geol.* Vol. 2. No. 1. pp. 53–64.

Chaudhry, M.N., Ghazanfar, M. & Ashraf, M., (1983). A Plate Tectonic Model for Northwest Himalayas., *Kashmir Journ. Geol.* Vol. I, No. 1. pp. 109–112.

Ghazanfar, M., Chaudhry, M.N., (1984). A Palaeozoic Ophiolite and Island Arc Sequence of Hazara - Kashmir Syntaxis, District Mansehra. *Kashmir Jour. Geol.* Vol. 2 No. 1. pp. 37-38

Holmes, A, (1965). Principles of Physical Geology Thomas Nelson and Sons Ltd., Middlesex 2nd. Ed.

Latif, M.A., (1972). Lower Palaeozoic (Cambrian) Hyolithids from Hazira Shale, Pakistan. *Nature, Phy. Sci.* Vol. 240, No. 100 P. 92.

Latif, M.A., (1974). A Cambrian Age for Abbotabad Group of Hazara, Pakistan Geol. *Bull Punj. Univ.* No. 10 pp. 1-20

Lydekker, R., (1883). The Geology of Kashmir and Chamba territories and the British district of Khagan *Geol. Surv. Ind., Mem.* Vol. 22, pp. 1–334.

Lydekker, R. (1878). Notes on the Geology of Kashmir, Kishtwar and Panji; *Geol. Surv. Ind. Rec.* Vol. 2 pp. 30–60.

Mattauer, M., (1975) Sur Le macanisme de formation de le schistosite dans L. Himalaya; *Earth and Planetary Sci. Letters.* Vol. 28, pp. 144–154.

Powell, C. McA., (1979). A Speculative Tectonic History of Pakistan and Surroudings: Some Constraints from the Indian Ocean; *Geodyn. Pak. Geol. Surv. Pakistan,* Quetta. pp. 5–24.

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

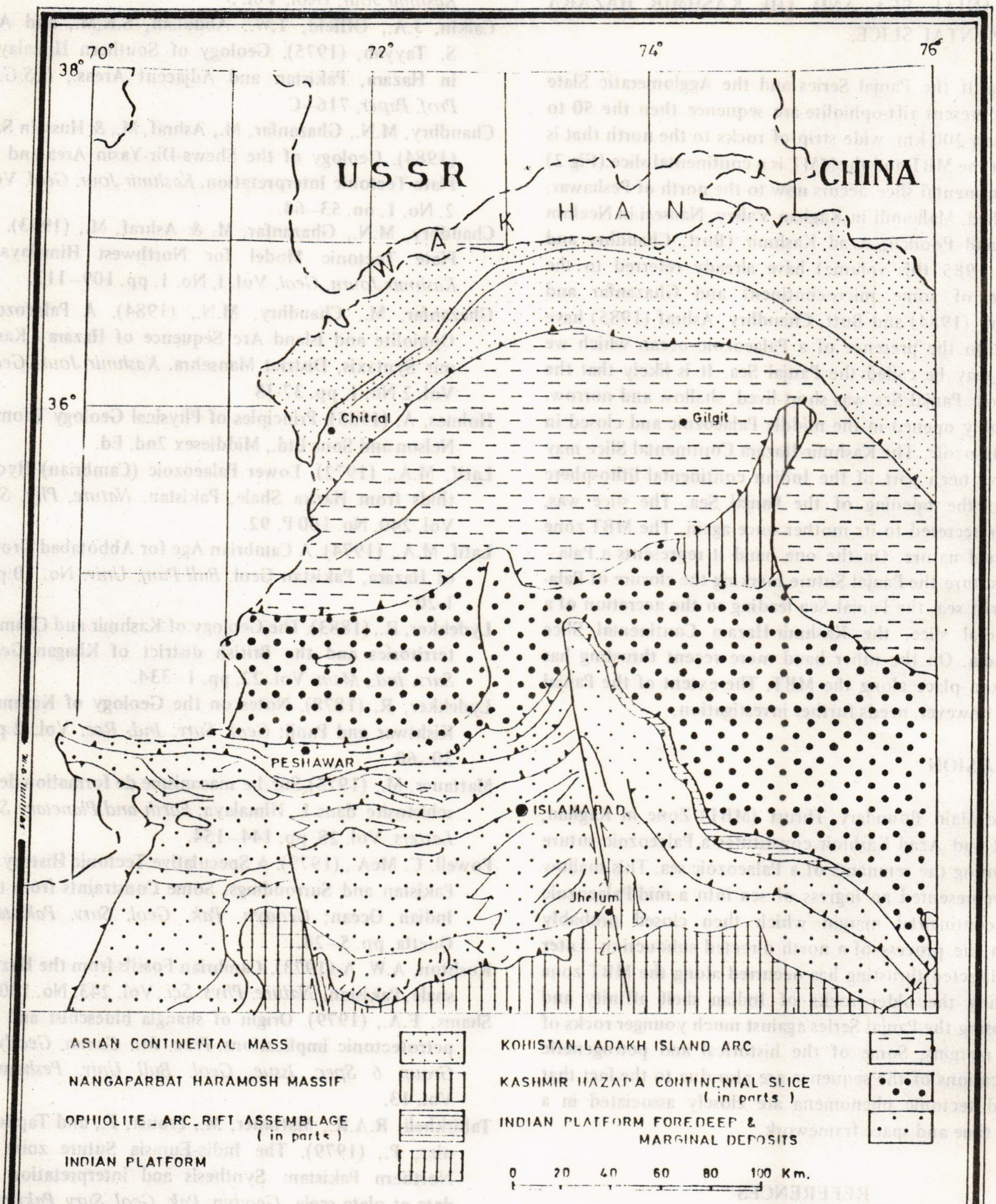
Shams, F.A., (1979). Origin of shangla blueschist and its petrotectonic implications. *Proc. Int. Comm. Geodyn. Group 6 Spec. Issue, Geol. Bull Univ. Peshawar,* Vol. 13.

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

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

Wadia, D.N. (1931). The Syntaxis of the N.W. Himalaya *Rec. Geol. Surv. of India,* Vol. 65.

Wadia, D.N. (1961, 1975*) Geol. of India, Tata McGraw-Hill Publishing Co. New Delhi 4th ed. *Revised by Meher, D.N. Wadia (Mrs.).



