KASHMIR JOURNAL OF GEOLOGY

Volume 1 No. 1

1983

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

KASHMIR JOURNAL OF GEOLOGY

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

EDITORS :

S . TAYYAB ALI

MOHAMMAD ASHRAF

Published by : Syed Tayyab Ali for the Institute of Applied Geology, The University of Azad Jammu & Kashmir, Muzaffarabad. Tel: 2706.

Printed by: M/s H Farooq Associates Ltd, Shahra-e-Quaid-e-Azam, Lahore. Tel: 321960 325374

Price : Rs. 50/- (In Pakistan)
U.S – $ 10/- (Foreign)

MESSAGE

The Institute of Applied Geology, University of Azad Jammu and Kashmir, deserves congratulations for bringing out at short notice the first issue of "Kashmir Journal of Geology". It is a daring venture and a commendable effort to introduce the geoscientific research activities of the Institute to the readers in order to familiarise them with the subjects of Earth Sciences.

To acquire knowledge, to subjugate the forces of nature and conquer space is a positive injunction of Islam. The outlook of Islam is fundamentally different. Science is subservient to moral values and the overriding principles of Islam . As Dr. Iqbal has said (بولہب را حیدر کرار کن) The mass of knowledge is Abu-Laheb, a non-believer. The duty of a Muslim is to convert it in to Haider-Karrar, the staunch believer and a warrior of Islam.

I wish the Journal a fruitful career.

A.A. SALARIA
Vice Chancellor,
Azad Jammu & Kashmir University
Muzaffarabad (A.K.)

EDITORIAL

Volume one of the Kashmir Journal of Geology is herewith presented to the readers for their critical review. The subject matter presented in this volume envelopes a wide range of the geoscientific spectrum. Since the receipt of the first article and the date of issue of the journal almost a year.s span exists. Extreme pains have been taken to overcome the numerous hurdles i.e. obtaining the declaration/authorisation, selection of suitable press, toning various articles for printable shape, and above all reading of proves, pasting of corrections and arrangement of funds.

We take this opportunity to thank all those who have in one way or other helped us bring out this issue. The persons who figure out prominantly in this effort include A. A. Salaria, Vice Chancellor, University of Azad Jammu and Kashmir, Mian M. Rafique, Principal, University College Muzaffarabad and A. A. Qureshi, Director Finance of the University. The Declaration/Authorisation to publish the journal, issued by the Ministry of Kashmir Affairs, Government of Pakistan, through Shahid Hussain Deputy Commissioner, Muzaffarabad is also acknowledged with thanks.

Last but not the least, thanks are due to all the contributors without whose prompt response, this issue would not have seen the light of the day. The second volume (1984) is now in hand, contributors are requested to send in their valued articles by middle of December, 1984.

Editors

CONTENTS

GEOLOGY OF TITHWAL KEL AREA NEELUM VALLEY, AZAD JAMMU AND KASHMIR

BY

MUNIR GHAZANFR,[1] MIRZA SHAHID BAIG[2]

M. NAWAZ CHAUDHRY[3]

ABSTRACT.– More than three hundred and eighty five square km area between Tithwal and Kel in the Neelum Valley on the right bank of river Neelum has been mapped for the first time. However, of the section between Doarian and Kel only a reconnaissance sketch was prepared. A detailed description and a preliminary petrography of all rock units between Tithwal and Kel is presented. The rocks between Tithwal and Loat comprise a psammatic-pelitic sequence which resembles the Tanol Formation as found elsewhere. This huge sequence is quite different from rocks of the Salkhala Formation as found further north in Neelum valley, north of Jared in Kaghan and elsewhere in the region. The rocks found in the vicinity of Authmuqam have also been considered as part of same psammite pelite sequence and not Dogra Slates as proposed by Wadia (1928). The extensive pelitic-calcareous sequence found north of Loat has been named as Sharda Group. We suggest the term Sharda Group should replace the term Salkhala Formation as type of rocks described in literature as Salkhala Formation are nowhere to be found around Salkhala village. Three different granite batholiths have been described. The two southern ones Jura and Neelum granites are possibly Tertiary while the Kel granite in the north is Palaeozoic or older. The whole sequence of country rock has been regionally metamorphosed. Very broadly speaking the grade of metamorphism increases from south to north (biotite grade at Authmuqam and kyanite grade at Gamot). Two major structures have been detected. The major synclinal structure in the south has been called Salkhala syncline and the major anticlinal structure in the north has been called as the Kel anticline. The Neelam granite appears to be post-tectonic while the Kel granite is pre-tectonic.

INTRODUCTION

The present work comprises an investigation of the middle and upper portions of Neelum Valley, State of Azad Jammu and Kashmir. The investigated area lying between the villages of Tithwal and Kel is confined to the right bank of river Neelum as the cease-fire line between the Indian- held Kashmir and Azad Kashmir comes frequently close to the left bank of the river in this area. The area covered by detailed mapping and reconnaissance is well over 500 sq. km. and is covered by portions of 1 : 50,000 sheets No. 43 F/14, 43 F/15, 43 J/1, 43 J/2 and 43 J/5 of the Survey of Pakistan. The area between Tithwal and Doarian was mapped in detail while only reconnaissance examination of the area between Doarian and Kel was carried out.

Earlier observations of some significance made about Neelum Valley are to be found in the work of Wadia (1928). Wadia's work however, was only of a broad regional character. He collectively termed the rocks of the area as the Salkhala Series, Dogra Slates and Tanol without delineating

1,3. Institute of Geology, University of the Punjab, Lahore, Pakistan.

2. Institute of Applied Geology, The University of Azad Jammu and Kashmir, Muzaffarabad, Azad Kashmir.

them or carrying out a mapping of the lithologic units or metamorphic grades.

Shakoor (1976) working in Nauseri area described the southern part of Tithwal Schists between Tithwal and Jargi.

The present study was initially started as part of the M.Sc. research carried out by a group of students at the Department of Geology, Punjab University in 1978 under supervision of Munir Ghazanfar. The then student party comprised Mirza Shahid Baig, Azad Muzaffar Hussain, Muhammad Ashraf Qureshi, Hassan Pervez and Waqar Ahmad. The present writers visited the area a number of times since then to carry out sampling and examination of the rocks and structure.

The Neelum Valley has a mountainous rugged topography and high relief. The elevation varies between 1050 m. at Tithwal (river level), 2000 m. at Kel (river level) to 4760 m. at Rattapar lake on the Kaghan watershed. In the west the Neelum valley is bound by the high Kaghan watershed which separates the valleys of river Kunhar and Neelum and has a general altitude of over 3650 m. with many peaks exceeding 4570 m. The climate is mountainous subhumid with most of the precipitation taking place in winters. The higher reaches receive heavy snowfall. The landforms are mainly fluvial but the Kaghan rides has many ice-scoured features like horns and cirques (some now occupied by lakes). The area north of Authmuqam is fairly well forested by conifers except where the height exceeds the snow line.

DESCRIPTION OF THE ROCK UNITS.

In the section between Tithwal to Kel over a road distance of over 110 Km three different granite batholiths and one small body are intruding an extenesive stretch of metamorphics. The metamorphic complex or the granites of the Neelum Valley have not been differentiated in the past. Below we give a first time description of the metamorphic and igneous rock units occurring between Tithwal and Kel. The reader should refer to the accompanying geological map (Fig. 1) and sections for the position and trends of these units on the ground. This description is followed by a discussion of some stratigraphic problems.

TANOL FORMATION.

Tithwal Garnetiferous Chlorite Schist.

This extensive unit occurs on the roadside from Barian to South of Tithwal. It is characterised by greenish grey to silvery grey colour on the fresh surface and weathers to light greenish grey with some rusty staining or at places to a dark brown colour.

Apart from well developed chlorite and at places chlorite porphyroblasts, small porphyroblasts of garnet though small in size and variable in amount are persistent in occurrence throughout the widespread occurrence of the unit. Some pyrite crystals are also found at places.

The Tithwal garnetiferous schists are distinguished from other garnetiferous schists occurring further north by the abundance of chlorite and consequent greenish look. The rock is fine grained but schistosity is moderate to well developed. No Marble bands were seen.

The unit is intruded by a number of dolerite sills and quartz veins lineations and jointing is well developed.

The northern contact, opposite village Barian, with the Jura granite is sheared. The contact shows no hornfelsing, no lit par lit injections, no baking and granite apophyses. It is faulted. On the road side a dolerite sill is emplaced within the chlorite schist near the faulted contact. The contact dips northeast and the schists underlie the granite.

This unit was first described by Shakoor (1976) who studied it between Tithwal and Jargi but did not study its northern part in contact with the Jura granite. Excerpts from his description are reproduced below :–

> "The contact of schists with (Nauseri) granite gneiss (South of Tithwal) is gradational. As one moves from schists toward their contact with the granite gneiss one observes the amount of biotite, feldspar and quartz increases considerably. With the increase in the amount of these minerals the grain size also increases and the rock starts changing from schists to gneiss. The quartz and feldspar grains develop parallel to the planes of schistosity and the feldspar grains are eye-shaped near the contact. The gneissic texture becomes more and more pronounced until the rock becomes truly gneissic The foliation of (Nauseri) gneiss is parallel to the foliation planes of schists."

Shakoor then mineralogically describes three different types of schists he found in this rock unit. He calls these Chlorite Schists, Quartz Mica Schists and Garnet Mica Schists, though all three varieties contain small but variable amounts of garnet. He describes these varieties as follows:–

Chlorite Schists.– These are fine grained greenish looking schists in which schistosity is moderately well developed. They are mainly composed of quartz (55 %) muscovite (25 %), chlorite (15 %), garnet (3 %) and iron ore (2%).

Iron ore is haematite and pyrite. Larger flakes of chlorite give a spotted appearance to these schists at places. Lineation is not present."

Quartz Mica Schist. – More prominently developed Tithwal. They are light coloured arenaceous schists consisting chiefly of quartz (75%), and muscovite (15%), Other minerals are biotite (3%), chlorite (2%) garnet (1%) and magnetite and pyrite (4%). Schistosity is poor to moderate. Bands of poorly developed quartzites are also present.

Garnet Mica Schists. – They are silver grey in colour and in them the schistosity and the lineation are well developed. Important constituents are quartz (50%) muscovite (30%) biotite (8%), garnet (5%) and iron ore (7%) Both magnetite and pyrite are present. Garnet though small in size, is abundantly developed. Folding is common and quartz veins are abundant. The distinguishing feature in the field is that the garnet can be seen with the naked eye.

Authmuqam Biotite - Chlorite Phyllites and Schists.

This unit outcrops on the roadside between Bugina in the north of Athmuqam and Bata to its southwest.

It has a remarkably deceptive field appearance. The unit looks like a sedimentary sequence. The general colour is light grey to bluish grey except for a graphitic band which is dark grey to dark grrenish grey. The rocks are soft, easily scratched with knife and are banded but the schistosity is generally poor or absent except in the graphitic band. The rocks are fine grained and at many places break with conchoidal fracture.

Although the rocks can be mistaken for claystones or marls in the field their true nature comes out under the microscope. Petrographic study shows them to contain abundant chlorite along with a fair amount of biotite. However, since the schistosity is generally missing or poor and the grain size is small, these cannot be termed schists. They are therefore, termed phyllites.

A graphitic band contained in the unit outcrops twice on the roadside, once just upstream of Shahkot village and once opposite the Salkhala village forming an asymmetric open syncline plunging to the east. The change of strike is prominent and the core of the syncline lies between Shahkot and Salkhala.

The Authmuqam biotite-chlorite phyllites also contain a few bands of greenish grey quartzites and a few micrometaconglomerates. The whole sequence is marked by an absence of calcareous material and is intruded by quartzo-felspathic dykes and minor aplite veins from the nearby granite body and by dark green to blackish dolerite dykes and sills. Quartz veins are also found.

The Authmuqam phyllites make a faulted discordant contact with the Neelum granite in the north at Bugina. The phyllites have been hornfelsed here with a 90 to 120 m. aureole but the effects are mild and mainly a growth of biotite is observed. Close to this contact slight granitization and veins and apophyses of granite are also found in the phyllites.

The southern contact at Bata is with the Kundalshahi-Nagdar garnet mica schist. This contact is also sharp and faulted. The fault has removed the gradational part as structurally the Kundalshahi – Nagdar garnet mica schists appear to be a more highly metamorphosed part of the phyllite sequence.

The whole unit may be subdivided into 4 rock types : micrometaconglomerate, felspathic and micaceous quartzites, phyllites and subphyllites and graphitic schist. These 4 rock types have been petrographically studied and described below :–

Petrography :

Micrometaconglomerates. – One sample of micrometaconglomerates was studied petrographically. The rock is rather well foliated and subschistose. It contains small granules and pebbles of quartz, granite and quartzite. An occasional piece of epidosite is met with. The matrix is composed of chlorite and fine grained quartz. It contains quartz. 55%, chlorite 30%, quartzite pebbles 5%, granite 1%, feldspar 5%, epidosite 0.5%, magnetite 3% and tourmaline 0.5%.

Felspathic Micaceous Quartizites. – A sample of felspathic quartzite was examined in the thin section. It shows granoblastic texture with quartz grains often well-sutured. A few angular garnet grains are also present. The percentage composition is quartz 72%, fledspar 10%, chlorite 4%, biotite 4%, calcite 4%, magnetite 2%, epidote 2.3%, garnet 1%, tourmaline 0.5% and zircon 0.2%.

Phyllites and Subphyllites. – Six samples of pelitic phyllites and subphyllites were studied in thin section. These are phyllitic to subphyllitic, very poorly foliated and often contain porphyroblasts of chlorite which are poikioblastic. Some knotty biotite aggregates are also present. Chlorite porphyroblasts may enclose biotite grains and they appear to belong to a second phase of metamorphism. On the basis of the study of the six thin sections mentioned above the following percentage ranges are recorded : quartz 34–58%, chlorite 3–12%, biotite 2–13%, muscovite 20–40%, magnetite 3–5%, haematite/limonite traces to 2.2%, tourmaline 0.5–2.7%, zircon 0.2–1%, epidote traces to 4%, felspar traces to 5%.

Graphitic Schist.– Four samples of graphitic schists were studied petrographically. It is found that the rock is subschistose and contains streaks of graphite at an angle to the schistosity. Mica-rich and mica-poor bands often alternate with each other. The following percentage ranges were recorded : quartz 42–48%, muscovite 35–40%, microcrystalline graphite 5–10%, haematite/Limonite 1–6%, magnetite traces 2.2%, chlorite-traces to 2%, zircon 0.2%, tourmaline 1–1.5%, epidote 0.3–1%, feldspar 1–2%, rutile 0.6–1%, pyrite 0.3–0.5%, biotite 2% (present in one out of four samples).

Kundalshahi Nagdar Garnet Mica Schists.

This rock unit appears in the form of two separate outcrops separated on the roadside by the Athmuqam biotite-chlorite phyllites and the Keran outcrop of the Neelum granite. In the light of field appearance and petrographic analysis, however, they have been considered here essentially similar and treated as a single unit. A combined description and petrography, therefore, follows :

The Kundalshahi outcrop appears on the roadside between Bata in the north and Rampura in the south. The northeastern contact with the Athmuqam biotite-chlorite phyllites is faulted and moves from Bata on the roadside northwest to Gujar Baihk turning north to Mingal across the Katha Nar and then northeast across Natpathra Nar until it is truncated by Neelum granite southwest of Saran. The southwestern hornfelsed contact with the Sandok outcrop of Neelum granite appearing near Rampura on the roadside moves northwest for many miles through Sundargran Nar, Sarsangar Nar, Mari Nar to Jamgar Nar and beyond.

The Nadgar outcrop has its southern contact with the Neelum granite. From Neelum on the roadside it moves westwards for many miles till it crosses Shilihat Nar and then starts turning northwards to cross Domel Nar. The northern margin of the Nagdar outcrop is marked by a thick band of quartzite. This quartzite band has a faulted contact with the Doarian garnet mica schists and gneisses. This fault which may be called the Loat fault appears on the roadside a few hundred yards upstream of Tarli Loat then moves westwards to cross Chutari Nar and then passes north of Danna peak.

The Kundalshahi – Nagdar garnet mica schists are fine grained light to silvery grey on fresh surface and grey to brownish grey on weathered surface. The unit represents a pelitic facies but there are a number of psammatic bands as well.

The size of the garnet is small. At some places it is too small to be detected with the naked eye. The size of the garnet is also small in the Tithwal garnet chlorite schists at places. However, the Tithwal schists are marked by their characteristic green colour. Both the Kundalshahi – Nagdar garnet mica schists and theTithwal garnet chlorite schists represent a pelitic pasmmatic facies and lack marbles.

An interesting feature of the Kundalshahi-Nagdar garnet mica schist is the presence of patches of chlorite schist within garnet grade. These may indicate a retrogressive metamorphism.

Petrography.

Within the Kundalshahi-Nagdar garnet mica schists two different lithologies can be distinguished viz., (i) garnetiferous quartzites and garnetiferous quartzitic schists and (ii) garnet mica schists. Petrography of these two units is separately described below :

Garnetiferous quartzite and garnetiferous quartzitic schists.– Garnetiferous quartzites and garnetiferous quartzitic schists vary from massive granoblastic to subschistose in texture. They are from poorly foliated schistose to almost massive. They are either porphyroblastic and poikioblastic or granoblastic.

At places they show evidence of superimposed metamorphism resulting in the development of secondary chlorite porphyroblasts and shells of garnet growing over previously existing garnet crystals.

Ten samples of these rocks five each from Kundalshahi and Nagdar outcrop were studied for petrography. They show the following mineral ranges: quartz 67–77%, biotite 5–22%, muscovite 1–20%, chlorite 0–5% magnetite 0.5–4%, potash feldspar 9% and 20% (present in 2 samples only), zircon 0.5–1% (present in 3 samples only), epidote 0.5 and 1% (present in 2 samples only) sphene 0.5–1% (present in 3 samples only), pyrite 1% (present in one sample only). The petrographic study indicates an original lithology of micaceous sandstones.

Garnet Mica Schists.– The garnet mica schists of Kundalshahi-Nagdar area show well developed schistosity. They are often porphyroblastic and poikioblastic. Second generation chlorite porphyroblasts often cut across the schistosity. Two generations of garnet and garnet shells over garnet may be seen at places.

Ten slides were studied and the percentage ranges of different minerals were found to be as follows :–

Quartz 36–46%, muscovite 14–35%, biotite 2–20%, chlorite 1–12%, garnet 3–6%, iron oxide 4–9%, tourmaline 0.5–2%, sphene 0.5% present in only one sample, epidote 3% and 4% (present in two samples). The petrographic study indicates an original lithology of shales.

SHARDA GROUP.

Upstream of Loat there is a huge and extensive development of garnet mica schists and gneisses, calc-schists and marbles, garnetamphibole-calc-gneisses,a nd Kyanite bearing gneisses, calc-gneisses, graphite schists and para-amphibolites cut by Kel granite gneisses. This group of rocks extends over extensive areas north and northwest of Doarian, Sharda, and Kel, Gamot andTarli Domel. The Sharda group is here named after the village Sharda a beautiful scenic spot where the archaeological ruins of an ancient Budhist University are located.

The appearance of calc-pelitic facies of the Sharda group represents a sudden change from the pelitic arenaceous material so far met within the Neelum Valley from Tithwal to Loat.

The calc-pelites represent the Sharda group (the so-called Salkhalas of Wadia) while the pelitic arenaceous material of the Tithwal schists, Kundalshahi-Nagdar schists and of the Athhmuqum biotite chlorite phyllites in our opinion collectively represents the Tanol (Tanowal) formation. The remarkably sharp contact between the two is marked by a fault along the northern margin of a quartizite band just upstream of Tarli Loat. The fault is marked by the presence of cataclasite.

The Sharda group of rocks is characterised by a ubiquitous development of generally large sized garnet, calcareous material, marble bands and a generally gneissic texture which is more well developed to the north.

Within the Sharda Group on the basis of dominant lithologies, two formations can be distinguished, the Sharda formation and the Gamot formation.

A petrographic study of the Sharda group of rocks indicates in original lithology of Shales, calcareous shales, carbonaceous shales, marls and limestones. Thus the rocks of this Group which occur from Loat in the south to beyond Tarli Domel in the north comprise a calc-pelities facies as against the non-calcareous pelitic psammitic facies occurring south of Loat.

The rocks of the Sharda Group have been metamorphosed to garnet mica schists and gneisses, calc-schists, marbles, garnet-amphibole-calc-gneisses, graphite schists and gneisses, kyanite schists and para-amphioblites intruded by metadolerites and granite gneisses.

From south to north the whole group shows an increasing intensity of regional metamorphism. On the roadside the garnet grade extends between Loat and north of Kharigam. North from Kharigam the rocks have been metamorphosed to staurolite grade but because of the calcareous nature of pelites, staurolite has not formed. Instead the amphibole, and almandine occur. Still further north beyond the Kel granite gneiss the rocks have been metamorphosed to Kyanite grade.

As mentioned above the lithological difference between the Sharda formation and Gamot formation lies in the calcareous and non-calcareous nature of the pelites. Most of the pelites of the Gamot formation are generally non-calcareous although they are interbedded with bands of marble. On the other hand the pelites of the Sharda formation are generally calcareous. Both the Sharda formation and the Gamot formation contain graphitic bands but the proportion and the number increases in the Gamot formation.

Sharda Formation.

The rocks of the Sharda formation occur on the roadside between Loat in the south and Kel Seri & Sheikh Bela in the north. In the field these rocks comprise garnet mica schist and gneisses, minor graphitic schists, marbles calcschists and gneisses and garnet- amphibole calc-gneisses. However, southwards towards Doarian this rock unit predominantly comprises garnet mica schists and gneisses with a few bands of graphitic schist. The garnet generally is large sized and the graphitic parts are generally non-calcareous. Schistosity at places is developed but commonly the rock is gneissose and quite massive. Generally speaking two different lithologies are present in the southern part. This is on the roadside between Loat and Doarian. These are (i) garnet mica schists and gneisses and (ii) calcareous quartz mica gneisses. Petrographically these two lithologies are described below separately.

Garnet Mica Schist.– The rocks are schistose to gneissic and porphyroblastic to poikioblastic. Thin section study reveals the following percentage ranges of minerals : quartz 40–46%, biotite 10–25%, garnet 7–15%, muscovite 7–25%, iron ores 4–7%, graphite traces to 5%, epidote

2–3%, plagioclase traces to 8% sphene traces to 1%, tourmaline traces to 1%, chlorite traces to 5%, and calcite 1–5%.

Calcareous quartz mica gneisses.– The rocks are strongly gneissic and often subporphyroblastic. Four samples were studied in thin section and the following percentage ranges were noted : calcite 22–70%, muscovite 7–18%, biotite 1–6%, chlorite 0.5%, garnet 1% (present only in one out of 4 samples studied), quartz 10–48%, epidote 1–8%, tourmaline 0.5–1%, graphite traces to 4%, iron ore 2–8%.

The petrography indicates an original composition varying from calcareous pelites to argillaceous carbonates with occasional sandstone band.

Changan Marbles.– In the vicinity of Changan Sharda formation is distinguished by the predominance of marbles along with alternating bands of calc-schists and gneisses. The marbles are generally light grey to medium grey in colour with white bands. The marbles are generally light grey to medium grey in colour with white bands and show minor flow folds. The schists show large sized garnets. On the surface where marbles and schists are closely intercalated they show solution effects and differential etching. Petrography of the marbles occuring near Changan is described below.

The marbles are granoblastic to subpoikioblastic and corarse grained. The percentage range of various minerals in three slides are found to be as follows : calcite 85–91%, quartz 4–12%, muscovite 1–3%, graphite traces to 0.5%, haematite traces to 0.5%.

Shadra gneisses.– The rocks of the Sharda formation in the vicinity of Sharda are represented by garnet-amphibole-calc-gneisses, some bands of marbles and a few minor graphitic bands. The Sharda meta-gneisses are medium bluish grey on fresh surface and light earthy brown on weathered surface. Some cliff faces show patches of yellowish grey and brown. On the weathered surface the rock may show effects of differential weathering. The garnet porphyroblasts in the gneissic part are small while in the schistose part they are large. The garnets appear to be slightly stretched. Between Kharigam and Sharda amphibole starts appearing in the gneiss in the form of black needles and prisms which in the hand specimen can be confused with silliminite or staurolite. Petrography of the garnet amphibole calc-gneisses from the vicinity of Sharda is described below.

Three samples of garnet amphibole gneiss were studied. The rocks are sharply gneissic. They are porphyroblastic as well as poikioblastic. amphibole occurs as columnar and prismatic crystals and their aggregates. The percentage of various minerals are as follows : quartz 48–55%, garnet 5–6%, biotite, 6–8%, amphibole 10–13%, muscovite 4–7%, magnetite 5–7%, tourmaline 2–3%, plagioclase 2–3%. The petrography indicates an original lithology of calcareous shales.

Gamot Formation

To the north of Surgan and Dokharian the Gamot formation is represented by Kyanite gneisses, marbles, calc-gneisses, graphitic gneiss and para-amphibolites.

THE GRANITES

Jura Granite Gneiss.

Along the roadside its outcrop is exposed for about four miles between Barian and Jura extending east-west on both sides of the river Neelum. The northern contact proceeds westwards more or less following the Kuchi Nar and then moving on the northern slopes of the Lugra Nar towards the Kaghan watershed. The southern contact with Tithwal schists exposed on the roadside near Barian moves first west and then southwest passing through the village of Chulai.

The colour of the Jura granite on the fresh surface is light grey or whitish grey while on the weathered surface it appears yellowish grey or brownish black. The rock is highly porphyritic and the microcline perthite phenocrysts are greater in number and larger in size (2 to 6 cm) then those in the Neelum granite (2 to 3 cm). Apart from feldspar the main minerals seen in the hand specimen include biotite, muscovite and quartz. The Jura granite is distinguished from the Neelum granite by its distinctly gneissic and foliated nature and coarser grain size.

The foliation in the Jura granite is parallel to the foliation of the schist at the contact. Basic dykes cut across the foliation of the body. At Jura bazaar a big screen of metamorphics is present within the gneiss.

The contact with the Neelum granite exposed on the roadside on the left bank of Kuchi Nar show a mixed zone about half kilometer thick. At the margin the Jura granite gneiss is being intruded by apophyses of Neelum granite and many screens of Jura granite gneiss are present within Neelum granite. The southern contact with the Tithwal schists is faulted across the foliations of schist and granite, which however, are parallel to each other. The fault dips northeast and shearing effects are clearly seen. Near this contact the granite also contains some garnet. Aplite and micrograite veins about a foot and half thick are also seen near this contact.

The Jura granite is strongly porphyritic and gneissic and the phenocrysts are of well-twinned microcline perthite. The phenocrysts are at places poikiolitic. Myrmekite growth is frequently observed. The plagioclase crystals show well developed zoning. Eight thin sections were examined and the percentage range of minerals is as follows : microcline perthite 20–53, albite 10–36%, quartz 20–45%, epidote 1–3%, biotite 2–8%, muscovite 2–10%, iron ore traces to 1%, apatite traces to 2%, sericite 1–5%.

Neelum Granite.

The Neelum porphyritic granite makes two roadside outcrops extending east-west across the river. One outcrop extend from Kucchi Nar Katha in the south to Rampura in the north over a distance of about 6.5 Km on the roadside. The second outcrop extends on the roadside for a distance of about five miles between Lala in the south to Neelum in the north. Although these two outcrops have not been fully extended in the west on the Kaghan ridge to prove that they represent a single batholith still field and petrographic studies indicate very close similarities. The two bodies have, therefore, been described under the single title of Neelum granite.

The Neelum granite is a medium grained, porphyritic, two mica post-kinematic intrusion. The size of the potash feldspare phenocrysts generally grows away from the contact to an average of 2 to 3 cms. Small xenoliths are also present near the contact. The granite is brownish grey to light dirty earthy grey on weathered surface and whitish grey on fresh surface with numerous specks of brownish black biotitel. Along some joint faces black-radiating aggregates of tourmaline are found.

The Neelum granite near Dainyar on the roadside contains a later coarse grained granitoid body. The Neelum granite at its contact with the granitoid has been metasomatised with the production of porphyroblasts/megacrysts of microcline perthite. The Neelum granite is also intruded by numerous dolerite dykes and some simple pegmatites and aplite bodies.

Effects of chilling, mixing and hornfelsing are noticed on the contacts where not faulted.

A chilled and hornfelsed contact is found between Neelum granite and the Kundalshahi Nagdar garnet mica schist outcrop. It is exposed on the roadside just downstream of Rampura. Here the sequence is as follows :–

Kundalshahi Nagdar garnet mica schist, andalusite hornfelses, garnetiferous andalusite hornfels, banded andalusite hornfelses with alternate andalusite and biotite-rich bands, chilled Neelum granite. Flow foliation, xenoliths and garnetiferous quartzofelspathic veins are seen in granite near the contact.

The roadside contact between Neelum granite and Athmuqam biotite phyllites at Lala Bugina is sharp, mildly hornfelsed and faulted. Further West the contact passes south of Mianwach Baihk. From here still further westward the contact is between Neelum granite and kundashahi Nagdar Schist and moves through Tubdat, Khori, Doga to Khaloadar and Saran. The contact aureole is perhaps 90 to 120 m. The hornfelses are of biotite type and there is some mixing of granitic material with the argillites.

The contact with the Nagdar outcrop of garnet mica schist is faulted.

At its contact with the Jura granite the Neelum granite contains numerous screens of Jura granite gneiss. This zone of mixing is nearly half a kilometer thick and indicates that the Jura granite gneiss is being intruded by apophyses of the younger post-kinematic Neelum granite.

The Neelum granite is hypidiomorphic subporphyritic. It is non-gneissic. The small phenocrysts are of microcline perthite. Zoning in the albite is rare. Eight samples were studied in thin section and the following percentages were found : –

microcline-perthite 20–28%, muscovite 5–10%, biotite 1–12%, sericite 1–2%, garnet 4% (only in one sample), silliminite 1–4% (found only in two samples).

Towards its contact with the Dainyar granitoid the Neelum granite is metasomatically reconstituted and shows big porphyroblasts of microcline enclosing a large number of minerals of the ground mass like albite, biotite, muscovite and quartz.

Dainyar Granitoid.

Near Dainyar mainly for a distance of nearly one mile on the roadside a non-porphyritic coarse grained granitoid body intrudes the relatively finer grained Neelum granite. It extends westwards away from the road but the outcrop was not fully mapped. As against Neelum granite the Dainyar granitoid is characterised by the predominance of muscovite with either no or subordinate biotite and by the relatively high values of albite and by the ubiquitous presence of tourmaline. The Neelum granite is thus a composite body with two phases, one porphyritic biotite phases and another nonporphyritic tourmaline-muscovite-albite bearing coarser phase.

One thin section of Dainyar granitoid was examined. It is found to be non-porphyritic and non-foliated hypidiomorphic. It is basically a soda granite rich in albite and tourmaline. Biotite is conspicuous by its absence. It should be noted that biotite is present in Jura granite as well as Neelum granite which are incidently also relatively poor in albite and rich in potash feldspar.

The Dainyar granitoid is found to be composed of the following mineral percentages : albite 38%, microcline perthite 15%, tourmaline 17%, quartz 25% and muscovite 5%.

Kel Granite Gneiss.

This garnetiferous granite gneiss has an outcrop exposure on the roadside between Kel Seri, a few kms. from Sharda, to beyond Kel, except for a short patch of garnet mica schists and gneisses belonging to the Sharda formation near Kel Seri.

The Kel granite gneiss was not investigated thoroughly but from the relatively small structural and petrologic evidence that was collected it is involved in folding along with the metasediments and most probably represents transformed metasediments. The very small garnet mica schists pieces seen in it look like relic schist pieces.

Only one thin section was examined. The rock is formed to be gneissic, subporphyritic. Pregranitisation metamorphic relics of garnet-muscovite-biotite (+ quartz) are present. The rock is coarse grained. The percentage range of minerals and their mode of occurrence is as follows :–

Plagioclase 15%. It is an oligoclase. Occurs as well twinned phenocrysts showing minor alteration to sericite. Small crystals in the groundmass and myrmekite growths are seen.

Microline. 38%. Occurs as few small crystals and also as megacrysts. The crystals range in size from 0.35 mm to 6.0 mm. The crystals are rich in inclusions of muscovite and also contain some garnet, biotite and quartz. Poorly perthitic to non perthitic. Encloses some plagioclase, quartz and microcline grains.

Quartz 28%. Strongly strained anhedral grains with sutured outline. Size 0.20 to 2.50 mm.

Muscovite. 10% Aggregates of small flakes. Often included in feldspar megacrysts. Size 0.15 to 1.5 mm.

Biotite. 5%. Aggregates of flakes often associated with muscoite and garnet. Size 0.15 to 1.0 mm.

Garnet. 4%. Occurs as small grains (almandine) intimately associated with micas. Size 0.10 to 0.25 mm.

HORNFELS.

Both Neelum and Jura granites are magmatic but faulting has eliminated evidence of thermal effects along certain contacts. The thermal effects are best preserved at the contact of Neelum granite with Kundalshahi-Nagdar garnet mica schist at Rampura where a contact aureaole shows the development of three grades of thermal metamorphism viz from schist to the chilled granite margin, biotite hornfels, andalusite hornfels and silliminite hornfels. The andalusite and silliminite hornfelses are described below .

Three samples of andalusite hornfelses were studied petrographically. They are subhornfelsic to hornfelsic. They contain piokioblastic porphyroblasts of muscovite, biotite and andalusite. The percentage composition is as follows :–

Quartz 40–42% muscovite 18–20% biotite 14–15% andalusite 13–15%, garnet 2–5%, magnetite 7–8%.

Three samples of silliminite andalusite hornfelses were studied petrographically. The rocks are strongly hornfelsic. Biotite and muscovite form porphyroblasts and piokioblasts. The precentage composition is as follows :–

Quartz 32–59%, biotite 10–12%, muscovite 12–18%, andalusite 4–20%, silliminite 3–12%, magnetite 5–6%, and tourmaline 1–2%.

STRUCTURE

Strike and dip.– The general strike in the area between Tithwal and Kel is northwest-southeast.

The general dip direction from Tithwal to Salkhala villlage is northeast and from Salkhala to Kel the general dip is in the opposite direction i.e., southwest. Locally the dips vary e.g. Southeast at Changan, South at Doarian Nar, northwest at Doarian and southeast and northeast near Athmuqam. The average dip in the section between Bugina and Barian is nearly 60° while over the entire mapped area the amount of dip is generally more than 45°.

Folds. – There is a distinct syncline, the Salkhala Syncline, between the villages of Shahkot and Salkhala with its axis running east west and plunge towards east. This structure however, directly involves the Athmuqam biotite-phyllites (in the core) and the Kundalshahi-Nagdar mica schist on the outside. The extensive rock units to the south and north also dip generally in opposing directions and seem to be involved the same structure.

Corresponding and complementing the Salkhala Syncline in the south. there is a major anticlinal structure in the north. Its axis runs in a northwest-southeast direction and passes close to Dokhran few miles northeast of Kel. The Kel Seri granite gneiss is involved in Kel anticlinal structures.

Folding is not a very noticable feature in the area. Where seen the folds are generally of open parallel type. The plunge is generally east upto Nagdar while north of Nagdar the plunge starts shifting to the south.

Faults. – Contacts between some units are clearly faulted. Some such noticeable faults are Barian fault, Bata fault, Lala fault, Neelum fault and Loat fault.

Barian fault.–The contact between the Tithwal schists and the Jura granite is faulted and dips to the northeast at about 30°. Effects of shearing are prominent.

Bata Fault. The fault between Athmuqam biotite-chlorite phyllite and the Kundalshahi Nagdar garnet mica schist appears on the roadside at Bata and is then folded along with the surrounding units to appear again southwest of Saran where it is abruptly truncated by the Lala fault.

Lala fault.–The contact between Neelum granite and the Athmuqam biotite-chlorite phyllites is also faulted. This contact moves southwest to Tuladat and from thence southwest but it is not faulted everywhere.

Neelum fault.–The contact between Neelum granite and the Kundal Shahi-Nagdar garnet mica schist is faulted too. It is partially covered by overburden at roadside near Nagdar. Away from the road this faulted contact moves west to Shillhat Nar and beyond.

Loat fault.–North of Tarli Loat the contact between a quartzite band occurring there and the Doarian garnet mica schist is faulted. The effect of shearing is apparent and locally the rock has been converted to cataclasite.

DISCUSSION

Metamorphism.

The rocks belonging to the Tanawal Formation and Sharda Group exposed in Neelum Valley have been regionally metamorphosed from biotite grade to Kyanite grade of regional metamorphism. Except for structural reasons the grade of metamorphism generally increases from south to north. The Athmuqam rocks belonging to the Tanawal Formation are phyllites and subphyllites and quartzites and micaceous quartzites. They show ubiquitous presence of biotite. Garnet is absent. They therefore belong to biotite grade of regional metamorphism. The Tithwal, Kundalshahi and Nagdar metasediments show ubiquitous development of almandine garnet. These rocks which belong to the Tanawal Formation fall in the garnet grade of regional metamorphism. They most probably fall in Epidote-Almandine subfacies. The Sharda Formation is from schistose to gneissic and falls in Almandine-Amphibolite subfacies.

Although no staurolite was observed at Sharda these rocks fall in the staurolite grade. The mineral assemblages in this calc-pelite metamorphic sequence support this conclusion.

The rocks near Gamot, Chattawala, Kundi, Ratta change and Naril Baikh fall in the Kyanite grade of regional metamorphism. This is proved by the development of kyanite in the pelitic facies of Gamot Formation at places mentioned above.

Polymetamorphic effects like the ones observed by Shams (1969) in Mansehra area can be observed in the KundalShahi and Nagdar metamorphics. In the Kundal Shahi metamorphics chlorite porphyroblasts develop at a later stage and enclose biotite.

In Nagdar schists in addition to chlorite porphyroblasts small second generation garnets start appearing and shells of garnet grow over garnet. These features show at least two phases of metamorphism.

Thermal metamorphism is well developed in the aureole of Neelum Granite near Rampura-Dhanabela, Sundargran Nar, Sarsangar Nar and Jamgar Nar along Dulur. Along this contact a thermal aureole about 400' thick is developed and contains biotite hornfelses, andalusite-cordeorite hornfelses and banded andalusite-biotite hornfelses.

The second thermal aureole is developed near Lala and Bugina, Mianwach Baikh, Khori, Doga and Gabdori Nar. Along this contact only biotite hornfelses have developed. Andalusite or sillimanite has so far not been observed.

Stratigraphy.

While describing the rocks in the vicinity of Hazara Kashmir Syntaxis Wadia (1928) has discussed the characters and distribution of the Salkhala Series. He says that are characterised by the presence of schists, limestones marbles and graphitic bands and enclose large bodies of granites. Although his description of the distribution is vague he appears to suggest that Salkhalas extend from close to Nauseri in the South to over extensive areas in the north of Neelum Valley. In Wadia's words "The outer border of the Salkhalas is defined by a thrust plane of low inclination. At Machhiara the intensity of the thrust is at its maximum and having trespassed over some miles breadth of the latter successive members of carboniferous-Eocene, Salkhala schists touch, and almost rest upon, the edge of the Murrees covering the foreland from Machhiara the outcrop still two miles wide and containing thick masses of granite, runs southeast towards Balgiran" continuing Wadia says "The inner boundary of the Salkhala series with the Dogra Slate is more difficult to depict with certainty; it runs along the steep cliffs of the ranges that enclose the narrow Kaghan valley to the north . . . . . Wherever limestones are not present, the extensive granitization of this part makes it difficult to separate the thermally altered Dogra Slates from the true schists of the older series . . . . . North of Kaghan village, granite intrusions increase in volume and at many places constitute more than half of the Salkhala series, Between Narange (34° 53' : 73° 38') and Babusar pass into the Chilas region of the Indus valley, the rocks are a finely stratified series of alternating gneiss and graphite , mica, and garnetiferous schist with marble.

Shah (1977) discusses these rocks in the following words :–

"Wadia (in Pascoe 1930) introduced the same Salkhala Series' to a sequence of schists phyllite, quartzite and carbonaceous material exposed in Kashmir and designated the type section at Salkhala village on the Kishenganga River (river Neelum), Kashmir . . . . . . marble, graphite schist, quartz schist and quartz felspathic gneiss are the main constituents of the formation in this Hazara area.... "

Now in the rock examined from Tithwal to Loat over a road distance of many miles calcareous material is almost non-existent. Carbonaceous material is also extremely restricted. On the other hand the rock section from Tithwal to Loat resembles the argillaceous and arenaceous character of the Tanol (Tanawal) formation. The Tanol (Tanawal) has been described by Wadia as fine grained well laminated sandy slates, phyllites and felspathic quartzites and schists full of false bedding marks. He further says the granite gneiss bodies intruding Tanol has granitised it by permeating it with lit-par-lit infections producing migmatites as at Balakot. Stratigraphically, therefore, the major part of the section between Tithwal and Loat must be considered Tanol and not Salkhalas as considered by Wadia.

It is unfortunate that the type locality of Salkhalas (South of Athmuqam) happens to occur in a section of Tanol. It is difficult to understand how the description of Salkhala formation as given by Wadia can be fitted on the rocks in the section referred to above.

We have, therefore, renamed the so-called Salkhalas of Wadia as the Sharda group, a calc-pelitic sequence which occurs in the Neelum valley north of Loat. While the pelitic arenaceous material of the Tithwal schists, Kundalshahi-Nagdar schists and of the Athmuqam biotite chlorite phyllites in our opinion collectively represent Tanol (Tanawal) formation. As we have already described above, the remarkably sharp contact between the two is marked by a fault along the northern margin of a quartzite band just upstream of Tarli Loat.

REFERENCES

Shah, S. M. I., (1977). Stratigraphy of Pakistan. *Mem. Geol. Surv. Pakistan.* Vol. 12. pp. 4–5.

Shakoor, A. (1976). The geology of Muzaffarabad – Nauseri area, Azad Kashmir, with comment on the engineering behaviour of the rocks exposed. *Geol. Bull Punjab Univ.* No. 12. p. 79–90.