70°
72°
74°
76°
38°
36°
USSR
CHINA
Chitral
Gilgit
PESHAWAR
ISLAMABAD
Jhelum
ASIAN CONTINENTAL MASS
NANGAPARBAT HARAMOSH MASSIF
OPHIOLITE ARC. RIFT ASSEMBLAGE (in parts)
INDIAN PLATFORM
KOHISTAN.LADAKH ISLAND ARC
KASHMIR HAZARA CONTINENTAL SLICE (in parts)
INDIAN PLATFORM FOREDEEP & MARGINAL DEPOSITS
0 20 40 60 80 100 Km.
Adapted from G.S.P Tectonic map of Pakistan (1982) by A.H.Kazmi, Riaz A.Rana
drawn by. Masudminhas

Fig. 2

SHORT COMMUNICATIONS ABSTRACTS AND REVIEWS

REMEDIAL MEASURES USED TO ENSURE STABILITY IN SLOPES

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ABSTRACT:– This paper sets out the main remedial measures which can be employed to prevent or stabilise slope movement and the factors to consider in deciding when each is appropriate. Four case histories are given to illustrate these considerations. The examples detail constructions in Great Britain which have taken very different approaches to ensure slope stability mainly due to the geological situation and economic factors.

INTRODUCTION

Not all engineering projects causing potential instability to slopes are like the one which would have been rendered unstable by removing support from the base of the slope. Changes of fluid level, and to a lesser extent loading, either by the action of natural or man induced processes, are also responsible for slope instability.

Conversely there are three types of remedial work which can be applied to make a slope stable. These are a change in fluid level, a change in load or a change in the support of the slope. The causes of instability therefore are also the cures and as such prevention of any failure can be achieved. However this can only be done if site investigation is thorough enough and the remedial methods are a viable proposition and are implemented in time.

Having said this it is almost inevitable that the initial proposals of a site investigation will not be sufficient and that remedial measures will have to be changed, modified or increased in number to allow for the unforseen circumstances which are sure to arise. A good site investigation report is one in which these possibilities are pointed out and proposals be formulated should they arise. Even then not all circumstances can be predicted and as such it is important to investigate a site during and after construction.

Bearing the above in mind it is now possible to consider the alternative remedial methods which can be used to overcome slope instability.

TYPES OF REMEDIAL MEASURES

The measures which can be used to arrest or prevent slope failure can be put into six main categories :

1. *Loading or unloading of the slope:* The types of treatment involved in changing the load are ;

   a. Reducing the volume at the head of the slope
   b. Increasing the volume of the toe of the slope

Reducing the volume at the head of the slope generally involves the movement of much more material than that required to load the base and as such the latter is more common. If the type of material is suitable, that removed from the head can be used to load the toe.

Loading of the toe of a slope is usually achieved by the construction of a berm which is commonly of sand but may be of other readily available types of fill material. Building up of the toe depends on the shear strength of the layer which will underlie the fill. If it is large then it is a good method, if it is low the fill may be placed in front of the toe rather than at the toe. It is important particularly in the latter case that the toe should be drained. This may be achieved by putting in a gravel layer at the base of the fill. If a slope is already moving it may be quicker to put in drainage fill than to install horizontal drainage boreholes. The drainage fill may have to be placed some distance from the toe of a moving slide or protective gravel fill can be dumped on the surface of a slope, particularly in clays to try to stabilise it. The sooner this fill is placed the greater is the safety of the slope due to the changes in lateral stress brought about and the subsequent change in drainage. Such a fill should be self supporting and only its inside layer needs to be of permeable material.

2. *Drainage:* Strictly speaking it is slope de-pressurisation not drainage that is important as it is water pressure not the quantity of water within the unstable area which cause problems.

Three basic principles have to be regarded.

a. Surface water must be prevented from entering open tension cracks and fissures.

b. Water pressure must be reduced in the vicinity of the potential slip by selective surface and subsurface drainage.

c.. The drainage must be kept where it is needed and surrounding areas should not be drained unnecessarily.

i) *Surface Drainage:* A drainage system should be designed to intercept run off before it reaches the unstable area particularly in the vicinity of tension cracks at the crest of slopes. Heavy plastic linings can be used to line drains or drains may be steeply graded to stop ponding and to speed up water movement so as to minimise silting up. These methods also minimize maintenance costs and infiltration of water.

Diversion of all rivers, streams, water courses and springs should be carried out to stop water being fed to the slope. Down pipes and flumes may be used for this but should avoid the areas which potentially are highly unstable on the slope.

The upper surface of the slope should carry the bulk of remedial drainage measures. The surface of a slope, particularly one which has already failed, is uneven, hummocky and fissured. In such places water can accumulate thus adding to the instability of a slope. Behind the crest in particular, pounded water must be prevented otherwise it will inevitably seep into tension cracks and fissures. Grading of the slope, filling of small hollows, and removal of piles of rock waste and overburden which could cause damming is required. Sometimes a flexible layer or plastic memberance is used to seal the slope surface such as in laterite soils.

A drainage ditch at the head of the slope is the most commonly used remedial method but ditches on benches in midslope may also be dug in rock slopes but they must be kept debris free.

Open tension cracks can be very dangerous if they occur in areas of high intensity rainfall as this can induce high water pressure and so cause slope failure. Surface water should be diverted away and the cracks sealed with a flexible impermeable material. If the crack is large it should be filled with waste gravel before the flexible material is placed so that any water entering the rock can flow out again easily. These cracks should not be grouted or concrete filled as this creates an impermeable dam which can create high water pressures.

ii) *Subsurface Drainage:* Groundwater is one of the major causes of instability in slope and therefore subsurface drainage is very important remedial treatment. However there is no point in designing subsurface drainage until the geological and hydrogeological investigation is completed. A number of alternative types of subsurface drain can be used as required depending mainly on economics.

Horizontal drains can be drilled into a slope face which intersect tension cracks or failure planes and can provide very useful drainage. The number of holes is controlled by slope geometry and the discontinuities in rock. To a certain extent it may need trial and error in order to place them in optimum positions apart. Piezometers should be installed before these drains otherwise change in water pressure cannot be predicted, as ultimately the drains must reduce this pressure and not simply volume.

Vertical drainage wells can be drilled from the slope surface downwards and are fitted with pumps. Their advantage is that they can be brought into operation at any time to keep effective stress in the rock or soil high. They also speed up the time taken to depress water level required for slope design.

Drainage galleries are the most effective means of subsurface drainage either with or without fans of radial holes. They are however very expensive, generally five times the cost of boreholes and are only considered where economic benefits are great.

Piezometers give a valuable idea of the effectiveness of drainage measures. Overall ground water flow patterns must be known if drainage is to be of maximum effect. Drainage can never do any harm when much water is present so any drainage is better than no drainage and should be implemented immediately where possible.