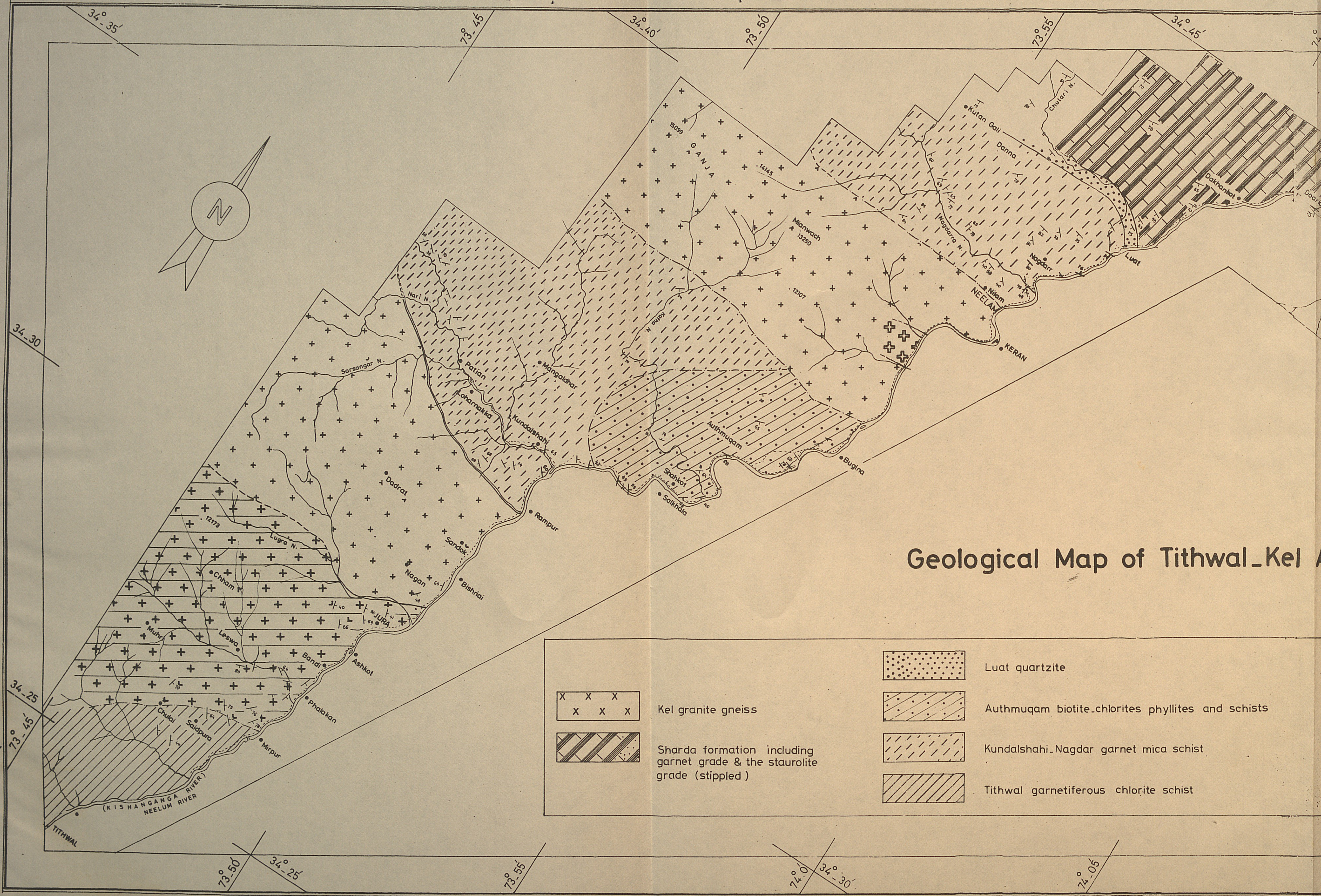
Shams, F.A., 1969 Geology of Man Sehra - Amb State area Northern West Pakistan. *Geol. Bull. Punjab Univ.*, vol. 8, No.1.

Wadia, D. N., 1928; The geology of the Poonch State (Kashmir) and adjacent portions of the Punjab. *Geol. Surv. India. Mem.* V. 51, pt. 2, pp. 185–370.

Wadia D. N., (1931). The syntaxis of the North-West Himalaya, it's rocks, tectonic and orogeny : *Ibid.*, V. 65, pt. 2, pp. 189–220.

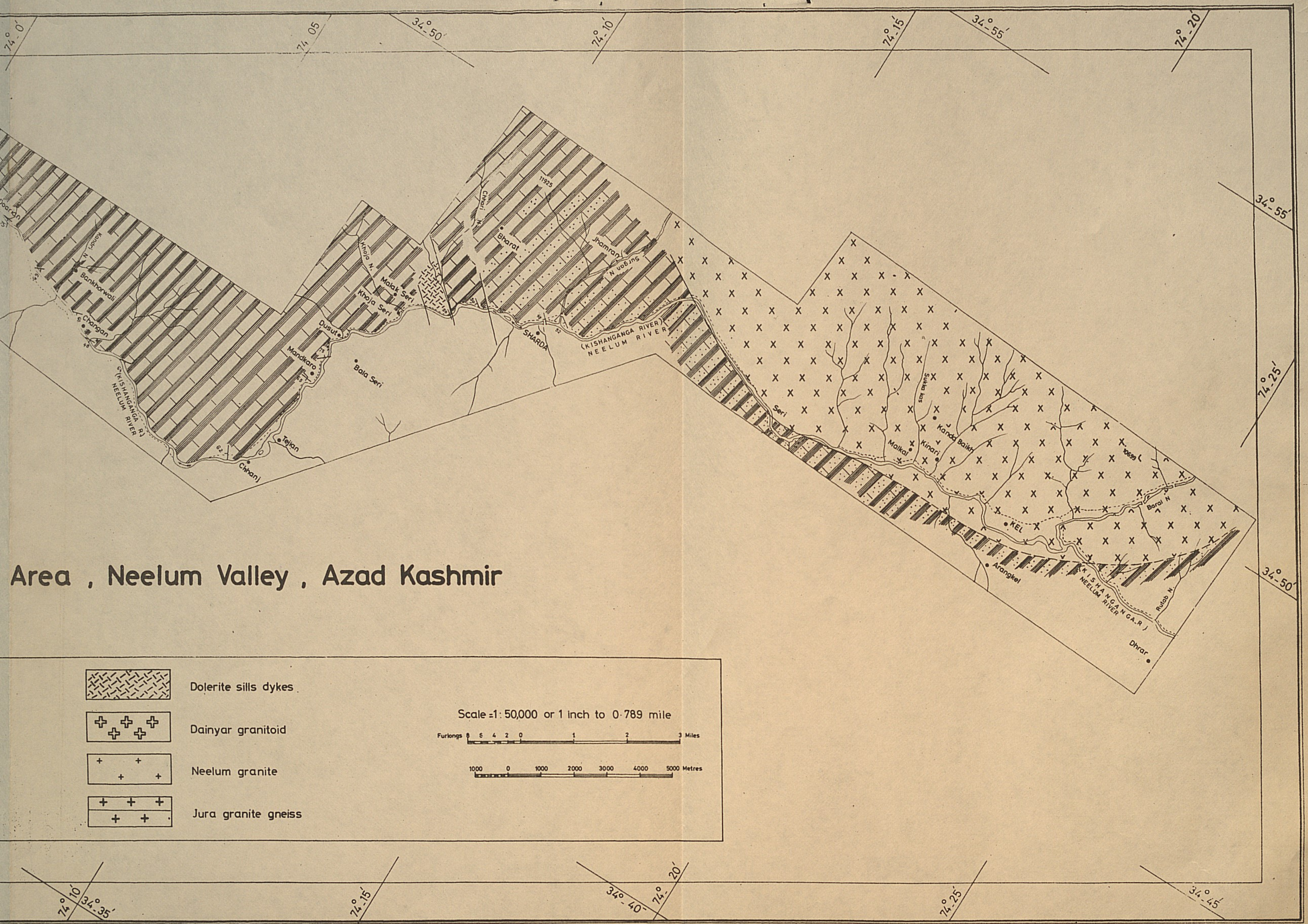
Wadia D. N., (1957). Geology of India : Mac. Millan & Co., London, 3rd El., pp. 536.

Geological Map of Tithwal_Kel A



Symbol	Formation
x x x	Kel granite gneiss
	Sharda formation including garnet grade & the staurolite grade (stippled)
	Luat quartzite
	Authmuqam biotite_chlorites phyllites and schists
	Kundalshahi_Nagdar garnet mica schist
	Tithwal garnetiferous chlorite schist

Area , Neelum Valley , Azad Kashmir



Geological mapping by: Munir Ghazanfar , Mirza Shahid Baig , Mohammad Nawaz Chaudhry , Azad Muzaffar Hussain , Hasan Perwaiz , Waqar Ahmad (Drawn by: M.A.Minhas)

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

TECTONIC PROBLEMS OF THE SUB-HIMALAYAN REGION OF PAKISTAN.

BY

E.R. GEE[1]

INTRODUCTION

Much of my geological work during the 30 years following the late 1920's entailed wandering over the attractive countryside of the Sub-Himalayan region of Pakistan, south of the main mountain ranges, using the excellent topographical maps which fortunately were available. Anyone who had, or still has, this opportunity should consider himself very fortunate.

Together with the Himalayan region, there must be few areas in the World of comparable size which offer such scope for geological observation and imagination. That these regions have, since the last one and a quarter centuries attracted the attention of many distinguished geologists and geomorphologists is no surprise. That it continues to do so, utilising more advanced techniqures is equally understandable.

For obtaining results of maximum value in geological research on areas of complex stratigraphy and structure, close co-operation with foreign specialists, leading to an interchange of ideas, is universally desireable; in fact, now-a-days with advancement in the techniques it is essential. With the development of rapid air travel facilities, for studying the geology of related areas in other countries, have vastly improved. Such co-operation proves beneficial to both parties.

It is good to note that Pakistan has been liberal in pursuing this policy, which it is hoped will continue. Its results are evident in the publications of the Geological Survey of Pakistan and of the country's academic organisations. Of these, particular mention should be made of the excellent papers included in the GSP 1979 publication entitled "Geodynamics of Pakistan" edited by Abul Farah and Kees Dejong. Such joint endeavours deserve every encouragement. The publication contains the results of recent research in the Sub-Himalayan and adjoining high mountain regions.

The area discussed in this contribution is illustrated in Figs. 1 and 2. It overlooks the alluvial plains of the Punjab which lie to the south; it includes the Salt Range-Potwar Plateau-Kala Chitta Range in the east of the Indus River and their continuation westwards across the Indus within the Kohat and Bannu districts.

It represents the outermost (southerly) region of north Pakistan which was severely affected by the Himalayan Orogeny, mainly in later Tertiary and Pleistocene times. Structurally, it contrasts with the Punjab plains the Foreland to the south, beneath which very gentle folding is a feature but only sporadically.

The region comprises a sequence of Late Precambrian, Cambrian, Permian, Mesozoic and Tertiary sediments which, in the Potwar, have proved productive of oil/gas. As such, it is of great interest in relation to the economy of Pakistan.

We are reasonably well-acquainted with the surface geology of the region but, to determine its possible oil potential, an accurate picture of its geological structure in depth is essential. In the case of the Potwar, this objective has in a number of instances been achieved. In other instances it has not: In the areas west of the Indus considerable doubt persists regarding this vital factor.

In this note, certain of the problems involved are discussed and the necessity of additional geological and geophysical research is emphasized.

SUMMARISED GEOLOGICAL HISTORY IN RELATION TO OIL/GAS POTENTIAL.

As above mentioned, we have a good idea of the surface stratigraphy of much of the region, though there is ample scope for more detailed research. In the Salt Range and Trans-Indus Ranges, the formations are well exposed

1. Director (Rtd.), Geological Survey of Pakistan. 3, The Orchard, Manor Way, Aldwick, Bagnor, Regise, Sussex, PO 21 4HX, U.K.

and the evidence of test wells for oil within the Potwar to the north has proved their extent north wards beneath the late Tertiary exposed sequence. Variations in the succession within these southern ranges are illustrated in Fig. 3, the principal feature being the development of the Cambrian clastic formation in the east and of the Permian and Mesozoic sediments to the west. This feature continues beneath the Potwar.

From Fig. 3, it is apparent that the succession is marked by three major unconformities:

(1) Separating the Cambrian and the Lower Permian (Tobra Conglomerates) formations. This unconformity is indicative of epeirogenic movements following Cambrian deposition. They resulted in gentle tilting downwards in a southeasterly direction, accompanied by erosion, which exposed the Late Precambrian-Cambrian, saliferous formation (Salt Range Formation) in the west and northwest during Late Cambrian Carboniferous times.

(2) Basal Tertiary unconformity, often characterised by a red lateritic bed. Tilting in the reverse direction to (1) is indicated by this unconformity.

(3) Eocene-Miocene unconformity, separating the marine Lower Eocene limestones and shales from the overlying freshwater and lacustrine Murree-Kamlial-Siwalik sequence.

In certain areas of the Salt Range and northern Potwar, Pleistocene conglomerates (Kalabagh Conglomerates) rest with a marked unconformity on the older formations, indicating the continuation of the Himalayan orogeny beyond end Teritary times.

The Pre-Miocene sequence is mainly composed of marine, shallow water sediments; it includes source rocks and no lack of reservoir rocks for oil/gas. With the exception of the Late Precambrian-Cambrian salt formation, the Cambrian-Eocene succession is relatively thin, totalling a maximum of only a few thousand feet in the area east of the Indus and in the Trans-Indus Ran℮e. This factor has no doubt had an important bearing on the date of hydrocarbon migration within the sequence.

As above mentioned, the stratigraphy in depth beneath much of the Potwar area is reasonablly well-established. That is not so in the case of its extension west of the Indus within the Kohat Salt Region. There, the oldest formation exposed is the Paleocene (Tarkhobi limestone) which crops out in the extreme north. Elsewhere, Eocene and younger sediments from the surface outcrops. Beyond the region, within the Tirah-Samana Range in the north and the Kala bagh-Surghar Range in the south, Mesozoic formations together with the Permian in the south, are exposed. There is, therefore, good reason to conclude that beneath the exposed Tertiary formation of Kohat, the Mesozoic and, probably the older formation, as proved in the western part of the Potwar occur in depth, thus indicating a possible oil-potential there also.

Again, in contrast to the Potwar area, a Lower Eocene Saline sequence (rocksalt and gypsum) developed within the Kohat region. These incompetent, plastic formations (Bahadur Khel Salt and Jatta Gypsum Formations) are an important factor in attempting to predict the geological structure in depth; obviously detailed geophysical surveys are essential.

As mentioned above, until Late Cretaceous times earth-movements within the Sub-Himalayan Region were mainly epeirogenic. With the commencement of the Himalayan orogeny in Late Eocene-Oligocene times, the situation changed dramatically.

Relative uplift along the general E-W trend of the present Salt Range and westwards into southern Kohat was accompanied by subsidence in the area to the north. This subsidence increased in intensity northwards, resulting in the development of the Soan trough and its westward extension in northern Kohat. Within this trough during Miocene to Early Pleistocene times, the Murree-Kamlial and Siwalik formations, fluviatile and lacustrine, were deposited. The Murree-Kamlial sequence increases in thickness northwards to some 3000m in the northern Potwar; the Siwalik formations attained a thickness of about 4000m in the deeper parts of the trough.

No marked unconformities occur within this thick, Middle and Upper Tertiary succession, indicative in this region that the intense pressures from the north occurred during the later phases of Himalayan orogeny in Late Tertiary-Pleistocene times. These pressures resulted in the major thrusts that occur at, or within a short distance of the Salt Range, Surghar and Khisor Ranges; also separating the Kala Chitta-Tirah uplands from the Potwar and the Kohat Salt Region (Fig.4). In addition, they were responsible for the folding and faulting of the region as seen today.

In Late Tertiary and Pleistocene times, an additional factor was responsible for the uplift at least in the case of the Salt Range anticlinorium. With the greatly increased isostatic pressure exerted by the weight of the thick

Miocene-Early Pleistocene sequence within the Soan trough, the incompetent rocksalt deposits of the Salt Range Formation in all probability flowed southwards into the Salt Range area, where the stratigraphical succession was relatively thin. This movement of the Precambrian-Lower Cambrian salt resulted in the formation of broad E–W trending anticlines such as in the eastern part of the Range where, at Dhariala, a borehole proved the duplicated Salt Range Formation to be more than 2130 m in thickness. It underlay, with no apparent discordance the formations of the Cambrian Jhelum Group. At total depth the borehole was still in the salt formation. Only in a few instances, as at Vasnal and Kalabagh the salt been intruded through the younger clastic sediments.

In the case of Potwar, the surface anticlines that have been tested by drilling continue to be developed in depth but a number have yet to be defined accurately. In Kohat, the case is probably very different. There, as above mentioned, an Eocene salt formation of unknown thickness occurs in the exposed anticlinal structures. These exposed structures are very complex. It is unlikely that such complex structures continue in depth, involving the clastic, Mesozoic and Palaeozoic formations that in all probability underlie the Tertiary sequence.

PROBLEMS, MAINLY STRUCTURAL, REQUIRING SOLUTION.

In the above summary of the geological history of the Sub-Himalayan Region of Pakistan, important factors in relation to future scientific research required for assessing fully the petroleum potential are :–

(i) Until Miocene times, the combined thickness of the sedimentary sequence was probably insufficient to cause appreciable migration of hydrocarbons.

(ii) Prior to the Himalayan orogeny, the earth movements were almost entirely epeirogenic. During that orogeny, acute folding and faulting took place, involving a much thicker sedimentary sequence (including the Miocene and higher Tertiary formations). This orogenic phase resulted in the development of numerous anticlinal structures into which migration might well have occurred.

(iii) Formations, rendered plastic under gravitational and tectonic pressures, occur in the sequence and have added to the uncertainities of structure in depth.

For a more complete determination of the geological structure of the region, additional research involving detailed fieldwork is obviously important. However, of the highest priority is the need for geophysical, particularly seismic surveys.

Regarding the latter, much valuable work has been carried out by the Oil and Gas Development Corporation in the areas east of the Indus resulting in the discovery of new oilfields; and the Geological Survey of Pakistan has added a useful quota of geophysical research. Areas deserving attention by the geophysicist, both from the economic and scientific standpoint are :–

Salt Range (Fig.4)

The extent of the decolement at the base of the scarp needs determination. Has the displacement southwards over-riding the Foreland, been limited, or, do the major thrusts extend at a low angle beneath the Range resulting in a repetition of the sedimentary sequence at depth? In other words, is the displacement southwards a question of kilometres, as has been suggested in personal discussions with geological friends? Were the horizontal over-riding considerable, the underlying repeated sequence could be of economic interest.

Potwar Area.

The determination of the structure in depth of the untested, acutely folded anticlines and of the steeply faulted Eocene-Miocene area in the north is essential.

Kohat Salt Region.

As previously mentioned, a well-developed sedimentary sequence of Lower Tertiary, Mesozoic and Palaeocene age can be expected to occur throughout this region, with structures disharmonic to those exposed in the complex, outcropping salt anticlines. Until defined and tested by drilling, the oil/gas potential of such structures obviously cannot be assessed, but the possibility of their potential being of value to the economy of the country is real.

Bannu Plain.

This extensive, alluvial area in all probability incudes a clastic succession in depth, of Mesozoic and Palaeozoic age as exposed in the Khisor Range and with the Paleocene-Eocene formations in the northern part (reference the Surghar Range Sequence), the whole being overlain by formations of the Siwalik Group. Test-wells in the

bordering Marwat and Pezu anticlines proved unsuccessful. Oil/gas seepages occur in the Surghar, Khisor and Pezu Ranges. Should geophysical surveys over the alluvial plain indicate the existence of closed anticlinal structures, the petroleum potential of the area would require reconsideration.

The above suggestions involving a more complete assessment of oil/gas resources of the Sub-Himalayan Region of Pakistan will require considerable expenditure, mainly in the seismic surveys and drilling. The possibility of obtaining results favourable to the economy of Pakistan is considered sufficiently promising to warrant such a programme. It should be given high priority and deserves to be included in the aid-projects covering scientific research and the assessment of the mineral resources of Pakistan.

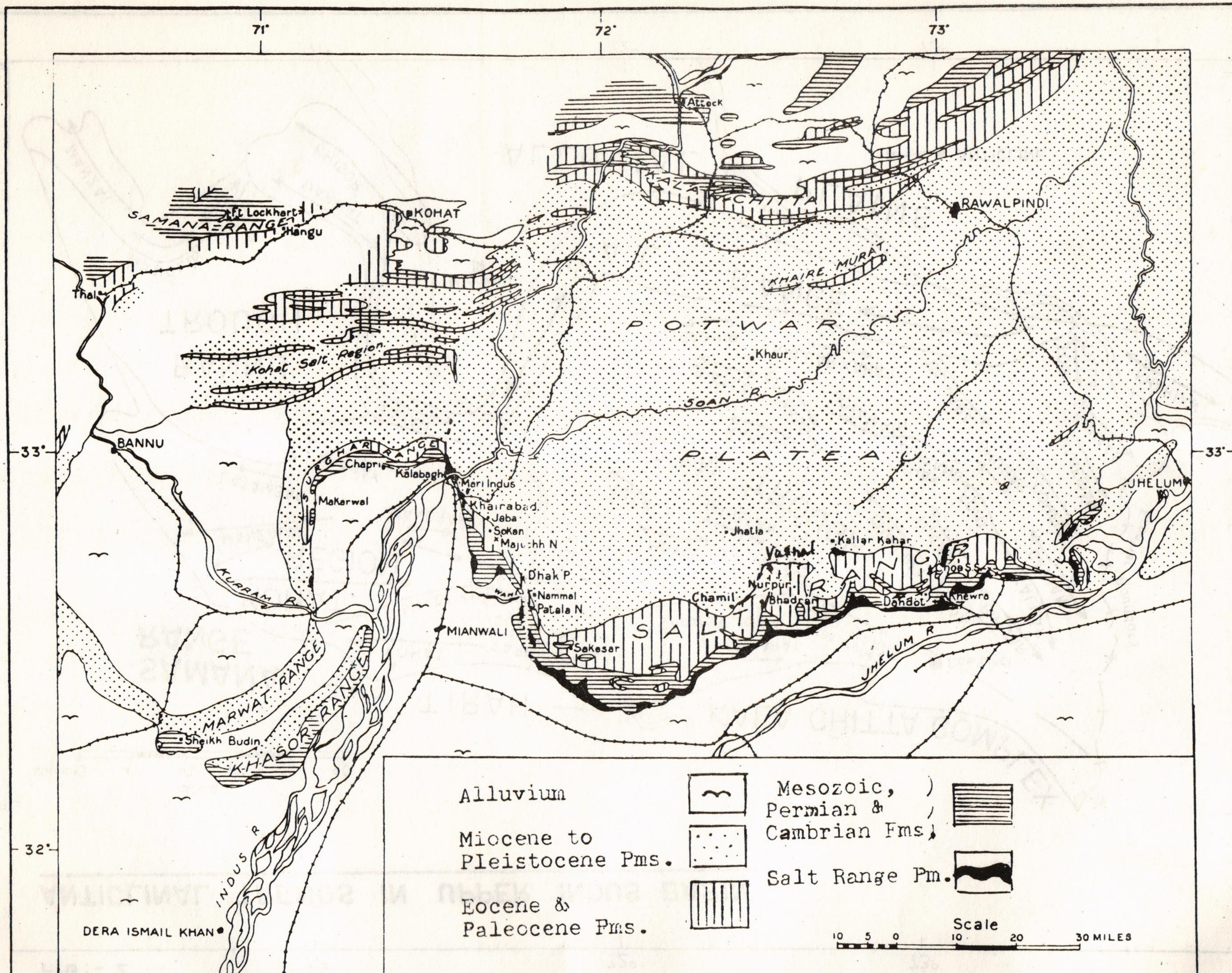
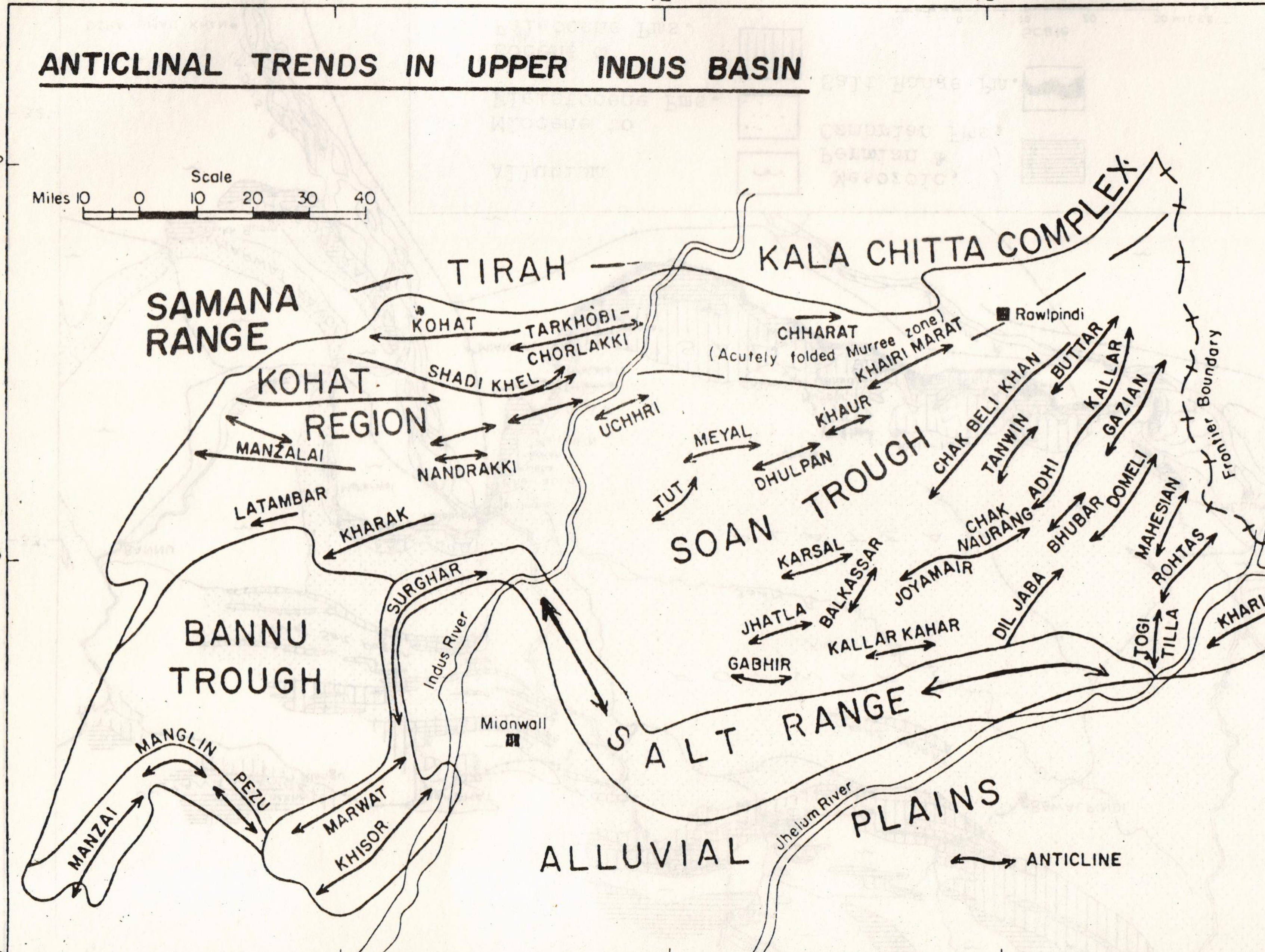


FIG:-I SIMPLIFIED GEOLOGICAL MAP OF THE REGION.

FIG :- 2



ANTICLINAL TRENDS IN UPPER INDUS BASIN
71°
72°
73°
34°
33°
32°
Scale
Miles 10 0 10 20 30 40
TIRAH
KALA CHITTA COMPLEX
SAMANA RANGE
KOHAT REGION
KOHAT
TARKHOBI-CHORLAKKI
SHADI KHEL
CHHARAT
(Acutely folded Murree zone)
KHAIRI MARAT
Rawlpindi
BUTTAR
KALLAR
GAZIAN
UCHHRI
MANZALAI
NANDRAKKI
MEYAL
KHAUR
DHULPAN
TUT
LATAMBAR
KHARAK
SOAN TROUGH
CHAK BELI KHAN
TANWIN
ADHI
CHAK NAURANG
DOMELI
BHUBAR
MAHESIAN
ROHTAS
Frontier Boundary
KARSAL
BALKASSAR
JOYAMAIR
DIL JABA
JHATLA
KALLAR KAHAR
GABHIR
TOGI
TILLA
KHARIAN
SURGHAR
Indus River
BANNU TROUGH
Mianwali
SALT RANGE
MANGLIN
PEZU
MANZAI
MARWAT
KHISOR
Jhelum River
ALLUVIAL PLAINS
ANTICLINE

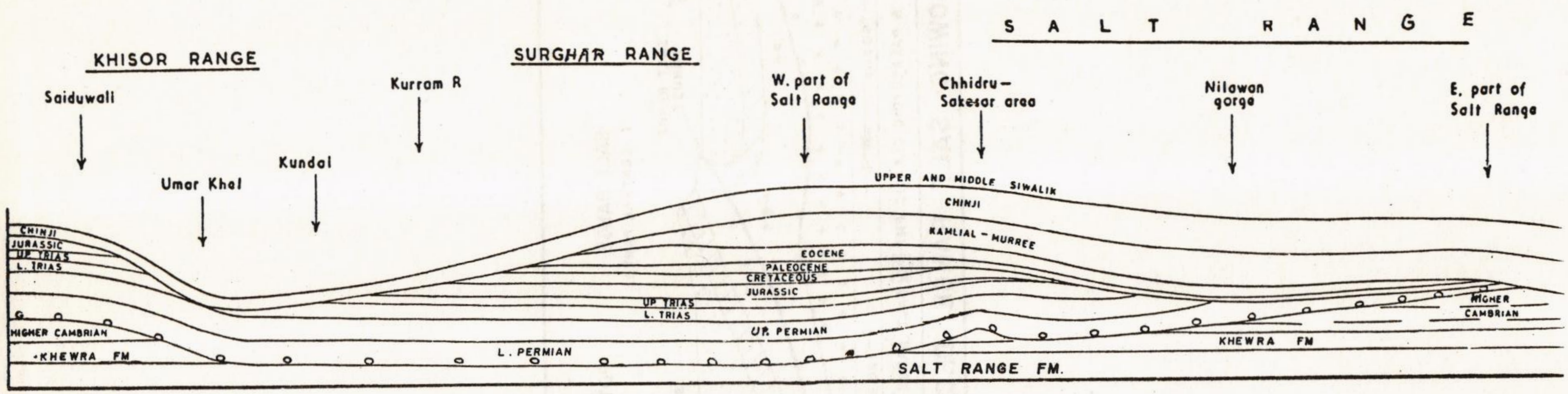


FIG:- 3 SKETCH SECTION ILLUSTRATING SALT RANGE / **SURGHAR** RANGE/KHISOR RANGE STRATIGRAPHY

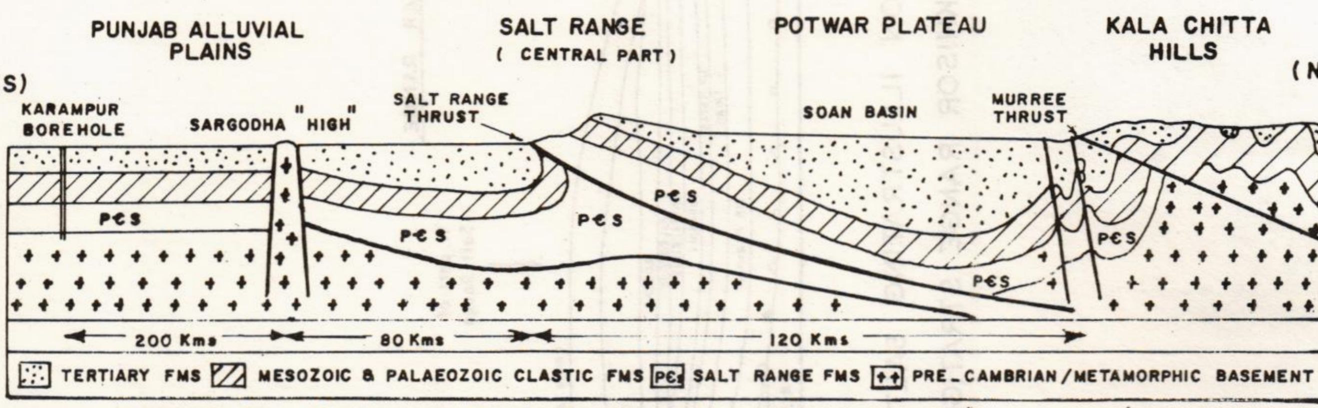


FIG:- 4 SECTION SHOWING SALT RANGE DECOLEMENT

STRATIGRAPHY OF KOTLI AREA OF AZAD KASHMIR AND ITS CORRELATION WITH STANDARD TYPE AREAS OF PAKISTAN

BY

MOHAMMAD ASHRAF[1]

M. NAWAZ CHAUDHRY[2]

KALEEM AKHTAR QUREISHI[3]

ABSTRACT.– In Kotli area, rocks, Precambrian to Pleistocene age have been found and studied. The Precambrian rock formation is, Dogra Slate which has been reported by authors for the first time in Nail Nala. Cambrian rocks are correlated with Abbottabad Group (consisting of basal boulder bed and overlain by thick sequence of Sirban dolomite/quartzite). In this area apart from lower Cambrian (Abbottabad Group) all the formations of Paleozoic and Mesozoic are missing. Either they were not deposited or were weathered to form bauxite/laterite-representing an unconformity of a big gap. In the Tertiary period Patala Formation, Margalla Hill Limestone, Murree Formation and rocks of Siwalik Group were deposited. Section measurements were done to establish the stratigraphy etc.

INTRODUCTION

The lithostratigraphic units described in this paper range in age from Precambrian to Recent and consist mainly of sedimentary rocks with minor intrusions of basic sills and dykes.

Two prominent unconformities exist in this area. The older one marks a period of non-deposition from Late Cambrian to Early Paleocene and is represented by 1.5 to 4.5 m thick bauxite/fireclay rocks with a brecciated zone at the base.

The second unconformity indicates the period of non-deposition from Late Eocene to Early Miocene and therefore, Margala Hill Limestone (Eocene) is in direct contact with Murree Formation (early Miocene). The generalized stratigraphic sequence of the area is given in Figs. 1 to 4.

STRATIGRAPHY.

Precambrian :

Dogra Slates.– Authorship. – **The term "Dogra Slates" has been introduced by Wadia (1928). Synonyms: "Panjal Slates" of Lydekker (1876), Hazara Group of Latif (1974).**

In Kotli area, this rock formation was discovered for the first time. The only exposure was found in Nail Nala at coordinates 302106 of 43 K/3 toposheet of Survey of Pakistan.

The slates are dark grey to black, with well developed slaty cleavage. These are argillaceous, thin bedded and fine-grained, with lenticular quartz veins along joints and cleavage planes. The slates closely resemble Kalamula Slates of Poonch District, however, the slaty cleavage is

1. Institute of Applied Geology, The University of Azad Jammu and Kashmir, Muzaffarabad, Azad Kashmir.
2. Institute of Geology, University of the Punjab, Lahore, Pakistan.
3. Geological Survey of Pakistan, Punjab Regional Office, Lahore, Pakistan

somewhat imperfect in the Nail Nala slates. The lower exposed zone contains scattered grains of pyrite (2 to 9 mm in size). The lower contact is not found whereas the upper contact with Sirban formation is unconformable, having a thin brecciated bed.

Topographic Expression.– **Forms** steep slopes and escarpments.

Thickness and Age.– The exposed thickness of the formation in Nail Nala is (30 to 45 m). The rocks are completely unfossiliferous, however, a Precambrian age has been assigned by Wadia (1928) and by Latif (1974) to equivalent rocks in Poonch and Hazara areas respectively.

The Dogra Slates have been correlated by Wadia (1928) with the slates of Hazara group, on the basis of lithology, age and stratigraphic position. The slates of Hazara group in the type locality are overlain by Kakul formation (Cambrian) which is overlain by Sirban formation (Latif 1974).

In Kotli area the slates are overlain by a brecciated bed 0.9 to 1.2 m thickness. The pebbles are 2 cm to 5 cm in size with calcareous to siliceous matrix. The pebble bed is overlain by the Sirban formation.

Cambrian :

Abbottabad Group.– Authorship.– The Abbottabad formation of Marks and Ali (1962) has been formalized as Abbottabad group by Latif (1974), who has subdivided the group into a lower Kakul and an upper Sirban formation. In the project area, the base of the Sirban formation is generally not exposed except at one locality (coordinates 302106) the Precambrian Dogra Slates have been exposed along a fault plane. The Kakul formation appears to be not developed in this area.

Sirban Formation.– Authorship.– The term "Sirban formation" has been used by Latif (1974). Synonyms : Muzaffarabad formation of Calkins (1968). "upper dolomite member" of Marks and Ali (1962) and "Great Limestone" of Wadia (1928).

The Sirban formation is an interesting rock unit, it always occupies the cores of plunging anticlines which extend in NW-SE direction. The formation is exposed from Bangang (Khuiratta) in the south to Tattapani in the north over a stretch of about 29 km having a maximum width of about 4 km near Shisetar. It is normally composed of a lower dolomite and an upper quartzite member. (Fig. 1).

a) Dolomite member.– The dolomite member can arbitrarily be divided into three zones.

The basal zone is fine grained, light grey to cream grey thinly to thickly bedded having frequent cherty layers and bands.

The middle zone consists of grey to dark grey dolomite, which is thinly bedded at most of the places. The joints are thinly developed. The encrustations developed on the joints are of yellow to orange colour.

The uppermost zone is also typical dolomite, showing chopboard weathering. It is light grey, having chert bands in the topmost part. These chert bands range in thickness from a few mm to 50 mm, and appear to be contemporaneous with dolomite. Some bands are, however, secondary in nature. In the middle and the upper zones hydrothermal mineralization is found in the following forms :–

(i) Ankerite-siderite-haematite-magnetitie-calcite mineralization along shear zones, fissures and in the joints.

(ii) Limonitic-brecciated zone found along the joints and in the fissures. This type may also contain lead mineralization.

(iii) Galena and malachite occur in thin fissures and also in brecciated fault zone.

b) Quartzite member.– The quartzite overlies the cherty dolomite in Palana-Bangang and Goi areas. It is well developed on the south-eastern plunge of Khuiratta anticline from Devigarh peak to Bangang. This quartzite is fine-grained, snow-white to white, having brownish to yellowish encrustations on the joints. The fresh surface is always snow-white to white. The thickness of quartzite varies from 9 to 25 m and it is the uppermost part of Sirban formation, which is brecciated at the top and is unconformably overlain by buxitic clays and bauxite.

c) Topographic Expression.– Forms cliffs, and steep to almost vertical slopes.

d) Thickness and Age.– The lower contact of the formation is not exposed in the mapped area. The contact with Dogra Slates in Nail Nala is faulted. It is, therefore, not possible to measure the true thickness of the formation.

The exposed thickness of dolomite member as measured during the present investigation in Janjora nala, is 493 m whereas the thickness of quartzite member is 25 m in Karjai (coordinates 142286). The formation is completely unfossiliferous. Wadia (1928) assigned Permocarboniferous age to the formation and correlated it with the upper dolomite member of Infra-Trias group of Hazara. Latif (1974) has renamed the Infra-Trias as Abbottabad group and, as described above, has referred the dolomite member as Sirban formation. A Cambrian age has been assigned to these rocks by Latif on definite stratigraphic and paleontological evidences. It is, therefore, named as Sirban formation and is thus considered to be of Cambrian age.

Early Paleozoic to Early Cenozoic Eras.

There is a break from Cambrian to Early Tertiary periods. Thus instead of normal marine sequence, alumina rich deposits of fireclay and bauxite are found to represent the above mentioned geological periods (Ashraf, 1980). *Bauxite and Fireclay.*– The bauxite/fireclay unconformably overlie the Sirban formation with brecciated dolomite, having abundant quartz pebbles, at the contact. Three distinct lithologies have been identified with these rocks based upon physical characters.

i) Brecciated Zones (C Zone)'– It is the basal zone, and is composed of aluminous to calcareous clays, with abundant quartz and chert pebbles. The thickness of this zone varies from 1.5 to 3.0 m.

ii) Non-pisolitic Bauxite or Fireclay (B Zone).– This is the lower zone and is composed of cream to grey and sometimes dark grey clays. These are non-pisolitic, occasionally oolitic, compact and splintery in nature.

The thickness of this zone varies from 0.9 to 1.5 m, however, in Dhanwan (coordinates 078443) and Nikial (coordinates 16373) it reaches a thickness of 2.3 m. The contact of fireclays with the underlying brecciated zone (C Zone) is quite sharp whereas the upper contact with pisolitic bauxite is transitional.

iii) Pisolitic Bauxite (A Zone).– This is the topmost zone and is mainly composed of pisolites and oolites. It is reddish brown to cream coloured and partly lateritized. The normal thickness of the zone ranges from 0.6 to 1.5 m, however, some 2.5 m thick zones have also been found in Nikial area (coordinates 164373). The chemical analysis indicates the alumina content in this zone to be as high as 69.30%.

Topographic Expression.– Forms gentle slopes.

Thickness Age.– The total thickness of these rock ranges from 2.5 to 5 metres and represents a long geological time from Late Cambrian to Early Paleocene in which these rocks were formed.

Paleocene :

The Paleocene and Eocene rocks of the area have been mapped as a single unit. However, on the paleontological and lithological grounds these have been classified into Patala Formation and Margala Hill Limestone.

i) Patala Formation: Synonyms.– Subathu facies of Wadia (1928), Patala Formation of Fatmi (1973) and Latif (1976).

In Kotli area, the Patala Formation usually overlies the bauxite and fireclays, however, at places it is directly underlain by the Sirban formation. The absence of bauxite-fireclays may probably be the result of their complete erosion in such localities before the deposition of Patala Formation.

The formation is composed of Khaki, dark grey to black shales with subordinate (0.3 to 0.9 m thick) interbedded limestone. Shales are generally silty and splintery, however, sandy shales have also been noticed as in Dandili (coordinates 054417).

Lenticular good quality coal seams are found at two horizons within these shales. The lower horizon is near the contact of Patala Formation with bauxite-fireclay, whereas, the upper horizon is approximately 15 m above the lower horizon.

Another important feature is the repetition of yellowish brown, ferruginous mudstones or muddy ironstone beds which are 10–30 cm in thickness. These occur nearly 22 m above the contact with bauxite. The beds are relatively compact and hard being slightly phosphatic, having phosphatic nodules of dark grey to black colour. Good exposures of these beds have been found in Newal (coordinates 143304), Nikial (coordinates 164372), Dhanwan (coordinates 075457) and Dandili.

a) Topographic Expression.– Forms gentle dip slopes and moderate escarpment slopes.

i) Thickness and Age.– The thickness of this formation as measured in Nikial is 43 meters. Except for the limestones the formation is mainly unfossiliferous. The foraminifera identified from the limestone beds are :–

Assilina, Lockhartia, Discocyclina etc.

The age of the formation is Paleocene.

Eocene :

Margala Hill Limestone: Authorship. – **Latif (1970)**
Synonyms : "Nummulitic Formation" of Waagen and Wynne (1872), Hill Limestone of Wynne (1973) and Cotter (1933).