3 *Retaining walls and similar structures:* Retaining walls may serve one or a number of functions. They may stop loosening of the toe of a slope, stop movement of an unstable slope or protect a slope against frost action. They are constructed when space is at a premium and cheaper sand berms cannot be constructed. For walls which stop loosening of the toe, resistance is a function of their weight only, unlike pile walls, and therefore no design criteria, such as forces having to act on the middle possible. Low precast walls however tend not to stop frost action at the toe of slopes which can be important in causing instability. High retaining walls are used to support deep sliding masses or to preserve stability of a slope when considerable horizontal force is applied. Walls to stop movement of sliding masses may be buttress fill or a rigid concrete wall.

With the latter passive earth pressure must be taken into account.

Sheet pile walls are usually used when a temporary retaining wall is required and generally go up to about 3.5m high and resist passive pressure up to about 250 KN. It is important to drain the ground behind the sheet pile. The diameter of the pile can vary from 40-120 cm and determines the allowable horizontal force, which is approximately 200 KN for 80cm diameter piles and 400KN for 120cm piles. To reduce the loading of the wall it may be anchored or the soil may be drained or levelling of the soil may take place.

4. *Rock bolts and Rock anchors:* These are used to stabilise slopes in rock or soil by increasing shear strength across joints.

In their simplest form they consist of steel dowel bars which are used to stabilise thinly bedded material dipping parallel to the slope. Holes are drilled and the bars are grouted in. They are unstressed and weak when required to bend and so they are only used where narrow discontinuities exist.

Rock bolts are similar to steel dowel bars but are put under tension so that the rock can be compressed to increase its shear strength. They may be used individually for blocks or wedges or in groups for large areas and complex structures. Usually they are loaded up to 100KN and are 1.25 to 8m long.

Rock anchors are used for major stabilization work and often with retaining structures. They can be loaded with anything from 100KN to 5,000KN and often have length greater than 30m.

Bolts and anchors are prestressed across smooth even joints but need not be stressed across irregular joints as dilatancy effects cause them to become stressed. The angle of inclination of rock bolts and anchors should be examined carefully so that when deformation occurs tension in them will increase, otherwise they are of little use.

5. *Surface Protection of Slopes:* Slope surface are prone to erosion and may deteriorate due to weathering. Protection of the slope surface may reduce this but is controlled by local conditions and avaiiability of materials.

Vegetation is the best protection against soil erosion as it binds the soil together and reduces infiltration into the ground. Where vegetation is not enough or it is difficult to establish, surfaces may be covered with mortar or shotcrete or gunite. Drains must be left on the surface and prevented from blocking otherwise water pressure will build up behind the protective seal.

Surface protection may also be needed to guard against rockfalls. The falling of loose rocks and boulders can be dangerous and steps must be taken to dissipate the energy of falling, bouncing or rolling boulders. Protective canopies over routeways may be built in avalanche areas or areas prone to large rockfalls. Midslope benches which are fenced may also prevent rockfalls. For small slopes a free hanging wire mesh net may be dropped over the face which stops falling rock gaining momentum in a freefall and keeps boulders near the rock face. If possible the structure is to be constructed, be it a road or building, should be moved a little from the suspect face.

6. *The Hardening of Soil:* Drainage cannot be used for impermeable soils as only small areas can be drained using conventional techniques. Therefore a number of alternatives exist.

a. *Electro-osmosis.* Here water moves as a reaction to an electric field rather than to gravity. Water migrates towards the cathod in an electric field which consists of a perforated pipe from which water is removed by pumping. The method is used in silty soils of grain size 0.05-0.005mm, as in any coarser material gravity effects are too great. The amount of electrolytes in the soil water must be tested as if they are large they can reduce the rate of flow.

b. *Thermal technique:* This was used initially to harden loess. It uses bore-holes down which oil is poured and ignited which causes a draught exhausting from the borehole which drains and hardens the soil.

c. *Grouting:* This technique can be used to harden the subgrade under railway tracks and it can be used in clay shales, claystones and stiff clays but not in slaked material. Grout displaces water and on setting it creates a stable skeleton to the soil. Before grouting can occur the depth and form of the dip surface must be known in detail. Grouting should begin at the toe of a slope first to add support.

Lime may also be used to stabilise soils.

SCHEDULING REMEDIAL METHODS

The knowledge of the remedial methods is not enough. The order in which they are implemented must be considered. For instance it is wrong to put in protective fill before draining the subsoil. As a rule it is best to put the obviously needed measures immediately into operation before a long site investigation is carried out.

The first remedial methods should include:

1. Capture and drainage of surface water flowing into the slide or emerging at the head scarp area.

2. Pumping of water from all wells in the slide area and from any undrained depressions.

3. Filling and compaction of all open cracks with fill which could be entered by surface water but not allowing high water pressures to build up in them.

The schedule should pay due regard to weather conditions such as water logging of the site in winter or the covering of it in snow. Corrective installations should be regularly and readily be checked and maintained.

CASE HISTORIES OF REMEDIAL MEASURE PROGRAMMES

1. Example The stability of a road cut on the M4 north of Cardiff

Here a road cutting was to be made below the Wenallt reservoir. Dips of the local coal measure sandstone and shales were generally towards the reservoir (as shown in Fig. 1a) at 10-25° as found from borehole data from below the reservoir and along the line of the proposed motorway. On excavation of the slope below the reservoir a syncline existed with rock dipping 45-55° away from the reservoir (as in Fig 1b). Tension cracks were developed in the reservoir embankments. Initially these were halted from expanding by putting in a toe berm but further excavation had to be done for the road to be built and observations showed that the slope would become unstable if excavations continued.