The Margala Hill Limestone overlies the Patala Formation with a transitional contact. The formation is separated from Patala Formation on the basis of fauna, and higher proportion of limestone to shale.

The formation is composed of grey, dark grey to black limestone with subordinate greenish grey shales. The limestone is fine to medium grained, medium to thickly bedded, whereas the shales are silty and splintery in nature. The nodularity is well-developed in limestone with individual nodules varying from (6 to 15 cm). Associated nodules of pyrite as quite common on fresh surfaces, which when removed by weathering leave cavities on bedding surfaces. Milky calcite veins and patches are frequently found within the limestone. At places like Nikial and Tattapani well developed nodules of limestone have been found embedded in silty shales.

a) Topographic Expression. – **Forms gentle dip slopes and low cliffs.**

b) Thickness and Age. – **The thickness of the formation as measured in Nikial is 80 meters. The formation is fossiliferous and the following fossils have been identified in field :–**

Assilina, Lockhartia and Nummulities.

The age of the formation is Eocene.

Basic Intrusion. – **Sills and dykes of basic composition have been observed in many parts of Kotli district. The main occurrences are associated with dolomite of Sirban formation, however, at places these intrusions are seen to be penetrating the overlying bauxite/fireclay and Paleocene/Eocene rocks. Wadia (1928) has also reported such basic sills and dykes to have intruded the Eocene rocks and thus are supposed to be post-Eocene in age.**

The major occurrences are known from Samelote (coordinates 128288), Guni Malni (coordinates 051455), and Palana (coordinates 122294).

The Samelote intrusion is composed of altered dolerite, and is the biggest known intrusion of the area. It is more than 300 m long and upto 90 m in width. The basic body has penetrated the dolomite, fireclay and bauxite. The contacts of the basic body with the country rocks are not clear due to scree and overburden, however, close fractures and shearing is commonly seen.

The intrusive rock is medium to coarse grained and dark bluish grey to greenish grey in colour. The weathering colour is light grey.

The Guni Malni occurrence is about 30 x 9 m. The country rock is dolomite. A small marble deposit, probably formed due to thermal effects of basic intrusion on dolomite, is present at the contact.

The Newal and Palana intrusions are similar in all respects.

Oligocene:

During Oligocene time the area again faced a period of non-deposition. The Fateh Jang zone present in other areas at the base of Murree Formation is absent here and a yellowish grey, pelecypod (occasionally broken) rich zone is present. In Dandili and Balmi areas a yellowish cherty zone is found at the contact of Margala Hill Limestone and Murree Formation.

Miocene:

Murree Formation. – **Synonyms : Mari group of Wynne (1884), Murree beds of Middlemiss (1896) and Murree series of Wadia (1928).**

The Murree Formation occupies the major extent of the mapped area, especially in the northern part. It unconformably overlies the Margala Hill Limestone, whereas in Khuiratta area it has a faulted contact with Sirban formation.

The Formation is composed of alternating series of shales and sandstones of predominantly buff colour, however, grey, green and purple facies are also quite common. Wadia (1928) divided Murree Formation into a lower and an upper part, on lithological basis. The two parts have been identified in field. Generally, the sandstone of Lower Murree Formation is hard, fine-grained, non-micaceous, ferruginous, deep red, purple to grey with frequent pseudo-conglomerate beds. The associated shales are also red, purple and splintery, however, occassional, greenish grey shales are present at the base of the formation. Abundant calcite veins and patches are rare limestone nodules are also found.

Structurally the Lower Murree Formation shows a far greater amount of compression in the form of tight isoclines and overfolds with repeated faulting and fractures.

In the Upper Murree Formation, the sandstone is soft, coarse grained and micaceous with pale grey to brownish grey colouration. The interbedded shales are red, purple, buff and grey,Structurally Upper Murree Formation shows open, broadfolds which have been weathered into strike ridges and valleys with and succession of escarpments and dip slopes.

Red or purple colour of Murree Formation is due to the presence of disseminated iron minerals.

According to Wadia (1928) the source of Murree Formation was the iron bearing Purana Formation of the peninsular higher lands of southern India.

a) Topographic Expression.– Forms ridges and hilly terrain.

b) Thickness and Age.– The reported thickness of the rock formation is about 3000 m. It is devoid of vertebrates and invertebrates, however, some plant fossils have been reported. The age of the formation is Early to Middle Miocene (Wadia 1928).

Late Miocene to Pleistocene :

Siwalik Group.– Synonyms. "Siwalik Series" of Oldham (1893) or Siwalik System of Holland (1913) has been classified by Wadia (1928) into Lower Palandri, Middle Mang, and Upper Sand Rock Stage.

Stratigraphic Committee of Pakistan (1973) has formalised it as Siwalik Group in Potwar area and divided into :–

1.	Soan Formation	Pleistocene
2.	Dhok Pathan Formation	Pliocene
3.	Nagri Formation	Upper Miocene
4.	Chinji Formation	Middle Miocene.

The Siwalik group is composed of sandstone, clays, shales and conglomerates. The sandstone is grey to greenish grey in colour with subordinate bands of brownish, reddish or grey coloured clays and shales. Generally the sandstone beds are 6 to 9 m thick, coarse grained and soft and easily scratchable. Sometimes concretions and coarse pebbles are seen in the sandstone. Cross bedding and calcite veins are also frequent.

Lower Siwaliks are absent in the area due to the main boundary fault (Wadia 1928).

a) Topographic Expression.– Forms strike ridges and sunken valleys.

b) Thickness and Age.– The reported thickness of this group is over 4500 m. Only vertebrate fossils have been reported from these rocks. The age of the group is Late Miocene to Late Pleistocene.

Recent Alluvium:

The gentle slopes and flat plains of the area contain stream, river and wind blown deposits of Recent age.

The Kotli city is situated over the alluvial deposits of Poonch river. These deposits are composed of clay, fine-silt and sands with boulders and pebbles of varying sizes and compositions. The boulders are usually subangular to subrounded. The alluvial deposits provide fertile lands for agricultural purposes.

GEOLOGIC HISTORY OF KOTLI AREA.

The geological record of the are ranges from Pre-cambrian to Recent. During considerable part of this time the area was submerged under the sea except for a long period ranging from late Cambrian to early Tertiary.

The lower most stratigraphic unit exposed in the area is the environments for equivalent rocks in Hazara (Hazara formation of Latif 1974). However, Calkins et al. (1968) disagreed with the concept, indicating that limestone gypsum and graphite are unlikely to be present in a turbidite sequence.

The exposure of Dogra Slate in the project area is limited to Nail Nala and this exposure is also very small making it quite difficult to study the lithological variation; however, Wadia (1928) has reported the presence of limestones in these rocks. Thus it is postulated that during deposition of these rocks shallow to relatively deep marine water conditions were prevailing with rapidly submerging basin or rising cordillera. As these rocks were burried under great thickness of the overlying strata the temperature and pressure affected them and changed them into low grade slates. The intensity of this metamorphism was low, so that only the less resistant argillaceous portions were changed into slates whereas less susceptable limestone portion were left apparently unaffected.

The presence of a conglomerate bed at the top of Dogra Slate indicates emergence of land deposition of stream deposits. The conglomerate probably represents the absence of rocks, equivalent to Kakul formation of Hazara (Latif, 1974).

After a period of non-deposition during lower Cambrian the area again underwent transgression of sea and deposition of Sirban formation took place.

The extremely monotonous nature of dolomite of the Sirban formation and absence of sedimentary structure indicates relatively deep and calm water conditions, however, the process of dolomitization, would also be responsible for these characteristics. The formation of dolomite could be by direct precipitation from sea water. The replacement of dolomite appears to have been volume for volume rather than molecule for molecule. It is extremely difficult to ascertain the time of replacement, as the replacement could have occurred even during deposition and before burial or it might have taken place after burial and uplift. The early replacement is the result of reaction of lime carbonate sediment and the magnesium bearing sea water, whereas the later replacement would be the product of reaction of the limestone and either magnesium-bearing connote brines or circulating meteoric waters. Daly (1909) suggested that the older the rock the greater the probability that it would come in contact with magnesium-bearing waters and become dolomitized.

Overlying the Sirban formation is bauxite/fireclay deposits which represent very interesting deposition and environments. The bauxite/fireclay represents the major unconformity at the erosional brecciated surface of dolomite. The formation of the bauxite/fireclay appears to be a product of desilication of the post Cambrian dolomite covering middle Cambrian to Pre-Paleocene rocks in humid tropical to sub-tropical climate. This is such an unconformity which is widely present in Pakistan marked by bauxite/fireclay and laterite etc. in the Salt Range, Hazara, Kala Chitta (Ashraf 1972 a, 1972 b; Fatmi, 1973).

Overlying bauxite/fireclay are the Patala Formation and Margala Hill Limestone of Upper Paleocene to Eocene age. These rocks display a remarkable succession of cyclic deposits, as a result repetition of shale, limestone, coal and ironstone has been observed. Such cyclotherums are typically associated with unstable shelf or interior basin conditions in which alternate marine submergence and emergence occurred. During the emergent stages, local disconformities may be developed in the previously deposited sediments before the succeeding unit is deposited. Clay, shale and silt derived from rising elements in source areas were deposited over the low emergent plain mainly as alluvial detritus. As the source areas was lowered by eroison these were succeeded by marl & fresh water-limestone deposits. The inflow of detrital material diminished & the broad plain was occupied by swamps or marshes. Such conditions were suitable for the accumulation of peat which was later transformed to coal. The accumulation of peat required restricted fresh to brackish water conditions. These conditions were followed by a relative clearing of sea during which dense limestone was deposited. Restricted shallow marine conditions commonly developed after the initial limestone deposition to form the black laminated shale. As the cycle of sedimentation progressed, the environment lost its restrictions, developed open circulation and eventually the biosparite limestone was deposited in shallow current agitated water.

After the deposition of Margala Hill Limestone, the Murree Formation was deposited, no lithological sign of emergence is noticed and the absence of Oligocene Epoch is a debatable point and needs careful study of the contact.

According to Wadia (1919) a great upheaval took place at the end of Eocene Epoch, which contributed to the formation of Alpine-Himalayan mountain system. The deposition of Murrees took place after this upheaval.

The lower Murrees were deposited under brackish water and the Upper Murrees under comparatively fresh water condition.

Termination of Murree period in the Middle Miocene coincided with another violent episode in mountain building on the northern borders of the subcontinent.

A long narrow depression was formed in front of the rising mountains. The depression called 'foredeep' was the site of the deposition of Siwalik strata. Numerous short streams must have flown from the rising mountains into the foredeep in a direction transverse to the later.

The coarse and usually unsorted sandstones show that they must have been borne by rapidly flowing large masses of water and laid down in wide depression of shallow water or in swampy areas. The alteration of deposition was the result of coarse material during flood and fine material during dry seasons. The enorous thickness and uniformity of lithology over vast areas indicate that the source rock and the fore-deep were similar and continuous with other later sinking in pace with sedimentation. The Siwaliks give evidence of a warm humid climate. The break in the Upper Pliestocene time coincides with the lying down of a thick mantle of loessic silt, which includes aeolian, fluvial and lacustrine sediments. Subaerial deposition seems to be the most acceptable.

REFERENCES

Ashraf, M., Chohan, N. A., and Faruqi, F. A., (1972 a). Bauxite and clay deposits in the Katha area, Salt Range, Punjab West Pakistan. *Econ, Geol., Vol.* 67. p. 103.

Ashraf, M., Qureshi, M. W., and Faruqi, F. A., (1972 b.). Preliminary studies on the economic geology of bauxite-laterite deposits, Katha area, Salt Range, Punjab, Pakistan. *Geol. Bull. Punjab Univ.*, No. 9, pp. 43–54.

Ashraf, M., Ahmed, M. and Faruqi, F. A., (1976). Jurassic bauxite and Kalonite deposits of Chhoi area, Kala Chitta Range, Punjab. *Geol, Bull. Punjab Univ.*, No. 12, P. 41–54.

Ashraf, M., and Chaudhry, M. N., (1980). Caly ey bauxite and clay deposits of Kotli district, Azad Kashmir. *Contr. Geol. Of Pakistan.*, p. 82–108.

Calkins, J. A., and Matin, A. S. A., (1968). Geology of Garhi Habibullah Qadrangle. PK. U.S. Depastment of Interior, Washington.

Cotter, G. de. P., (1933). The geology of the part of Attock dsitrict, West of longitude 72° 45' E. *India Geol. Surv., Mem.*, Vol. 55. p. 63–161.

Holland, T. H., and Tipper, G. H., (1913). Indian geological terminology. *India Geol. Surv. Mem.*, , Vol. 43, pt. I.

Latif, M. A., (1970). Explanatory note on the geology of South-Eastem Hazara, to accompany the revised geological map. *Jb. Geol. B. A. Sonderbond.* 15, S, pp. 5–20.

Latif, M. A., (1974). A Cambrian age for the Abbottabad Group of Hazara, Pakistan. *Geol Bull. Punjab. Univ.*, No. 10 p. 1–20.

Latif, M. A., (1976). Stratigraphy and micropalaeontology of Gails Croup of Hazara. Pakistan. *Geol. Bull. Punjab. Univ.*, No. 13.

Ledekkar, R., (1976). Notes on the geology of the Pir Panjal and neighbouring districts. *Rec. Geol. Surv. India.*, Vol. 9, p. 155.

Marks, P., and Ali, C. M., (1961). The geology of the Abbottabad area. with special reference to the Infra-Trias. *Geol. Bull Punjab Univ.*, No. I, p. 47–55.

Middlemiss, C. S., (1986). The geology of Hazara and Black Mountains. *India Geol. Surv. Mem.*, Vol. 26, p. 302.

Oldham, R. D., (1886). A note on the olive group of the Salt Range. *India Geol. Surv., Rec.*, Vol. 19, pt. 2. p. 127–137.

Waagen, and Wynne, A. B., (1972). The geology of Mount Sarban in the Upper Punjab. *India Geol. Surv. Mem.*, Vol. 9, p. 331–350.

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

Wynne, A. B., (1873). Notes from a progress report on the geology of parts of the upper Punjab. *India Geol. Surv. Rec.* Vol. 67. pt. 3. pp. 59–64.

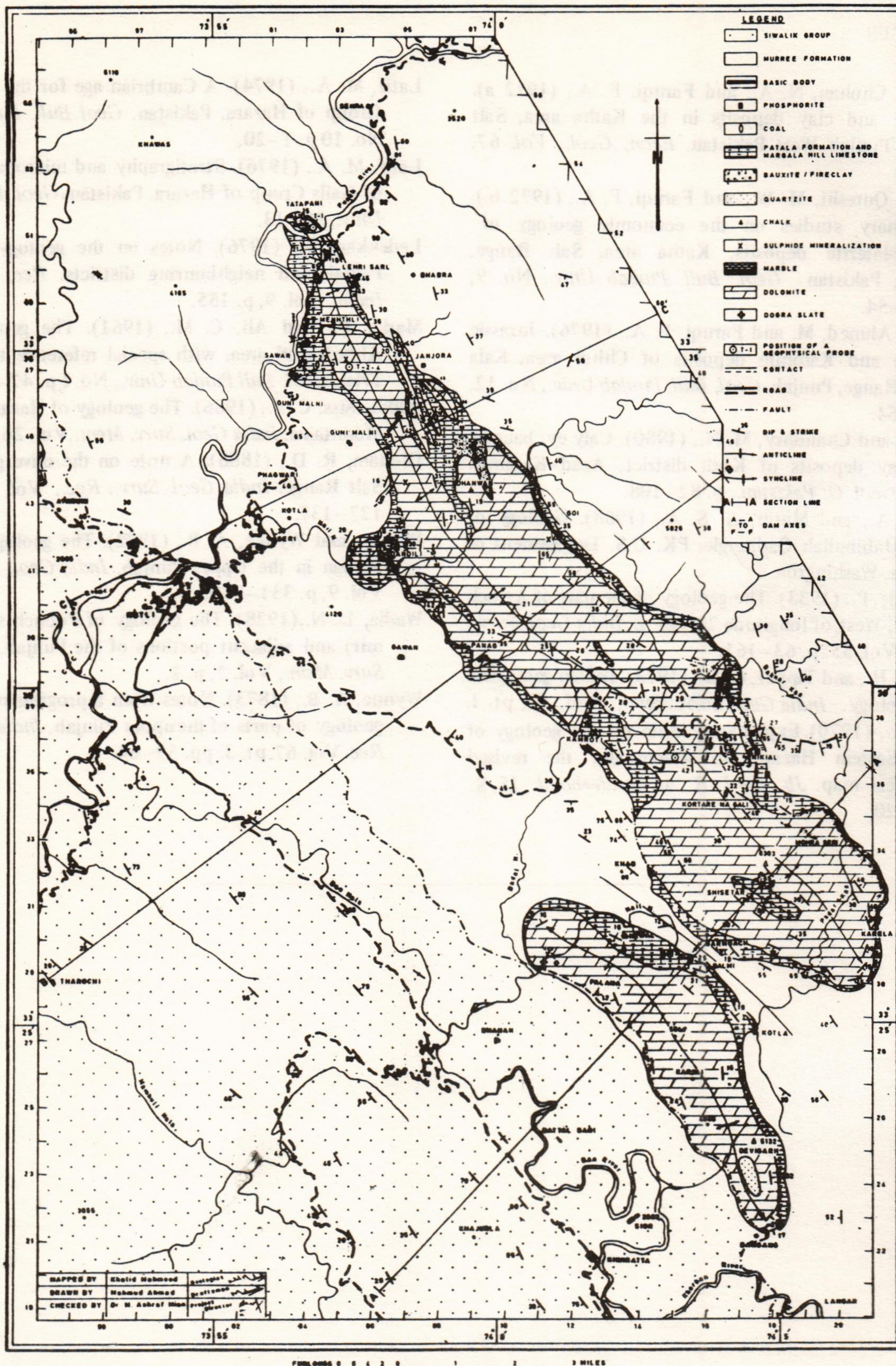


Fig. 1 GEOLOGICAL MAP OF KOTLI AREA SHOWING IMPORTANT MINERAL DEPOSITS / SHOWINGS AND PROPOSED DAM SITES.

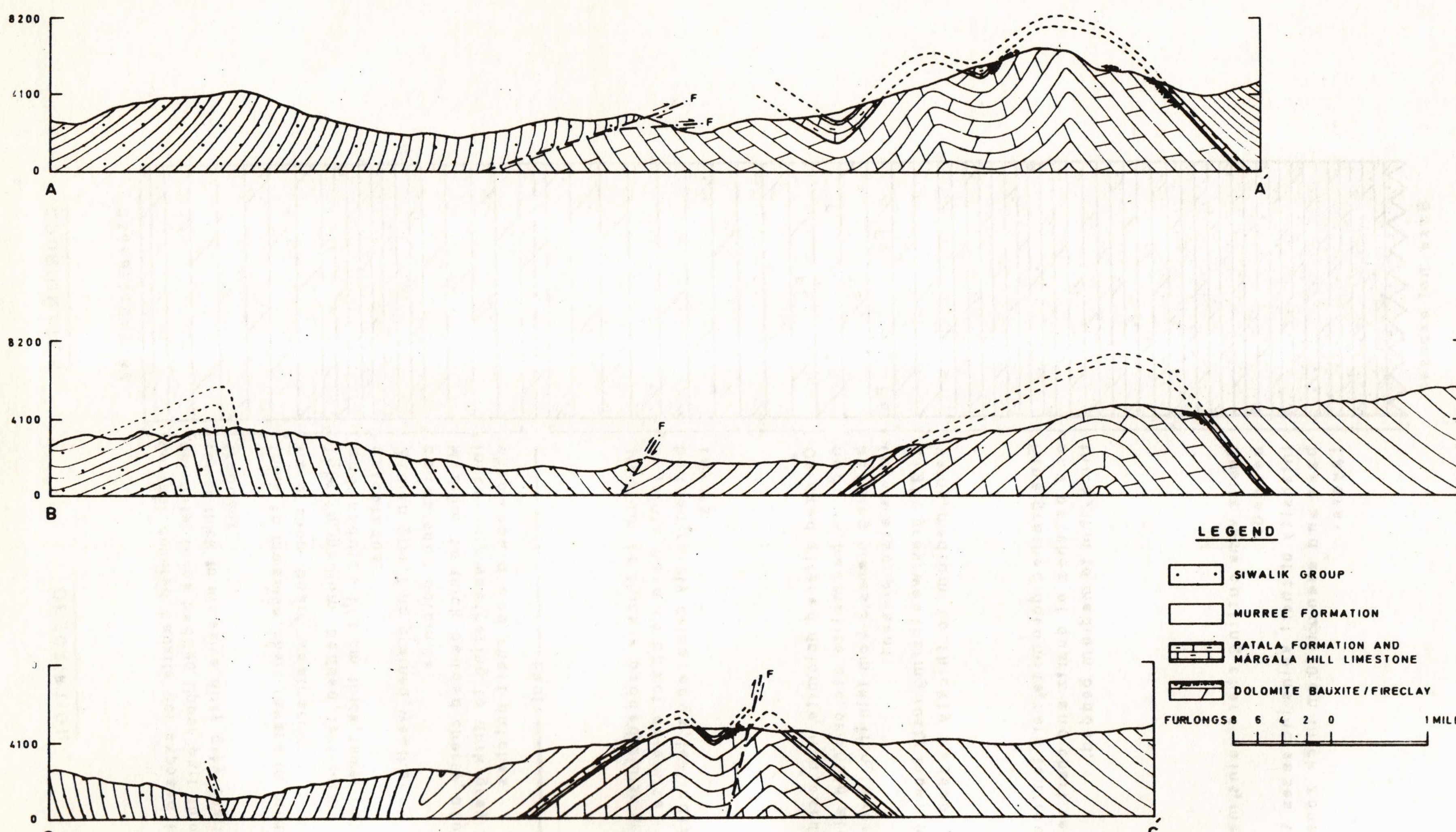


Fig. 2. GEOLOGICAL CROSS-SECTIONS AT POINTS A A' B B' C C' ON GEOLOGICAL MAP Fig. 1.

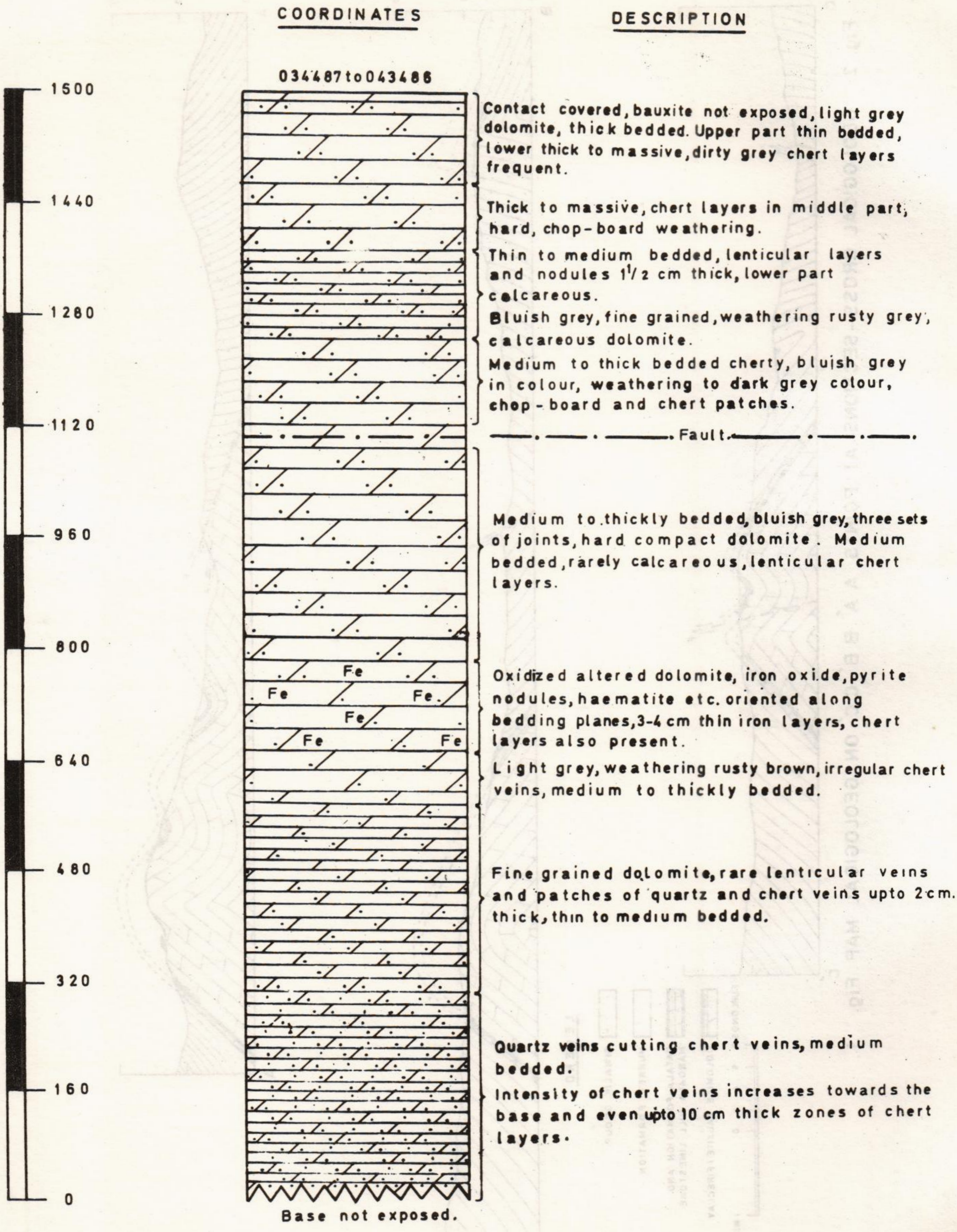


Fig. 3 LITHOSTRATIGRAPHIC SECTION OF SIRBAN FRMATION JANJORA NALA SECTION.

GEOCHRONOLOGIC UNITS			LITHOSTRATIGRAPHIC UNITS OF KOTLI AREA		LITHOSTRATIGRAPHIC UNITS OF HAZARA (AFTER LATIF 1974)	
ERA	PERIOD	EPOCH				
CAINOZOIC	QUARTERNARY	RECENT		ALLUVIUM		ALLUVIUM
		PLEISTOCENE		SIWALIK GROUP		
	TERTIARY	PLIOCENE				
		MIOCENE		MURREE FORMATION U.C.	RAWALPINDI GROUP	MURREE FORMATION U.C.
		OLIGOCENE		U.C.	GALIS GROUP	KULDANA FORMATION CHORGALI FORMATION MARGALA HILL LIMESTONE
		EOCENE		MARGALA HILL LIMESTONE		
		PALEOCENE		PATALA FORMATION U.C. BAUXITE AND FIRECLAYS		PATALA FORMATION LOCKHART LIMESTONE HANGU FORMATION U.C.
MESOZOIC	CRETACEOUS	LATE			HOTHLA GROUP	KAWAGARH FORMATION LUMSHIWAL FORMATION CHICHALI FORMATION U.C.
		EARLY				
	JURASSIC	LATE			THANDIANI GROUP	SAMANA SUK FORMATION SHINAWARI FORMATION DATTA FORMATION U.C.
		EARLY				
	TRIASSIC	LATE				
		EARLY				
PALEOZOIC	PERMIAN TO ORDOVICIAN					U.C.
	CAMBRIAN			U.C.		TARANWAI FORMATION
			ABBOTTABAD GROUP	SIRBAN FORMATION TANAKI CONGLOMERATE	ABBOTTABAD GROUP	SIRBAN FORMATION KAKUL FORMATION
PROTEROZOIC	PRE-CAMBRIAN			DOGRA SLATES	HAZARA GROUP	TANOL FORMATION LOWER FORMATION

Fig. 4 STRATIGRAPHIC CORRELATION CHART OF KOTLI AND HAZARA.

LEAD-ZINC MINERALISATION OF LOWER KOHISTAN DISTRICT, HAZARA DIVISION, N.W.F. PROVINCE, PAKISTAN

BY

M. NAWAZ CHOUDHRY[1]

MOHAMMAD ASHRAF[2]

S. SHAHID HUSSAIN[3]

ABSTRACT.– Lead and zinc mineralisation of galenasphalerite type was discovered for the first time from Besham area of Kohistan. The mineralisation is mainly of hypothermal to mesothermal vein type. Economically important deposits occur as veins within the igneous metamorphic zones formed by the interaction of Lahor granite and pelitic-calcareous metamorphics. Disseminated lead-zinc mineralisation also occurs in skarns, altered granites, silicified granites and quartz veins. Petrography, ore microscopy, and chemistry of the mineralised rocks is presented and related to the field evidence to draw conclusions about the nature and origin of mineralisation.

INTRODUCTION

Lead/zinc mineralisation has been discovered from areas around Besham on both sides of the Karakoram Highway. Lead/zinc mineralisation is a part of a wider mineralised area of igneous-metamorphic and hydrothermal mineralisation which lies at a distance of 150 km from Havelian rail head.

The area was poorly studied geologically earlier due to difficult approach. The geological mapping of the area was carried out on toposheets 43 F/1 and 43 B/13, on a scale of 1: 50.000. The mapping was done to delineate the general geology and mineralisation in the area.

Precambrian Lahor granite, Susalgali granite gneiss, Jijal ultramafics and associated Tanawal and Salkhala metamorphics are the major rock units exposed in the area (Ashraf et al. 1979, Shams 1969).

GEOLOGY

Lead/Zinc mineralization is associated with Lahor granite and Thakot metamorphics of Precambrian age. These rocks lie just to the south of the Main Mantle Thrust of Kohistan (Tahirkheli et al. 1969) Lahor granite covers about 1000 sq. km. in Swat, Mansehra and Kohistan districts. Lahor granite is a complex body composed of foliated and gneissic fine to medium grained components, abundant pegmatites and pegmatoids and granitised and pegmatised screens. Ungranitized screens are also present. The northern contact of the granite with ultrabasics along Karakoram Highway is faulted.

Microcline, plagioclase and quartz are essential minerals and biotite and magnetite are common accessories. At some places silicification has taken place resulting in the formation of quartz rich rocks. Hydrothermal alteration of granite is a common phenomenon. This results in the addition of pyrrhotite and many other sulphides. In the altered zone quartz and micaceous minerals increase in quantity. Epidote and some clay minerals are also developed.

Lahor granite is intruded in metamorphosed sediments of pelitic psammitic, calcareous and graphitic nature. Besides numerous small sized screens, big screens are present around Besham and Lahor, west of Opal and along

1. University of The Punjab, New Campus, Lahore, Pakistan.
2. Institute of Applied Geology, The University of Azad Jammu and Kashmir Muzaffarabad, Azad Kashmir.
3. Gemstone Corporation of Pakistan., Peshawar, N. W. F. Province, Pakistan.

Indus River at many places.

Calcareous rocks are interbedded with other meta-sediments. Most of the calcareous beds in the screens of granite show contact metamorphism and are mineralized. These are changed to skarns composed generally of calcite, siderite, amphibole, pyroxene, garnet, muscovite, biotite, quartz, pyrite and magnetite etc. (Ashraf et al. 1980).

Lead/zinc mineralisation is in Ghaus Banda – Serai, Shorgar, Opposite Kishar, Kund and Pazang areas of Kohistan and Besham.

Three types of mineralisation are noticed in the area :–

1. Skarns
2. Altered and silicified granite.
3. Hydrothermal veins.

The sharn and hydrothermal mineralisation overlap forming continuous zones at a number of places like Ghaus Banda–Serai area.

SKARNS

Skarns of Ghaus Banda, Serai, opposite Kishar, Shorgar and Kund contain galena and sphalerite alongwith other minerals. Three bodies are present at Ghaus Banda, one at Serai, one opposite Kishar and one at Shorgar. Ghaus Banda bodies are inter-related and may be the extension of one body underneath.

Pb/Zn bearing skarn exposures are 0.5 to 7 metres thick and upto 68 metres long. The rocks are dull black to brownish black at weathered surface whereas fresh rocks are light grey and greenish grey. Joints and irregular fractures are common. Limonite and goethite are formed by the alteration of pyrite. Feldspar coating is observed along the joints. Skarns are usually highly disturbed and show folding and faulting. Due to silicification bedding is not prominent.

Lead/zinc minerals are present as thin veins and randomly disseminated crystals. Other associated metallic minerals are quenselite, pyrite, chalcopyrite and molybdenite etc. The quantity of these minerals varies from place to place. Pb–Zn minerals constitute 5 to 20% of the rock. These are concentrated in small pockets. Veinlets are 0.5 cm thick and pockets are a few cm across. Galena is grey and sphalerite is brownish and dull coloured. Gangue minerals are generally quartz, amphibole, calcite, garnet, epidote, feldspar, barite and siderite.

ALTERED AND SILICIFIED GRANITES

A mixed zone in Pazang is composed of granite apophyses, pegmatites and metamorphics. Silicification and alteration of granites is common in this area at localities like Bela, Derai, Maidan and Frid Garhi. These rocks contain lead/zinc minerals at a number of places. The mineralisation is haphazard and the quantity of these minerals varies considerably. Altered granites are brownish and rusty green at weathered surface whereas their fresh colour is grey, dark grey and greenish grey. Rocks are jointed and generally massive. Granites are composed of quartz, feldspar, pyrite, amphibole, biotite, muscovite, epidote, garnet and magnetite. Biotite forms small sized pockets. Garnet is pink to red coloured. Galena and sphlerite are randomly distributed. At a few places their concentration in pockets and veins is also seen. Quantity of galena and sphalerite is variable. They form about 1 to 5% of the rock.

Brecciated granite, exposed at the slopes of Derai-Pazang and Maidan-Pazang, is highly silicified and contains galena at many places. Such zones are a few hundred metres in length and a few metres wide. These are cut by quartz veins and pegmatites. The distribution of galena is random and haphazard.

HYDROTHERMAL VEINS

Lead and zinc bearing hydrothermal veins are found in the mixed zone of Pazang and in some skarns of the area (Kishor). The exposures of veins are from 15 cm to 0.7 metre thick and from 14 to 84 metres in length. Veins are carmine and grey at weathered surface and light grey to grey with brownish tinge at fresh surface. Rocks are hard and compact. The mineral constituents are quartz, mica, pyrite, garnet, chalcopyrite, sphalerite and galena. Galena is shining grey and sphalerite is dull brown. Both the minerals are disseminated in the veins. Veinlets upto a few mm thick of sphalerite are common. Quantity of lead/zinc in veins ranges from 7 to 20%.

PETROGRAPHY

In the following, samples of different areas are described. The mineral composition is given in Table – 3.

Ghaus Banda.– One sample No. GB-79-SIR-128 of Ghaus Banda was studied. The rock is medium grained & hypidioblastic. Ore grains are subhedral to anedral & distributed along specific zones. The mineralisation is associated with silicification. The rock is composed mainly of anhedral &

welded grains of quartz (62.0%), 15.0% amphibole and 3.0% goethite.

Galena (6.0%) and sphalerite (9.0%) occur as small subhedral to anhedral grains and as aggregates. They form streaks and bands.

Sample No. GB-79-SIR-130 is medium grained. The mineralisation is again associated with silicification. It is hypidioblastic. Fine to medium grained quartz (53.0%) forms aggregates of welded grains which show very pronounced strain effects. Medium subhedral green and strongly pleochroic amphibole makes up 15.0% of the rock. Pyrite (2.0%) and albite (3.0%) occur as small anhedra. Goethite forms grains (14.0%).

Galena (5.0%) forms small subhedral to anhedral grains while sphalerite (8.0%) forms tiny anhedra.

Serai.–Sample No.SI-70-S-144 is from Serai. It is medium to coarse grained and hypidioblastic. Ore is disseminated. Subidioblastic to idioblastic garnet makes up 50.0% of the rock. It is pink and isotropic. Amphibole and pyroxene make up 10.0% each and are closely associated. They are subhedral. Quartz (10.0%) occurs as tiny anhedra. A small patch of calcite (5.0%) is composed of subhedral medium crystals.

Subhedral to anhedral galena (4.0%) and anhedral sphalerite (6.0%) occur associated but in a disseminated form.

Two samples from Serai, No. SI-79 SMIR- 154 A were studied petrographically. They are medium to coarse grained and show uneven segregation of epidote and amphibole. Sulphides occur in streaks.

Amphibole is 31.0 and 30.0%. It is subhederal and medium grained. It is moderately pleochroic. Epidote (34.0 and 40.0%) occurs as aggregates. They are subhedral to anhedral. Both clinozoisite and zoisite are present.

Anhedral and irregular goethite and haematite make up 10.0% and 12.% of the rock. Anhedral magnetite makes up 3.0% and 1% of the rock. Anhedral barite makes up 5.0% and 2.0% of the rock. Subhedral pink garnet of medium size is 5.0% and 3.0% of the rock.

Small to medium sized subhedral to anhedral galena makes up 5.0% and 4.0% of the rock. It is very closely associated with sphalerite which is mostly fine grained and anhedral. It makes up 6.0% and 8.0% of the rock. Both galena and sphalerite form streaks and veins in the rock.

Shorgar.–The sample No.SR-79-117 & 117A are from Shorgar. The samples are hypidioblastic & subporphyroblastic to porphyroblastic. Quartz is 50.0% and 40.0%. It occurs as small to medium anhedra and very irregular aggregates. Amphibole comes next to quartz and is 17.0% and 25.0%. It is medium grained and subhedral. It looks like a normal hornblende. It is closely associated with pyroxene. Pyroxene is 7.0% and 10.0%. It is mostly subhedral, medium grained and colourless. It appears to be diopsidic. Garnet is 5.0% and 3.0%. It occurs as randomly distributed subhedra. Pyroxene, amphibole and garnet tend to be associated together. Pyrite is an important constituent of the rock and makes up 8.0% and 10.0% of the rock. It is fine to medium grained and occurs as aggregates along with galena and sphalerite. Anhedral barite forms only 5.0% and 2.0% of the rock.

Subhedral fine to medium galena crystals (5.0% and 6.0%) and anhedral sphalerite crystals (3.0% and 4.0%) occur closely associated and with pyrite. Sulphides occur in poorly defined bands.

Derai.–One sample (PG-79-S-191) of galena bearing zone within granite was studied petrographically. It is a highly pyritised zone. The individual minerals are very irregularly distributed. The rock is porphyroblastic and poikioblastic.

Pyrite makes up 47.0% of the rock. It forms solid aggregates as well as a mesh which encloses biotite and garnet. Pink subidioblastic to idioblastic crystals of garnet have been enclosed by pyrite net. It is opaque in crossniclos. Biotite (10.0%) occurs as flakes, and aggregates which is closely associated with garnet.

Black sooty and amorphous looking pyrolusite/quenselite makes up 4.0% of the rock. It occurs as random films, patches and encrustations.

Hematite/goethite (7.0%) are secondary. They form after pyrite. Tiny quartz pieces make up only 1.0% of the rock.

Small anhedral and randomly distributed grains of galena make up 1.0% and tiny anhedra of sphalerite make up 2.0% of the rock. Random molybdenite flakes appear to be present.

One sample PG-79-NS-236 from Pazang was studied. The rock is hypidioblastic and porphyroblastic. It is composed of 15.0% biotite flakes, 10.0% green amphibole subhedra, 6.0% subhedral to anhedral garnet, 6.0% tiny quartz anhedra, 2.0% clinozoisite and 23.0% talc (?).

Sulphides are galena (8.0%), sphalerite (12.0%) and pyrite (5.0%). Galena, sphalerite & pyrite are closely associated. They are fine to medium grained and subhedral to anhedral.

Sample No. PG-79-233 was taken from an altered silicified and brecciated zone in granite. It is a mafic part of this zone (which otherwise is silicified). The rock shows banding. This sample contains an amphibole band. The rock is medium to coarse grained and hypidioblastic. Pyroxene (60.0%) is colourless and has a high relief. It appears to be a diopside. It is coarse and subhedral. Amphibole (25.0%) forms a band but also occurs within the pyroxene mass.

Galena (1.0%) occurs as small anhedra associated with tiny sphalerite (0.5%) grains. Other accessories are quartz (2.5%), biotite (3.0%), Prehnite (5.0%), muscovite (2.0%) and haematite/limonite (1.0%).

ORE MICROSCOPY

Several samples of ores were studied for the identification of ore phases. They are discussed in the following :–

Ore minerals occur in an irregular network of veins. Pyrite contains inclusions of galena whereas colusite invariably shows a zonal texture. Sphalerite-pyrite intergrowths are common, whereas sphalerite hosts fine droplets or lamellae of pyrite. Ore microscopic results are given in Table –4.

Sphalerite: It is typically brownish grey and fine grained. It occurs as independent grains, only rarely intergrown with pyrrhotite.Fine granularity does not permit determination of VHN and reflectivity.

Pyrrhotite: It occurs as fine intergrowths with sphalerite and galena. It is distinguished by its pale pinkish brown colour, allotriomorphic granular aggregates coupled with hardness and reflectivity given in Table 2.

Galena: It generally occurs as fine veins but is also found as coarse discrete grains. It is identified by its high reflectivity of 42.2% (six determinations) and low VHN = 75. Veins of galena cut across sphalerite grains. It characteristically exhibits triangular pits.

Colusite: Yellow colour and distinct zonal structure formed by darker and lighter bands aids in its identification. It almost always occurs in ore vein fillings.

Pyrite/Chalcopyrite: Pyrite and chalcopyrite are generally closely associated. Both minerals are identified by light yellow colour, the former being slightly higher.

CHEMISTRY

Two samples of Pb-Zn ore, one from Ghaus Banda and one from Shorgar were analysed chemically. The contents of Zn are 7.48% and 0.95%, those of Pb are 4.68%, those of SiO_2 are 24.10% and 61.85%, those of $Al_2 O_3$ are 7.93% and 6.78%, those of $Fe_2 O_3$ are 20.49% and 4.56%, those of MgO are 15.27% and 1.78% and those of CaO are 7.12% and 3.56%. The contents of S are 8.87% and 4.61% (Table 5).

SPECTROCHEMISTRY

The samples related to lead-zinc mineralisation were of two types. Firstly from vein type deposits within granite or country rocks from within igneous-metamorphic zones and secondly from altered granites or skarns with disseminations. The results are given in Table 6.

Five samples from the vein type deposits were studied. One sample is from Pazang, two from Ghaus Banda, one from Serai and one from Lahor Nala. The contents of Pb range from 2.20% to 10.0%, those of Zn range from 5.00% to 8.00%. Zn in general and on the average tends to be higher than lead. The contents of MnO_2 range from 4.0% to 10.0% and Fe_2O_3 ranges from 10.0% to 30.0%. The contents of Cd are 0.1% to 0.20% in three samples and traces and 0.01% in one sample each. The contents of silver range from 5 ppm to 20 ppm.

For other elements, Table 6 may be consulted. These five samples are from bodies which are economically promising.