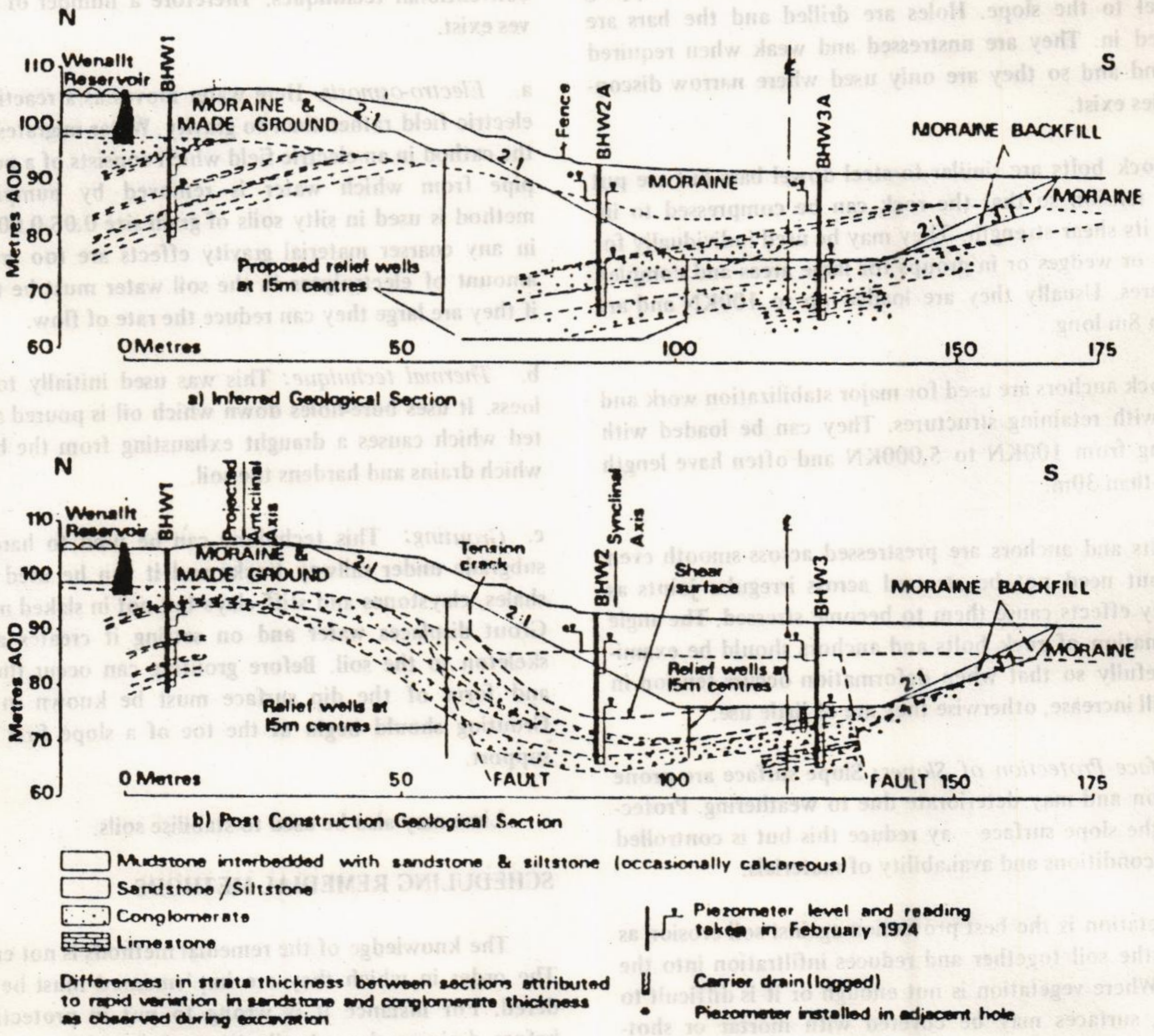

Fig. 1 Wenallt Cut. Geological sections.

Remedial Measures: Stabilizing with a toe weight or anchors was thought impractical due to the low strength of the underlying rocks. The use of shear keys was then suggested. These would comprise concrete filled trenches fixed in place with rock anchors and sited at or near the toe of the slip plane. However the material to be excavated needed a stand up time of 12 hours for these works to be possible but as it only stood for 1 hour this alternative was not possible. Therefore the only viable option was to dig out and backfill the whole slope. First the material below the reservoir was excavated, followed by the slipped mass. Excavation took place in 10-15m stages with back filling occurring before excavation continued. The lower part of the slope was refilled producing a large crescent shaped berm. A drainage blanket was placed over and behind this fill and horizontal relief wells were dug 20m into in situ strata and then back filled. The slip moved 1.5m after excavation before becoming stabilised. Figure 2 shows the final remedial works at the site. On completion the remedial works were found to give a high factor of safety.

2. Example Road Cutting on the A45 in Northamptonshire

A landslip occurred during the construction of the A45 near Deventry. Excavations along the northern edge of a small range of hills of Jurassic age cut into relict landslips which had multiple slip planes between 3m and 5m below the surface. Sliding took place as a slab slide with the creation of a back scar.

Remedial Measures: The line of the road was moved further away from the slope to avoid the area of landslip debris. Several stabilisation methods were considered but due to difficulties with each, an on-going maintenance strategy was adopted. Debris which encroached over a 10m catchment area between the slope and the completed road is cleared approximately twice a year. Extension of the back scar has not occurred despite continued slope movement during winter months.

As the road could be relocated this was thought the best and cheapest method, as prediction of these relict slides are particularly difficult. Therefore a policy of avoidance rather than interference was employed.

3. Example : Revetment of a Rock Slope on the M5 West of Bristol

Where the M5 climbs into the Clevedon Hills Carboniferous Limestone has been thrust over Pennant Sandstone. A road cutting had to follow the line of this thrust for 2500m. Problems also arose due to the presence of cavities fissures and jointing. Cavities were found particularly in the vicinity of the thrust fault. Other routes were considered but even with the remedial measures this one was thought to be cheapest. Due to the steep slopes at the site the motorway carriageways were set at two levels, so less excavation would be needed.

Remedial Measures

a. A reinforced concrete retaining wall would be needed between the carriage-ways where they followed the thrust faults to save space. A more economic mass concrete gravity wall was used elsewhere.

b. Retaining walls were needed where the motorway crossed gulleys. These gulleys would have to be filled.

c.. Extensive grouting of joints and fissures would be needed.

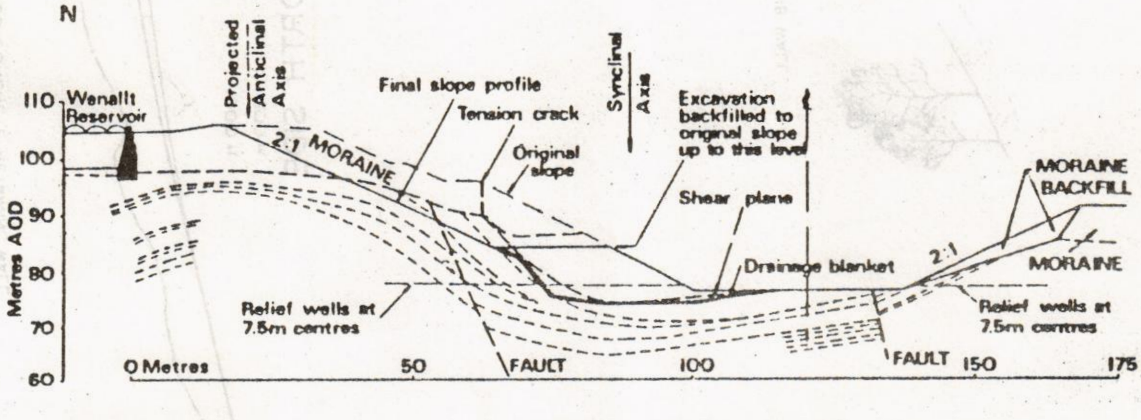

Fig. 2 Final remedial measures.

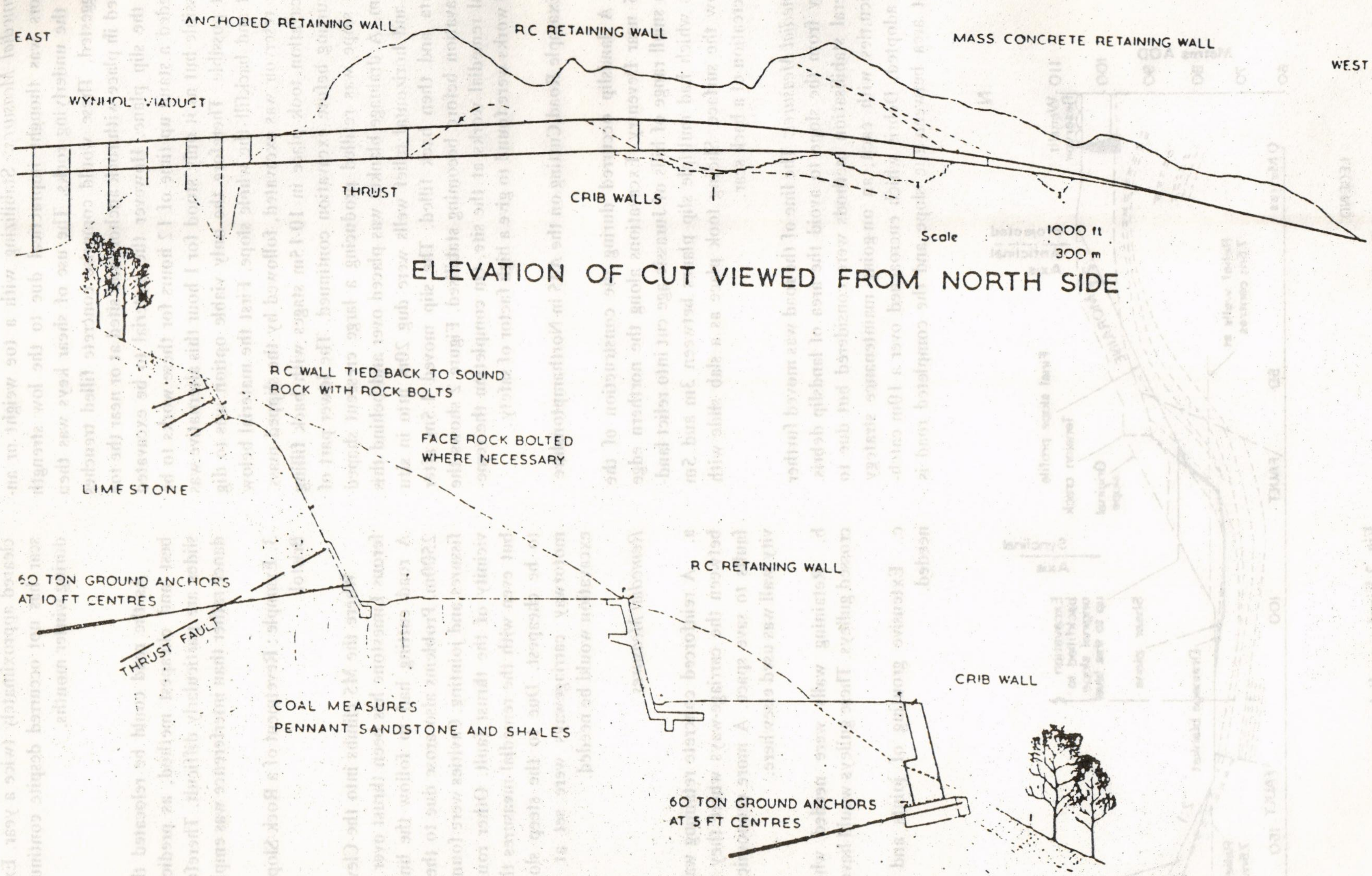

FIG. 3 Motorway in rock cutting.

d.. Underpinning with rock anchors of the thrust fault took place.

More retaining walls and rock anchors were needed than expected as the top 2m of the rock was highly weathered.

e. 9m high crib walls were used at the base of the slope to retain fill material in the fault zone. These walls have been anchored where they are based on faulted pennant sandstone.

f. Clay bands in the limestone and extremely weathered layers were stabilised using a skin reinforced concrete wall and rock bolts. Where necessary 60 ton rock anchors at 3m centres were used.

g. A plastic galvanised wire mesh was placed over the rock surface to encourage the growth of plant roots.

h. A 3m wide ditch with a 1.8m high chain linked fence was placed at the base of the slope just above the motorway to catch falling rocks.

Figures 3 and 4 summarise the above remedial measures.