Five samples of altered granite from Pazang were also studied. The contents of Pb in these sample range from 0.02% to 0.60%, those of Zn range from 0.10% to 1.00% In these zones Zn is again generally and on the average higher than Pb. Cadmium was determined in four of these samples and ranges from 0.00%% to 0.08%. The content of MnO_2 in four samples is 2.0% to 9.0%, and in one sample it is only 1.0%. The contents of $Fe_2 O_3$ in three samples are 2.0% to 20.0%. In two samples it is 60.0% and 85.0%. These two samples are in fact iron rich rocks containing substantial quantity of pyrite and pyrrhotite within altered granite but contain Pb and Zn also. For other constituents Table 6 may be seen. In fact the vein type deposits described above show close geochemical affiliations to the altered granites.

The skarn samples from Pazang were also studied. They contain 0.01% to 0.08% Pb, 0.002% to 0.50% Zn. MnO_2 was determined in three samples and is 2.0% in two samples and 1.0% in third sample. Fe_2O_3 is 2.0%, 5.0%

and 10.0%. Skarn sample No. SI-79-SMR-153 of Serai contains 0.50% Zn, 0.08% Cu & 10.00% Mn.

To sum up, vein type deposits, altered granites and skarns of specific types have been mineralised to varying degrees. The contents of elements suggest close genetic affinity of mineralisation.

DETAILED SPECTRAL, DIFFRACTION AND ORE MICROSCOPIC STUDY OF THREE SAMPLES FOR UPGRADATION PURPOSES.

Three samples from Ghaus Banda, Lahor were studied in detail by spectral survey, Table 1 X-ray diffraction & ore microscopic analysis. One sample was also subjected to wet chemical analysis. The purpose of study was to distinguish all phases present, to study the nature and type of intergrowths and to measure the grain size. Such studies are necessary for upgradation purposes.

X-ray diffraction analysis were carried out to study all phases present. This method was employed to ensure that no sub-microscopic phase remains unidentified.

Each sample was carefully ground and an average sample of each was taken to carry out the X-ray investigations. Phases detected are given in Table 2

The samples studied are

Sample (1) GB-79-SIR-128

Minerals: Sphalerite, galena, pyrite, pyrrhotite, magnetite, traces of chalcopyrite: gangue minerals.

Grain size: Sphalerite 5 micron to 320 micron major part below 250 micron, galena 5 micron to 650 micron major part below 150 micron, pyrite 5 micron to 350 micron major part in the range of 30 micron to 150 micron, pyrrhotite 10 micron to 460 micron major part below 200 micron, magnetite has maximum grain of 100 micron.

Intergrowth: Sphalerite is mainly as inclusions in the gangue. Coarser particles of sphalerite partly show fine inclusions (upto a maximum of 50 micron) of gangue. To a smaller degree sphalerite is intergrown with galena. Partly this is a real intergrowth (i.e. galena and sphalerite are lying side by side in the gangue). Partly galena has inclusions of sphalerite. But there are also coarser sphalerite particles which sometimes have inclusions of galena.

Galena is partly intergrown with gangue and partly with sphalerite. In the gangue galena is partly found as coarse masses and partly as fine inclusions upto a maximum size of 70 micron. Intergrowth between galena and pyrite could seldom be observed.

Pyrite is partly found as inclusions in the gangue and partly intergrown with sphalerite. So pyrite grains have fine inclusions of sphalerite and sphalerite has also fine inclusions of pyrite.

pyrrhotite is partly intergrown with gangue and partly with pyrite. Coarser grains of Pyrrhotite has also been observed as fine inclusions in sphalerite.

Magnetite is found as fine inclusions in the gangue.

Chalcopyrite is intergrown with sphalerite in some cases. It could also be observed as fine inclusions in sphalerite.

Conclusion: Microscopic investigations show, the sample is a fine intergrown ore. For preparation purposes disintegration below 150 micron or even 100 micron will be necessary. Details have to be determined by preparation tests.

Sample No. 2. GB-79-SIR-129

Minerals: Pyrite, magnetite, galena, pyrrhotite and chalcopyrite have very low contents. Traces of covellite and sphalerite are also present.

Grain Size: Pyrite from few micron to 450 micron major part below 200 micron, magnetite 10 micron to 650 micron major below 200 micron, galena from few micron to 220 micron, major below 100 micron, pyrrhotite and chalcopyrite have maximum grain size of 30 micron. Covellite has maximum grain size of 20 micron. Sphalerite is from a few micron to 100 micron. The gangue is from a few micron to several micron.

Intergrowth: All ore minerals are found partly as coarse and partly as fine inclusions in the gangue.

Coarse pyrite particles often have fine inclusions of gangue. Pyrite is partly very well crystallized.

Magnetite is intergrown only to a very small degree with galena and pyrite. Galena is intergrown with sphalerite to a small degree.

Whilst pyrrhotite could only be determined as inclusions in pyrite which is also the case with chalcopyrite, but chalcopyrite is also to be found as fine inclusions in the gangue. But the major part of chalcopyrite is observed as very fine inclusions in the pyrite. Chalcopyrite has partly been converted to covellite.

Conclusion: With respect to ore preparation the same has to be said as for sample 128.

Sample No. GB-79-SIR-130

Minerals: Sphalerite, galena, magnetite, pyrite, traces of chalcopyrite and pyrihotite, very small amount of cerussite and covellite, and gangue minerals.

Grain Size: Sphalerite is from a few micron to 260 micron major part below 100 micron, galena from 1 micron to 370 micron major below 150 micron magnetite from a few micron to 370 micron major part below 150 micron, pyrite a few micron to 350 micron major part below 150 micron. Chalcopyrite and pyrrhotite have a maximum grain size upto 45 micron, cerussite is from 1 micron to 40 micron, covellite has a maximum grain size of 30 micron and gangue is from a few micron to 800 micron.

Intergrowth: Here we have very complex ore with lots of intergrowths. Sphalerite partly as finer and partly as coarser inclusions in the gangue. At the same time as inclusions in sphalerite. It is intergrown also with galena, pyrite and magnetite. Furthermore sphalerite particles contain partly very fine inclusions of sphalerite. The grain size of these inclusions reaches upto a maximum of 40 micron. Galena is partly found free in the gangue and partly it is intergrown with sphalerite and magnetite.

Galena to a small extent is converted into cerrusite at the boundary and cracks of the grains.

Magnetite is partly intergrown with a gangue in an uncomplicated way. The grains of magnetite show larger number of fine inclusions which partly consist of gangue and partly of pyrite. Magnetite also shows, to a small extent, inclusions of galena. Very often cracks in the magnetite are filled with gangue.

Pyrite is partly intergrown with gangue and partly with sphalerite. Rarely pyrite is also intergrown with magnetite. Chalcopyrite is found as inclusions in pyrite, but in some cases chalcopyrite was also found intergrown with galena as inclusions in sphalerite. Pyrrhotite is also observed as inclusions in sphalerite.

Covellite replaces chalcopyrite and is intergrown with it.

Conclusion: This sample is finely intergrown complex ore. For preparation disintegration below 100 micron is necessary but also with this disintegration normal marketable concentration is to be expected. Further treatment must be determined by preparation tests.

PETROGENESIS

Pre-cambrian Lahor granite, the source of metallic mineralisation, was formed by the ascent of deep granitic fluids which acting on deep sediments alongwith rising heat gradient caused partial anataxis and mobilisation of large sections. The resulting granitic matter moved moderately from its root zones. The palingenetic fluids specially rich in metals intermingled with transformed matter. The resultant granitic mobile mass was anomalous in metals like Pb, Zn, Fe, Mo, U, Cd, Bi, Sn and W etc. This fact is clearly born out by the background metal values of granite.

The occurrence of lead-zinc mineralisation is mainly within igneous-metamorphic zones. The Pb-Zn mineralisation is closely associated and overlaps with the igneous metamorphic skarns and magnetite mineral deposits both in time and space.

The igneous metamorphism is well developed around borders of the Lahor granite and in roof pendants and screens. Magnetite in the area mainly develops as an igneous metamorphic deposit. Ore deposits of this type are thought to form under high temperatures and pressures deep within earth (Park and Mac Diarmid, 1964 and Stanton 1972).

The carbonates have been recrystallised and reconstituted. Silicon, aluminium, iron, magnesium and volatiles have been added. At this stage the minerals formed in addition to magnetite are hedenbergite, diopside, amphibole, garnet, epidote, micas, quartz and some metallic sulphides.

Depending upon the nature and amount of material added, there developed the magnetite-carbonate skarns, the siliceous magnetite skarns and the magnetite-silicate skarns. Minor sulphide mineralisation also developed at this stage. Anomalous concentrations of Pb, Zn, Sn, W, Mo and Mn were found from these zones.

This stage was followed and overlapped by the hypothermal and mesothermal stages of mineralisation. Lead and zinc mineralisation is mainly of hypothermal to mesothermal type.

Details of careful spectral, X-ray diffraction and Ore microscopic studies of three samples have been presented above. From the type of growths, inclusions and replacements it is clear that the high and medium temperature assemblages are closely associated. Pb-Zn mineralisation falls in igneous-metamorphic category as well as hypothermal to mesothermal categories. Even superimposition of low temperature processes is noticed. So it can be rightly concluded that it is a polyphase superimposition of processes of different P-T regimes.

The mineralisation was accompanied and followed by premineral ground preparation for hypothermal and mesothermal vein deposits. This preparation consisted of silicification and subsequent brecciation. Brecciation also took place in quartzites as well as granite along zones of dislocation. Vein formation mainly occurred along such zones of weakness. In this period altered mineralised zones also developed in granites. At this stage the fluids were enriched with Pb and Zn resulting in the formation of Pb-Zn vein type deposits as well as altered mineralised granite patches. The latter formed through metasomatism where vein formation was not possible (E.C.L. 1979)

REFERENCES

Ashraf, M., Chaudhry, M.N. and Hussain, S.S., (1979). General geology and economic significance of the Lahor granite and rocks of southern ophiolite belt in Allai-Kohistan area. *Proceed. Intern. Committee on Geodynamics (Group-6, Alpine-Himalayan Region).*

Ashraf, M., Chaudhry, M.N., Hussain, S. H., (1980) Magnetite deposits of Lower Kohistan District, Hazara Division. *Pak. Metaleurgist* Vol. 2, No. 26 P. 15-23.

Engineers Combine Ltd., (E.C.L), (1979). Exploration of magnetic and other minerals in Allai-Kohistan.

Jan, M. Q., (1977), Kohistan basic complex-A summary based on recent petrological research. *Bull. Centre Excell. Geol. University. Peshawar* No. 1, Vol. 9-10.

Part, C. P. and MacDiarmid, R. A., (1970). Ore deposits, W. H. Freeman & Co. San Franciso, U.S.A.

Shams, F.A. (1969). Geology of the Mansehra-Amb State area N. W. Pakistan. *Geol. Bull. Punjab University No. 8.*

Stanton, R. L. (1972). Ore Petrology. McGraw Hill Book Co. N.Y.

Table. 1

Spectral Survey Results

Approx %	Elements		
	Probe (1)	Probe (2)	Probe (3)
	GB - 79 - SIR - 128	GB - 79 - SIR - 129	GB - 79 - SIR - 130
10 to 100	Si,	Si, Ba	Si
1 to 10	Fe, Pb, Ba	Fe, Pb, Ca	Fe, Pb, Ba
0.1 to 1	Mn, Mg, Al, Na Ca, Zn	Mn, Mg, Al, Na, Sr	Mn, Al, Na, Zn
0.01 to 0.1	Ni, Ti, Bi, Sr	Ni	Mg, Ni, Ti, Ca, Sr
0.001 to 0.01	Cu, Cr	Cr, Ti, Bi, Cr	Cu, Cr
Trace	B	—	—

Wet chemical analysis of sample 1) GB-79-SIR-128 gave the following result :–

Zn 5.61 Wt %
Pb 4.11 Wt %
Bi 0.18 Wt %

Table 2

X - Rays Investigation Phases

Sp.No. GB-79-SIR-128		SP.No.GB-79-SIR-129		SP.No.GB-79-SIR-130	
Quartz, main.		Quartz, Main		Quartz, Main content	
Proxene, moderate		Barytes, moderate		Sphalerite	moderate
Sphalerite Galena	Moderate to minor	Galena,	minor to moderate	Galena	
				Hornblende,	minor to moderate
Pyrite Barite	Minor	Pyrite,	minor	Magnetite,	minor
Magnetite	Very low	Magnetite Pyroxene	Very low	Pyrite,	minor
				Pyroxene	very low
				Barite,	traces

Table - 3

Petrographic Composition of Lead-Zinc Ores

Sample No.	GR-79-SIR-128	GR-79-SIR-130	SI-79-S-114	SI-79-SMIR-154	SI-79-SMIR-154A	SR-79-SM-117	SR-79-SM-117A	PG-79-S-191	PG-79-NS-233	PG-79-NS-236
Coordinates	88101074	88211074	88131130	88121128	88121128	87240741	87240041	90060478	80060478	80050479
Locality	Ghaus Banda	Ghaus Banda	Serai	Serai	Serai	Shorgar	Shorgar	Pazang	Pazang	Pazang
Rock Name	Silicified Skarn	Silicified Skarn	Skarn	Skarn	Skarn	Silicified vein	Silicified vein	Altered granite	Altered granite	Altered granite
Galena	6.00	3.00	4.00	5.00	4.00	5.00	6.00	1.00	1.00	8.00
Sphalerite	9.00	8.00	6.00	6.00	8.00	3.00	4.00	2.00	0.50	12.00
Quartz	60.00	55.00	10.00	0.00	0.00	50.00	40.00	1.00	2.50	6.00
Pyroxene	15.00	0.00	10.00	0.00	0.00	7.00	10.00	–	60.00	–
Amphibole	5.00	15.00	10.00	31.00	30.00	17.00	25.00	–	25.00	10.00
Geothite	5.00	14.00	0.00	10.00	12.00	0.00	0.00	–	–	–
Albite	0.00	3.00	0.00	0.00	0.00	0.00	0.00	–	–	–
Pyrite	0.00	2.00	0.00	0.00	0.00	8.00	10.00	47.00	–	5.00
Garnet	0.00	0.00	50.00	5.00	3.00	5.00	3.00	28.00	–	6.00
Calcite	0.00	0.00	5.00	0.00	0.00	0.00	0.00	–	–	–
Epidote	0.00	0.00	0.00	34.00	40.00	0.00	0.00	–	–	–
Magnetite	0.00	0.00	5.00	3.00	1.00	0.00	0.00	–	–	–
Barite	0.00	0.00	0.00	5.00	2.00	5.00	2.00	–	–	–
Clay	0.00	0.00	0.00	1.00	0.00	0.00	0.00	–	–	–
Biotite	–	–	–	–	–	–	–	10.00	–	15.00
Pyrolusite	–	–	–	–	–	–	–	4.00	3.00	13.00
Haematite/Limonite	–	–	–	–	–	–	–	7.00	–	–
Prehnite	–	–	–	–	–	–	–	–	1.00	–
Muscovite	–	–	–	–	–	–	–	–	5.00	–
Clinozoisite	–	–	–	–	–	–	–	–	2.00	2.00
Talc	–	–	–	–	–	–	–	–	–	23.00

Analyst : Engineers Comine Laboratories, Gulberg, Lahore.

Table - 4

Ore Microscopy of Lead-Zinc Types Ores

Sample No.	Coordinates	Localities	MINERALS THEIR PROPERTIES AND PERCENTAGES.													
			SPHALERITE			GALENA			PYRRHOTITE							
			VHN	Rf% 50	%age	VHN	Rf%	%age	VHN	Rf%	%age	Py-rite %	Chalco-pyrite %	Colu-site-%	Quen-seli-te	Gan-gue
GB-79-SIR-129	88131072	Ghaus Banda	185	14.6	3	–	–	7	–	–	–	1	–	1	–	88
GB-79-SIR-149	88131084	Ghaus Banda	196	14.7	5	71	41.2	2	–		–	15		5	–	73
GB-79-SIR-130	88211074	Ghaus Banda	202	14.0	3	81	41.3	3	287	–	16	1	1	–	2	74
SIR-79-SMIR-135	88131131	Serai	211	14.5	3	73	41.3	3	–	–	–	14	2	–	–	78
PG-79-NS-236	88130470	Pazang	183	15.3	2	76	14.1	2	281	–	20	1	1	–	2	72
DI-79-SIR-260	00010400	Derai	200	14.9	8	79	43.1	3	270	–	15	3	1	–		63
GB-79-SIR-128	88101074	Ghaus Banda	197	14.8	8	70	42.0	3	–	–	–	2	–	–	3	82

Analyst : Engineers Combine Laboratories, Gulberg, Lahore.

Table - 5

Chemical Composition of Lead-Zinc Ores.

Sample No.	GB-79-149	SR-79-MIR-117
Coordinates	88131084	87240941
Locality	Ghaus Banda	Shorgar
Rock type	Zn-Pb ore (skarn)	Zn-Pb ore (Skarn)
Mo	1.30	3.24
Zn	7.48	0.95
Pb	4.68	2.86
SiO_2	24.10	61.85
TiO_2	0.00	0.00
Al_2O_3	7.93	6.78
Fe_2O_3	20.49	4.56
Mn O	1.27	2.04
MgO	15.27	1.78
CaO	7.12	3.65
Na_2O	0.80	0.36
K_2O	0.53	0.32
S	8.87	4.61
$BaSo_4$	0.00	3.95
I/L	0.10	2.91
Total :-	99.94%	99.77%

Analyst : Engineers Combine Laboratories.
Gulberg, Lahore.

Table - 6

Spectrochemical Composition of Lead-Zinc Ores

Sample No.	PG-79-NS-236A	GB-79-SIR-149A	SI-79-S-114A	LN-79-SM-17	GB-79-SIR-129	PG-79-MS-232	PG-79-NS-233
Coordinates	90050479	88131084	88151130	88121072	88131072	90220480	90060478
Localities	Pazang	Ghausc Banda	Serai	Lahor Nala	Ghaus Banda	Pazang	Pazang
Rock type		Lead-Zinc Veins			Skarn		Altered Granite
Ph	5.00	6.00	3.00	10.00	2.20	0.1	0.60
Zn	7.00	8.00	6.00	8.00	5.00	0.002	0.20
Bi	0.20	0.02	0.02	–	0.01	–	0.004
Cd	0.10	0.10	0.10	TR	0.10	–	0.005
As	0.006	–	0.005	TR	0.10	0.002	0.005
Sb	–	–	10.ppm	0.005	–	–	–
Cu	0.05	0.12	–	0.02	0.05	–	0.001
Ag	–	0.0005	–	20.ppm	0.005	–	–
Ni	–	0.005	–	0.001	–	–	–
Co	–	0.005	–	–	–	–	–
Mo	0.008	–	–	–	–	0.05	0.0005
Sn	0.005	0.005	6.00	–	–	–	–
W	50.ppm	–	0.01	–	–	–	–
MnO_2	5.00	7.00	10.00	4.00	10.00	2.00	2.00
TiO_2	0.10	0.04	6.00	0.06	0.04	0.02	0.02
Ba_2O_3	30.00	20.00	10.00	10.00	18.00	2.00	5.00
Al_2O_3	3.00	–	4.00	1.00	–	3.00	3.00
BaO	0;03	2.00	1.00	5.00	4.00	0.05	0.01
CaO	1.00	–	–	3.00	–	10.00	10.00
MgO	1.00	–	–	0.50	–	2.00	2.00
Na_2O	2.00	–	–	–	–	1.00	2.00
SiO_2	50.00	–	–	50.00	–	60.00	60.00
Sr	–	0.05	0.01	–	0.40	–	–

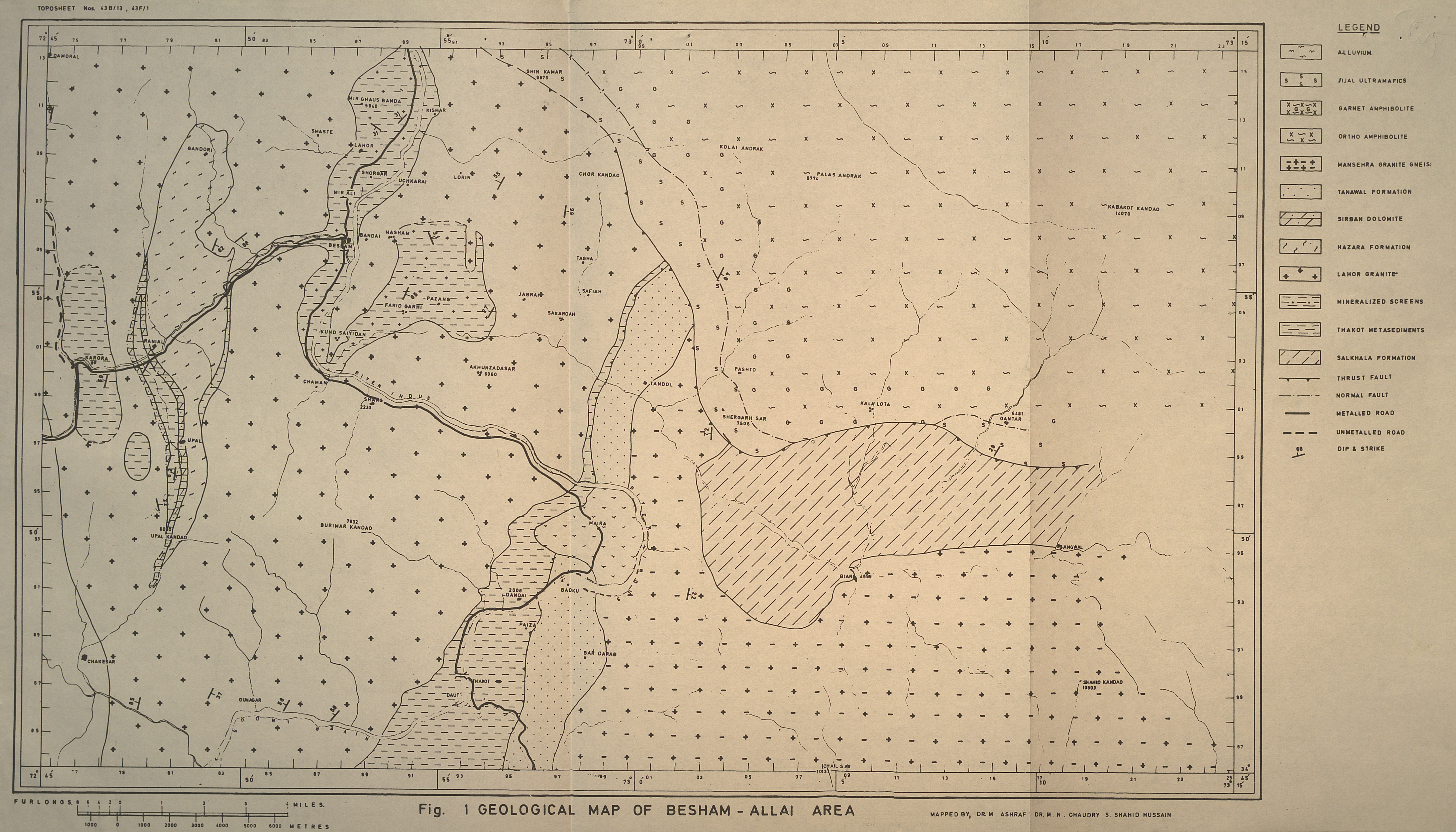


Fig. 1 GEOLOGICAL MAP OF BESHAM - ALLAI AREA

MAPPED BY, DR. M. ASHRAF, DR. M. N. CHAUDRY, S. SHAHID HUSSAIN

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

KOMATIITIC AFFINITIES OF ULTRAMAFIC ROCKS, SERPENTINITES AND ULTRAMAFIC AMPHIBOLITES IN THE AMPHIBOLITE BELT OF NORTHERN PAKISTAN.

BY

KHURSHID ALAM BUTT[1]

ABSTRACT.– A review of komatiites is presented and the existing chemical and petrographic data on amphibolites of Dir, Swat, Kohistan, Thak Valley, Nanga Parbat and Astor is re-evaluated. This study suggests that the association of amphibolites, ultramafic rocks, serpentinites, talc-carbonate rocks with occasional occurrence of pillow structures and ultrabasic volcanic breccias, all suggest komatiitic to tholeiitic affinities. Much of the ultrabasic material occurring within the amphibolite belt is interpretted to be submarine ultramafic to high MgO basaltic volcanic flows and minor intrusions. An oceamic crustal model proposed for this belt (Butt et al. 1979) is therefore further substantiated.

INTRODUCTION

An extensive belt of amphibolites extends from Afghan border near Khar, through Bajaur, Dir (Chaudhry et al., 1974 a), Chaudhry et al.,- 1974 b), Swat, Kohistan (Jan, 1979 a), Babusar (Butt and Zaidi, 1969), Nanga Parbat (Misch, - 1949) to Astor (Tahirkheli and Jan, 1978). Immediately north of the Main Mantle Thrust, this apparently monotonous sequence of amphibolites extends for a distance of sevral hundred kilometers. Major lithological units of this belt are noritic pyroxene granulites (Jan, 1979 b), Kamila amphibolites, Jijal garnet granulites (Jan, 1979 c), norites, southern and northern Dir amphibolites and acid intrusives (Chaudhry et al., 1974 b). Detailed petrographic accounts of the Kohistan part of the amphibolite belt is given by Jan (1979 a) whereas Chaudhry et al. (1974) presented a detailed account of northern and southern amphibolite belts of Dir area. Jan (1979 a) and Chaudhry et al., 1974) have described varying proportion of ultramafic rocks intimately associated with the amphibolites, the latter also show pillow like structures (Jan, 1979 a). Ultrabasic volcanic breccias with fragmental olivine crystals embedded in a glassy matrix of possibly basalt composition (Butt, in prep.) sampled from Buto Gah near Chilas also suggest a relationship between the volcanic activity and ultrabasic liquids.

Ideas relating to genesis of various petrographic varieties of amphibolites and associated ultramafic rocks of the amphibolite belt have been divided into two separate groups, i. e. amphibolites formed through metamorphism of either sedimentary and/or igneous material of appropriate composition (Chaudhry and Chaudhry, 1974; Jan, 1979, etc.) , whereas the ultramafic fractions were considered intrusive into amphibolites (Chaudhry et al., 1974) or tectonically emplaced slices of mantle (Jan, 1979). Ultramafic rocks associated with the amphibolites of Kohistan basic complex are considered as minor ultramafic and mafic bodies originated at different times and depths and are not related directly to amphibolites,pyroxene granulties and the Jijal complex (Jan, 1977).

The amphibolites of Dir area were interpretted by (Butt et al., 1979) as a part of an oceanic crust between the Indian Mass south of MMT and the Eurasian Mass north of MKT.

1. Pakistan Atomic Energy Commission, Lahore, Pakistan.

KOMATIITES – A BRIEF REVIEW

Definition and Nomenclature:

Definition and distinguishing criteria of komatiites of Arndt et al. (1977) are given below. Since it is a relatively new terminology, it is likely to change with the influx of new data and interpretations thereof.

According to Arndt et al. (1977) the komatiites constitute a suite that includes noncumulate rocks ranging from peridotite (> 40% MgO, 44% SiO_2) to basalt (12% MgO, 52% SiO_2) or andesite (8% MgO, 56% SiO_2) & cummulate rocks from dunite peridotite (> 40% MgO) to gabbro (> 12% MgO). Individual members are characterized by low FeO / (FeO + MgO), low TiO_2 and high MgO, Ni and Cr. Some, but not all, have high CaO/Al_2O_3 ratios. Also diagnostic are volcanic structures and textures such as spinifex and polyhedral jointing.

Distribution:

The ultramafic and mafic komatiites have been recognized in almost all well studied Archean shield areas. These rocks are most common in the greenstone belts, e. g. parts of Yilgarn block in Western Australia and the Abitibi belt in Canada. In such areas, komatites seem to be restricted to the basal stratigraphic levels of broad volcanic sedimentary cycles where they are associated with ultramafic and mafic layered sills, and Fe-and Ti-rich tholeiitic basalts. Overlying volcanic rocks include tholeiitic basalts, andesites, and dacites with more normal Fe contents succeeded by calc alkaline lavas and volcanicalstic units, and finally by sedimentary rocks (Naldrett and Goodwin, 1977; Jolly, 1975; Gemuts and Theron, .1975; Bickle et al., 1975). Komatiite lavas commonly alternate with tholeiites. In such cycles, the massive dunitic flows at the base host Ni–Fe sulfides (Ross and Hopkins, (1975;) Barrett et al., (1977).

Proterozoic komatiites are known only from Northern Quebec in the Canadian shield (Dimroth et al., 1970) whereas their occurrences in Phanerozoic terranis is not reported with a possible exception in Newfoundland (Gale, 1973; Upadhyay, 1976).

Diagnostic features of komatiites:

In the original definition (Viljoen and Viljoen, 1969) and in subsequent modifications (e.g. Brooks and Hart, 1974: Arndt et al., 1977) ,Komatites have compositions ranging from peridotite to basalt or andesite. The implication has been that these rocks represent magmas with a similar range in compositions. Of these magmas, only those with ultrabasic compositions and the rocks formed from them, are unique; the less mafic rocks have some unusual characteristics but do not differ sufficiently from other types of basalt to justify separate names. Definition of komatiites therefore relies heavily on identification of rocks formed by crystallization of ultrabasic liquids.. The characteristic features of these rocks then form a foundation of any set of diagnostic criteria. Other rocks that are said to constitute part of the series owe their status to features, either morphological, textural, mineralocical or chemical, that they share directly or by extrapolation with the rocks derived from ultrabasic liquids.

To identify the rocks formed from ultrabasic liquids, both textural and compositional criteria must be considered. Olivine spinifex textures, skeletal habits of mineral grains and an abundance of glass usually are sufficient to indicate that a rock is derived from a silicate liquid with little accumulation of mafic minerals. Mineral composition (high Mg/Fe in mafic manerals, high Cr/Al in chromite, etc.) , high modal abundances of mafic minerals, and ultrabasic whole - rock compositions may then be used to show that the liquid from which the rock crystallized was ultrabasic. The extent of such accumulation is not likely to be great, however, for example, if the rock has 28% MgO, the liquid from which it formed probably also was ultrabasic, although somewhat less magnesiam.

Other features, although they do not seem to relate directly to the unique character of rocks formed from ultradiagnostic role. Included here would be polyhedral jointing and chemical criteria (e. g. high MgO/ FeO); high CaO/Al_2O_3 can then be used to identify komatiite.

Finally, spinifex texture, where present, is a positive indicator of komatiitic affinity. Its absence, however, does not necessarily imply thata rock is not komatitic, Massive ultramafic lava grades along strike into spinifex textured lava in Archean areas. Proterozoic highly mafic lavas in the Cape Smith fold belt share so many of the features of Archean lavas that they too probably are komatiitic, but they do not show spinifex textures.

Eruptive environments of komatiites:

From the morphology and textures of komatiite lavas a number of deductions can be made about their eruptive environments: that they were subaqueous, and in all probability, submarine. The common presence of minor interlayered cherts and silliceous tuffs, pillows, clastic debris between pillows, and flow top or isolated hyalotuffs and breccias allow no other interpretation.

THE AMPHIBOLITE BELT

Banded amphibolites of Thak valley:

Butt and Zaidi (1996) first reported these rocks from Thak Valley. The composition and texture of foliated rocks is highly variable due to varying degree of segregation of mafic and felsic minerals. Bands rich in dark - green to black, needle - like amphibole alternating with those richer in quartz, epidote and feldspar are common. At places the amphibolites, though foliated, do not show banding. The felsic parts of these rocks commonly show ptygmatic folding. These rocks contain abundant inclusions which are usually melanocratic as compared to the host and suggest an igneous origin. At places the larger basic xenoliths may in turn host smaller xenoliths of ultrabasic composition.

Chemistry of these amphibolites was reported by Ahmad and Chaudry (1976). Shams and Ahmad (1979) reported 13 chemical analyses of norites and amphibolites and other related rocks of Thak Valley and concluded a tholeiitic parental magma for these rocks. Jan (1979) interpreted that the amphibolites derived from norites have a calc-alkaline parentage which is in direct contrast to the trends shown by Shams and Ahmad (1979).

Banded amphibolites host ultramafic bodies which are largely concordant. Chaudhry and Ahmad (1976) mapped such a peridotite body near Babusar which is totally enclosed within the banded amphibolites and shows no evidence of its structural emplacement.

Butt and Zaidi (1969) mapped several bodies of ultramafic rocks and ultramafic breccias in Thak Valley and adjoining Buto Gah. These bodies are enclosed within the noritic rocks or dioritic rocks whose ancestory to banded amphibolites ofThak Valley can be demonstrated in the field due largly to the gradational aspect of their contacts. Once again these ultrabasic rocks and breccias do not show evidence of tectonic emplacement, i. e. serpentinization and other features related to tectonism. Thus it is concluded that they owe their origin to either intrusive or extrusive activity in situ.

Amphibolites exposed at the border of Dir and Swat:

A traverse from south to north reveals a sequence of blueschists, structurally emplaced ultramafics of Alpuri - Shangla mass, followed by the amphibolite belt (Butt, - 1983). Tutan Banda and Ursak area in Dir District can be considered as type areas where ultramafic material is intimately associated with the amphibolites. They are typical rock assembledges indicating ultramafic amphibolite compositions.

The ultramafic amphibolites are amphibole-rich rocks with up to 30% olivine and /or serpentine and talc. Other varieties include the following compositions:–

Amphibole and serpentine	±	Talc
Amphibole + Talc	±	Serpentine
Amphibole + Talc	±	Corundum

Serpentinites are essentially composed of serpentine group minerals with relic olivine or pyroxene and some amphibole. Talc - carbonate rocks contain talc and magnesite as the major constituents with other accessories.

The rocks of the amphibolite belt in this area, therefore, containa significant amount of ultrabasic material which is intimately associated with amphibolites and is in no way derived from alpine - type ultramafic blocks that mark the MMT in this area near Shangla. These ultramafic rocks are far north of the major thrust and show no evidence of their structural emplacement. Moreover, since MMT has been described as a north dipping structure and since the ultramafic slices are obducted blocks, it is highly unlikely that such an obduction process will cause emplacement of these slices north of the thrust.

CHEMISTRY

Chemical data ECL,1978) on serpentinites and ultramafic amphibolites are plotted on Al_2O_3 vs. $FeO_T/(FeO_T + MgO)$ diagram developed by Arndt et al., (1977) to distinguish between komatiites and tholeiites (Fig. 2). However, they point out that such chemical parameters must be supported by textural field and petrographic criteria.

Although spinifex texture and polyhedra jointing has not been observed in the amphibolite belt, pillow like structures (Jan, 1979) and ultramafic breccias with volcanic glass of probable basaltic composition (Butt and Zaidi, 1969; Butt, in prep) have been reported, suggesting a submarine volcanic environment of the formation of these rocks.

Ultramafic amphibolites, serpentinites and associated rocks dominantly plot in the komatiites field (Fig.2) and form a continuous trend. The data from different bodies in amphibolite belt and metamorphic belt south of MMT all plot in the field characteristic of komatiites and produce a steep, or little differentiated trend in terms of the FeO/(FeO + MgO) but has a wide range in terms of Al_2O_3.

A close genetic relation between these rock suites is suggested by this plot and other similarities in mineralogy and chemistry.

AMPHIBOLITES OF THE KOHISTAN SEQUENCE

Jan (1979) described amphibolites from the Kohistan sequence. Amphibolites of the pyroxene granulite belt occur in small to large masses intimately associated with pyroxene granulites andmake about 1/4th of lthe total exposure. Jan (1979) suggested the possibility that these rocks are a product of metamorphism of norites, amphibole being produced where H_2O was available South of this amphibolite - granulite complex the amphibolites can be classified into banded amphibolite and homogeneous amphibolites.

Chemical data (Jan, 1979, actual data not reported) on banded amphibolites range from ultrabasic to intermediate. Based on chemical parameters such as variation diagrams, low igneous material, mainly tuffs and some flow.

Homogenous amphibolites of the Kohistan sequence have a plutonic igneous aspect and appear to have intruded the banded rocks, before amphibolite facies metamorphism (Jan, 1979). Alumina vs. alkali diagrams of the amphibolites of the southern belt straddle the fields of tholeiites and high alumina basalts, whereas on SiO_2 vs. alkali diagram they plot in thefield of tholeiites (Jan, 1979). The banded amphibolites also have some pillow lavas at the top. There is a possibility that some of the bandel amphibolites are deformed and metamorphosed pillow lavas (Jan, pers.-comm.).

AMPHIBOLITES OF DIR

In Dir area chaudhry et al. (1974) have defined two catagories of amphibolites from the belt. Norhtern Dir amphibolites are interpreted to be para - amphibolites after calcareous metasediments and southern Dir amphibolites after calcarouus metasediments and southern Dir amphibolites were formed by metamorphisn of plutonic igneous rocks. These amphibolites have been intruded by diorites, norites and acid porphyries. In this area minor bodies of ultramafic material have also been reported both as intruion, such as scyelite dykes of Chaudhry et al. I1974 a), as well as concordant bodies containing olivine/serpentine and highly melanocratic amphibolites approching ultrabasic composition. Once again in this area there is no evidence of structural emplacement of ultramafic meterial and the ultrabasic rocks encountered belong either to the intrusive sequence or the amphibolites. In most cases, however. they are more closely related to amphibolites. than the intrusiv rocks. No chemical data are published to date but unpublished chemical data (Chaudhry, pers. comm) are in conformity with the conclusions derived herein that amphibolites contain a fair proportion of ultramafic material.

DISCUSSION

Spinifex texture,where present, is a positive indication of komatiitic affinites. Its absence, however, does not necessarily imply that a rock is not komatiitic (Arndt et al., (1977). In structurally deformed and metamorphosed terrains of basic and ultrabasic material the possibility of preservation of textural evidence is rather limited .Other set of criteria must, therefore, be used to arrive at the parentage of thse rocks. In case of the amphibolite belt, the following field and chemical characteristics are presented as a case forkomatitic affinity of some of these rocks.

Pillow-type structures :– Jan (1979) has reported pillow-type structures from more basic amphibolites of Swat and Kohistan. His work suggests the existence of basic to ultrabasic compositions within the amphibolite as well as their extrusive nature.

Polyhedral jointing:– Butt and Zaidi (1969) observed such jointing on ultramafic rocks exposednear Chilas. Such jointing is a characteristic feature of the komatiitic volcanic lava flows.

Flow -top breccia Pyroclastics .– Several small patches of an ultramafic breccia were mapped in Thak Valley and Buto Gah (Butt and Zaidi, 1969). These rocks have an agglomeratic appearance with abundant pieces of dunite and peridotite composition welded togather with ash-type material. Petrographic examination reveals that in addition to dunite and peridotite compositions, certain clasts hav a deep yellow galss with embeded angular olivine phenocrysts. No feldspar or pyroxene was observed in such rocks. These bodies are now interpretted to be flow top breccias (?).

Chemical criteria:–Chemical data cited herin and presented in Fig.2 also support the view about the komatiitic affinity of parts of the amphibolite belt. Thus, it appears that the rocks of the amphibolfe belt contain komatiitic (this study) as well as as tholeiitic affinities (Shams and Ahmad, 1979).

Concluding remarks:– Most of the reported komatiitic occurrences are Archean. It is not clear whether komatiites exist in phanerozoic terrains. No clearly noncumulate ulteramafic lavas have been reported but aphanitic volcanic rocks with composition similar to Archean mafic komatiites conspicuously lower TiO_2 have been recorded within Palaeozoic ocean floor basalts in New Foundland (Gale, 1973; Upadhyay, 1976). In Rambler mine area, New Foundland, early Palaeozoic ocean floor rocks are uplifted and folded to form a part of the Appalachian orogenci belt. The rocks defined as komatiites are associated with tholeiitic ocean floor-type basaltic lavas and pyroclastics, cherts and felsic prophyries. The amphibolite belt also contains ultrabasic rocks of possible volcanic origin associated with rocks of tholeiitic affinity, pyroclastics (Butt and Zaidi, 1969) , pillows (Jan , 1979) cherts and felsic porphyries (Chaudhry et al., 1974) all showing a striking geological similarity to the ocean floor environments described from New Foundland (Gale, 1973, Upadhyay, 1976).

Himalayas are the youngest and Alps are the oldest of the The Tethyan sea, though several hundred kilometers across was, nevertheless, largly underlain by sialic crust with only minor basins of oceanic crust, some of which are now represented by ophiolites (Gilluly, 1971). Based on structural evidence, Coward et al. (1982) have argued that magmatism in northern Kohistan post-dates intensely deformed metaseddiments and volcanics. This throws doubts on the contribution of this igneous activity towards the development of the island arc. Sueh post-deformation diorites and tonalites are also instrusive into the amphibolites and associated rocks in Dir and Thak Valley. Since these amphibolites have been demonstrated to be oceanic basalts and related intrusives and since diorites and related volcanics in northern Kohistan zones may not represent magmatism related to an island arc (Coward et al., 1982) the existance of an island arc in this zone becomes doubtful. The author has already suggested an oceanic crustal model for Kohistan zone i. e. at least for its southern half (Butt et al., 1979). It is, therefore, proposed that the amphibolite belt and related ultramafics represent a minor basin of the Tethyan ocean floor with an oceanic crust caught up in continental collision with little evidence of subduction and a complimentary island arc. Coleman (1971) has argued that obduction of oceanic crust onto continental edges should be characterized by a lack of volcanic arc. The blue schists of Shangla (Shams, 1972, 1980) which are invariably cited as an evidence of a subduction zone could have been produced during obduction (Coleman, 1971).

AKNOWLEDGEMENTS:–

Suggestions from Drs. Qasim Jan and Hamidullah helped improve the manuscript substantially.

REFERENCES

Ahmad, Z and Chaudhry, M.N., (1976). Geology of Babusar area Diamir District Gilgit, Pakistan, *Geol. Bull. Punjab Univ.* No. 12, p.67-68.

Arndt, N.T., Naldrett, A.J., and Pyke, D.R., (1977). Komatiitic and iron rich tholeiitic lavas of Munro Township, Norht-east Ontario. Jour. Petrology vol.18, p. 319-369.

Barett, F.M., Binns R.A., Groves. D.I., Marston, R.J. & Mc Queen, K.G. (1977). Structural history and metamorphic modification of Archean Volcanic type nickle deposits yilgarn Block, Western Australian, *Econ Geol. vol. 72,* p. 1195-1223;

Bickle, M.J., Ford, C.E., Nisbet. E.G., (1977). The petrogenesis of peridotitic Komatiites: evidence fromhigh pressure melting experiments. *Earth Plat. Sci. letter* Vol. 37, p. 97–106.

Brooks, C.K., and Hart S.R., (1974. On the significance of Komatiites. *Geol.* vol. 2, p. 107-110.

Butt, K.A., (1983). Tectonic environments favourable for Ni and Pt group element sulfide deposits in Northern Pakistan presented at 2nd National Seminar on Development of Mineral resources, Peshawar (1983), pp 8.

Butt, K.A., Chaudhry, M.N., and Ashraf, M., (1979). An interpretational petrotectionic assemblage West of Western Himalayan syn axis in Dir District and adjoining areas in Northern Pakistan. *Geol. Bull. University Peshawar.* vol.13, p. 79-86.

Butt, K.A., and Zaidi, S.M.M., (1969). Petrology of Thak Valley igneous complex Gilgit Agency, unpublished M.Sc. thesis P. U. Lahore.

Chaudhry, M.N., and Chaudhry A.G., (1974). Geology of Khagram area Dir District N.W.F.P. *Geol. Bull. Punjab Univ.* No 11, p. 21-44.

Chaudhry, M.N., Mahmood, A., and Shafiq, M., (1974 b). Geology of Sahibabad Bibior area Dir District N. W. F.P. *Geol. Bull. Punjab Univ.* No. 10, p. 13-90.

Chaudhry M.N., Kauser, A.B., and Lodhi, S.A.K., (1974 a). Geology of Timergara-Lal Qila area, Dir District NWFP. *Geol. Bull Punjab Univ.* No. 11, p. 53-74.

Chaudhry, M.N, Mehmood, A, and Chaudhry A.G., (1974). The orthoamphibolites and the Para amphibolites of Dir District. *Geol. Bull. Punjab Univ.* No. 11, p. 81-96.

Coleman, R.G., (1971). Plate tectonic emplacement of upper mantle peridotites along continental edges. *Jour. Geophysical Res,* vol. 76, p. 1212-1222.

Coward, M.P., Jan MiQ., Rex, D., Tarney, J., Thirlwal, M. and Windley, B.F., (1982). Structural evolution of a crustal section in the Western Himalaya, *Nature*, vol. 295, p. 22-24.

Dimroth, E., Baragar, W.R.A., Bergeron, R. and Jackson, G.D., (1970). The filling of circumn-Ungara geosyncline. In: Precambrian basins and geosynclines of the Canadian sheild (A.L Baer, ed.).*Geol. Surv. Gen Pap*. 70-40 45-142.

Gale, G.H., (1973). Palaeozoic basaltic Komatiite and ocean floor type basalts from North-eastern New Foundland. *Earth Planet. Sci. Lett.*, vol. 18, p. 22-28.

Gemuts, I., and Theron, A., (1975). The Archean between cooligardic & Norseman-stratigraphy and mineralization. In economic geology of Australia and Papua New Guinea. I. Nelts (C.L. Knight, ed.) *Austral. Inst, Mining, Met. Moh.* 5, 66-74.

Gilluley, J., (1971). PlateTectonics and magmatic evaluation *Geol. Soc. Amer. Bull.* vol. 82, 2383-2390.

Jan, Q.M.,(1979). Kohistan basic complex a summary based on recent petrological research. *Geol Bull. Univ. Peshawar*, vol. 9-10, p. 36-42.

Jan M.Q., (1979). petrography of amphibolites of Swat and Kohistan. *Geol. Bull. Univ. Peshawar* (special issur), vol. 11, 51-64.

Jolly, W.T., (1975). Subdivision of Archean Lavas of the Abitibi area, Canada, From Fe-Ng-Ni-Cr Relation. *Earth Planet. Sci. Lett.* Vol. 27, p. 200-210.

Misch, P., (1949). Metasomatic granitizaion of batholithic dimensions. *Amer. Jour. Sci.* Vol. 247, p. 209-249.

Naldrett, A.J., and Goodwin A.M., (1977). Volcanic rocks of Blake river group Abitibi greenstone belt Ontario and their sulfur content. *Canadian Jour. Earth Sci.*, vol. 14, p. 539-550.

Nesbitt, R.W., (1971). Sheletal crystal forms in the ultramafic rocks of the Yilgrin block, Western Australia, evidence for an Archean ultramafic liquid. *Geol. Soc. Austral. Spec. Publ.* vol. 3, p. 331-348.

Nisbet, E.G., Bickle, M.J., & Nartin A.,(1977) The mafic and ultramafic lavas of the belingwe greenstone belt. *Rhodesia J. Petrology*, vol. 18, p. 521-566.

Ross, J.R., and Hopkins G.M.F., 1975) Kambalda nickle sulfide deposits in economic geology of Australia and Papue New Guinea I. Metals (C.L. Knight ed.) *Austral. Inst. Mining Melt. Non.* vol. 5, p. 100-121.

Shams, F.A.,(1972). Glaucophane bearing rocks near Topsin. First record from Pakistan. *Pak. Jour. Sci. Res.*, vol. 24, p. 343-345.

Shams, F.A., (1980). Origin of Shangla blue schists, Swat Himalaya, Pakistan. *Special Issue Geol. Bull. Univ. Peshawar.* vol.13. p. 67-70.

Shams, F.A., and Ahmad S., (1979). Petrochemistry of Thak Valley igneous complex Distt. Diamir, Northern area, Pakistan. *Pak Jour. Sci. Res.* vol. 31, p. 145-150.

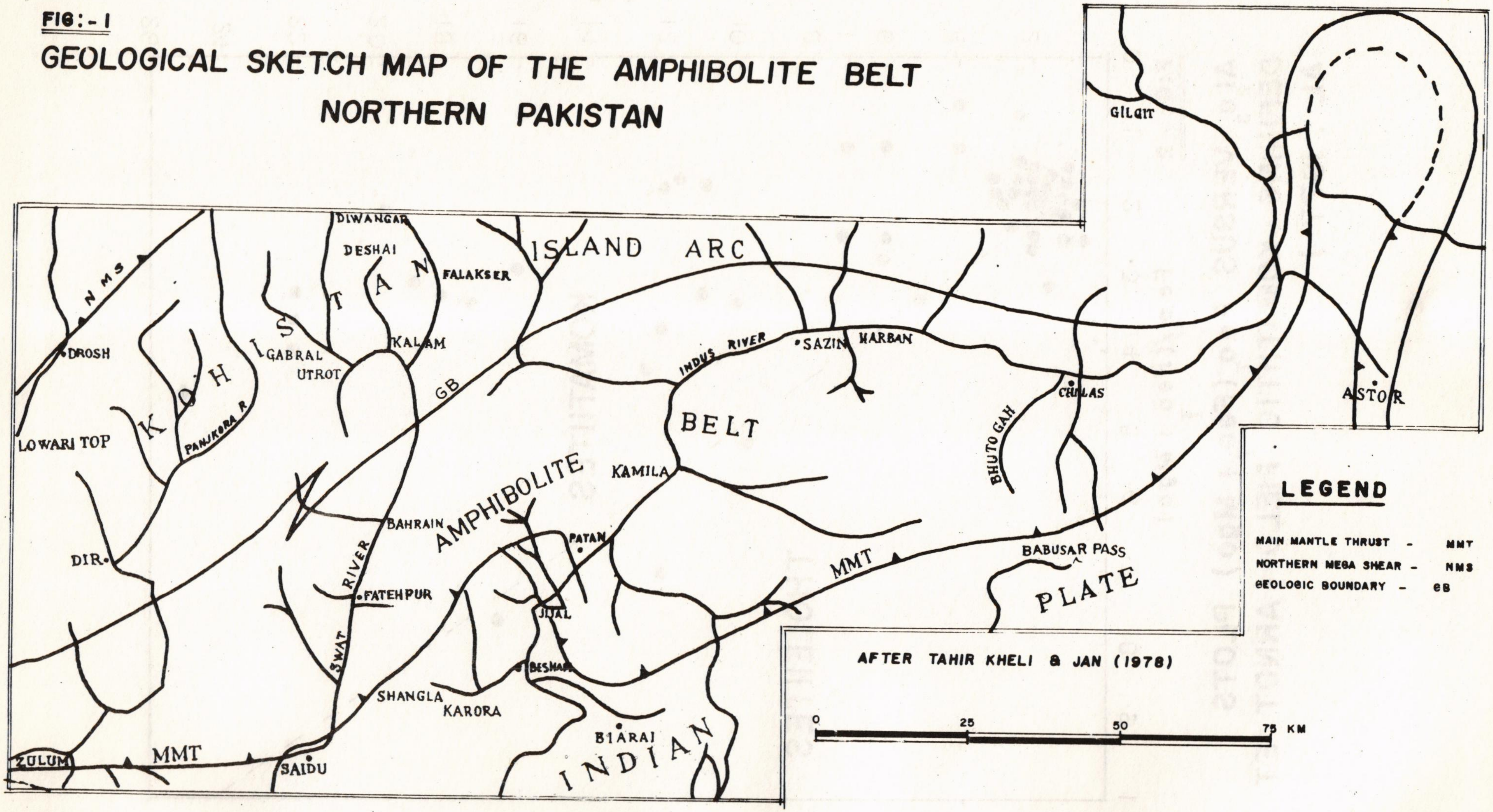
Tahirkheli, R.A.K., and Jan, M.Q., (1978). A priliminary geological map of Kohistan and adjoining area, N. Pakistan. *Centre. Excell. Geol. Pehsawar Univ.* Pakistan.

Upadhyay, H.D., (1976) Komatiites from Betts Cove, New Foundland. *Geol. Soc. Amer. Program Abst.* Vol. 8, p. 1150.

Viljoen M.J., and Viljoen R.P., (1969). The geology and geochemistry of lower ultramafic unit of the overwacht group and proposed new class of ingeous rocks. *Geol. Soc. S. Afr. Spec. Publ.* vol. 2, p. 55-86.

FIG:-1

GEOLOGICAL SKETCH MAP OF THE AMPHIBOLITE BELT NORTHERN PAKISTAN



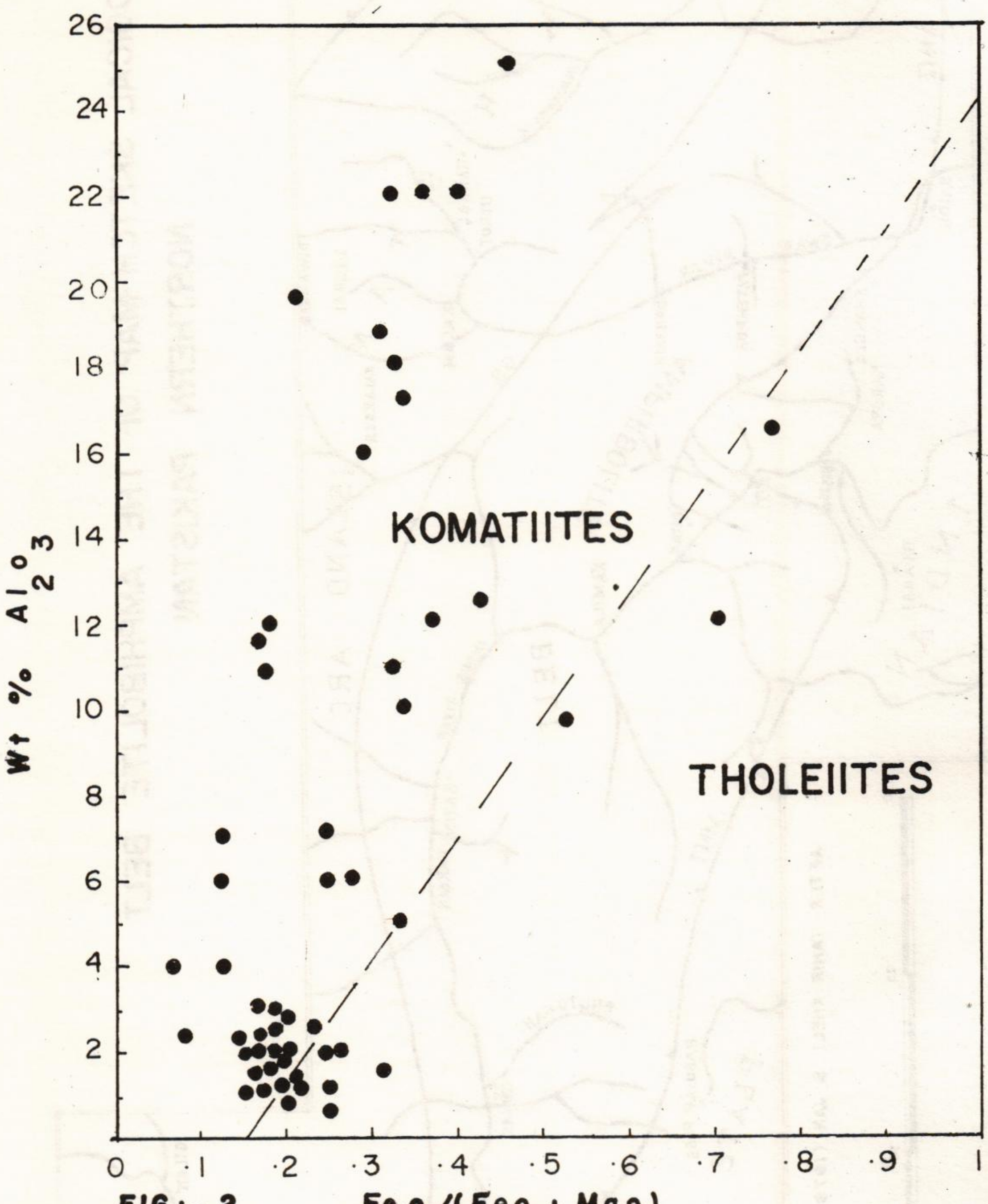


FIG:- 2

Al_2O_3 VERSUS $FeO_T(FeO_T + MgO)$ PLOTS DEFINING KOMATIITIC FIELD (ARNDT ET AL. 1977)

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

ON THE PERMIAN-TRIASSIC BOUNDARY IN THE SALT RANGE REGION

BY

KEIJI NAKAZAWA[1]

INTRODUCTION

The Upper Permian and the Lower Triassic sequence in the Salt Range and the Trans-Indus Ranges, is one of the important reference sections in the Tethyan province. The most notable work on this since Waagen's detailed papers (1879–1888 ; 1889–1891; 1895) is that summarized by Kummel and Teichert (1970) who paid a special attention to the Permian-Triassic boundary problems. Succeeeding this work the joint surveys of the Japanese universities staff and the members of the Geological Survey of Pakistan were performed twice, in 1975–76 and 1979. The preliminary report has been issued by the Pakistani–Japanese Research Group (hereafter abbreviated as PJRG) in 1981. The details of lithostratigraphy, biostratigraphy and sedimentology are now in preparation. Consequently, the author will discuss only briefly on the relation between the Permian and the Triassic which has not been settled yet, although the full description will be reported in the near future.

As to the stratigraphic classification of the Upper Permian and the Lower Triassic strata, that proposed by Teichert (1965) for the Permian and by Kummel (1966) for the Lower Triassic has been formally adopted by Stratigraphic Committee of Pakistan (Fatmi, 1973) and the Geological Survey of Pakistan (Shah, 1977) Table 1. The most important problem in the Permian-Triassic transition beds is the occurrence of the "Permian"–type brachiopods from the basal part of the Dolomite Unit of the Kathwai member in the Lower Triassic Mianwali Formation at Narmia in the Surghar Range. Kummel and Teichert considered these fossils as relict survivals from the Permian into the Triassic, when they discovered them (Kummel, 1966; Kummel and Teichert, 1970). On the other hand, Grant (1970) who described these brachiopod fossils insisted the Permian age and supposed the paraconformable relation between the Narmia brachiopods beds and the overlying Kathwai Member, and Newell (1973) expressed the opinion on the reworked origin of these fossils. To solve this problem more detailed sedimentological and biostratigraphical study is required. Nakazawa (in Nakazawa and Kapoor, 1977), based his observations together with S. Tayyab Ali, believed that the brachiopod beds are distinguishable from the main Dolomite Unit of the definitely Lower Triassic and referred the age as the latest Permian. This is endorsed by the following survey of the PJRG (1981). The further evidences will be given in this paper.

STRATIGRAPHY OF THE PERMIAN-TRIASSIC TRANSITION BEDS.

The Lower Triassic in the study area was named the Mianwali Formation, which is divided into the Kathwai, the Mianwali, and the Mittiwali, and the Narmia Members in the ascending order (Kummel, 1966), and the Kathwai Member is subdivided into the Dolomite Unit, the lower and the Limestone Unit, the upper by Kummel and Teichert (1970).

The upper limit of the Kathwai Member is defined as the last occurrence of *Opheceras* and the base of the Mittiwali Member by the first appearance of *Gyronites*. The basal part of the latter corresponds to the Ceratite Limestone of Wagaan (1895) which yields many ammonoid shells. However, the boundary is difficult to determine where the fossils are rare.

The subdivision of the Kathwai Member into the Dolomite and the Limestone Units is also difficult due to lateral lithological change from the dolostone to limestone or vice versa. It is more appropriate to subdivide it into three units, the lower, the middle and the upper which correspond to the lower Dolomite unit, the main Dolomite unit and the upper Dolomite unit plus limestone unit, respectively, of PJGR (1981).

1. Department of Geology and Mineralogy, Faculty of Science, Kyoto University, Kyoto, Japan.

The Lower Unit of Kathwai Member

The Lower Unit is characterised by the association of dolostone and sandstone or the predominance of terrigenous sand grains in the carbonate rocks. Cross lamination is characteristically developed. It is thickest at Narmia, about 80 cm thick, but generally less than 30 cm and at many places thins out.

The Middle Unit of the Kathwai Member

This unit corresponds to the Main Dolomite Unit, but at Chhidru its uppermost part intercalating thin muddy layers is excluded. It consists of massive or vaguely bedded dolostone with abundant dolomitized echinoid fragments. Thin layers of pale greenish grey dolomudstone are intercalated. Vertical burrows of *Skoliths* ichnofacies are found at Nammal. Coquinoid layers yielding numerous shells of *Eumorphotis waageni* and *Entolium* spp. are found at several horizons throughout the surveyed area excepting Narmia. The thickness and lithofacies are extremely uniform, ranging from 60 cm, 80 cm to 160 cm in thickness. *Ophiceras connectens,* though very rare, is sporadically found.

The Upper Unit of the Kathwai Member

This unit includes the upper dolomite unit and the limestone unit of PJRG (1981). The thickness and lithofacies are fairly variable in comparison with those of the Middle Unit. At Narmia it is represented by thin bedded limestone of 40 cm thickness, while at Chhidru it consists of alternating beds of dolostone and shale (the lower half) and of limestone and shale (the upper half) reaching 350 cm in total thickness. In the area between above two places, however, the thickness and lithology are rather uniform. In most places it is composed of the lower dolostone beds and the upper limestone beds, although dolostone/limestone ratio is variable. The thickness ranges from 140 cm to 220 cm. Ophiceratid ammonoids mainly occur in the upper limestone beds.

Mittiwali Member

The Mittiwali Member begins with the lower Ceratite limestone of Waagen and changes its lithology to thick greenish dark grey or black shale through alteration of shale and limestone.

CORRELATION OF THE TRANSITION BEDS

The preliminary correlation of the transition beds within the surveyed area was given in the previous report (PJRG, 1981) mainly based on the conodont zonation by Matsuda. The more detailed one is illustrated in Figure 1. The present zonation is slightly modified from the previous one in that the zone of *Hindeodus minutus* is defined by the association of the said species with *H. parvus* and *Isarcicella isarcica* while formerly the upper limit of this zone is referred to as the upper limit of *H. minutus*. The modified boundary lies stratigraphically slightly lower than the former one and coincides with the upper boundary of the Middle unit of the Kathwai Member, and the Upper Unit belongs to the zone of *Gondolella carinata* assemblage. Succeeding Zones of *Neospathodus kummeli, N. dieneri,* and *N. cristagalli,* in ascending order, occupy the lowermost part of the Mittiwali Member. *Ophiceras connectens* is limited in distribution within Zones of *H. minutus* and *G. carinata,* and species of *Gyronites* ranges from Zone of *kummeli* to lowermost part of *cristagalli.*

The Lower Unit of the Kathwai Member is scarce in conodont fossils. Only a small number of individuals of long-ranging *Hindeodus minutus* could be detected and the conodont zonation is impossible.

Although dolostone/limestone ratio or limestone/shale ratio is areally changeable, the illustrated correlation (Fig. 1) is also supported by other sedimentological characteristics. First, the Lower Unit and the basal part of the Middle Unit of the Kathwai are characterized by a relatively large amount of terrigenous clastic grains throughout the study area. Second, echonoids casts are common throughout the Kathwai Member, but rapidly decrease in the upper part, and almost absent entering into the Mittiwali Member. Thirdly, glauconite grains are found in limestone throughout the Kathwai and the lowermost part of the Mittiwali Member, but they have a tendency to be more common around the Kathwai–Mittiwali boundary.

It is a noticeable fact that the dolomitization of limestone is closely related to the amount of echinoid casts as schematically shown in Figure 1.

AGE OF THE BRACHIOPOD BEDS AT NARMIA AND PERMIAN-TRIASSIC BOUNDARY.

As stated in the introduction above, there are three explanations on the occurrence of the Permian type brachiopod fossils from the basal part (Lower Unit) of the Kathwai Member at Narmia. Kummel and Teichert considered them as relict survivals correlating the brachiopod beds to the basal part of the Kathwai at Chhidru, which yields many bivalves and *ophiceras connectens* of the Early Triassic age. But this is not true as supposed by Grant (1970). Actually the brachiopod beds or its equivalent, which are treated here as the Lower Unit, is changeable in thickness and at many places thins out. The lowermost 15 cm bed of Kathwai Member, west of Chhidru of Kummel and Teichert (1970, p. 38, Fig. 8 and p. 39, Fig. 9) is lithographically correlated to the Lower Unit of this paper, but this bed has no fossils excepting echinoid casts and is thinning out eastward, and fossiliferous Middle Unit directly lie on the 'White Sandstone Unit' of the Chhidru Formation. *Ophiceras* sp. is found in this part together with many shells of *Eumorphotis waageni* and *Entolium* spp. It should be mentioned that dwarfed form of *Crurythyris* is rarely contained, but this part cannot be referred to as the Lower Unit.

The occurrence of brachiopod shells at Narmia clearly indicate that they are transported by tractional currents, but the occurrence is very similar to that of the Triassic bivalve shells of the Middle Member and is essentially of interabasinal deposition, not reworked from the underlying beds. Furthermore, Grant (1970) pointed out the brachiopod assemblage is different from that of the Chhidru Formation.

In summary, it can be concluded that the brachiopod beds at Narmia are Permian in age paleontologically as well as biostratigraphically. Therefore, the Permian-Triassic boundary should be placed at the Lower and Middle Member boundary of the Kathwai Member. The exact age of the Lower Unit is difficult to determine, because the age assignment of the brachiopod assemblage is not accordant among the brachiopod specialists, for example, Dzhulfian age by Grant (1970), the post-Chhideruan and pre-Baisalian (Dzhulfian s.s.) by Waterhouse (1972), and Changshingian by Grant and Cooper (1973).

Based on the conodont zonation, Pakistani-Japanese Research Group (1981) pointed out the possibility comparing with that of Kashmir that the lower part of the Otoceras *wood wardi* zone is missing in the Salt Range by starved deposition. From the sedimentological view point, the Lower Unit is intimately connected with the Middle Unit of the Kathwai, and cannot be separated as a different member. This suggests the latest Permian age of the Lower Unit. The foraminiferal assemblage detected by PJRG strongly indicates that the Chhidru Formation is lacking in Dorashamian. Consequently, the hiatus between the Chhidru and the Kathwai may be greater than that between the Lower and Middle Kathwai.

ACKNOWLEDGEMENT

The author is most grateful to S. Tayyab Ali who first suggested to the author in Tehran, Iran to conduct a joint survey by the Japanese scientists and the staff of the Geological Survey of Pakistan and realized the project. Therefore, it is a pleasure to contribute to the first issue of Kashmir Journal of Geology.

REFERENCES

Fatmi, A.N. (compil.), (1973). Lithostratigraphic units of Kohat-Potwar Province, Indus Basin, Pakistan. *Mem. Geol. Surv.* Pakistan Vol.10, 80 p.

Grant, R.E.,(1970). Brachiopods from Permian-Triassic boundary beds and age of Chhidru Formation, West Pakistan. In Kummel B. and Teichert, C. (eds), Stratigraphic boundary problems Permian and Triassic of West Pakistan. *Spe. Publ. Univ. Kansas,* Vol.4, 117-152.

Kummel, B., (1966). The Lower Triassic Formations of the Salt Range and Trans-Indus Range, West Pakistan. *Bull. Mus. Comp. Zool.,* Vol. 134 (10), p. 361-429.

Kummel, B. and Teichert, C., (1970). Stratigraphy and Paleontology of the Permian-Triassic Boundary Beds, Salt Range and Trans-Indus Ranges, West Pakistan. In Kummel, B. and Teichert, C. (eds.) Stratigraphic boundary problems: Permian and Triassic of West Pakistan. *Spec. Publ. Univ. Kansas,* Vol.4, p. 1-110.

Nakazawa, K. and Kapoor, H. M.,(1977).Correlation of the marine Permian in the Tethys and Gondwana. Fourth *Gondwana Symposium Paper* Vol.2, p. 404-419.

Newell, N.D. (1973). The very last moment of the Paleozoic Era. In Logan, A. and Hills, L. D. (eds), The Permian and Triassic Systems and their mutual boundary. *Canad. Soc. Petrol. Geol. Mem.* Vol. 2, p. 1-10.

Pakistani-Japanese Research Group,(1981). Stratigraphy and Correlation of the Marine Permian-Lower Triassic in the Surghar Range and the Salt Range, Pakistan. *Kyoto Univ.* 25 p.

Tceichert, C., (1966). Nomenclature and correlation of the Permian "Productus Limestone", Salt Range, West Pakistan. *Rec. Geol. Surv. Pakistan,* Vol.15(1), 1-20.

Shah, S.M. Ibrahim,(1977). Stratigraphy of Pakistan. *Mem. Geol. Surv Pakistan,* Vol.12, 138 p.

Waagen, W., (1879-1889). Salt Range fossils. I. Productus-limestone fossils. *Paleontol. Indica, ser. 13. Geol. Surv. India.*

Waagen, W., (1889-1891). Salt Range fossils. IV. Geological Results. *Paleontol. Indica, ser.* 13, 4 (1)p.89-242, Geol. Surv. India.

Waagen, W., (1895). Salt Range fossils. II, Fossils from Ceratite Formation. *Paleontol. Indica, ser.,* 13, 2, p.1-323.

TABLE 1

Standard classification of the Permian and Lower Triassic.

Group	Formation	Member
	Mianwali Formation	Narmia Member Mittiwali Member Kathwai Member: Limestone Unit / Dolomite Unit
Zaluch Group	Chhidru Formation Wargal Formation Amb Formation	
Nilawahan Group		

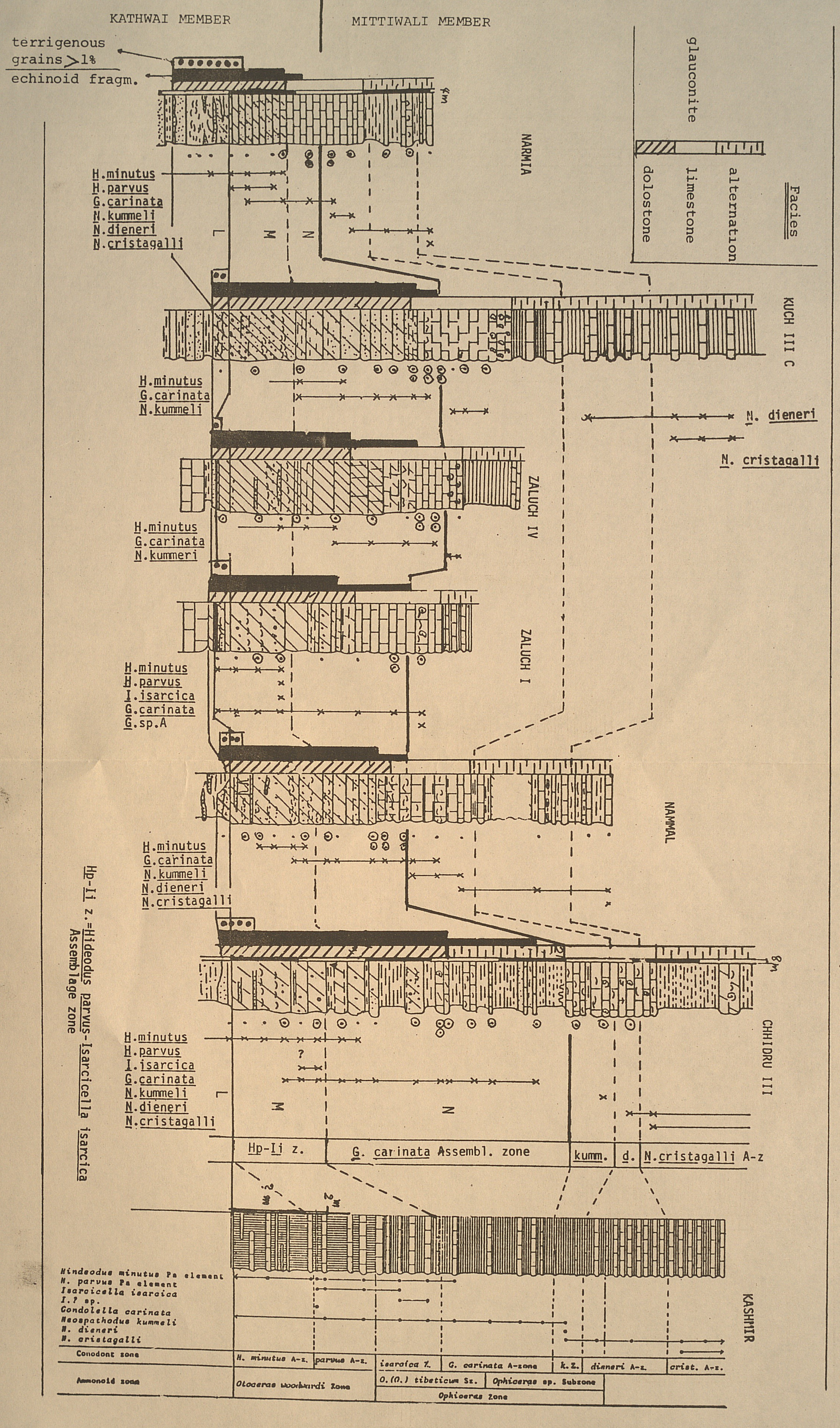


FIG:-1 COLUMNAR SECTIONS, LITHOFACIES AND CONODONT ZONES OF THE MIANWALI FORMATION. (LOWERMOST PART), SURGHAR RANGE AND SALT RANGE, PAKISTAN

L.M.U: LOWER, MIDDLE & UPPER UNITS OF KATHWAI MEMBER, RESPECTIVELY.

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

PETROLOGY OF SHAMOZAI AREA, DISTRICTS DIR AND SWAT NW PAKISTAN

BY

F.A. SHAMS,[1] ASAF MAHMOOD,[2]
KHAWAR JAMIL MIRZA,[3] ZAHID JAMALL MIRZA,[4]
ZAHID NAVEED AHMAD,[5] AND M. ASHRAF SIDDIQUI[6]

ABSTRACT.– The first detailed description of the Shamozai area, districts Dir and Swat is given on the basis of 1 : 10,000 mapping of about 206 km² North of the River Swat and including Southern edge of the Hornblendic Complex, Kohistan Zone. Petrographic and mineralogical details of various units are given. The structural features of the area and problem of metamorphism are briefly discussed.

INTRUDUCTION

Till publication of the first geological map of the Lower Swat region, N. W. F. P., (Martin *et al.* 1962) almost nothing was known about Southwestwards extension of the Himalayas across the River Indus. The said publication brought to knowledge various lithologic formations of the area and its regional structure. The tectonic line between the crystalline complexes in the South and the Upper Swat Hornblendic Group in the North showed juxtaposition of two different types of crustal sections in the Swat Himalayas. The detailed work by Jan and Kempe (1973) and mapping of the Khwazkhela area (Arif and Bajwa 1971, unpublished) revealed petrological nature of the hornblendic group. Further East, the discovery of blueschist metamorphism in the Topsin-Shangla (Shams, 1972, Desio and Ahams, 1980) established the basis for plate tectonic modeling between the Indo-Pak and the Eurasian lithospheric masses. Following Powell, C. Mc. A. and Conaghan, P. J. (1973). Bard *et al.* (1979) proposed the first plate tectonic model in which the area of Upper Swat Hornblendic Group was established as the fossil island arc, a situation comparable to the Transhimalayan Ladakh batholith, in the East of the Nanga Parbat. The tectonic line between the Hornblendic Group and the formations in the South was identified as a thrust by Martin *et al.* (1962) called Pattan Fault as extension of the upper Indus suture line (Desio, 1980; Desio and Shams, 1980) and called as the Main Mantle Thrust (MMT) by Tahirkheli *et al.* This situation necessitated extension of research along this suture to understand petrotectonic position elsewhere. The map of Martin *et al.* (1962) already showed the presence of greenschists in the south of the MMT, continuing Westwards from Shangla.

The Shamozai area was selected for detailed investigation including mapping on 1 : 10,000 scale using Survey of Pakistan toposheets Nos. 43 B/1, 43 B/2, 43 B/5 and 43 B/6. The geological map on reduced scale (1 : 50,000) is given as Fig. 1, covering an area of about 206 Km², lying between Long. 72° 2' 10" E to 72° 16' 5" E and Lat. 34° 39' 45" N to 34° 46' 8" N. The area is mainly situated Northwards from River Swat in the districts Dir and Swat.

Mapping and systematic sampling was done to distinguish lithologic units and metamorphic grades. Southern margin of amphibolites was included in view of petrotectonic importance of the area.

The terrain is rugged. The landscape composed of steep as well as gentle slopes. The highest altitude is 1625 m in Northern extremity of the area. The lowest altitude is 716 m at the bed of the River Swat in the SW of the area. The relief is about 908 m. There are a number of peaks of varying heights between these two extremes. Rock exposures are generally good.

1,6. Institute of Geology, University of the Punjab, Lahore.

DESCRIPTION OF LITHOLOGIC UNITS

1. Marble.– Marble is exposed as huge patches in the North of the River Swat. Its Northern contact is with garnet-mica schist but at places it is in contact with graphitic schist as well, such as in the central part of the area.

General colour of the rock is blackish and with black and white layers. It shows saccharoidal texture with prominant jointing and fractures. Bedding is marked at places with the help of quartz veins and thin layers of garnet-mica schist.

The constituent minerals are calcite (55–95%) as fine to coarse, anhedral, bent and strained grains with inclusions of quartz, iron ore, graphite and muscovite; quartz (0.5–40%) occurs as fine to coarse anhedral grains with wavy extinction; biotite (1–5%) occurs as small flakes showing weak pleochroism; ore minerals (0.5–5%) are present as fine to coarse grains of magnetic and hematite and spongy masses of limonite; graphite (1–4%) as dust like masses and muscovite (1–2.5%) is seen as small elongated flakes.

2. Garnet-Mica Schist.– Garnet-mica schist is mainly exposed North of the River Swat. Its Northern contact with graphitic schist is gradational whereas the Southern contact with marble is sharp. It is grey, brownish black and shiny black in colour. It is a strongly schistose rock with large porphyroblasts of garnet. Jointing, lineation and veins of quartz and calcite showing boudinage structures are frequent. The grain size of garnet decreases Northwards.

The constituent minerals are quartz (8–65%) as fine to coarse anhedral and strained grains with wavy extinction and sutured margins; graphite (2–50%) as flaky and dust-like forms; carbonates (45–55%) as anhedral coarse grains in which siderite is developed along cleavages and fractures; muscovite (2–30%) as elongated flakes with curved alignment around rotated garnet porphyroblasts; biotite (3–25%) as sheared and strained flakes with very weak pleochroism; garnet (3–20%) as medium to coarse subhedral to hexagonal fractures and rotated porphyroblasts surrounded by elongated flakes of muscovite and with inclusions of graphite, quartz and iron ore; iron ore (5–20%) as fine to coarse grains of magnetite, hematite and limonite with, some strained and spongy grains of limonite; chlorite (0–5%) occurs as elongated light green flakes.

Staurolite (0–3%) is also present at places in the middle of the main garnet-mica schist rock in association with garnet, quartz, muscovite, graphite, biotite and iron ore. It is pleochroic from colourless to yellowish brown, and occurs as coarse anhedral grains with irregular quartz inclusions.

Kyanite (0–2%) is present in southern part of the rock as colourless, elongated plates (C $\wedge$ Z, 30). It is altered to muscovite along fractures and cleavages. Quartz-kyanite veins of colourless to blue colour are also seen in this part of the rock unit.

3. Graphitic Schist.– Graphitic schist is exposed in contact with greenschists in the Western part of the area whereas in the Eastern part its Northern sharp contact is with quartz-biotite schist. In the Northern side at some places huge patches of carbonate rock are also found in contact with this unit. The Southern contact is with garnet-mica schist throughout the area except in the middle where it shows its contact with marble.

It is dark grey, greyish black to shining black in colour. It is a strongly schistose rock with lineation, jointing and quartz veining.

The constituent minerals are graphite (20–80%) in banded flakes and dust-like masses, with lepidioblastic texture and inclusions of quartz; muscovite (2–35%) as fine elongated flakes with parallel allignment; quartz (5–60%) as fine to coarse anhedral grains with sutured margins, wavy extinction; iron ore (2–20%) as fine to coarse anhedral grains of magnetite, hematite, limonite and siderite; carbonate minerals (0–10%) as anhedral coarse grains with inclusions of quartz, siderite is developed along cleavage; biotite (3–8%) in the form of flakes with prominant cleavage.

4. Carbonate Rock.– Carbonate rock covers very small area and is present in the form of isolated patches overlying the garnet-mica schist in the West and graphitic schist and greenschist in the East, showing sharp contact.

The rock is of yellowish brown and light greenish brown colour; it is very hard, massive and dense with quartz veins.

The constituent minerals are carbonates (15–94%) as fine to coarse anhedral grains with inclusions of quartz, along cleavages and margins it is altered to brown coloured siderite; quartz (1–50%) as fine to coarse grains with sutured margins and wavy extinction; ore minerals (1–25%) include magnetite, hematite, limonite, pyrite and siderite; mica minerals (4–25%) as fine to medium flakes of muscovite and biotite; graphite (1%) is rather rare.

5. Quartz-biotite schist.– Quartz-biotite schist is exposed in the Eastern part of the area, its Northern contact is with greenschists whereas the Southern contact is with graphitic schist.

It is light brown, brown and dark brown in colour and is strongly schistose rock with lineation, quartz veining and quartz boundinage structures.

The rock contains quartz (40–50%) as fine to medium-grained mineral with wavy extinction and sutured margins; biotite (5–43%) as large dispersed flakes with common inclusions of quartz; carbonates (37%) as medium to coarse-grained mineral in the form of aggregates with inclusions of iron ore and quartz as aggregates; iron ore (7–30%) as fine to medium sized plates and bladelets, also as anhedral, hexagonal and cubic form with small inclusions of quartz; graphite (6%) as scattered dust-like mass and rare muscovite (1%).

6. Greenschists.– Greenschists are present in the South of the Hornblendic Complex, and are the upper-most portion of the Lower Swat-Buner Schistose Group (Martin *et al.*, 1962). The Southern contact of the greenschists is with graphitic schist in the West and with quartzbiotite schist in the East, thus cutting across the rock boundary.

The greenschists are light green to green in colour, and are highly weathered. It is a fine-grained schistose rock with jointing and is traversed by quartz veins.

The green schists are mainly composed of chlorite schist but at some places very small deposits of talc schist are also found.

The chlorite schist component is composed of chlorite (5–64%) as light green to green pleochroic large flakes with inclusions of quartz, the flakes are elongated, curved and occasionally strained; quartz (25–65%) as fine to coarse anhedral and strained grains and aggregates, some grains showing sutured margins and wavy extinction; carbonates (10–30%) as anhedral coarse grains with inclusions of quartz and ore minerals; muscovite (7–20%) as elongated strained flakes, curved flakes surrounding quartz porphyroblasts; sphene (1–10%) as small rhombic grains and ore minerals (1–6%) as fine to coarse anhedral grains.

Talc schist is the other component of the greenschists with talc (60%) as the main mineral with association of chlorite, carbonates, quartz and ores. Fine to large plates of steatite and fibrous talcose aggregates with inclusions of quartz and iron ore are present.

7. Amphibolites.– Amphibolites of the area compose Southern edge of the Upper Swat Hornblendic Group (Martin *et al.* 1962), being next to the M.M.T. In the area only the marginal portion of the Hornblendic Complex is covered, having contact with the greenschists.

These amphibolites are light green to grey to blackish in colour, strongly jointed and weathered. The rock is traversed by numerous quartz and pegmatite veins, with horizons of volcanic tuff as a part of the amphibolite rock. It is a fine grained rock with prominant foliation and showing lineation parallel to the rock foliation.

The rock contains epidote (7–62%) charged with inclusions of quartz as vermicular intergrowths, big crystals are zoned while smaller crystals are inclusion free. Hornblende (20–60%) occurs as light bluish grey to greenish-blue large crystals with $C \wedge Z = 20$ as well as aggregates of small crystals, which appear to be product of granulation, also present as inclusions in epidote. Plagioclase (20–30%) is altered into micaceous aggregates; sphene (5%) is associated with hornblende as pools and as a dispersed phase; ore (1% to 10%) platelets and blades are aligned mutually within mafic mineral crystals.

In some cases, hornblende is dominant phase with rugged margins whereas quartz (5 to 20%) is prominant in some cases as anhedral and strained grains, this proportion is higher where the plagioclase is also dominant and make local patches of quartz-dioritic composition as an evidence to pegmatitic phase known to be associated with amphibolite zone. Muscovite (2 t0 5%) is also associated mostly with quartzofeldspathic patches and layers. Some amphibolites give a banded appearance with hornblende-epidot layers alternating with quartzofeldspathic layers. Strongly sheared amphibolites show augen shaped amphibole drawn out along the foliation plane. Plagioclase is in the sodic range. Some amphibolites are very rich in epidote minerals, with subordinate amphibole hinting towards epidositic trend.

Constituents of volcanic tuff are glass and cryptocrystalline material (71–79%), colourless to light brown in colour with cloudy appearance; carbonates (0–2%) occur as colourless, fine to medium sized anhedral grains with perfect rhombohedral cleavage. Quartz (1–10%) is present as fine to medium sized anhedral grains with sutured margins and sharp extinction; iron ore (0–8%) occurs as medium to coarse anhedral grains of hematite; chlorite (0–5%) as coarse flakes with weak pleochroism and fuchsite (0–3%) is seen as fine to medium sized flakes. Plagioclase (0–2%) occurs as fine to medium grained of albitic composition and some epidote (0–1%).