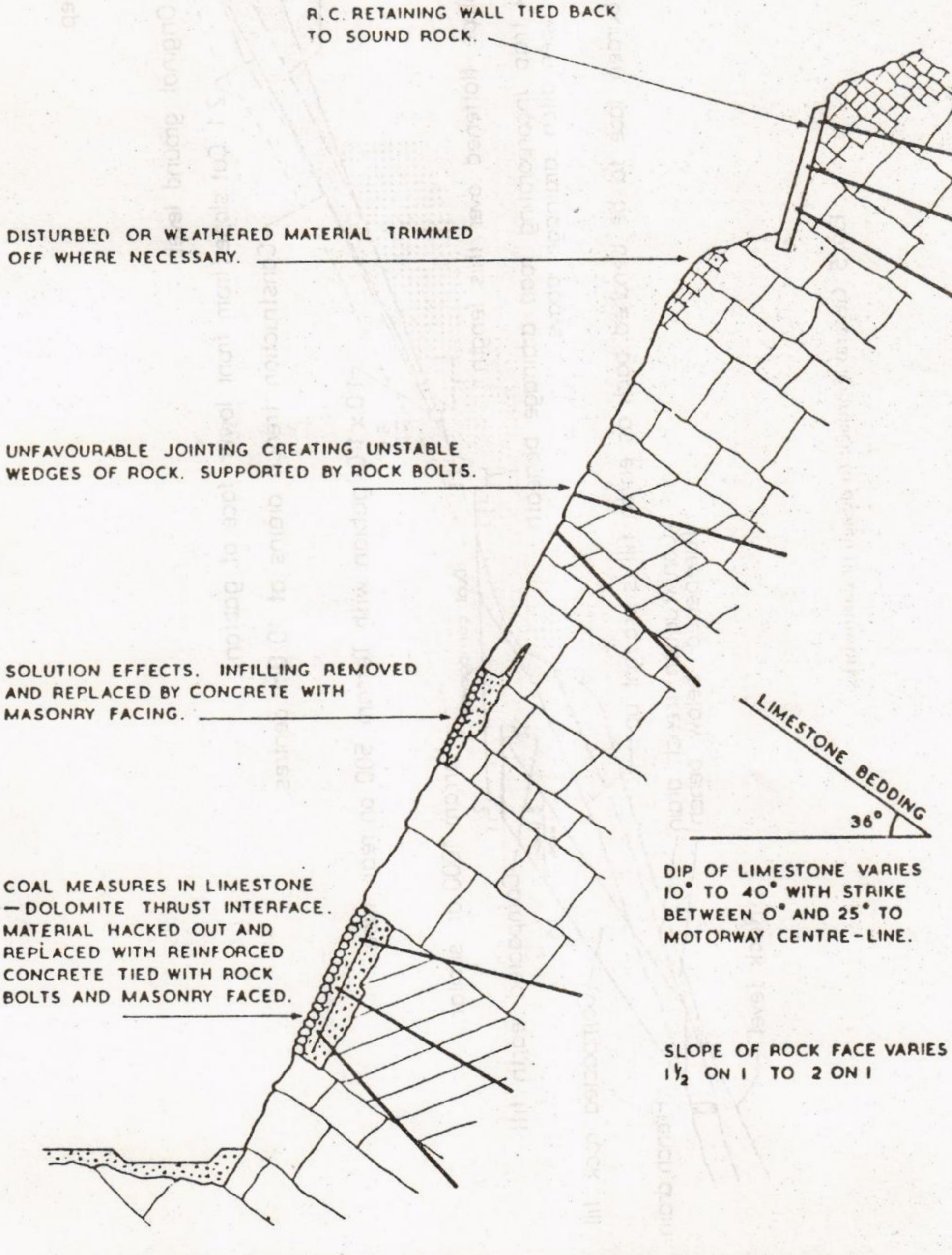

FIG. 4 Composite cross-section showing types of revetting on the main rock faces.

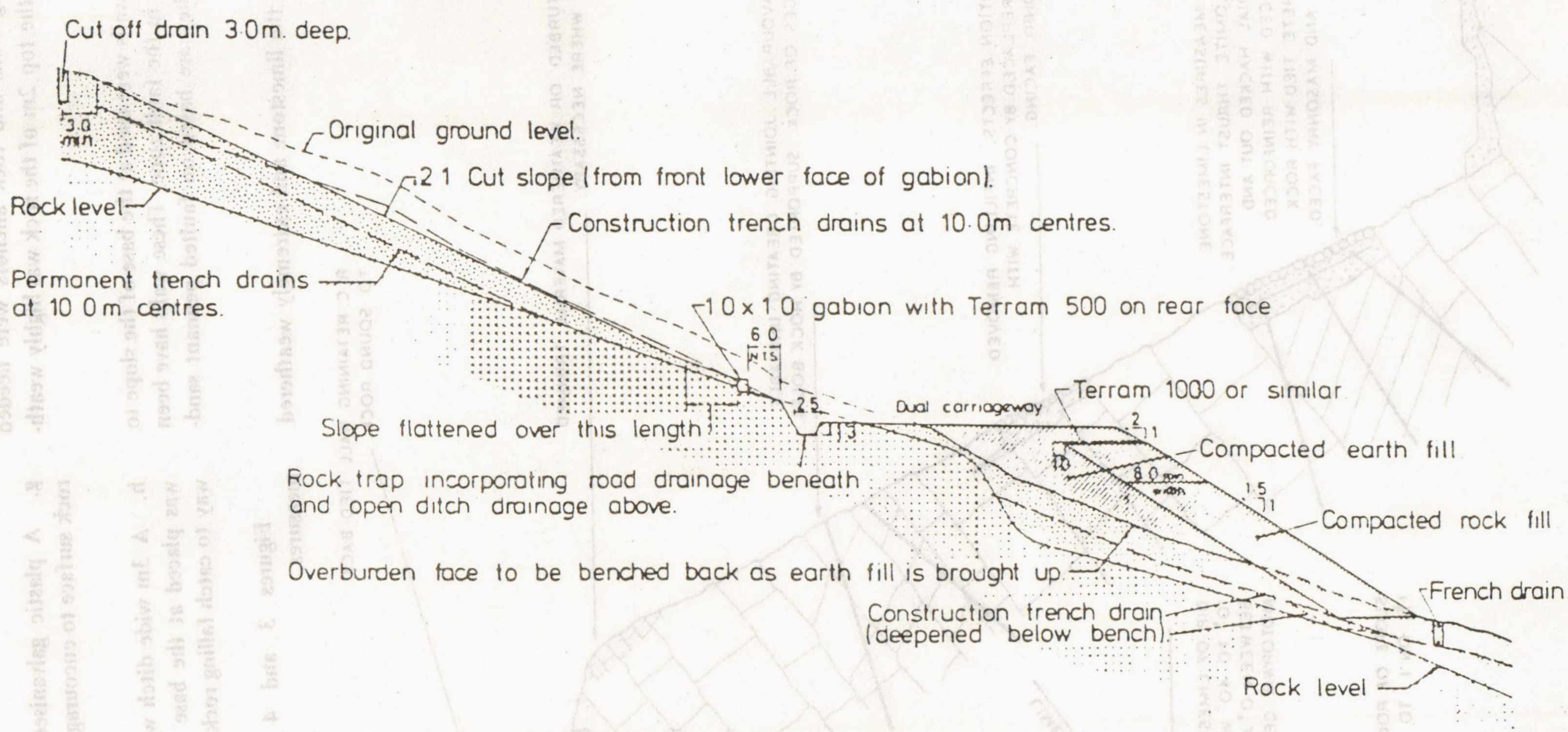

FIG. 5 General approach to design of earthworks.

Expenditure on remedial works on completion of the motorway was twice that anticipated. However the range of problems met had all been predicted by the site investigation. Fortunately clauses in the contract had been drawn up which made provision for the adverse problems which subsequently caused extra expense.

4. Example Road Cutting Along the A9 at the Killiecrankie Pass North of Pitlochry, Scotland

An area of unstable ground was indicated along the route of the road by a steep back scar, slip levees, backtitied trees and wet marshy ground in the centre of a depression. 3 main orientations of discontinuities were consisted of mudflows, tills, sands and gravel and top soil. Instability occurred where rock head is shallow, drainage is poor and seepage is occurring, and where artesian water is trapped on a large flat shelf in the bedrock surface. In its natura state the slope was found by analysis to be stable.

Remedial Measures: Sliding had to be stopped along natural discontinuities and had to stop seepage of the faces to be cut. This was done by the following methods and is shown in Figure 5.

a. Grading of slopes.
b. Extensive drainage measures.
c. Gabion retaining structures were constructed to provide protection against erosion of the toe of cut slopes, with filler material on the rear face to provide support.