STRUCTURE

The area under discussion is a small part of the Lower Swat region below the so-called Main Mantle Thrust (MMT) which is an intercontinental tectonic suture. According to Martin *et al,* the Lower Swat region has two directions of folding. The older structures have fold-axes North to South, and becoming Northwest-Southeast in the area under discussion; these major structures appear as alternating anticlines composed of granitic bodies and synclines composed of metamorphic rocks. Superimposed is the younger folding phase with fold axes running East-West and becoming Northwest-Southeast in the area under discussion. The older structures appear to be related to the syntaxis of the Northwest Himalayas, which is a prominent feature nearly 200 km in the East. The younger structures are due to Northwards underthrusting of the Indian shield along the MMT and/ or Southwards obduction of the Kohistan Zone. The granitic bodies lie in the South and Southwest of the area. Due to this cross folding, the roc rock formations suffered fracturing, microfolding and tectonic gliding. These are seen as open joints and fractures as well as filled with aplites, pegmatites and quartz veins, that are expected to belong to an older tectonic episode. In thin sections, the structural phenomena are seen as fracturing of minerals, anomalous optic and rotation of minerals. Syn-tectonic and post-tectonic mineral growth is commonly seen. Obviously, major conclusions of regional importance cannot be drawn from the small area under discussion.

DISCUSSION

The grade of metamorphism increases towards the South, marked by index minerals chlorite, biotite, garnet, staurolite and kyanite. The nature of the chlorite grade rocks is somewhat complicated. Their major mineralogy is chlorite, muscovite, quartz, carbonates and sphene which is comparable to the greenschist facies assemblages. However, the presence of talc-bearing rocks, to the extent of becoming talc rich even of economic concentration, shows the involvement of ultramafic material such as serpentinite. Therefore, parent material of the chlorite grade rock was of diverse nature that suffered facies convergence due to tectonic involvement.

This study produces following two problems :

(i) nature of regional matamorphism and its relation to the Alpine tectonics.

(ii) nature of the greenschist rocks.

The metamorphism of the sediments is believed to belong to pre-alpine era. Besides known stratigraphic age i.e., being Pre-cambrian, considered equivalent to the Salkhala Formation (Shah, 1982). This is also supported by the Palaeozoic age of the Lower Swat Granite (Malluski, in Jan, 1982), which are comparable to the Mansehra granite dated as Palaeozoic (Le Fort 1979). The granitic bodies being intrusive, show that the metamorphism belongs to pre-alpine period. During the alpine period another wave of metamorphism might have affected the area but it is difficult to distinguish between the alpine and the pre-alpine metamorphism purely on the basis of petrography. Nevertheless, the area is believed to have suffered poly-metamorphism. The visible effects of younger tectonics are seen as retrograde alteration of minerals. This brings up the second problem, the nature of the greenschist formation. Martin *et al,* (1962) did not discuss in depth the origin of the greenschists except giving their field description and major lithologic constituents.

The location of greenschists in the vicinity of the MMT gives it a special status. In the Shangla area, to the North-east, blueschist zone is known to exist as indicator of high pressure low temperature environments (Shams, 1972; Desio and Shams, 1981). The blueschists are enveloped in greenschist formation which extend towards the area under discussion. In the present location no blueschist was discovered although trench environments were recognised. The problem of greenschists is whether they were attached to the regional metasediments of the Lower Swat-Buner Schistose Group or to the trench sediments received from the over-riding Eurasian plate. In the former case the increase of temperature towards South as indicated by rise of metamorphic grades is difficult to explain because the zone of high heat flow existed North of the MMT and not towards South of it. In the latter case the greenschists will be a product of trench zone metamorphism i.e., high water vapour pressure and low temperature. Under these conditions all types of lithologies, these belonging to the pre-collision metasediments as well as post-collision metasediments will show facies convergence to produce the greenschist formation. The metasediments of the earlier period would have also undergone physical and chemical changes such that high grade minerals broke down to greenschist mineralogy.

The metamorphic zonation shows normal sequence i.e., the grade increases towards South or with stratigraphic depth. As is commonly seen in the Himalayas, the regions beyond the kyanite grade are also the areas where the granite exists. Further study is needed to clarify some of the major problems as hinted upon in the above.

REFERENCES

Bard, J. P., Maluski, H; Matte, Ph. and Proust, F.,(1979). The Kohistan Sequence : Crust and Mantle of an Obducted Island Arc. *Proc. Intern. Commit. Geodynamics, Grp. 6, Mtg. Peshawar Univ. p. 87–94.*

Davies, R. G.,(1965). The nature of the Upper Swat Hornblendic Group of Martin *et al.* (1962). *Geol. Bull. Panj. Univ.* vol. 5, p. 51–52.

Desio, A; and Shams, F. A., (1980). The age of Bluschists and the Indus Kohistan Suture Line, NW Pakistan. *Proceedings of the Italian Academy of Sciences Milan, Italy;* vol. 68, p. 74–79.

Jan, M. Q., and Kempe, D. R. C., (1973). The Petrology of the basic and intermediate rocks of the Upper Swat. Pakistan. *Geol. Mag.* vol. 110, p. 285–300.

Martin, N. Siddiqui, S. F. A., and King, B. C., (1962). A reconnaissance of the region between the Lower Swat and Indus River of Pakistan, *Geol. Bull. Panj. Univ.*, vol. 2, p. 1–12.

Powell, C. Mc. A., and Conaghan, P. J., (1973). Plate tectonics and the Himalayas; *Earth Planet. Sci. Lett;* vol. 20, p. 1–12.

Shah, S. M. I., (1977). Stratigraphy of Pakistan. Pakistan *Geol. Surv.* Memoirs, vol. 12.

Shams, F. A., (1972). Glaucophane bearing rocks from near Topsin, Swat. First record from Pakistan. *Pak. Jour. Sci. Res.* vol. 24.

Shams, F. A., (1980). Origin of the Shangla Blueschist, Swat Himalaya, Pakistan. *Geol. Bull. Peshawar Univ.* vol. 13, p. 67–70.

Shams, F. A., Jones, G. C., and Kempe, D. R. C., (1980). Mineralogy of the Blueschists of Swat Himalayas, Pakistan, *Min. Mag.* vol. 44.

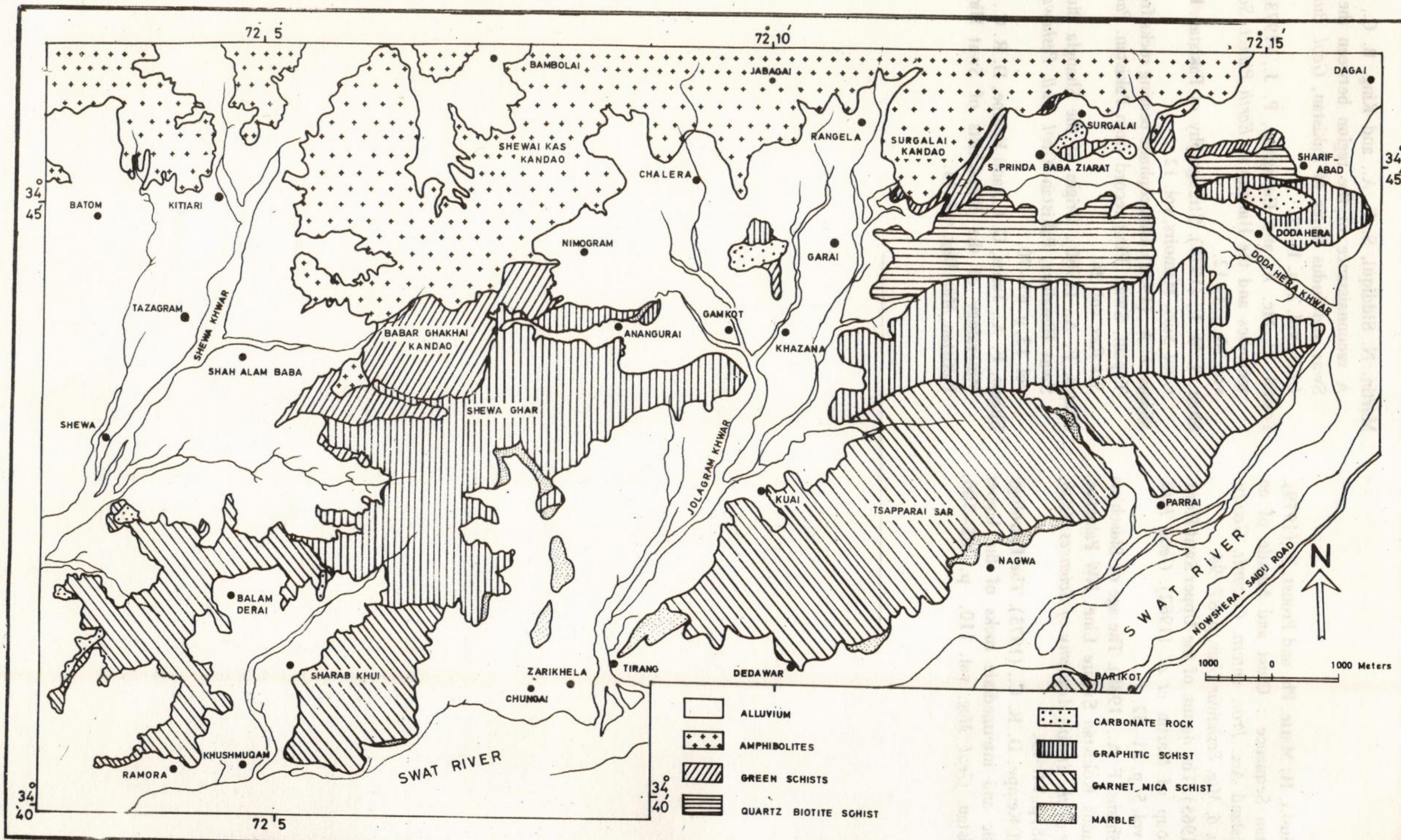


FIG: 1 **GEOLOGICAL MAP OF SHAMOZAI AREA, DISTRICTS DIR & SWAT.**

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

THE CRYSTALLINITY INDEX AND PALAEO ENVIRONMENTS

BY

S.R.H. BAQRI

ABSTRACT.– The crystallinity index of kaolinte was determined in 20 degrees (with at half height) using X-ray diffractograms, prepared from the oriented slides of the samples. The crystallinity indices of the three units (seatearths, coal mineral matter and roof shales) were compared to investigate the differences due to the palaeoenvironments. These differences were responsible for the variations in the crystallinities of the kaolinites.

INTRODUCTION

The coalfield of South Wales displays classic example of decreasing volatile matter in coals from east to west. The volatile matter of the coals reduces from 36% to 6% from east to west (Baqri, 1978). The coal measures belong to the Namurian Group of the Carboniferous Period. The crystallinity indices of kaolinite were investigated during the detailed mineralogical and geo-chemical investigation of the seatearths (89 samples), coal mineral matter (98 samples) and roof shales (86 samples) from the Carboniferous coal seems (Baqri 1977). The object was to determine the comparative crystallinity of kaolinite between the three sedimentary units to understand the differences in crystallinity due to the palaeo-environments.

All seatearths, roof rocks and coal samples were subdivided into two groups. The first group, called the high volatile group, consists of all the coals containing more than 11% volatile matter or roof rocks and seatearths associated with coals in this range of volatile matter. The second group, called low volatile group, includes coals in the range of 11% volatile matter and seatearths and roof rocks associated with coals in this range of volatile matter.

Methods of Investigations.– **The crystallinity index of kaolinite was determined by measuring the width at a half height of the (001 kaolinite reflection at 7.12 Å. Thus figure 1, represents the (001) reflection of kaolinite at 7.12 Å, and CD (width in 20° at half height) measures the crystallinity index. It has an inverse relation to the true crystallinity of kaolinite. The small values of which indicate a high degree of crystallinity. The crystallinity indices of the kaolinite were measured on the diffractograms of the oriented slides, prepared from less than 5 micron fraction of the samples.**

Previous Works.– **The formation and distribution of clay minerals and specially kaolinite in coal forming swamps has been discussed by many workers. Schuller (1956) carried out the most important investigations on the crystallinity of the clay minerals. He demonstrated that the clay minerals in coals may be divided into three groups. Two of the groups consist of large well developed crystalline material and optically crypto to microcrypto-crystalline material. The third group comprises amorphous material which often surrounds a kernel of true tonstein and is known as pseudotonstein. A mechanism for the development of clay minerals in coals was proposed by Hochne (1975). He suggested that these minerals are crystallised from a solution derived from colloidal source material which penetrated the swamp environment by subsequent transport.. He demonstrated that the disseminated grains of kaolinite were crystallised from solution and pointed out that kaolinite and quartz have often penetrated and**

1. Pakistan Museum of Natural History, Pakistan Science Foundation, Islamabad, Pakistan.

filled endosperm casts without destroying the organic membrane and the process may be similar to siliceous petrification.

Zaritski (1964) regarded the presence of dickite in the cell structure of rootless as evidence for this purpose. The mineral matter in elgian coals was studied by Scheera (1975). He supported a subsequent sedimentary origin for the clay minerals and claimed transformation of illite into kaolinite (1978) studied the clay minerals from Nagar Parker area of Pakistan and observed that the kaolinite was well crystalline. The process of leaching was responsible for the crystalline nature of kaolinite. Baqri (1979) also observed a well crystalline kaolinite associated with the apatite dirt bands in South Wales. Pietzner and Werner (1963) proposed that some or all of the constituents of the clay minerals in coals may be the oxidation products of the organic material. They observed that thorium and phosphorous are two trace elements which are much more abundant in the clay minerals of coal than in the clay minerals of shale facies. Hughes (1971) did a detailed work on the mineral matter associated with Illinois coal and found a significant amount of well crystalised kaolinite, illite and expandable clay minerals.

RESULTS

The main values of kaolinite crystallinity indices for all seatearths, all roof shales and coal minerals matter are given in Table 1. Figure 1 gives the comparative distribution of the kaolinite crystallinity indices in all seatearths, all coals and all roof shales.

The mean value of the kaolinite crystallinity index for 82 seatearth samples was 0.28 2θ degrees. The mean value for 41 seatearth samples in the range of more than 11% volatile matter was 0.30 2θ degrees, while samples in the range of less than 11% volatile matter (41 samples) gave a value of 0.25 2θ degrees. The mean value for roof shales samples was 0.27 2θ degrees. When the roof shale samples were divided into high volatile (44 samples) and low volatile (42 samples) groups, the mean values were 0.27 2θ and 0.26 2θ degree respectively. The mean value for the crystallinity index of kaolinite in all the coal samples (98) was found to be 0.17, 2θ degrees. The crystallinity indices of kaolinite in high volatile coals (22 samples) and low volatile coals (76 samples) were 0.19 and 0.17, 2θ degrees, respectively.

DISCUSSION

The presence of the mineral kaolinite in coals and coal forming environments could be due to the ordinary detrital suspension matter and essentially unaltered. It is also probable that the crystallinity of kaolinite increases due to the transformed material and due to the action of humic acid on it. It is also likely that the neoform clay from either ionic solution or from collodial suspension is more crystalline than the detrital clay. The crystallinity of the detrital clays probably decreases with their transportation

SUMMARY AND CONCLUSIONS.

1. Kaolinite in coals is significantly more crystalline (0.17 2θ degrees) than the kaolinite in seatearths (0.28 2θ) and roof shales (0.27 2θ degrees).
2. Figure 1. shows the distribution of the crystallinity indices of kaolinite in seatearths, coals and roof rocks. There is a clear distinction between the three groups, in that the mineral is distinctly better crystallized in the coals.
3. The Palaeo-environments were probably responsible for the variations in the crystallinity indices of kaolinite.
4. The Palaeo-geography also controlled the crystalline nature of the kaolinite.

ACKNOWLEDGEMENT

The author is thankful to the staff members of the Geology Department, University of Southampton, England for their cooperation and help during the research investigations of this project. I am also thankful to Professor F. Hodson, Department of Geology, University of Southampton, for his guidance and contructive criticism of the project. I also wish to pay my regards to Dr. Syed Riaz Ali Shah for reading the manuscript of this paper.

REFERENCES

Baqri, S.R.H., (1977). The mineralogy and chemistry of some coals associated sediments from the South Wales coalfield. Ph.D. thesis. University of Southampton, England.

Baqri, S.R.H., (1978). The mineralogy and geochemistry of some clays from Nagarparker *Jour. Sci. Ind. Res.*, vol. 21, No. 1.

Baqri, S.R.H., (1979). Apatite in South Wales anthracite. *Geol. Mag.*, 116 (6).

Hochne, K., (1957). Grundsatzliche Erkenntnisse uber die Tonsteinbildung in Kohlenflozen und neue Tonsteinvorkommen in ost, U.S.A., *Westkanda und Nordemxico, Akademieverlag, Berlin.*

Hughes, R.E.,(1971). Mineral matter associated with Illinois coals, Ph.D. thesis, University of Illinois, U.S.A.

Pietzner, H. and Werner, H., (1963). Die Kaolinitsynthese aus steinkohlenasche undihre Bedeutung fur die Entstehund der Tonstein des Ruhrkarcons. *Cing. Congress Intern. de Stratgr. et. al. Geologie due Carbonifere.* vol. 2, pp. 667–678.

Scheere, J.,(1957). The petrology of the claystone of Belgian coal. *Bull. Soc. Belge. Geol. Palaeontol. et. Hydrol.*, vol. 66, pp. 300–316.

Schuller, Arno.,(1956). Uber die Kaolinisie rung von Felspat und Climer bei der bilding von Tonstein. *Chemie der Erde,* vol. 18, pp. 45–55.

Zaritski, P.V., (1964). Exogenetic dickite in the concretions-septaria of Klandi coal basin (Czechoslovakia). *Min. Sb. 1, ovask. Gos. Univ.*, vol. 18, No. 4, pp. 475–479.

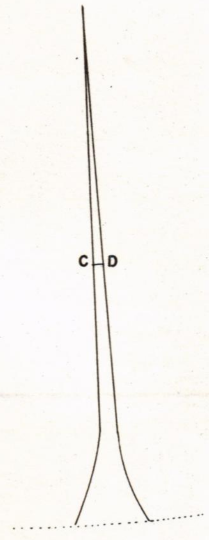


FIG:-1
MEASUREMENT OF THE CRYSTALLINITY OF KAOLINITE AT 7.12 Å. (WIDTH AT HALF HEIGHT _ CD)

TABLE - 1

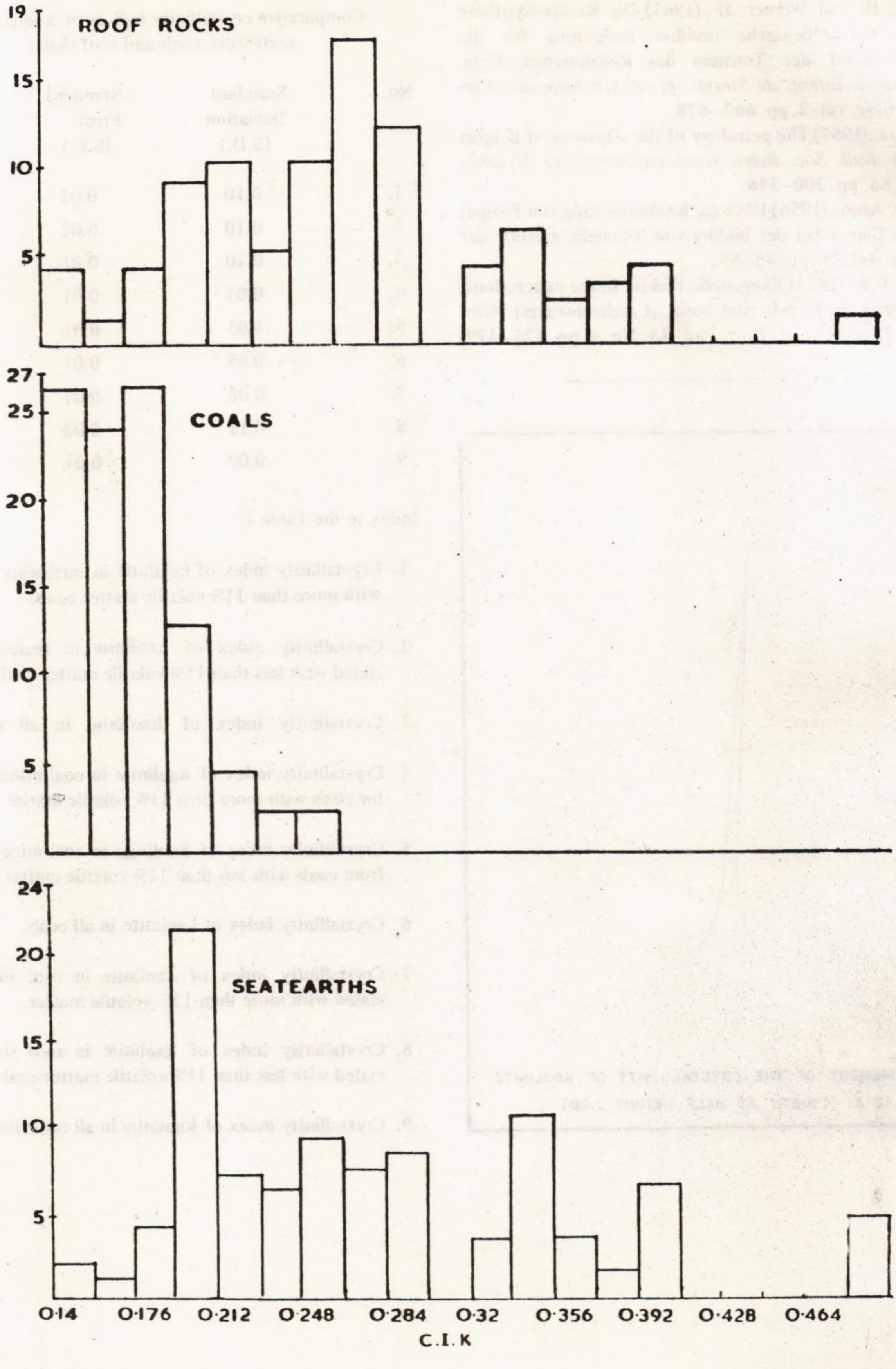
Comparative crystallinity indices of kaolinite for seatearths, coals and roof shales.

No.	Standard Deviation (S.D.)	Standard Error (S.E.)	Mean
1.	0.10	0.02	0.30
2.	0.10	0.02	0.25
3.	0.10	0.01	0.28
4.	0.05	0.01	0.19
5.	0.05	0.01	0.17
6.	0.05	0.01	0.17
7.	0.06	0.01	0.27
8.	0.11	0.02	0.26
9.	0.09	0.01	0.27

Index to the Table 1:

1. Crystallinity index of kaolinite in earthseats associated with more than 11% volatile matter coals.
2. Crystallinity index of kaolinite in seatearths associated with less than 11% volatile matter coals.
3. Crystallinity index of kaolinite in all seatearths.
4. Crystallinity index of kaolinite in coal mineral matter for coals with more than 11% volatile matter.
5. Crystallinity index of kaolinite in coal mineral matter from coals with less than 11% volatile matter.
6. Crystallinity index of kaolinite in all coals.
7. Crystallinity index of kaolinite in roof shales associated with more than 11% volatile matter.
8. Crystallinity index of kaolinite in roof shales associated with less than 11% volatile matter coals.
9. Crystallinity index of kaolinite in all roof shales.

Figure 2.: Comparative distribution of the crystallinity indices of kaolinite in seatearths, coals and roof shales.



Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

GENESIS OF PENNINE ORE FIELD, ENGLAND

BY

LAL BUKHSH BOZDAR[1]

ABSTRACT.– The Pennine ore field has been mined for lead, zinc, fluorspar and barytes. Dunham has been the main contributor to the genesis of this ore field and has worked out the most possible aspects of the genesis, that is, Juvenile water, meteoric waters, connate waters as the possible sources of the ore bearing fluids with the metal as the possible sources of the ore bearing fluids with the metal content leached from the intrusion beneath Weardale granite .

Sawkins has studied the genesis in the light of fluid inclusions. Toome put forward the idea of 'formation water's as the source of ore bearing fluids and Davidson gave the idea of early diagenetic brines which concentrated metals and later diagenetic sulphurated brine precipitated them.

The author made an attempt to outline the factors which might have affected mineralization and carried out the statistical analysis of various predictor variables (geologic factors). The statistical results of gravity and magnetic anomalies due to Weardale granite do not support the idea of any relationship of mineralization with Weardale granite (Juvenile waters).

From the statistical treatment of trace element analysis it is conceivable that sedimentary rocks could be the source of metals which were leached by connate water after getting heated at greater depths and mineralization has taken place in more than one phase.

INTRODUCTION

The Pennine ore field is one of the best known ore fields in the world and has been mined for lead, zinc, fluorspar and barytes. It is almost entirely made up of carboniferous rocks and covers about 3840 square km. and can be divided into :

i) Alston Block which occupies northern half.

ii) Askring Block which constitutes the central part

iii) Derbyshire in the south.

The ore deposit of this field are commonly held to be epigenetic telethermal type and possess similarities with the ore deposits of Mississippi valley region. The deposits are stratigraphically controlled in the sense that the ore zones are localised at favourable "bearing horizons".

In the veins open space filling appears to have been the major method of ore deposition although some replacement of wall rock has occurred in most places. Ore bodies show a striking concentration of mineralization at the horizon of the Great Limestone.

The primary sulphide minerals present in the ore field are galena, sphalerite, chalcopyrite and pyrite associated with fluorite, barite and quartz. Mineral zoning is an important feature of the ore field which has a vertical as well as a lateral direction, but since the main movement of the mineralizing fluids was lateral along ribbon or tube like openings the mineral zoning is more conspicuous in the

1. University of Sind, Jamshoro, Hyderabad, Sind, Pakistan.

lateral sense than in the vertical. The zoning is completely independent of the nature of the wall rock but is supposed to be mainly temperature controlled.

ORE GENESIS

There is very little doubt about the hypothesis that the Pennine ore deposits originated by deposition of minerals from aqueous solutions. The discordant nature of deposits indicates that elements have been introduced by fluids, which have in part precipitated them directly as vein minerals and in part deposited them by metasomatic reaction with limestone. Aqueous solutions either electrolytic or colloidal are the accepted media of transport.

The fundamental problem of ore genesis involves three questions :

1. The source of metals.
2. The source of fluids which transported the metals
3. The energy which promoted circulation.

The ore solutions may have originated from (i) Meteoric water (ii) Juvenile water (iii) Connate water (iv) Formation waters (v) Brines or (vi) Both Juvenile & connate waters.

Dunham (1934) has been the main contributor to the genesis problem of this ore field and has worked out the most possible aspects. In 1934 he came out first with the idea of hydrothermal solutions (Juvenile Waters) generated from a concealed granite responsible for the deposits. He (Dunham 1964) in another paper also argued that the ore solutions may have originated from meteoric waters which derived the metal content from the country rock by leaching Dunham[3] also considered the possible role of connate waters which leached the metal content during the course of their Journey and then deposited them.

Sawkins (1966) has studied the genesis in the light of fluid inclusions trapped by ore minerals & has suggested that the ores were formed by the mixing of Juvenile hydrothermal solutions with Connate barium rich solutions FIG1 and thus has been supported by Dunham (1966). Tooms (1970) put forward an idea that ore could be derived from deep "formation water and may belong to any genetic category.

According to Davidson (1966) early diagenetic brines concentrated metals and later diagenetic sulphurated brines precipitated them.

The author also made an attempt to outline the factors which may have affected the mineralization and carried out the statistical analysis of various predictors (geologic factors) * for this purpose and determined statistically correlation between the total lead production of this field and these factors (Table 1). From the results (Table 1) it is evident that there is no correlation between the lead production and the gravity and magnetic anomalies due to Weardale granite. Therefore this statistical study does not support the idea of any relationship of mineralization with Weardale granite (juvenile water) as suggested by Dunham. For the same reasons the author does not support the Sawkin's hypothesis which has been attacked by others also.

METHOD OF ANALYSIS

The ranking method was used for the purpose of analysis of the data. All the data were ranked. Production of lead was chosen as the base criterion for determining which variables should be used to delineate favourable areas and Spearman's co-efficient of correlation was chosen as a measure of association applicable to the ranked data. The production of lead was divided into five ranks. Similarly all the geologic factors data that could have influenced the deposition of ore were also divided into five factor levels. The highest percentage number under a factor level was given rank 1. Spearman's coefficient of correlation was used for the calculation.

* The factors which were considered to have possibly influenced the ore deposits and might have direct or indirect relationship with mineralization were :

i) The presence of igneous intrusion beneath Northern Peninne's Alston Field and a postulated one beneath the Askrig field Bouguer anomaly gravimatric maps were used for the study of this factor.

ii) Magnetic anomalies caused by the variable magnetic behavior of the rocks.

iii) Altitude of the principal host limestone. The Great limestone which has the bulk of the deposits in it.

iv) The structural features, which include the Stublick and the Pennine faults.

v) Trace element content in galena.

In addition to the above factors the other information included the estimates of total production of lead, geology of the deposits and the origin of the deposits.

Some workers have suggested relationship of granite with mineralization by assuming that mineralization might have been more directly associated with a later granite at a deeper level. However, this seems inprobable without any orogenic movement between the early intrusion and the later intrusion.

The statistical analysis has also suggested that there is a significant correlation between the altitude of the great limestone where there is main concentration of deposits and the mineralization (table – 1) that is, the altitude of great limestone has played an important role in mineralization.

The author also carried out the trace element analysis for silver, copper and antimony in the galena samples collected from underground veins of the ore field. The results showed marked regional and local variation in their content and these results were treated statistically to infer some results. From the trace element analysis and the statistical treatment of these results (mean, variance, standard deviation and coefficient of correlation Table 2–4) it was inferred that :

i) Sedimentary rocks could be the source of both the ore deposits and the trace elements since it is a well established fact that shales contain appreciable amounts (0.12 ppm) of all chalcophile elements. The amount of silver present in galena is quite high and granites contain only 0.05 ppm silver, this again supports that the source of ore and trace elements is sedimentary and not magmatic where the connate waters after getting heated at greater depths may have leached the elements from the sedimentary rocks and may be considered possible mineralizing fluids.

ii) Local variation in the content of trace elements within the same crystal is probably due to crystal structure and physiochemical properties of the ore solutions and suggest that there has been more than one phase of mineralization.

CONCLUSIONS

The data available at hand are insufficient to solve the genesis problem and more work is needed on the analysis of fluid inclusions and isotopes. Analysis of formation waters in relation to successive stages of diagenesis especially of the enclosing sediments, is also required:

i) Source of metals for the Pennine ore field is conceived to be sedimentary and metals have been leached by the heated connate waters.

ii) Mineralization has taken place in more than one phase.

REFERENCES

Dunham, K.C. (1934). The genesis of Northern Pennine ore deposits. Quarst. *Jour. Geol. Soc.* 90, pp 689–716

——— (1964). Neptunist concept in ore genesis *Econ. Geol.* 59, pp 1–25.

Dunham, K.C., (1959–60). Epigenetic mineralization in Yorkshire. *Proc. York. Geol. Soc.* 32, pp 1–25.

Sawkins, F. J., (1066). The genesis of North Pennine Ore field in the height of fluid inclusion studies. *Econ. Geol* 61 pp 385–401.

Dunham, K. C., (1966). Pole Juvenile solutions, connate waters. and evaportic brines in the genesis of lead-zinc-barium fluorine deposits. *Trans. Inetu. Min. and Metall.* 75, B-226 B-229.

Tooms, J. S., (1970). Review of knowledge of metallifarous brins and related deposits. Transn. *Instu. Min & Metall.* 79, B–107 – B–115.

Davidson, C. F., (1966). some genetic relationship between ore deposits and evaporites. *Trans. Instu. Min & Metall.* 75, B–216, B–225.

Bozdar L.B., (1973). A Statistical study of Factors Affecting the distribution of Lead Deposits in the North Pennine Ore Field. Ph. D. Thesis (unpublished) Department of Mining and Mineral Sciences University of Leeds U.K.

Table - 1

Spearman's Coefficient of Rank Correlation for factor levels that were analysed 91.00 and 0.9 indicate significant concordance)

FACTORS	LEVELS 1	2	3	4	5
Gravity Gradient Value.	0.2	0.0	–	–	–
Gravity Mean Value	0.6	0.7 0.4	–0.7	–	–
Magnetic Gradient Value.	0.6	0.3	0.5	1	0.6
Magnetic Mean Value	0.7	0.9	–	–	–
Great Limestone Structure Contour Gradient Value	0.7	0.9	–	–	–
Great Limestone Structure Mean Value	–0.9	+1.0	–1.0	–	–
Distance from Pennine Fault	–0.1	0.9	0.3	0.1	–0.7 –0.5
Distance from Stublick Fault.	0.6	–0.2	–0.2	–0.0 –0.9	

Table - 2

Arithmatic Mean and Variance (2)

Vein Sampled	TRACE ELEMENTS: ANTIMONY		COPPER		SILVER	
	Mean	Variance	Mean	Variance	Mean	Variance
Waterhole	1260.08	247791	12.0	175.94	90.64	3277
Red	1776.46	1897670	11.49	103.89	1173.46	564327
Blackdene	1102.4	657988	4.80	16.8	187.0	3757
Slitt	1214.4	354484	3.60	3.17	449.0	67130

Table - 3

Mean, Variance and standard deviation (STD) of log values

Veins Sampled	TRACE ELEMENTS								
	ANTIMONY			COPPER			SILVER		
	Mean	Variance	STD	Mean	Variance	STD	Mean	Variance	STD
Waterhole	3.046	0.033	0.183	0.958	0.090	0.301	1.878	0.068	0.261
Red	3.095	0.161	0.401	0.946	0.89	0.298	0.977	0.087	0.295
Blackdene	2.954	0.078	0.279	0.595	0.078	0.280	2.250	0.020	0.142
Slitt	3.013	0.080	0.283	0.503	0.046	0.215	2.573	0.076	0.277

Table - 4

Coefficient of Correlation

Sample Area	TRACE ELEMENTS					
	Ag/Sb		Gu/Sb		Ag/Cu	
	Coeff	Std. error	Coeff	Std error	Coeff	Std. error
Waterhole vein	0.672	0.134	0.284	0.173	0.095	0.296
Red vein	0.722	0.274	0.729	0.257	0.640	0.226
Blackdene vein	0.078	0.271	0.204	0.267	0.300	0.260
Slitt vein	0.696	0.198	0.084	0.276	0.30	0.210

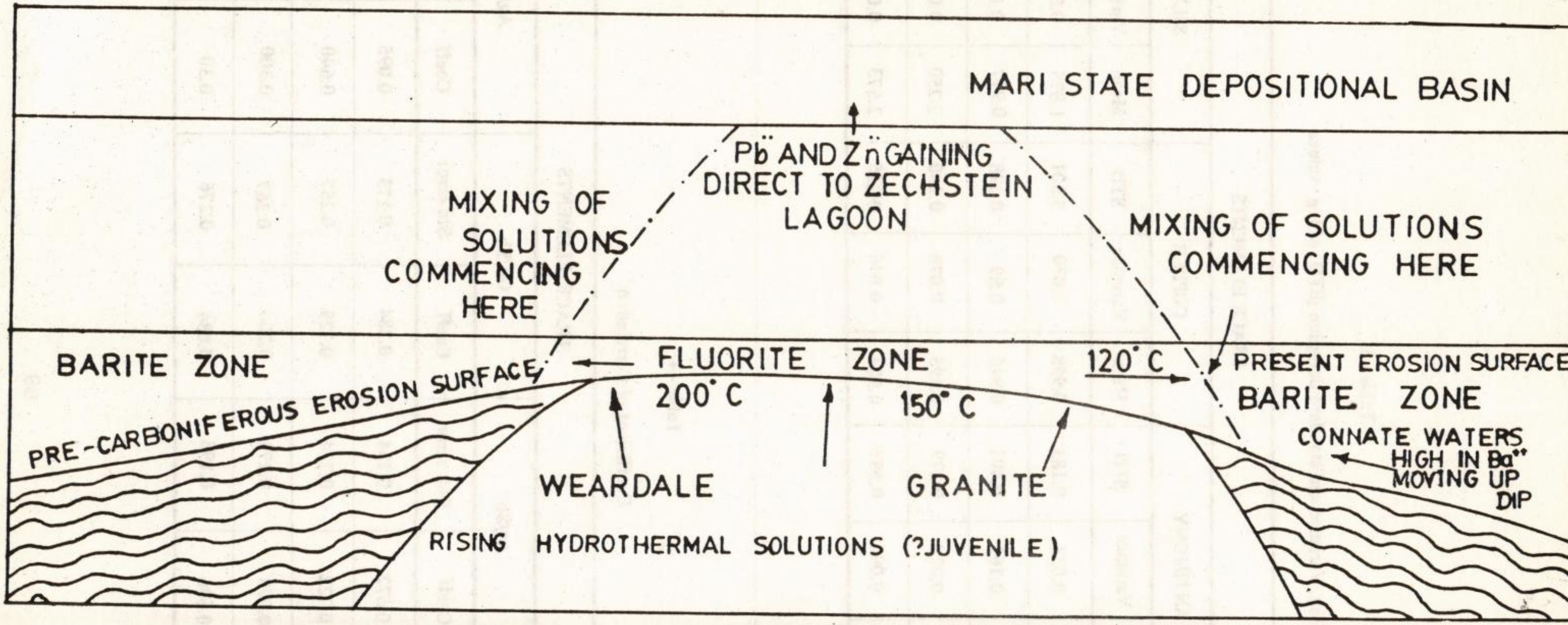


FIGURE 1 ILLUSTRATION OF MIXING HYPOTHESIS
VERTICAL EXAGGERATION ×10 (AFTER SAWKINS 1966)

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

A STUDY OF LEI CONGLOMERATES, RAWALPINDI, PAKISTAN

BY

AZAM ALI KHAWAJA[1]

ANIS AHMAD ABBASI[2]

ABSTRACT.– The Pleistocene Lei Conglomerate is a monogenetic conglomerate. It is clast-supported with equant, oblate and prolate shapes. Uplift of the Eocene Margala Hill Limestone followed by erosion and transportation by fluival-glacial streams to a distance of about 20 kms, resulted in the accumulation of these conglomerates mostly as channel lag gravels.

INTRODUCTION

The Terrace I corresponding to the second interglacial of the Terra and Paterson (1939) is now referred to as the Lei conglomerate following Gill (1952) and is in the process of being formalized as a formation name by the Stratigraphic Committee of Pakistan (e.g. Iqbal and Shah, 1980). For other assigned names of the Lei Conglomerate, see Shah, 1977.

Excellent exposures of this Pleistocene conglomerate occur in the Soan valley especially near the Lei *Nullah* around the Fauji Foundation Hospital, Rawalpindi. This study presents additional data to that already existing in order to provide a better understanding of the Lei conglomerate.

RESULTS AND DISCUSSIONS

The Lei conglomerate forms vertical cliff like exposures in areas eroded by the Soan river. It is either exposed at the surface or covered by less than 10 m thick deposits of dominantly unstratified silt-size material. At places, the silt material is observed to have filled the erosional depressions made in the conglomerate. Palaeosols particularly in the upper half of the formation is a characteristic feature of this formation.

At the type locality the framework is clast supported, the clasts ranging in size from smooth and polished boulders to pebbles. They are prominantly composed of micritic limestones and thus are oligomict conglomerates or monogenetic conglomerates following the terminology of Hatch and Rastall (1973 p. 76). Some gravels have been brecciated and healed with vein calcite. Fig. 1 shows the grain size distribution of 10 matrix samples from the type area. As can be seen, the matrix consists dominantly of sand followed by silt. A notable feature is the absence of clay-size particles from the matrix. Data based on 117 gravels indicate that all gradations from well-rounded to subangular exist, but dominantly the clasts are rounded to subrounded. Following Zingg (1935), based on the d_I/d_L and d_s/d_I ratios (Fig. 2), the main shapes are equant (equiaxial or spherical) followed by oblate (tabular) and prolate. The same samples plotted in Fig. 3 on a sphericity-form diagram for particle shapes (after Sneed and Folk, 1958) show the maximum projection sphericity of each gravel.

Lithologically the gravels of the Lei Conglomerate resemble the Eocene Margala Hill Limestone which acted as a source for the conglomerates. Numerous examples of oligomict conglomerates exist in the rock record. They represent unusual conditions of accumulation which allowed the erosion of limestone as gravels rather than its removal by solution. Mostly they are considered to have accumulated on the down-thrown side of an intermittently active fault where the up-thrown side contains limestones (Friedman and Sanders, 1978; p; 192). Such a situation existed at the time of Lei Conglomerate deposition. This is indicated by the presence of the Main Boundary Thrust (Hazara fault of Seeber and Armbruster, 1979) between

1. Department of Earth Sciences, Quaid-e-Azam University, Islamabad, Pakistan.
2. Geography Department, University of the Punjab, New Campus, Lahore, Pakistan.

the older and Eocene Margala Hill Limestone and the younger formations to the north-west of the Lei Conglomerate type area.

The Margala Hill Limestone (source of the conglomerate) is present on the upthrown side of the fault. Preliminary magnetic polarity dating indicates the timing of Lei Conglomerate accumulation to be between 0.7–0.5 million years (Randell, 1980). Presence of palaeosols within the stratigraphic succession indicates that transportation and deposition of the clasts was not continous. These factors lead to the inference that uplift and high relief of the limestone (necessary for the conglomerate accumulation) was being provided by the fault intermittantly, at least during the time period specified above.

Krumbein (1941) has shown that the limestone fragments become well rounded at about the equivalent of 11.2 Km of travels. Field studies of Plumley (1948) from two areas in South Dakota (U.S.A.) confirm these estimates He concluded that limestone pebbles become rounded at about a distance of 17.7 Km to 37 Km. The type section of Lei conglomerate is at a distance of 19.2 Km (12 miles) from the source, thus indicating a similar transport distance for the gravels.

Cailleux (1952) calculated the degree of flatness of carbonate gravels from various environments. Fig. 4 shows, the degree of flatness of gravels from the present study and their environment of deposition. As can be seen from Figure 4, the gravels reflect three environments, the major one being as channel lag gravels. More work regarding the detailed environmental interpretation of the Lei Conglomerate is in progress. It seems likely that alluvial fans on fluvioglacial stream followed by coalescing of these fans to form piedmont deposits were largely responsible for the accumulation of these conglomerates. Possibly, channel filling by the gravels forced the flow to divert and thus cause brading of the streams.

REFERENCES

Cailleux, A., (1952) Morphoscopische Analyse der Geschiebe und Sankorner und ihre Bedeutung fur die Palaoklimatologie, Geol. Rundschau, Vol. 40, p. 11–19.

De Terra, H. and Patterson, T. T., (1939) Studies on the Ice Age in India. *Carnegie Institute, Pub*. 493.

Friedman, G. M. and Sanders, J.E., (1978). Principles of Sedimentology. John Wiley, N. Y. p. 792.

Gill, W. D., (1952). The stratigraphy of Siwalik series in the Northern Potwar, Punjab. *Geol. Soc. London, Quart. Jour.*, Vol. 107, p. 375–394.

Hatch, F. H., Rastall, R. H. and Greensmith, J. T., (1973). Petrology of the Sedimentary Rocks. Thomas Murby and Co. p. 503.

Iqbal, M. W. A. and Shah, S. M. I., (1980). A guide to the stratigraphy of Pakistan. *Rec. Geol. Sur. Pakistan,* Vol. 53, p. 1–34.

Krumbein, W. C., (1941). Measurement and geologic significance of shape and roundness of sedimentary particles. *Jour. Sed. Petrology.* Vol. 11. p. 64–72.

Plumley, W. J., (1948). Black Hills terrace gravels, a study on sedimentary transport. *Jour. Geology,* Vol. 56. p. 526–577.

Randell, H. M., (1980) New perspectives on the Pleistocene and Holocene sequences of the Potwar plateau and adjacent areas of northern Pakistan. Paper read at Int. Conf. Recent Tech. Advances in Earth Sciences, Qaide Azam Univ., Islamabad.

Seeber, L. and Armbruster, J., (1979). Seismicity of the Hazara Arc in Northern Pakistan, decollement VS. basement faulting. In Geodynamics of Pakistan. Farah and De Jong (Eds). *Geol. Surv. Pakistan,* p. 131–142.

Shah, S. M. I., (1977). (Ed). Stratigraphy of Pakistan. *Mem. Geol. Surv. Pakistan,* Vol., 12.

Sneed, E. D. and Folk, R. L., (1958). Pebbles in the lower Colorado River, Texas, a study in particle morphogenesis. *Jour. Geology,* Vol. 66, p. 114–150.

Zingg, Th., (1935). Beitrage zur Schotteranalyse, *Schweizerische Mineralogische u. Petrographische Mitt.,* Vol. *15 p. 39–140.*

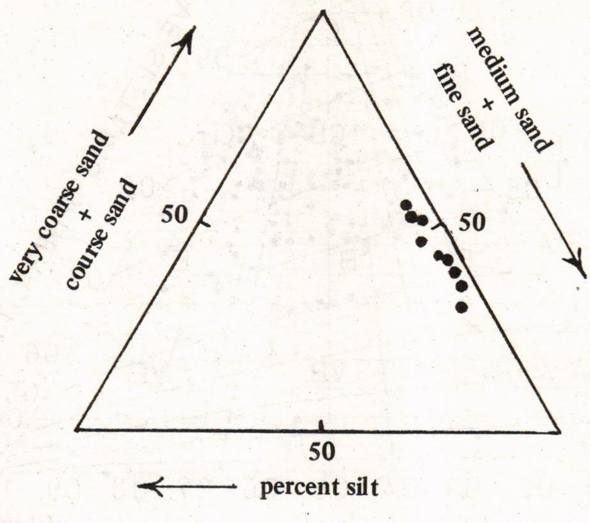


Fig. 1. Distribution of matrix constituents of the Lei conglomerates.

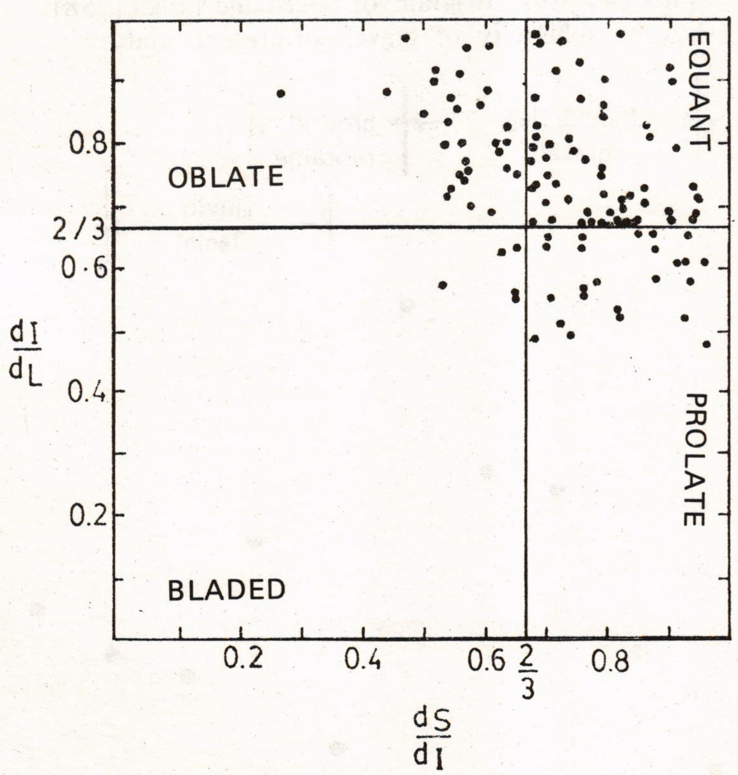


Fig. 2 : Zingg diagram showing gravel shapes

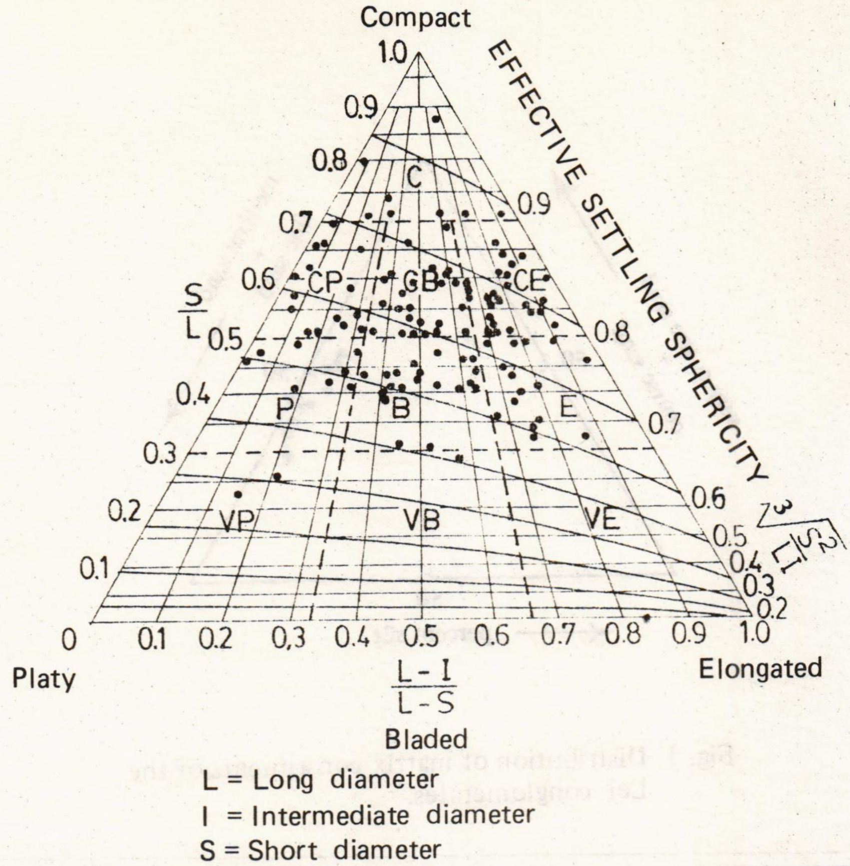


Fig. 3: Sphericity form diagram of sneed and Folk (1958) showing sphericity of gravels of present study.

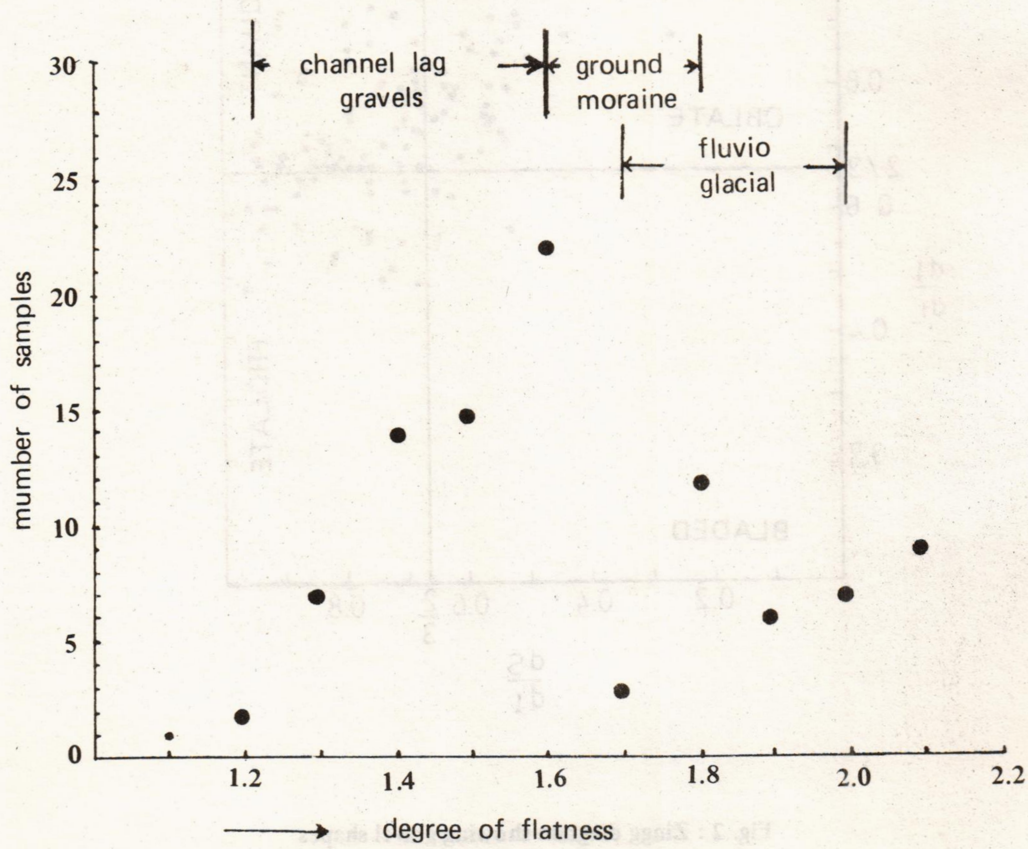


Fig. 4: Distribution of the degree of flatness in relation to the gravels interpreted environment of deposition.

GEOLOGIC SUMMARY OF THE IRON SPRINGS DISTRICT, MOFFAT COUNTY COLORADO, U.S.A.

BY

ROBERT H. CARPENTER[1]

INTRODUCTION

Disseminated gold, silver and heavy minerals in black sands occur in approximately 1,000 feet of sandstone, siltstone, mudstone and shale. They are included in the Upper Wasatch formation in an area some forty miles on a side between the Yampa and little Snake river valleys northwest of Craig, Colorado. Locally, gold and heavy minerals concentration may have economic potential.

REGIONAL GEOLOGY

These sedimentary beds were deposited some 55 million years ago in broad river valleys, along lake shores and deltas. This material was eroded from the Pre-Cambrian granitic core of north-south trending Park Range located some 50 miles east of this mineralized area.

LOCAL GEOLOGY

Where exposed in stream banks and mining excavations these sediments consist of river channel and beach sands with a few pebble lenses and of river flood plain silts, muds and shales. They interfinger laterally illustrating the shifting courses of the ancient rivers. At some time after they were deposited, they were folded into a shallow syncline which plinges gently to the north-west.

Most of the sandstones have a fine, silty matrix which fills in around the sand grains. The fine grained gold and silver occur in this matrix and in the silts, muds, and shales as well. Studies of the occurrence of gold and silver in various size fractions indicate that almost all of the gold and silver particles in the interval of less than 40 mesh (40 openings to the square inch in a screen) to larger than 350 mesh. The gold occurs largely as micron size "flakes" in this fine material. Under the microscope at 8,000 times magnification these flakes consist of clusters of intergrown gold crystals which could not have been transported very far.

The heavy mineral constituents in the "black sand" fraction of the sediments include the potentially valuable mineral monazite with its included rare earth oxides, rutile which contains a high percentage of titanium and zircon, a zirconium oxide. These and other "heavy" minerals occur in all of the sediments from the coarser sands to the very fine grained shales.

ORIGIN OF GOLD AND HEAVY MINERALS

The origin of gold and silver is yet to be determined but there are two favored theories. The first is that the gold was eroded from the core of the Park Range and carried westwards by the rivers to the Iron Springs area and deposited with sands, silts, muds and shales. They may have been transported as metal ions and colloids in the river waters, or within organic trash or clay particles and subsequently precipitated in the sediments as very small, free gold "flakes".

The second theory envisions hydrothermal (hot) waters as playing a major role in the distribution of gold and silver in the sediments. Some million years ago a very extensive volcanic center formed just east of the Iron Springs area. The volcano itself has been eroded, but the root zone is exposed in the Black Mountains. Within the Black Mountains is an extensive area where very hot waters have converted the volcanic rocks to clays and other alteration products.

Usually the lavas in these volcanic centers are fed by

1. Professor Emritus, Geology, Colorado, School of Mines, Golden, Colo. USA.

an extensive magma chamber, several miles beneath the surface. Such a chamber may have outwards to the west beneath the Iron Springs and caused waters in the overlying, mineralized Upper Wasatch sediments to be heated, and to have been circulated by thermal convection both vertically and horizontally throughout the sands, silts, and even the shales, causing widespread disperson of gold and silver. There may have been some introduction of gold and silver by hydro-thermal fluids (hot waters and gases) from the magma chamber as well.

The heavy minerals or black sands can be considered as durable, clastic debris eroded from the core of Park Range and deposited in the sands, silts, muds and shales. Monazite, Rutile and Zircon are found in all four types of sediments. Uranium also is associated with the precious and heavy minerals.

PROSPECTS AND DEVELOPMENT OF PHOSPHATE DEPOSITS OF LAGARBAN AREA ABBOTABAD, PAKISTAN

BY

MOHAMMAD ASHRAF[1] M. I. MALIK[2]

ABSTRACT.– Sedimentary Phosphorite of Lagarban is 7.831 million tonnes as in-situ rock and is 5.039 million tonnes recoverable reserves from East, Batkanala, Southern and Lagarban South Phosphorite. 840 tonnes can be mined per day. The undiluted ore contain 28.55 to 30.20% P_2O_5 *in the four orebodies. Mineralogically the ore consists of collophane with minor dahllite as phosphorite minerals. The other ubiqutous to accessory minerals are dolomite, chalcedony, chert, quartz, goethite, pyrite, chlorite, clay, mica, organic matter etc. It is found that variation in grade and the proportion of impurities is a function of original sedimentary variations, and the amount and nature of contamination and dilution during and after the deformation are by physical & chemical mechanisms. The benefication of the ore is possible by HIMS and acid leaching methods but the proposition appears expensive. However, ROM blending with Jordan ore may be viable after some more plant trials and tests.*

INTRODUCTION

Phosphorite of Lagarban area occurs in the upper Sirban Formation of Cambrian age (Latif, 1974). The phosphorite is sedimentary in origin and is associated with dolomite, siltstone and red beds. The phosphorite is considered to have been deposited as a single horizon with Sirban Formation. Subsequent repetition of and breaking up of the phosphorite is the result of the Himalayan orogeny (Coward et al, 1982). The repetition of orebodies has been identified as follows :–

1. **Eastern Phosphorite.**
2. **Lagarban South Phosphorite.**
3. **Batkanala Phosphorite.**
4. **Southern Phosphorite.**

These orebodies strike north to south and dip steeply to the east. The strike and dip are variable, as in the thickness, grade and nature of the impurities contaminating the phosphorites. In many areas, the orebodies are disrupted by normal or imbricate faults.

The estimation of in-situ reserves made as measured and indicated for four orebodies are as follows :–

(i) Eastern Phosphorite	**1,166,000(M)**	**1,637,000(I)**
(ii) Lagarban South Phosphorite	**1,496,000(M)**	**697,000(I)**
(iii) Batkanala Phosphorite	**492,000(M)**	**886,000(I)**
(iv) Southern Phosphorite	**1,042,000(M)**	**415,000(I)**

1. Institute of Applied Geology, The University of Azad Jammu and Kashmir Muzaffarabad (Azad Kashmir).
2. Sarhad Development Authority Ltd., Peshawar, N.W.F. Province, Pakistan.

Previous work in area is that of Latif (1972–74) United Mines Ltd (1973), PD, NCB (1977), Ghaznavi and Karim (1978), Hasan and Ghaznavi (1980), BMCL (1982) and Ishaque (1983) and Ali (1973).

CHEMISTRY AND MINEROLOGY

Chemical assaying of the four orebodies was extensively carried out taking into consideration variation of each zone of each intersection. Each zone was particularly assayed for P_2O_5, CaO, I/L and specific gravity. Considering cut off grade as 22% P_2O_5 – the ore-reserve sections were assayed for P_2O_5, CaO, MgO, Fe_2O_3, Al_2O_3, CO_2, Organic matter, moisture, acid insolubles, ignition loss and specific gravity.

Based on data available, the weighted average P_2O_5 content and the range of assayed grades in each of the four main orebodies, are as follows :–

	% P_2O_5 average (Measured ore)	% P_2O_5 assayed grade Range
1. Eastern Phosphorite	29.36	23–33
2. Lagarban South Phosphorite	28.55	23–34
3. Batkanala Phosphorite	30.20	25–33
4. Southern Phosphorite	29.57	25–33

The major impurities from the point of view of mining and beneficiation are magnesium, aluminium and iron expressed as MgO and R_2O_3 (Al_2O_3 and Fe_2O_3).

The weighted average % MgO and % R_2O_3 content and the range of assayed percentages by block in each of the four main orebodies are as follows :–

	% MgO		% R_2O_3	
	Weighted average	Assayed Grade Range	Weighted average	Assayed Grade Range
Eastern Phosphorite	0.26	0.2–2.3	3.47	1.5–6.4
Legarban South Phosphorite	2.20	0.2–3.9	3.67	1.7–5.9
Batkanala Phosphorite	3.80	1.5–7.7	2.18	0.9–2.5
Southern Phosphorite	2.54	0.2–5.5	2.82	1.5–4.6

MINERALOGY.

Variation in grade and the proportion of impurities is a function of two factors :–

(i) Original sedimentary variations related to the proportion of phosphatic minerals to other sedimentary components and to the nature of those components.

(ii) The amount and nature of contamination and dilution during and after the deformation by physical and chemical mechanisms.

i) Sedimentary Variations.– The prominent phosphate mineral in the rock is collaphane with a minor proportion of dahllite as an alteration product. The other minerals in the rock can be considered in two groups :–

(a) minerals deposited primarily by solution of which dolomite, chalcedony, chert, opal and phosphates are the major components.

(b) Clastic minerals of which quartz, chert, mica, goethite, chlorite, pyrite, clay, organic matter and other accessory minerals are the main components.

The Major source of MgO in the rock is dolomite with minor amounts originating from the clastic components. The major source of Al_2O_3 is from the clay minerals and the Fe_2O_3 is primarily from goethite, with minor amounts from the chlorite, pyrite and other accessory minerals.

The proportion of clastic materials increases northwards from Lagarban South Phosphorite towards Lagarban North Phosphorite, the phosphorite grade is significantly reduced by dilution, primarily by siltstone and has a high R_2O_3 value.

The upper dolomite (overlain by phosphorite) is thin or absent in the Eastern Phosphorite. The absence of this gradational contact from phosphorite to dolomite has meant that contamination of the ore by dolomite is less than in other areas. The MgO content is therefore low. However, there is a gradation from phosphorite to silty sandstone and siltstone. The Eastern Phosphorite, therefore, has a larger clastic component and contains high proportion of silty sandstone and volcanic material, consequently, the Eastern Phosphorite has a high R_2O_3 value.

ii) Variations Due to Deformation.– There are two major process responsible for variations due to deformation :–

(a) In areas where considerable shearing has taken place, physical mixing of the phosphorite with the hanging wall and footwall rocks often took place. This is particularly noticeable where the phosphorite is sandwiched between two dolomite layers, as physical break up admixing can be considerable on shear planes within and close to the weaker phosphorite.

(b) Migration of materials by chemical means was also a function of the intensity of deformation. Considerable recrystallization of chert and dolomite material took place in shear zones. The dolomite and chert occur as veinlets, criss-crossing fractured rocks, as cement for breccias or rarely, as major veins.

At the Southern end (Tarnawai area) considerable shearing has taken place in Batkanla , Southern and Eastern dolomite has resulted in lower grades due to dilution and higher MgO percentages due to the increased dolomite in the orebody. This process is mostly clearly shown by the high MgO values in samples taken from the Southern end of the Eastern Phosphorite which show MgO values between 1 and 2.3% whereas elsewhere in the Eastern Phosphorite, where samples have been taken, MgO is generally less than 1%.

The chemistry of the Lagarban South Phosphorite and the major part of the Eastern Phosphorite is not significantly affected by deformation.

iii) Dilution.– In undeformed areas significant dilution from the hanging wall dolomite is not a consideration as the contact is well defined and the dolomite is generally hard and competent. The footwall contact is gradational to dolomite or siltstone or silty sandstone and difficulties may arise in identifying the grade cut off point during mining operations. Dilution material from the footwall may average upto 15% P_2O_5, but it is also likely to be high in impurities, predominantly MgO.

In sheared areas, especially in the southern part of the area avoiding excessive dilution may prove difficult. Rapid variations in thickness are normal and loose and broken rock may be present on both the hanging wall and the footwall. Often the "C" zone rocks are not present and the grade cut off is, therefore, sharp on both sides of the band.

SIZE OF MINE.

The chemical and physical properties of the orebodies are not constant and there is considerable variation in grade, thickness and inclination between the main orebodies. If a homogenous run of mine (ROM) product is to be used directly as a fertilizer plant feedstock or sent to the beneficiation plant for processing, careful scheduling of the mining areas to be worked is required.

The workable ore contained in the measured and indicated categories amount to 7.831 million tonnes. At the present estimate 75% of indicated ore has been included with measured reserves. Thus reducing the insitu reserves to 6.922 million tonnes and with a recoverable mining factor of 65% the reserves will be available upto 4.499 million tonnes. Dilution which is expected to be 12% will give total recoverable reserves upto 5.039 million tonnes. The life of the mine has been provisionally fixed at approximately 20 years to provide a reasonable period in which to write off major items of capital investment.

With this mine life figure, the projected annual ROM production rate will be 252,000 tonnes and assuming the mine will operate 300 days per day, an average daily production of 840 tonnes is envisaged. It is proposed to operate the mine two shifts per day, six days per week. A third shift could be introduced to increase production without any significant increase in capital expenditure if required.

BENEFICIATION

The objectives of beneficiation were to assess the need for different techniques to produce a feedstock for use in the manufacture of phosphatic fertilizers. The problem was the removal of nuisance impurities rather than upgrading the percentage of P_2O_5 content and in defining and appropriate quality objective for beneficiation studies, the following criteria were followed :–

(i) MgO – maximum 1% preferably less than 0.7%.

(ii) R_2O_3 (Re_2O_3 + Al_2O_3) – maximum 3% preferably less than 2%.

Initial beneficiation studies showed that of the many techniques available for the reduction of each impurities dry, high intensity magnetic separation (HIMS) and acid leaching gave the best results.

Dry, HIMS treatment on the Lagarban south ore provide very effective in removing the Fe_2O_3 and MgO impurities and optimum conditions corresponding to an operation in which the composite product, after HIMS treatment assayed in the order of 28.1% P_2O_5, 1.63%

Fe_2O_3 and 2.42% MgO.

Acid leaching provide effective in reducing the MgO contained in either HIMS treated feedstocks or ROM ore samples. Both nitric and sulphuric acid produced satisfactory results; and the use of nitric acid, by leaching out both the CaO and the MgO constituents of the dolomite, would effect a significant increase in grade. Indeed when using nitric acid, products assaying 31% P_2O_5 or higher, with MgO levels well below 1% were readily obtainable.

FULL SCALE PROCESS

Process scheme for the complete beneficiation of Lagarban south-type ROM ore was developed as :–

(i) Two stage crushing of the ROM ore to approximately – 12 mm.

(ii) Dry grinding to produce – 1.2 to 0.5 mm and –0.5 mm product fractions.

(iii) De-dusting and thereafter classifying into three preferred coarse size fractions of + 0.05 to –0.15 mm; + 0.15 to –0.5 mm and 0.5 to – 1.2 mm.

(iv) Dry, HIMS of the three separate fractions.

(v) Acid leaching of the three HIMS fractions.

In the case of nitric acid being used for the leaching operation, a beneficate assaying 31% P_2O_5, 1.8% Fe_2O_3, 0.9% Al_2O_3 and 0.7% MgO would be expedited at an overall P_2O_5 recovery level of 75%.

The sulphuric acid route, on the other hand would produce an apparent poorer quality product owing to the levels of residual gypsum. Nevertheless, a composite product assaying 29% P_2O_5, 1.7% Fe_2O_3, 0.8% Al_2O_3 and 0.7% MgO should be expected, which is still useable as a feedstock for the manufacture of phosphoric acid.

In appraising the technical and economic feasibility of the Hazara Phosphate Project, three basic development operations are considered by BMC (1982) :–

(i) Full benefication of the ROM ores employing both dry, HIMS and sulphuric acid leaching (option Al), or nitric acid leaching (option A2).

(ii) Partial benefication of the ROM ores employing sulphuric acid leaching (option B1), or nitric acid leaching (option B2) to reduce the MgO content, and then blending the leached ore with imported ore to reduce, by dilution, the remaining Fe_2O_3 percentage content.

(iii) Straightforward blending of ROM ores with imported phosphate rock (optionC) to reduce both Fe_2O_3 and MgO impurities to below their defined respective limits of acceptability.

The Capital and Operating costs for each of the Options considered are :–

	Option	Capital/ Cost Million (Rs.)	Production '000 tons.	Annual Operating cost Million (Rs.)	Cost/ tonne (Rs.)
Full Benefication	A1	133.5	139	24.2	174.1
	A2	131.4	125	23.8	190.4
Partial Benefication	A1	86.4	166	27.3	164.5
	B2	84.4	148	26.9	181.8
ROM Blending	C	52.9	196	4.4	22.4

Option A1 and A2 would require the highest capital investment and yield the lowest quantity of useable phosphate. It is, therefore, unlikely to give the best rate of return.

Option C although low in capital cost would require large and continuous expenditure of foreign exchange.

Option B1 and B2 would appear to be the most favourable.

FERTILIZER PRODUCTION

The potential use of Lagarban ores for making Single Super Phosphate (SSP) either alone or in a combination with imported Jordanian Phosphate is under consideration of Warren Spring Laboratories, England and NFC, Faisalabad.

The suitability has been assessed on the basis of two main criteria, namely; handleability of the product, and the proportion of the contained phosphorous that can be converted to a water soluable form.

The Eastern phosphorite rock can be processed for SSP manufacture. The physical state of the product is alright. 17.9% P_2O_5 is available on dry basis and 16.23%

on wet basis (at 10% moisture). Water soluable P_2O_5 is however 15.42% and 14.69% respectively. Thus low availability on plant trials is due to 10% unreacted phosphatic rock in the final product. The slurry was processable satisfactorily. Inspite of the unreacted rock the SSP product is satisfactorily porous (and dry after normal curing).

The phosphorite of Batanala and Southern being poor in P_2O_5 (26.4% and 25.6% respectively) and high in MgO, gave rise foaming in mixer and as a result does not get enough acid for reaction thus reducing the P_2O_5 availability. The product was wet even after long curing. similarly R_2O_3 will disperse the P_2O_5 availability and product of unsatisfactory physical form.

The Jordan rock was blended with East, Batkanala and Southern Phosphorite in ratio 1:2, 1:1 the result produced are marginal on plant trial. Recently Americans have developed a chemical (Oral Communication, Dr. Bignall) which if added can accelerate the availability of P_2O_5 as required.

However, work is in hand to use the rock successfully, employing various combinations etc.

REFERENCES

Ali, S.T., (1974). Phosphate deposits of Pakistan. In : Symposium on utilization on natural resources in Pakistan for self reliance. *West Pak. Engg. Congress Lahore,* VR. 14, p - 81 -- 106.

Coward, M.P., Jan, M. Q., Rex, D. and Windley, B.F. (1982). Structural Evolution of a crustal section in the Western Himalaya. *Nature* Vol. 295 No. 5844.

Ghaznavi, M.I., and Karim. T.,(1978).Phosphorite deposits of Kaludi Bandi and Lagarban area, Distt. Hazara, NWFP *G.S.P. Inf. Release* No. 103.

Hasan, M.T. and Ghaznavi, M.I.,(1980).Phosphate deposits of Hazara Division, NWFP. *Rec. G.S.P.,* Vol. 50.

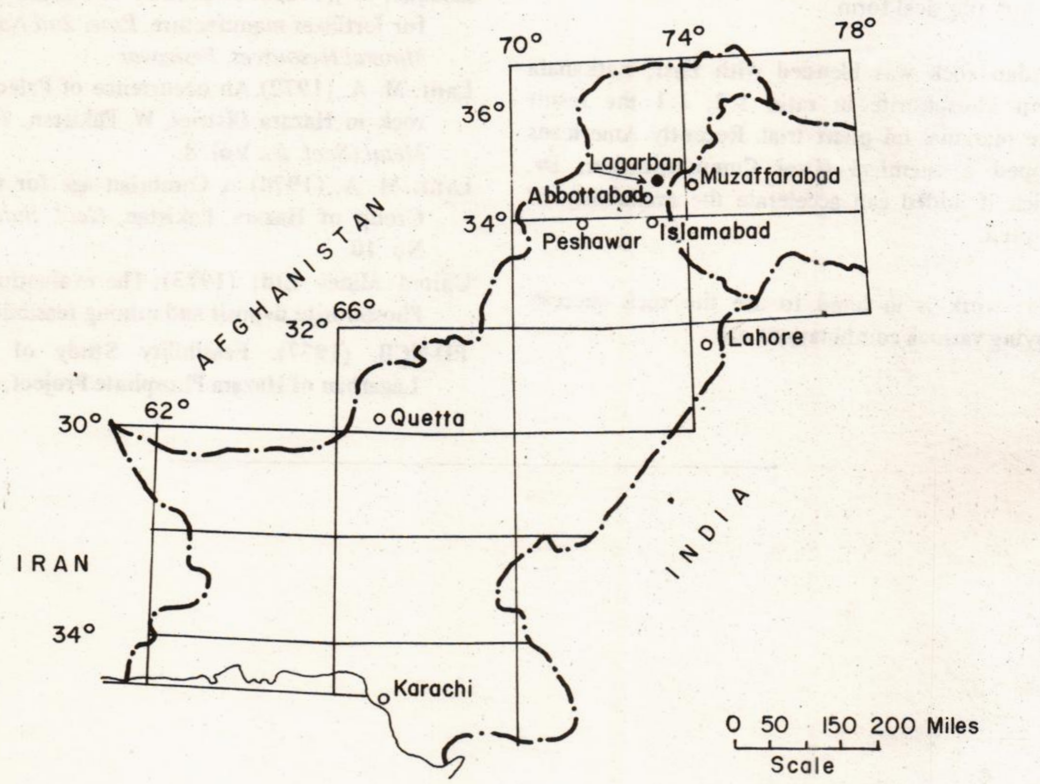
Ishaque, M.,(1983). Utilization of Hazara Phosphate Rock for fertilizer manufacture. *Proc. 2nd Nat. Seminar Dev. Mineral Resources, Peshawar.*

Latif, M. A.,(1972). An occurrence of Paleozoic Phosphate rock in Hazara District, W. Pakistan. *Trans. Inst. Min. Metal (Sect. B),* Vol. 8.

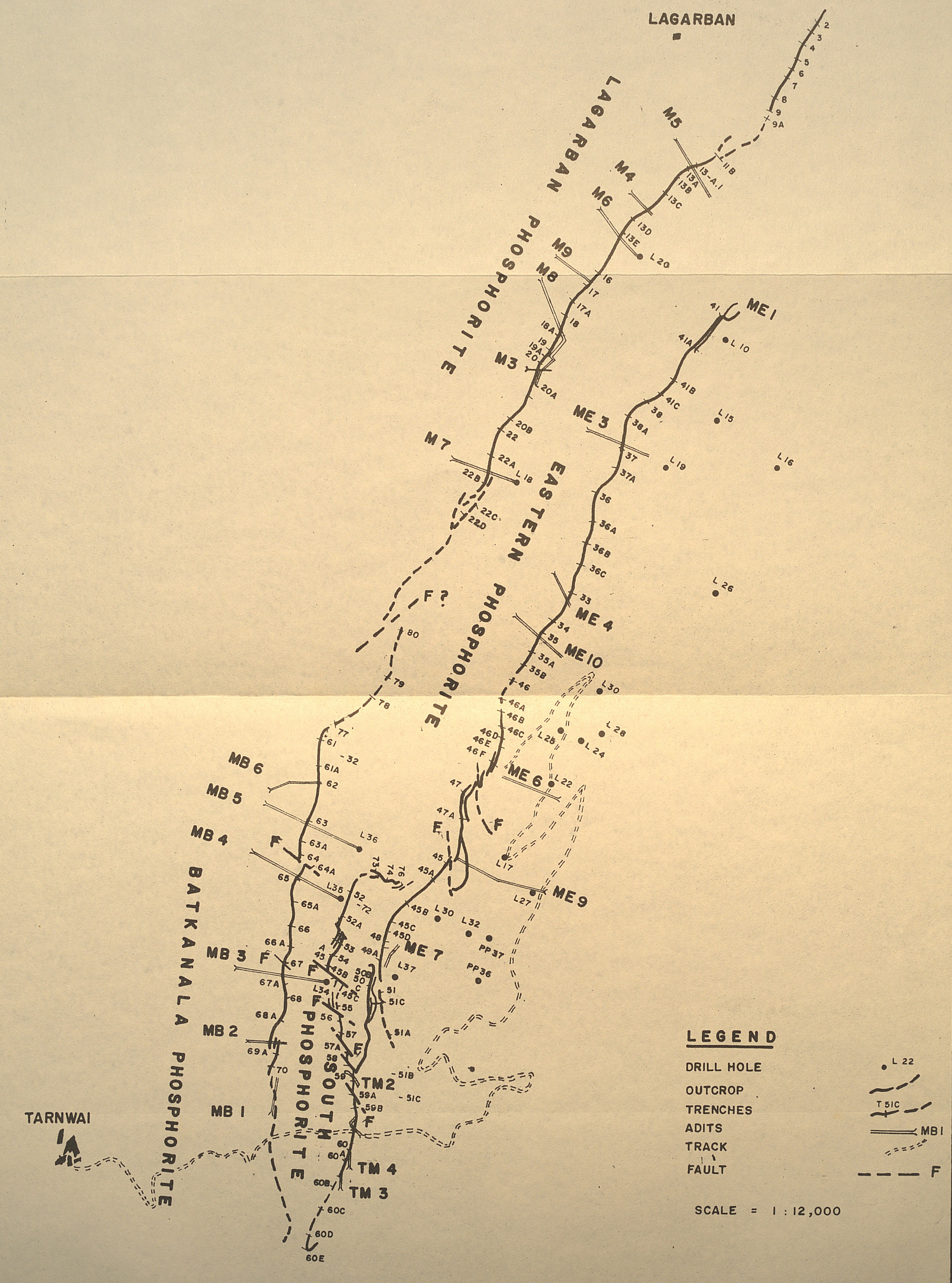
Latif, M. A.,(1974). A Cambrian age for the Abbottabad Group of Hazara, Pakistan. *Geol. Bull. Punjab Univ.* No. 10.

United Mines Ltd; (1973). The evaluation of Lagarban Phosphorite deposit and mining feasibility.

PD-NCB, (1977). Feasibility Study of Target area II Lagarban of Hazara Phosphate Project, Vol. IV.



INDEX MAP OF PAKISTAN SHOWING THE LOCATION OF PHOSPHATE DEPOSITS AREA



PHOSPHORITE OUTCROPS IN TARNWAI _ LAGARBAN AREA, PAKISTAN

"CONCAVIGLEICHENIIDITES" A NEW MIOSPORE GENUS FROM DATTA FORMATION (JURASSIC) WESTERN SALT RANGE, PAKISTAN.

By

KHAN RASS MASOOD.[1] A. A. BHUTTA.[2]

ABSTRACT.–A new trilete bearing miospore genus viz "Concavigleicheniidites" is described from the Jurassic shales (Datta Formation) of the Western Salt Range, Pakistan. Miospores are characterized by having well defined commissure bounded by dark and curved labra, ends of which bifurcate, forming sigmoid claws, ultimately merging into the torus.

INTRODUCTION

A rich assemblage of spores and pollen from the "variegated shales" near Nammal gorge was first described by Sah (1955). The samples were subsequently critically reinvestigated by Jain & Sah in (1968) and (1969), who described some additional micro & megaspores from that material which consisted of the following important Mesozoic genera viz *Todisporites, Matonisporites, Trigrisporites, Osmundacidites, Podocarpites* and *Classopollis.* In order to obtain a more comprehensive and detailed palynological information about the Datta Formation, the writers undertook a paleobotanical expedition in 1980, which mainly aimed at collecting samples from a 150 feet thick outcrop of Datta Formation near Nammal gorge.

The coordinates of sampling site are latitude 32° 39" 30" N and longitude 71° 48' E. A thick succession of Jurassic rocks encompassing Datta Formation is well developed near Nammal gorge. The lithology at the sampling locality consists of variegated (red, maroon, grey and white) sandstone, shale, siltstone and mudstone, with irregularly distributed calcareous dolomite, carbonaceous & ferruginous glasssand and fireclay horizons (fatmi, 1977). During the course of palynological analysis of the Datta Formation samples, one new miospore genus has been discovered which exhibits the presence of new combinations of morphographic characters.

MATERIAL AND METHODS

The samples were collected from the exposed surface of the rocks in the form of shales. Samples were first examined macroscopically and information regarding their morphological aspects was noted. Samples were crushed to 2mm sized pieces and treated with commercial nitric acid for complete oxidation and then with potassium hydroxide to get rid of humic acids. After this the residue was washed 4 times with distilled water, by decantation method. Completely neutralized and macerated material was stained with aquas safranine and was mounted in glycerine jelly for microscopic analysis. Slides were sealed with enamel paint and were deposited in the palynology and paleobotany museum of the Botany Departmemt. Punjab University, Lahore.

1. Atchison College, Lahore.
2. Department of Botony, University of the Punjab, Lahore.

SYSTEMATIC PALYNOLOGY

Anteturma SPORITES H. Potonie, 1893.
Turma TRILETES Reinsch emend. Dettmann, 1963
Suprasubturma Acavatitrilates Dettman 1963
Subturma AZONOTRILETES Luber enend. Dettmann, 1963
Infraturma LAEVIGATI (Bannie and Kidson) Potonie 1956

Genus CONCAVIGLEICHENIDITES gen. nov.

Type species : *Concavigleichenidites nammalensis* n.sp. Pl.I. Fig. 1, Text Fig. 1.

GENERIC DIAGNOSIS

Amb triangular to sub triangular, tetrad markings and contact area distinct, contact area represented by short plane field torus, laesurae arms gradually tapering towards the radial region, commissure guarded by dark thick labrum, extremities of which bifurcate, forming siphon like sigmoid claws, merging with the short plane field torus.

DERIVATION OF NAME : After its concave amb and Gelichenioid characters.

Convavigleicheniidites nammalensis n.s p. Pl. 1. Fig. 1, Text Fig. 1.

HYLOTYPE : Plate I, Fig. 1, Text Fig. 1.

DISTRIBUTION : Common.

DIMENSIONS : (44-specimens) Equatorial Diameter 41 (48) 62 ;u.

DIAGNOSIS :

Miospore, trilete, amb triangular, angles rounded, sides concave, anisoplar, tetrad marking and contact area distinct, arm of laesurae extended upto equator, commissure protected by well defined labrum, the extremities of labra bifurcates forming sigmoid claws, which merges with short plane field torus. Exine laevigate to intrapunctate ± 2 u thick.

DESCRIPTION.

Miospore, trilete, amb triangular, angles rounded, sides concave, polar view, anisopolar, laevigate to infrapunctate, tetrad marking and contact area distinct. Laesurae open, 18 u long, ± 4 ,u apart, open, gradually tapering towards the radial region. Lips smooth, more wide in the center than at the tips. Commissure bounded by dark and curved ± 5 ,u thick labra, ends of labra bifurcate forming sigmoid claws, which ultimately merge into the tours.

In some of the specimens the tips of open laesurae were extended to form hollow globular thickenings in the radial region.

DERIVATION OF NAME : After Nammal Gorge, Western Salt Rang.

PROBABLE AFFINITES : Gleicheniaceae.

HORIZON : Datta Formation, Western Salt Range.

SLIDE NO : P_7K-Bulk/one/C_6.

FILM NO : 19/251082/6.

DISCUSSION

Morphologically the specimen under discussion has features which are shared by the genus *Concavisporites* Pflug and *Gleicheniidites* (Ross) Delcourt and Sprument in Thomson & Pflug (1953). But the original authors have not categorically indicated the sigmoid type of configuration at the angles which is an extension of labrum. This configuration may become flute like, with its sides ultimately merging into narrow band type of torus. The presence of torus is significant for "gleichenoid" spores which occur during the late Mesozoic in a great variety of forms. These Gleichenoid spores still occur in the oldest Tertiary (cf Kremp 1968). The torus can embrace the entire exospore wall or it can be restricted to only the inner lamellae, while the outer exposore lamellae smoothly cover the swelling. These features have not yet been investigated in detail. Kremp (1968) has classified tori into seven different forms but did not mention any thing about the sigmoid type of configuration of labra ultimately merging with the torus. Kremp (1968) in Fig. No. 128 has shown pseudotori claws which are the outgrowth of the torus, where as in specimen under discussion, these claws are outgrowths of the labrum. The presence of torus is a feature shared by the genus *Concavisporites* Pflug and *Gleicheniidites* Ross . Generic assignment of the present sporomorph would be rather confusing if we try to accomodate it in the genus *Concavisporites* Pflug or *Gleicheniidites* Ross, because, the sigmoid type of labrum extermites merging with narrow band field torus is not a part of the diagnosis, given for the above mentioned genera, or any other genus known so far. For this reason a new gensus *Concavigleicheniidites* has been errected, to accomodate spores bearing well defined labrum, sigmoid extremities, ultimately merging with the torus. This genus can also be considered as an important index fossil for the Jurassic system.

REFERENCES

Fatmi A. N.,(1977).Mesozoic of Pakistan in Stratigraphy of Pakistan. *Mem. Geol. Surv. Pak.* Vol. 12, p. 29.

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, 127–136.

——— 1969. A lower Jurassic Miospore Assemblage from the variegated shales, Nammal Gorge, Salt Range, West Pakistan, Palaeobotanist, Vol. 19 (2),103–117.

Kremp, G.O.W., (1965). Morphologic encyclopaedia of Palynology : Univ. Arizona Press, Tucson : 185 p.

Sah, S.C.D., (1955). Plant microfossils from a Jurassic Shales of Salt Range, Punjab (West Pakistan). *Palaeobotanists,* Vol. 4 : p. 60–7.