SUMMARY

From these few examples it can be seen that the number of possible remedial measures may be large but in specific cases only one may be a viable alternative. The choice may be to leave the slope as it is and accept failure but at other sites a number of different measures may be employed at the same time to secure a slope. Every construction or excavation adjacent to a slope will effect that slope in different ways. Remedial measures must therefore be planned accordingly and carefully scheduled so that no disaster occurs at any stage during or after construction.

REFEDRENCES

Biczysko, S.J.,(1981). Relic landslip in West Northamptonshire, *Q.J. of Eng. Geol.* Vol. 14, No. 2 p. 169.

Buist, B.S., Burnett, A.D.,(1978). and Sanders, M.K. Enginering geological case study of the site investigation and design of a major trunk road cutting in Carboniferous rocks. *Q.J. of Eng. Geol.* Vol. 11, No. 2, p. 161.

Chaplow, R.,(1983). Engineering geological investigation of a possible landslide, Killiecrankie Pass, Scotland, *Q.J. of Eng. Geol.* Vol. 16, No. 4, p. 301.

Eyre, W.A.,(1973). The revetment of rock slopes in the Clevedon Hills for the M5 motorway. *Q.J. of Eng. Geol.* Vol. 6, p. 223.

Fookes, P.G. and Sweeney, M.,(1976). Stabilization and control of local rock falls and degrading rock slopes, *Q.J. of Eng. Geol.* Vol. 9, No. 1, p. 37.

Hoek, E. and Bray, J.W., (1977). Rock Slope *Engineering. Institute of Mining and Metallurgy, London.*

Newboury, J and Barker, D.A., (1981). The stability of cuts on the M4 north of Cardiff. *Q.J. of Eng. Geol.* Vol. 14, No. 3, p. 195.

Zaruba, Q. and Mencl, V., (1969). Landslides and their control. Developments in geotechnical engineering. Vol. 31

CONSTRUCTION OF A PETROLEUM DATABASE A CASE HISTORY FROM SONATRACH, ALGERIA

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ABSTRACT:– Till 1972 the petroleum-well-data in Algeria consisting of reports, notes, logs, tables and charts, analyses reports and descriptions remained scattered in the files of petroleum companies and other government agencies. In view of the fact, that a lot of professional efforts were wasted on non-professional work of searching the documents, extraction of the data, listing the information and preparation of routine or special reports, it was then decided to create a computerised data base. In Pakistan, the situation is analogous to that of Algeria. The significance of this short article is to give a brief idea as to how the work of data-handling was switched from man to the machine. This may be helpful in doing the same thing in Pakistan.

INTRODUCTION

The author had been associated with the Petrodata Service of SONATRACH (Algerian National Oil & Gas Organization) for over ten years and remained deeply involved in all the phases during the construction of the Database consisting of about 4000 petroleum wells. The work included the selection of all types of data about each drilled well, tabulation of this data on different formats, running the input on computer with the collaboration of system analyst/programmer and the correction of errors printed by the computer. The data might have to be run several times and corrected before it was declared error free by the computer. It was then stored on the Database for future reterievals or application and if necessary might be up-dated.

It is not within the scope of this short article to embrace all the detail as to how the final stage of putting a well on the Database is arrived at. The subject has been touched briefly with a view to inspiring an interest for organising the data in Pakistan petroleum industry with the help of computer.

SELECTION AND TABULATION OF DATA FOR THE DATABASE

Information or data of wells was scattered among various documents. Decision regarding the important parameters to be stored in Database was taken by the technical personnel of the organisation after holding many meetings and discussions. A well-edited "Final Report" was considered to be the most authentic source document. Other supporting documents were also used to select information about core-analyses, drill stem test results, water, oil and gas analyses and porous zones etc. Data was then tabulated on 80-column card Formats (card types) in Alpha, Numeric or combined Alpha/Numeric codes. Codes used for each item of data were listed in a Manual.

Each well was given a unique 6-digit catalogue number to avoid confusion when two wells happen to have the same name. This catalogue number had to be coded in the first six columns of each card.

Table 1 shows a "Tabulation File" on which the record of each tabulated well was maintained. It also contains the various sets of information coded for each well and the reports used as source documents. The parameters or the data of wells considered necessary for tabulation and storing on the Database are summarised below:–

1. *Location:* In this set of information, co-ordinate values, surface elevation (GE), reference elevation (KB), total depth, plug-back total depth, category of the well (whether exploratory or development etc.), a unique fields code for the field and the final status of the well were coded.

2. *Identification:* Year of implantation, detail of lease/concession, name of the operator company, full field name, spud-in date and rig-release date were tabulated under this category.

3. *Initial Potential:* This information belongs to the producer well only and included the name of producing formation, initial potential of the well in volume of oil or gas per hour, gas-oil ratio, source test of initial potential and the size of choke used in the test.

4. *Logs:* All logs run on the well during or after the drilling of the well were coded. The data included type of log, name of the log operator company, date on which log was run, depth of the interval and the scale.

5. *Perforations:* Interval of each perforation, its type, the name of the formation and the number of porous zone in which the perforated interval falls were coded in this set of information. In addition, any treatment done on the perforation (acidization, fracturization or squeezing) must also be recorded.

6. *Core and their analyses:* Three card types were used to accommodate all important information about cores. The interval of each core and meterage recovered were coded in one card type. The other two cards were used only when a particular core was analysed. The interval of the analysed part of the core, name of the formation and the porous zone in which the core falls, the name of the company which analysed the core, the type of the coring technique, horizontal and vertical permeability, porosity, percentage of oil water and gas saturation, density and raw-core description, if any, were also coded.

7. *Net Pay:* The thickness of the reservoir which is actually yielding oil and or gas was calculated and coded in this set.

8. *Formation Tops:* This is the most important set of information and includes name and depth of the top of each formation encountered during drilling. Type of top whether normal, faulted, projected or unconformity was also to be coded in this set.

9. *Porous Zones:* All porous zones were picked up from the logs or on the basis of any fluid recoveries/loss during various tests. Top and bottom depths of such zones were coded alongwith the type. All doubtful porous zones were clearly indicated through codes so that the user has a fair choice to select or reject a particular zone.

10. *Problem Zones:* Problem of fishing, loss of circulation, high pressure formation, tight hole, heaving shales etc. were coded in this category alongwith the depth at which such a problem was encountered.

11. *Water Analysis:* The information about water analyses was split into two parts and, therefore, coded on two card types. The items of data in this set included depth interval of the well from where the sample was taken, source test, name of the analysing company, specific gravity, dry residue, resistivity, PH value, salinity, the quantity of Ca, Mg, K, Na, Li, Fe, Cl, Br, I, So_4, Co_3 and CHO_3

12. *Oil Analyses:* This set included the depth interval of the oil sample in the well, source test, analysing company, specific gravity, API value, viscosity of the sample at 20°C, sulphur percentage, pour point value and date of analyses etc.

13. *Production Tubing:* In case of producing wells, data about the diameter and depth of the production tubing alongwith the date of installation of such a tubing was coded.

14. *Contacts:* All contacts (gas-oil, oil-water and/or gas-water), their well depth, name of the formation and the number of the porous zones in which the contact exists were coded under this category.

15. *Drill Stem Test (DST):* Information about drill-stem tests, consists of many parameters and was therefore, accommodated in three card types. The data in this category includes, number of test, date of test, interval, name of the company, type of test, depth of recorders, open hole and casing size, duration of initial tool open, final tool open, initial shut-in, final shut-in times, choke size, all types of pressures and recoveries etc.

16. *Casing:* The diameter, depth set-at, type and grade of casings and liner (if any), open-hole size, quantity of cement used during each phase were the parameters coded for this set of information.

17. *Drilling Mud:* The type of mud during drilling and its important characteristics were coded in this set. The information included, density, viscosity, amount of filtrate, thickness of filter cake, salinity, pH value and all the additives used in the mud and the well depth interval for which a particular mud type was used.

18. *Lithology:* Two card types were used to code lithology and other characteristics of rocks recovered from a certain interval of the well. Major rock types, their secondary or tertiary characteristics, type and grade of porosity, degree of oil shows, fossils recovered, colour, percentage of each major rock type in a specific interval, carbonate alternation, degree of sorting, degree of dolomitisation and grain size were the major parameters coded under this category.

19. *Gas Analyses:* In case gas samples were collected from a well and analysed, the depth of well from where the sample was taken, name of analysing company, the

source of sample, percentage of O_2. N_2, CO_2, H_2S, He, Methane, Ethane, Propane, Iso-Butane, Normal Butane, Iso-Pentane, Normal Pentane and higher members were all coded.

20. *Production Tests:* Production tests are run in the producing wells from time to time to measure production rates of oil and/or gas, tubing head pressure, casing head pressure and temperature. All such information was coded under this set alongwith date of test, choke size etc. and gas/oil ratio.

21. *Remarks:* While coding any of the above mentioned sets of information, if there is any extra information which is necessary but could not be incorporated in the relevant set, then the remark-card is used. The extra information or explanation can be quoted either in normal text or by using codes.

22. *Correction:* Data of a well comprising all or any of the information mentioned above was fed to the computer. The computer was programmed to check and cross-check the data and print error messages. These errors printed out by the computer were corrected and the corrections were coded again on 80 column correction card. Any information existing previously in computer memory may be corrected/deleted or replaced by coding appropriate message on this card.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of author's experience in Sonatrach, it is inferred that the decision to shift from conventional to computer handling of data was a very important positive decision. It caused healthy changes in the working of the organisation and brought about fruitful results with respect to their hydrocarbon exploration activities. Some of the advantages are summarised below:

(i) An electronic archive or "Data Bank" came into being. It replaced the ancient archive which consisted of thousands of shelves and cabinets.

(ii) The old-well-data was earlier scattered among various documents and in various organisations. This national heritage was under constant danger of being lost or becomming useless. By computerising it was thus safe-guarded.

(iii) The data became easily accessible to the users. Lot of professional time was saved which, otherwise, was wasted in locating the documents and searching the required data out of these documents. It may be appreciated that time is a critical factor in the development of new exploration efforts. The data should be at the disposal of an exploration geologist without delay. This became possible only after the computerisation.

(iv) The data could be retrieved from the database in the form of listings, tablets, charts, machine-made cross-sections or maps effortlessly.

(v) Computerisation of data also brought Sonatrach in line with the other modern oil and gas organisations of the world. They could exchange ideas easily and beenfit from new techniques of hydrocarbon exploration used in the developed countries.

In the light of above discussion it is suggested that national organisations like OGDC, HDIP, DGPC, POL and PPL dealing with the petroleum data should switch over to modern techniques in data handling.

ACKNOWLEDGEMENTS

The author is thankful to Mr. M. Baghdadly, Chief of "Service Traitment Automatique d' information", SONATRACH (Algeria), for his help in the comprehension of the new system. Thanks are also due to Mr. Riaz Ahmed, Principal Geologist of HDIP whose encouragement prompted the author to bring his experience in Sonatrach into black & white.

TABLE 1

Tabulation File to record each coded well, indicating the sets of information coded and the documents used for coding.

CATALOGUE NO. **DATE OF TABULATION:**

NAME OF THE WELL:

No. of Card	Name of the set of Information:	No of Card	Name of the set of Information	
01	LOCATION	12	OIL ANALYSES	REPORTS USED: –
02	IDENTIFICATION	13	PRODUCTION TUBING	————————
03	INITIAL POTENTIAL	14	CONTACTS	————————
04	LOGS	15	DRILL STEM TEST (DST)	————————
05	PERFORATIONS	16	CASING	————————
06	CORES/ANALYSES	17	DRILLING MUD	————————
07	NET PAY	18	LITHOLOGY	REPORTS MISSING: –
08	FORMATION TOPS	19	GAS ANALYSES	————————
09	POROUS ZONES	20	PRODUCTION TESTS	————————
10	PROBLEM ZONES	21	REMARKS	————————
11	WATER ANALYSES	22	CORRECTIONS	————————

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The articles should be written in English accompanied with adequate abstract, type written (double space) on one of the foolscap paper, with wide margin and should be submitted in duplicate. The illustrations (figures, diagrams, and maps) should be drawn in black ink on tracing paper with allowance for reduction in final print. Lettering should be preferably done with stencil. Colour photo prints can be arranged on payment. All tables, illustrations maps and photographs should be self-explanatory. International symbols should be used on maps as for as possible. In all maps and illustrations linear scale should be used. The Maximum length of the articles generally should be around 20 foolscap pages including diagrams. One copy of the book for publishing reviews on it in the Kashmir Journal of Geology, should be sent for consultation.

References should be arranged as follows:

Latif, M.A., (1976). Stratigraphy and micropaleontology of the Gali's Group of Hazara, Pakistan. *Geol. Bull. Punjab Univ.*, No. 13, p. 1-65.

Calkins. J. A., Offield, T.W., Abdullah, S.K.M., & Tayyab Ali, S., (1975). Geology of Southern Himalayas in Hazara, Pakistan and adjacent areas. *U.S. Geol. Survey, Professional Paper,* 716-C, 29 P.

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