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

PLATE 1

Fig I

Text Figure I: Concavigleicheniidites nammalensis n.sp. showing well defined labra with bifurcating extremites forming sigmoid claws, ultimately merging into the short plane field type of torus.

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

LITHO AND BIOSTRATIGRAPHY OF THE WEST CENTRAL PART OF THE WESTERN DESERT, EGYPT.

BY

M. I. YOUSSEF,[1] M. A. BASSIUNI,[2]
M. BOUKHARY,[3] M. HAGGAG.[4]

ABSTRACT. – Ten sections were studied. The lowest unit is the Estna Shale followed by the Farafra Limestone, which is overlain in several sections by shales and sand-stones forming what is called here the Qur Zugag Formation. The top of the sequence is composed of limestones which are given the new name : Quss Abu Said Formation. Where the Qur Zugag formation pinches out, the overlying and underlying calcareous units form a single limestone which is treated as one rock unit, the Farafra Limestone.

The planktonic forminifera (67 species and sub-species) were separated from the samples of the ten sections, were identified and only the zonal markers are illustrated.

Planktonic forminiferal zonation resulted in recognising seven zones of regional and world wide extension.

These studies resulted in emphasizing the occurrence of Middle Eocene rocks and the discovery of an Upper Eocene sequence. Both are the first authenticated records at this latitude in the western Desert.

INTRODUCTION

The area under investigation extends from the northwest of the Dakhla Oasis to the northeast of the Farafra Depression between Latitude 25°50' and 27°37' N and Longitude 27°25' and 28°35' E. In this area, the following ten sections are studied : West of Mawhub (1) Scarp south of Qur Zugag, (2) Plateau north-east of Qur El Malik, (3) Scarp northwest of Qur Zugag, (4) & (5), Qasr Minqar (6), Scarp northwest of El Minqar (7), South of El Qussa Abu Said (8), Southwestern part of El Qussa Abu Said (9), and South of Naqb El Sellim (10). The location of measured section is given in Figure 1.

Measurement and sampling of the studied sections and others were carried out by geologists of Geofizika (Zagreb-Yugoslavia) in collaboration with Professor Mourad I. Youssef. The lithologic description of the samples representing the beds of the sequence was mainly carried out by the authors.

The present work is mainly concerned with (a) the litho-stratigraphy of the sequence and its subdivision into rock units including two new formations; (b) the identification of 67 planktonic forminiferal species and subspecies; (c) the bio-stratigraphic evaluation of the studied foraminifera.

LITHOSTRATIGRAPHY

The investigated outcrops in the west-central part of the Western Desert, consist mainly of the following

1,4. Department of Geology, Faculty of Science, Ain Shams University, Egypt.

2,3. Department of Geology, University of Qatar, Doha, Qatar.

formations :–

TOP :

4. Quss Abu Said Formation
3. Qur Zugag Formation.
2. Farafra Limestone.
1. Esna Shale.

The formations are lithostratigraphically and biostratigraphically studied in sections exposed along the escarpment extending from the northwestern end of the Dakhla depression (Gharb El-Mawhub), through the western escarpments of the Farafra Depression and one section was measured on the plateau separating the Farafra and the Bahariya Depression.

The following are the 10 measured and sampled sections :

Section No.	Locality
I.	West of Mawhub (section I, Fig. 1)
II.	Scarp south of Qur Zugag (sect. II. Fig.3)
III.	Plateau northeast of Qur-El-Malik, (section III, Fig. 4).
IV.	Scarp northeast of Qur Zugag (section IV. Fig. 5).
V.	Scarp northwest of Qur Zugag (section V, Fig. 6).
VI.	Qasr Minqar (Section VI, Fig. 7).
VII.	Scarp northwest of El Minqar (section. VII. Fig. 8).
VIII.	South of El Quss Abu Said (section VIII, Fig. 9).
IX.	Southwestern part of El Qusa Abu Said (section IX, Fig. 10).
X.	South of Naqb El. Sellim.

1. Esna Shale :

The term Esna Shale is used here in accordance with Said's (1962) definition. In the studied sections, the base of Esna is not exposed and it grades upward into the overlying Farafra Limestone (SAID 1960; 1962).

2. Farafra Limestone :

The formational name Farafra Limestone was established by Said (1960) from the El Guss Abu Said Section, Farafra Oasis. This formation, in the area under investigation, underlies the Qur Zugag Formation (new formational name) and overlies the Esna Shale.

3. Qur Zugag Formation (New Formational Name, See Below):

Definition.–The bulk of the Qur Zugag Formation is composed of shales with minor sandstones. It overlies the Farafra Limestone and underlies the Quss Abu Said Formational name).

Name.– The name is after Qur Zugag, a locality about 112 km southeast of Qasr Farafra.

Type-Locality.– West Mawhub - Farafra area.

Type Section.– Scarp south of Qur Zugag, Lat. 26°07' 45" N., Long. 28°27' 15" E.

Diagnostic Description and Thickness in the Type Section.–The Qur Zugag Formation 34.5 m thick in the type section is mainly composed of light grey, light olive green and light greenish brown shale and pale yellow sandstones that become conglomeratic at the top of the formation. These shales and sandstones are intercalated by thin beds of marly shale, chalk, marly limestone, calcareous sandstone and limestone. Halite and gypsum veinlets are found in the shales.

Remarks.– In the Farafra area, the Formation, in the type section (section II, Fig. 3), consists mainly of shale in the lower part and sandstone in the upper part which becomes calcareous in section V and marly in section IX, and changes into marls and shales in section IV, VIII and X.

Age in the type of locality.– Middle Eocene.

Thickness of the Formation.– The Qur Zugag Formation occurs in the following five sections :–

i. Section IV with thickness of 41 m.
ii. Section V. Thickness 71.5 m.
iii. Section VIII. Thickness 29 m.
iv. Section IX. Thickness 99 m.
v. Section X. Thickness 61 m.

Age of other sections.– The age of the formation is late early Eocene in section V, Early Middle Eocene in section X, Middle Eocene in sections IV, and VIII, and Middle Late Eocene in section IX.

4. Quss Abu Said Formation (New Formation Name):

Definition. **The Quss Abu Said Formation is composed of marly limestone and hard limestone. It caps the Qur Zugag Formation and its top is unknown as it forms the uppermost part of the succession in the area.**

Name.– **The formational name Quss Abu Said is derived from the Quss Abu Said plateau, Farafra area.**

Type Locality.– **West Mawhub – Farafra area.**

*Diagnostic Description and Thickness in the Type Section.–***The Quss Abu Said Formation (28 m thick) is mainly composed of light yellow and slightly reddish yellow marly limestone and pale yellow hard limestone. These are locally intercalated by very thin beds of nodular limestones and sandy limestones.**

Type section.– **The type section is located in the south-western part of El Quss Abu Said (section IX) Latitude 26°49' 15" N; Longitude 27°25' 30" E.).**

Remarks.– **The limestone of the Quss Abu Said Formation is cavernous in section II, marly and siliceous in section IV, nodular in the lower part in section V, marly in the type section (section IX) and consists of chalk in section VIII. In section X the limestone of Quss Abu Said Formation is nodular in its lower part, crystalline in the middle part and crystalline and siliceous in its upper part.**

Age in the Type section.– **Late Eocene.**

Thickness of the Formation in other sections.– **The Quss Abu Said Formation occurs in the following sections :–**

i. **Section II. Thickness of the formation 6.5 m.**
ii. **Section IV, Thickness of the formation 4 m.**
iii. **Section V. Thickness of the formation 5.5 m.**
iv. **Section VIII. Thickness is 2.75 m.**
v. **Section X. Thickness of the formation 20 m.**

Age in other sections.– **In section II, Fig. 3, the age of the formation is Late Eocene. In section IV, Fig. 5, section VIII, Fig. 9, and section X, the formation is barren but its stratigraphic position suggests a Middle Eocene or younger age. In section V, Fig. 6, the lower 4.5 m. belong to the Middle Eocene and the upper one metre is barren and may be Middle Eocene or younger.**

BIOSTRATIGRAPHY

As a result of the study of the stratigraphic distribution of the planktonic foraminifera separated from the paleocene, Lower, Middle and Upper Eocene rocks of the west-central part of the Western Desert, the following seven planktonic foraminiferal zones are recognised (from top to base) :

7. ***Globortlia cerroazulensis-cocoaensis* Zone.**
6. ***Globigerinatheka kugleri* Zone.**
5. ***Globorotalia bullbrooki* Zone.**
4. ***Globorotalia-formosa-formosa/Globorotalia-aragonesis* Zone.**
3. ***Globorotalia-velascoensis* Zone.**
2. ***Globorotalia-velasconesis* Zone.**
1. ***Globigerina-daubjergensis* Zone.**

Figure 12 shows the range of the identified planktonic foraminiferal species in the studied sections.

The zonation is mostly in accordance with that of Bolli (1966). The *Globigerina-daubjergensis* Zone in the present work, however, corresponds to the *Globorotalia-pseudo-bulloides* Zone and Gr. trinidadensis Zone of Bolli (1966). Bolli's four Paleocene zones *(Globorotalia-unicinata, angulata, Gr.* Pusilla-pusilla *and* Gr. Pseudomenardii Zones) that are usually present between the *Gl. daubjergensis* Zone and the Gr. velascoensis Zones are not represented in any of the studied sectons. The Globorotalia formosa-formosa Zone and Gl. aragonesis zone are combined here as the *Globorotalia-formosa-formosa/ Gr. aragonesis Zone.* The following four Zones of Bolli that occur between the *Globigerinatheka-kugleri Zone and Globoro*talia-cerro-auzulensis Zone, are not recognised here. These are :–

1. ***Globorotalia-lehneri* Zone.**
2. ***Porticulasphaera-mexicana* Zone.**
3. ***Truncorotaloides-rohri* Zone.**
4. ***Globigerinatheka-semiinvoluta* Zone.**

The youngest Eocene zone of Bolli (1966) Globorotaliacerro-azulensi Zone is present in the study area.

The lower two biozones (1 to 2) mentioned above, belong to the Paleocene, while the upper five bio-zones (3 to 7) are of Eocene age. The *Globigerina-daubjergensis* Zone is of Early Paleocene age, the *Globorotalia-velascoensis* Zone is of Late Paleocene age. The *Globorotalia-formosa-formosa/Globorotalia-aragonesis* Zone is of late Early Eocene age. The *Globorotalia-bullbrooki Zone the Globigerinatheka-kugleri* Zone are of Middle Eocene age. The *Globorotalia-cerroazulensis-cocoaensis* Zone of the present work, is Late Eocene in age.

The Upper Paleocene/Lower Eocene boundary is located at the top of the *Globorotalia-velascoensis* Zone, where the zonal marker becomes extinct. The Lower

Eocene/Middle Eocene boundary is determined by the first appearance of the typical Middle Eocene forms: *Globorotalia-renzi-Bolli, Globorotalia bolivariana* (Petters) *Globorotalia-bullbrooki-Bolli, Globorotalia spinuloinflata (Bandy), Globorotalia-spinulosa-Cushman, Truncorotaloides-rohri Bronnimann* and Bermudez, *Truncorotaloides topilensis (Cushman) and Catapsydrax-echinatus* Bolli.

METHOD

The identified planktonic species have different frequencies in the different parts of the ten studied sections. The frequency symbols used in the distribution charts (Fig. 13 to 22) are :–

R = Rare (< 3) , C = common (4 – 10) and

A = abundant (more than 10).

The planktonic foraminifera were counted in approximately 1 gm of washed residue. The identified specimens are either numerous helping in the recognition and establishment of the different zones or they are rare and badly preserved. Moreover reworking in some parts of the sections is so intensive that the number of indigenous planktonic forms, form a minority in comparison with the derived fossils. The latter have either fairly well preserved tests or are thin walled, badly preserved polished and stained with iron.

DISCUSSION

In five of the ten studied sections. faunal breaks are found between the Lower and Upper Paleocene, the Lower and Middle Eocene and the Middle and Upper Eocene. Two faunal breaks are recognised in section I, one of them is found between the top of the Lower Paleocene (Upper Danian) and the base of the upper Upper Paleocene. As mentioned above four zones are missing between the *Globigerina-daubjergensis* Zone (Lower Paleocene) and the *Globorotallia-velascoensis* Zone (upper Upper Paleocene). The second faunal break (section I) is between the top of the lower Lower Eocene *Globorotalia-velascoensis* Zone and the base of the Middle Eocene *Globorotalia-bullbrooki* Zone. Thus *Globorotalia-formosa-formosa/ Globorotalia-aragonesis* Zone is missing in the section. The same break is traced also in section IV. The occurrence of a sandstone bed with detrital glauconite (thickness 0.5m) at the top of the Esna Shale, may also be a corroborating evidence of the existence of an uncomformity in section I. A conglomeritic bed (thickness 1.6m) marks this break in section IV. In sections II and III, a faunal break separates the Middle Eocene *Globorotalia-bullbroki* Zone and the Upper Eocene *Globorotalia-cerroazulensis-cocoaensis* Zone.

Five Zones i.e., *Globogerinatheka-kugleri* Zone, *Globorotalia-lehneri* Zone, *Porticulasphaera-mexicana* Zone, *Truncorotaloides-rohri* Zone and *Globigerinatheka-semi-involuta* Zone, are missing in these sections. A sand bed, that is conglomeritic at the top (thickness 5.5m), separates the *Globorotalia-bullbrooki* Zone from *Globorotalia-cerroazulensis-cocoaensis* Zone in section II, while in section III, there is no traceable change in the lithology between the two zones. In section IX, a faunal break is recognised between the Middle Eocene *Globigerinatheka-kugleri* Zone and the Upper Eocene *Globorotallia-cerroazulensis-cocoaensis* Zone. The four zones missing in this section are : *Globorotalia-lehneri, Porticulasphaera-mexicana, Truncorotaloides-rohri* and *Globigerinatheka-semi-involuta* Zones. A shallow water sand bed (thickness 4.1m) with *Ostrea* spp. separates the two unconformable zones.

The uppermost 2 m of section III, 4 m of section IV, 2.5 m of section V, 1 m of section VII, 2.5 m of section VIII, and 18 m of section X yielded no fauna. Furthermore, barren intervals (12.5 m and 34.87m thick) are found in section II and V respectively.

CONCLUSIONS

The results of the study can be summarised as follows :–

Lithostratigraphy:

The work involves the description of four stratigraphic rock units (Esna Shale, Farafra Limestone, Qur Zugag Formation and Quss Abu Said Formation) that compose the ten studied sections. The Qur Zugag Formation and Quss Abu Said Formation are new formational names introduced here for the first time.

Biostratigraphy:

The time-rock units in the west-central part of the Western Desert are sub-divided into the following seven planktonic foraminiferal zones :–

7. *Globorotalia-cerroazulensis-cocoaensis* Zone.
6. *Globigerinatheka-kugleri* Zone.
5. *Globorotalia bullbrooki* Zone.
4. *Globorotalia-formosa-formosa/Globorotalia-aragenesis* Zone.
3. *Globorotalia-subbotinae* Zone.
2. *Globorotalia-velascoensis* Zone.
1. *Globigerina-daubjergensis* Zone.

These zones range from the Lower Paleocene to the Upper Eocene.

None of the studied sections include, as in recorded sections from other localities in the area. Upper Cretaceo us rocks.

Indigenous fauna forms, in some cases, are a minority in comparison with the derived forms.

The most important addition to the biostratigraphy of this part of the country is emphasizing beyond doubt the occurrence of the Middle Eocene and the authenticated first record of the Upper Eocene. These two additions to the stratigraphy of the area will no doubt have an influence on the regional picture of the Eocene transgressions and regressions in southern Egypt.

In the five of the ten studied sections, uncomformities are found between the Lower and Upper Paleocene, Lower and Middle Eocene and Middle and Upper Eocene.

REFERENCES

Beadnell, H.J.L., (1901). Farafra Oasis, its topography and Geology. *Egypt Surv. Deptt. Cairo,* p. 1–39, pl.1–3.

Beckmann, J.P., El Heiny, I., Kerdany, M.T., Said, R., and Viotti, C. (1969). Standard Planktonic Zones in Egypt. *Proc. 1st Intern. Conf. Plankt. Microf. Geneva.* p. 92–103.

Kerdany, M.T., (1969). Biostratigraphy of the Mesozoic and Tertiary paleontology and regional correlation studies of the Upper Cretaceous and Lower Tertiary rocks of Middle Egypt. Ph. D. Thesis. Fac. Sc., Ain Shams Univ. Egypt.

Leroy, L.W., (1953). Biostratigraphy of the Maqfi section, Egypt. *Geol. Soc. Amer., Mem.* No 53, 73 p. 11 Pl.

Said, R. and Kerdany, M.T., (1961). The geology and micropaleontology of the Farafra Oasis, Egypt. *Micropaleontology* vol. 7, No 3, p. 317–336, pl. 1–2.

Youssef, M.I., and Abdel Aziz, W., (1971). Biostratigraphy of the Upper Cretaceous-Lower Tertiary in Farafra Oasis, Libyan Desert. *Symposium on the Geology of Libya Fac. Sc. University of Libya.* p. 227–249. Pl. 1–3.

Zittel, K.A., (1883). Beitraege Zur Geologie and Palaeontologie der Libyschen Wuste und der angrenzenden Gebiete von Aegypten. *Palaeontographica,* vol. 30, 147 p.

EXPLANATION OF PLATE NO. 1

1a – C. *Globigerina daubjergensis* Bronnimann, 1953.
West of Mawhub, Esna Shale, Sample 2.
Lower Paleocene X 62

2a – C. *Globorotalia velascoensis (Cushman, 1925)*
Scarp NW of Qur z Zugag, Esna Shale, Sample 2.
upper Upper Paleocene X 57

3a – C. *Globorotalia subbotinae* Morozova, 1939
S of Naqb El Sellim, Qur Zugag Formation, Sample 5,
lower Lower Eocene X 55

4a – C. *Globorotalia formosa formosa* Bolli, 1957
Plateau NE of Qur EL Malik, Farafra Limestone, Sample 1.
upper Lower Eocene X 51

5a – C. *Globorotalia aragonensis* Nuttall, 1930.
Qasr Minqar, Esna Shale, Sample 10.
Middle Eocene X 88

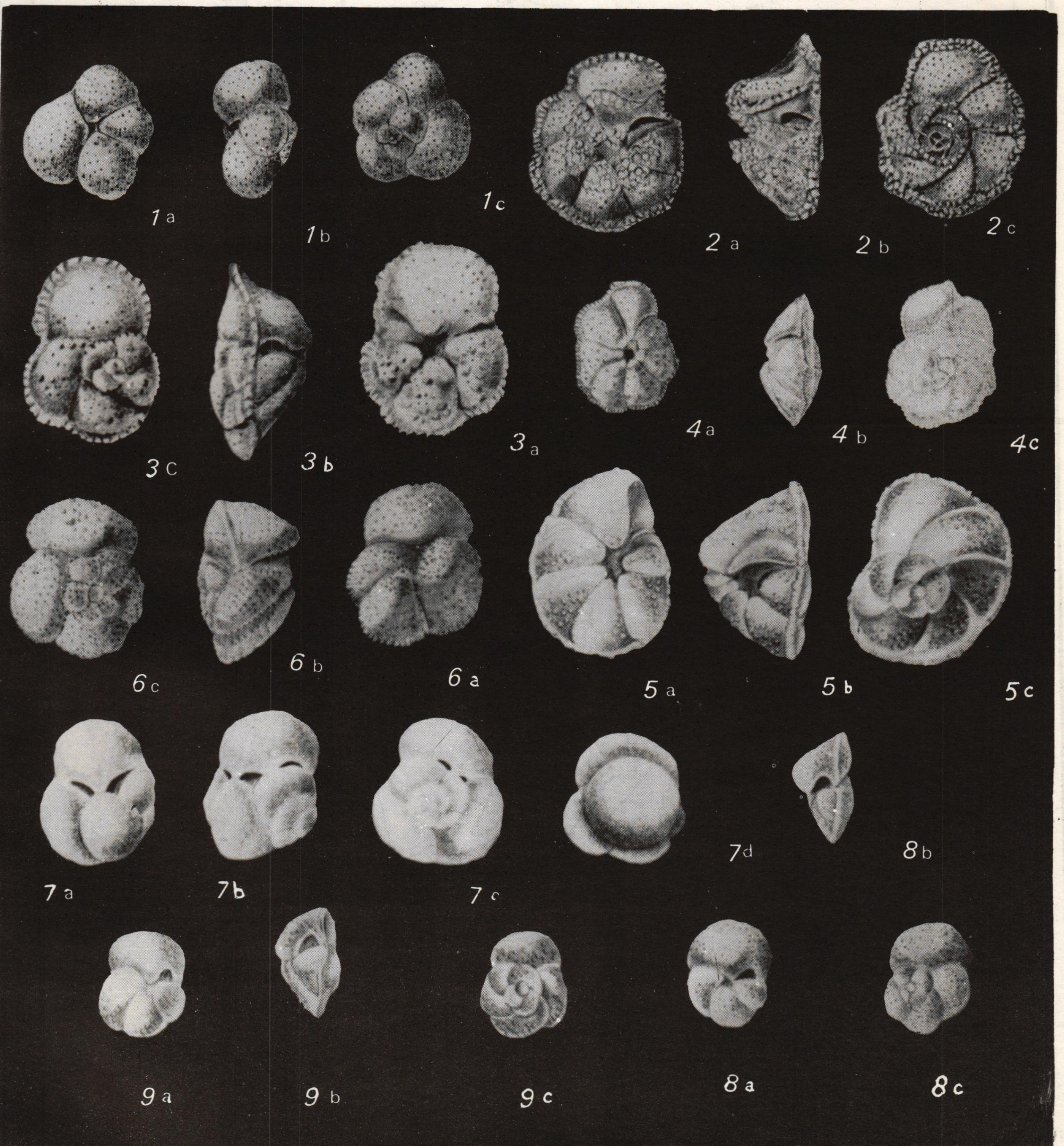
6a – C. *Globorotalia bullbrooki* Bolli, 1957
S of EL Quss Abu Said, Qur Zugag Formation, Sample 6,
Middle Eocene. X 52

7a – d *Globigerinatheka kugleri* (Bolli, Loeblich & Tappan, 1957)
SW part of El Quss Abu Said, Qur Zugag Formation Sample 1,
Middle Eocene X 62
a – Ventral view b – Dorsal view c, d – Secondary apertural views

8a –gc. *Globorotalia cerroazulensis cocoaensis* Cushman, 1928.

8a – c Plateau NE of Qur El Malik, Farafra Limestone, Sample 8,

9a – c SW part of El Quss Abu Said, Qur Zugag Formation, Sample 14,
Upper Eocene. X 88


1a
1b
1c
2a
2b
2c
3c
3b
3a
4a
4b
4c
6c
6b
6a
5a
5b
5c
7a
7b
7c
7d
8b
9a
9b
9c
8a
8c

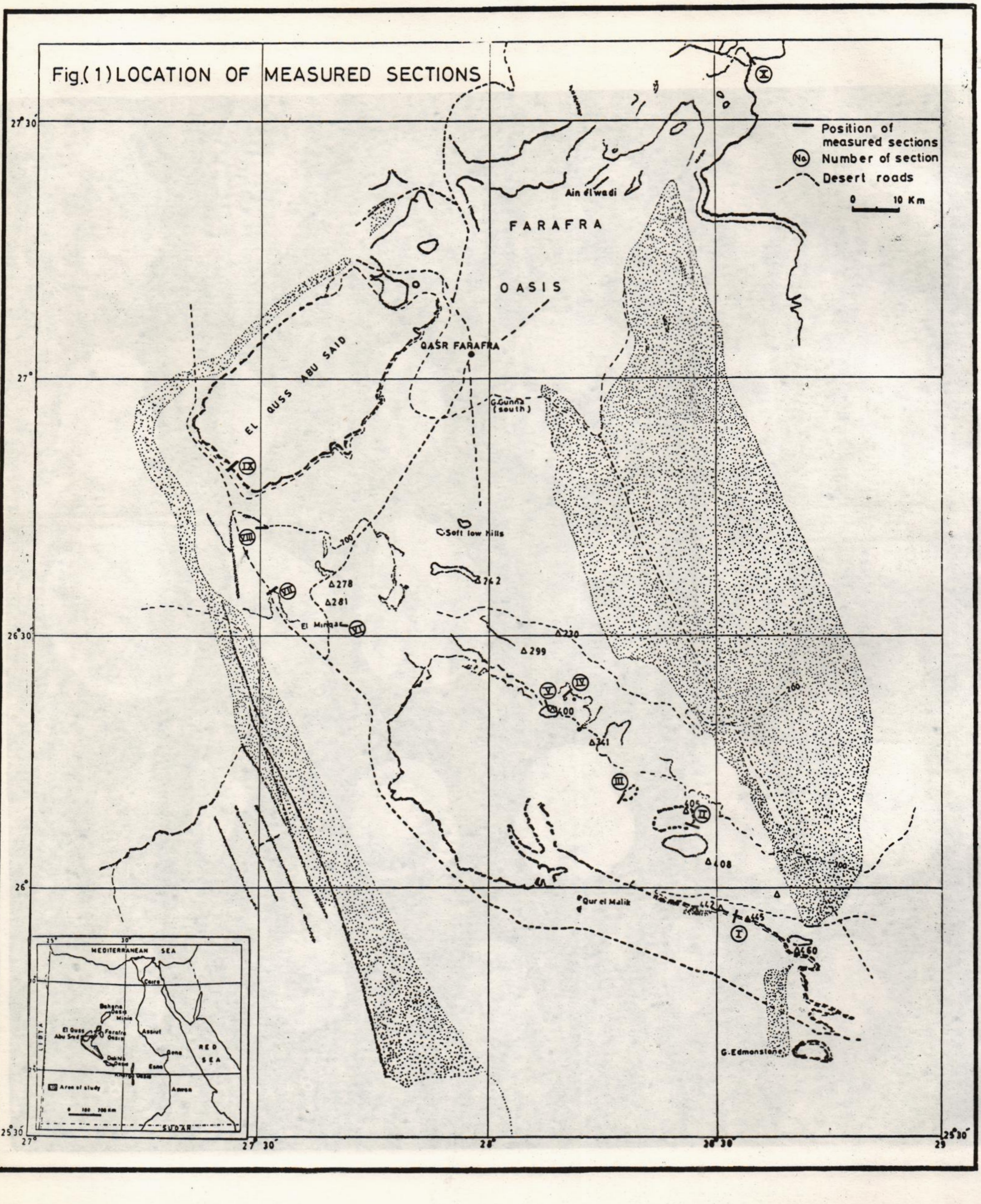
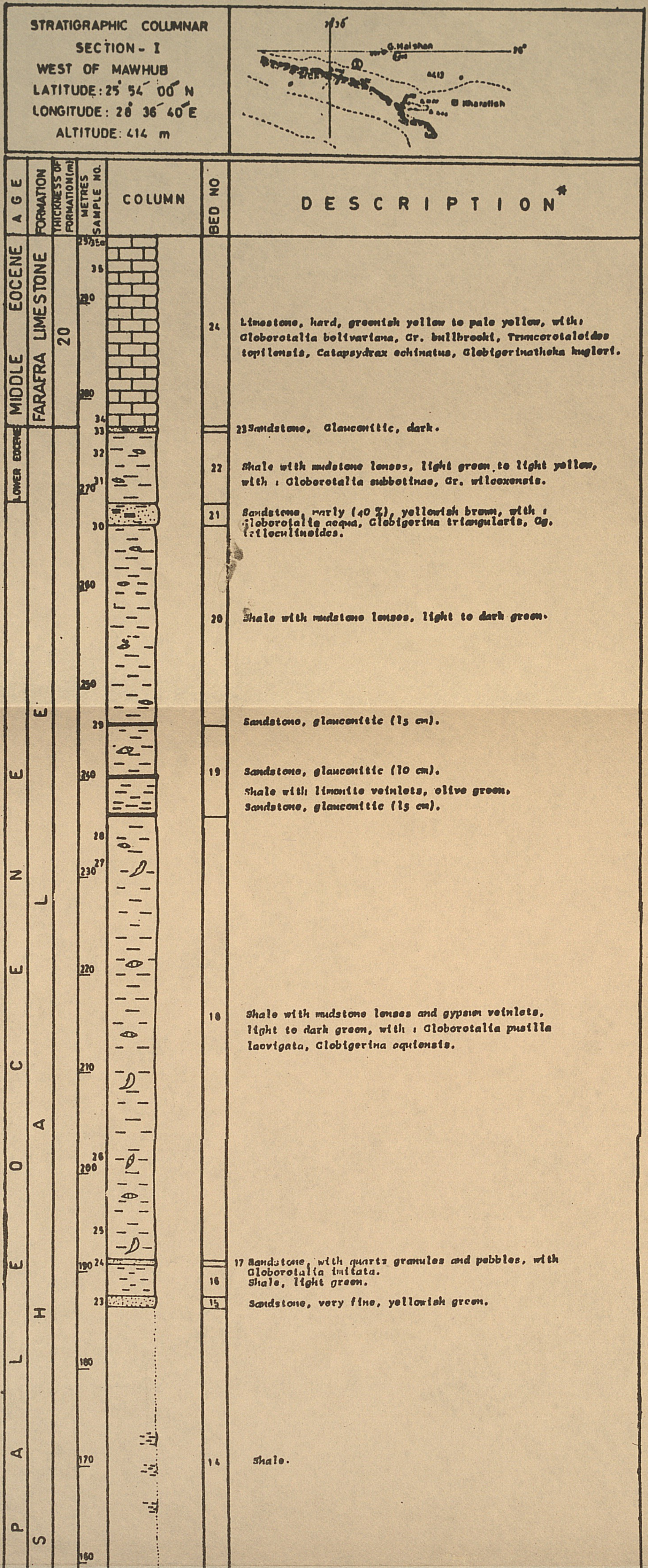
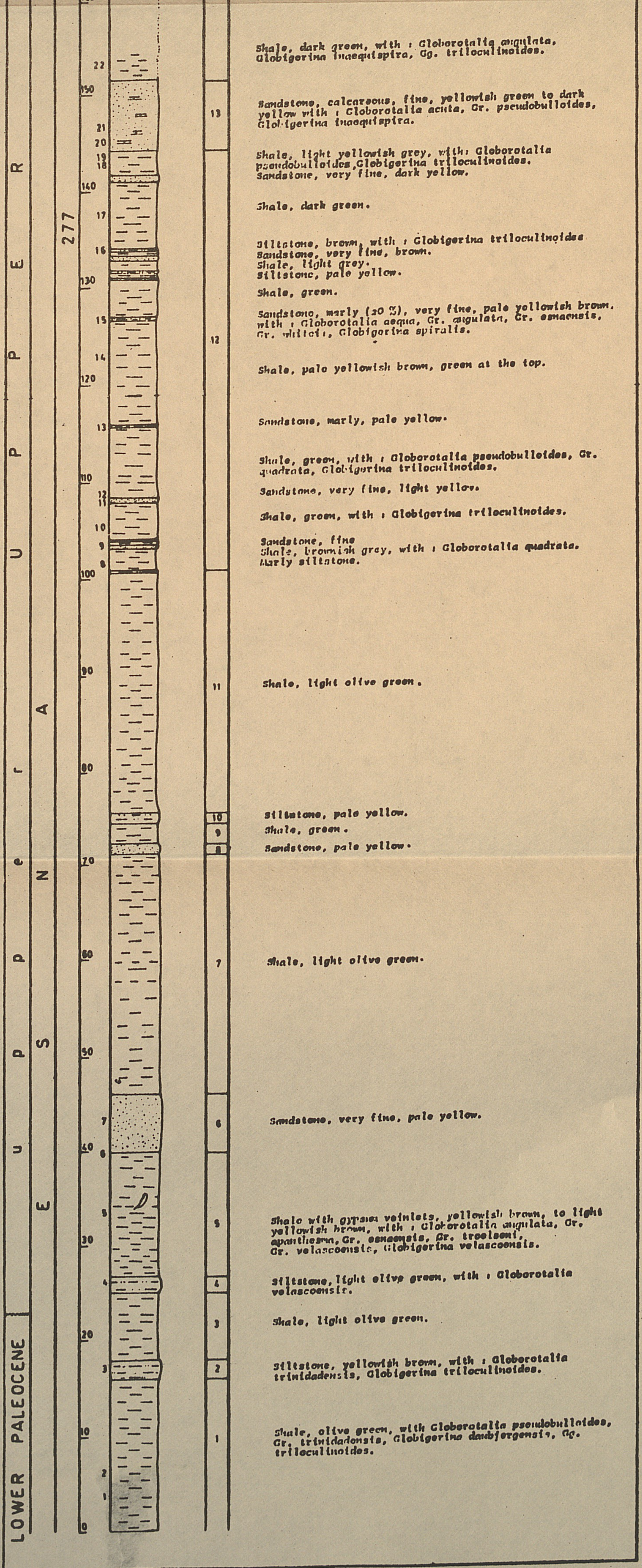


Fig.(1) LOCATION OF MEASURED SECTIONS

Fig (2)

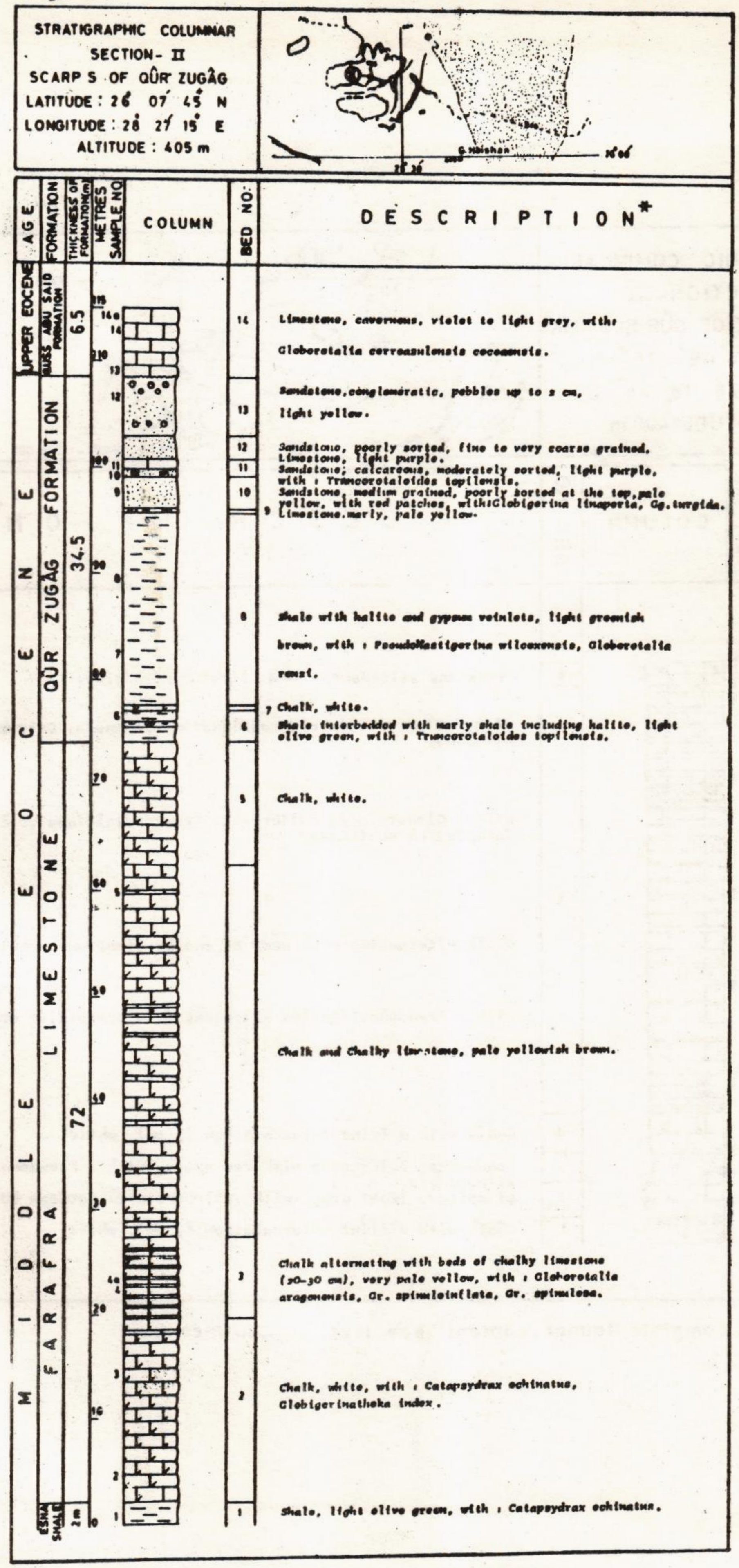

STRATIGRAPHIC COLUMNAR SECTION - I
WEST OF MAWHUB
LATITUDE: 25° 54' 00" N
LONGITUDE: 28° 36' 40" E
ALTITUDE: 414 m
Kharafish
AGE
FORMATION
THICKNESS OF FORMATION (m)
METRES
SAMPLE NO.
COLUMN
BED NO.
DESCRIPTION*
MIDDLE EOCENE
FARAFRA LIMESTONE
20
LOWER EOCENE
PALEOCENE
ESNA SHALE
24 Limestone, hard, greenish yellow to pale yellow, with: Globorotalia bolivariana, Gr. bullbrooki, Truncorotaloides topilensis, Catapsydrax echinatus, Globigerinatheka kugleri.
23 Sandstone, Glauconitic, dark.
22 Shale with mudstone lenses, light green to light yellow, with : Globorotalia subbotinae, Gr. wilcoxensis.
21 Sandstone, marly (40 %), yellowish brown, with : Globorotalia aequa, Globigerina triangularis, Gg. triloculinoides.
20 Shale with mudstone lenses, light to dark green.
Sandstone, glauconitic (15 cm).
19 Sandstone, glauconitic (10 cm).
Shale with limonite veinlets, olive green.
Sandstone, glauconitic (15 cm).
18 Shale with mudstone lenses and gypsum veinlets, light to dark green, with : Globorotalia pusilla laevigata, Globigerina aquiensis.
17 Sandstone, with quartz granules and pebbles, with Globorotalia imitata.
16 Shale, light green.
15 Sandstone, very fine, yellowish green.
14 Shale.



* : For complete faunal content see text.

~~ : Unconformity

Fig.(3)

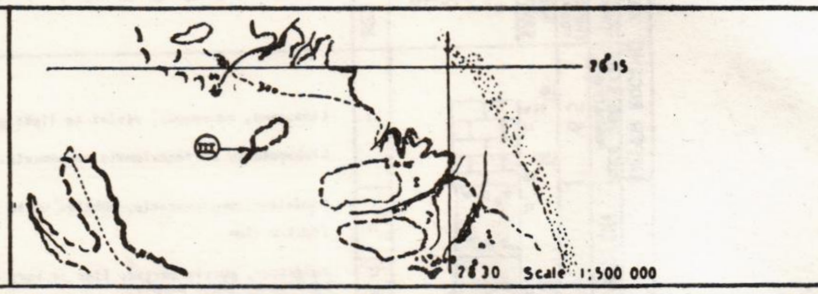


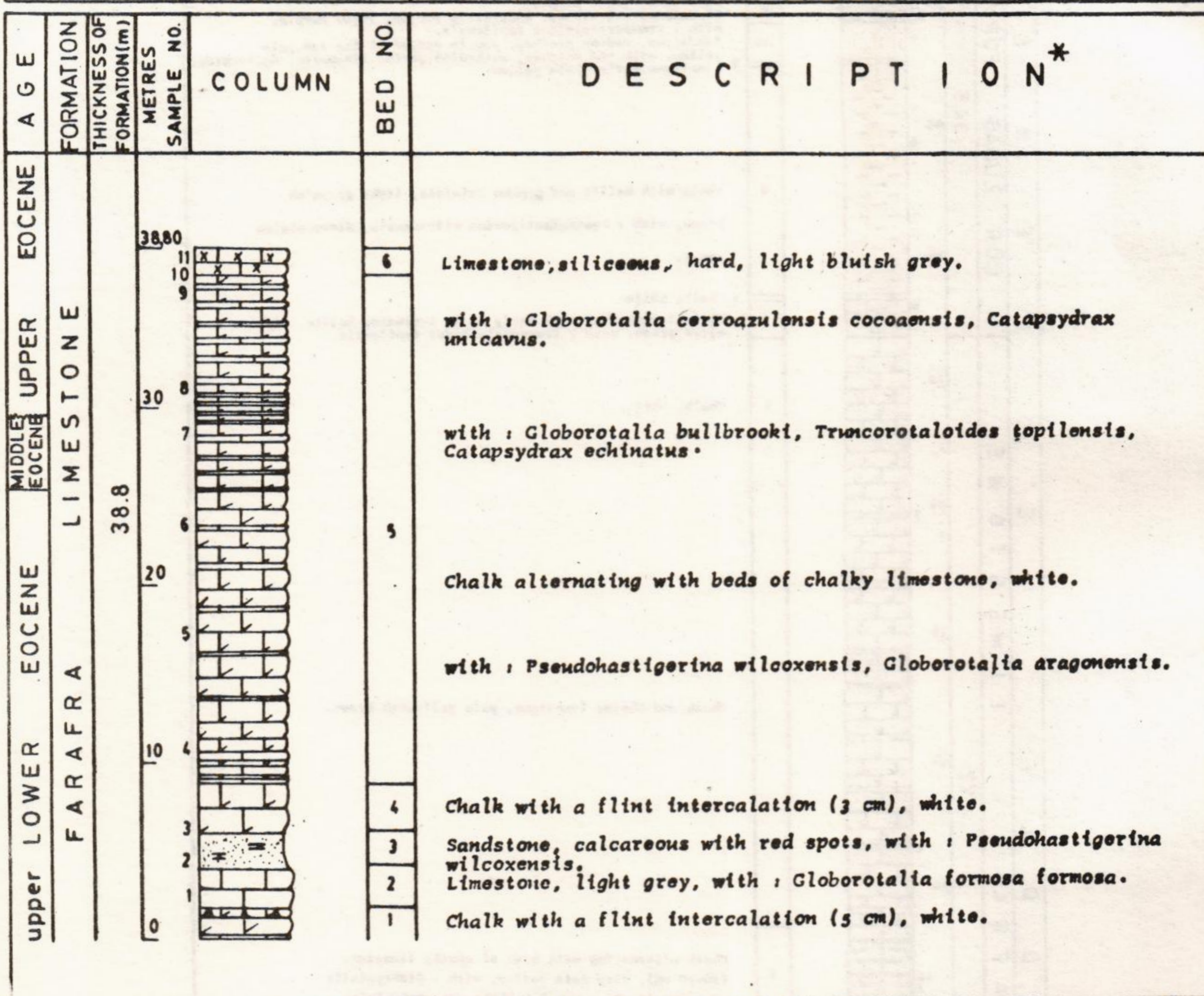
*: For complete faunal content see text

~~~~ Unconformity
~~~~

Fig.(4)

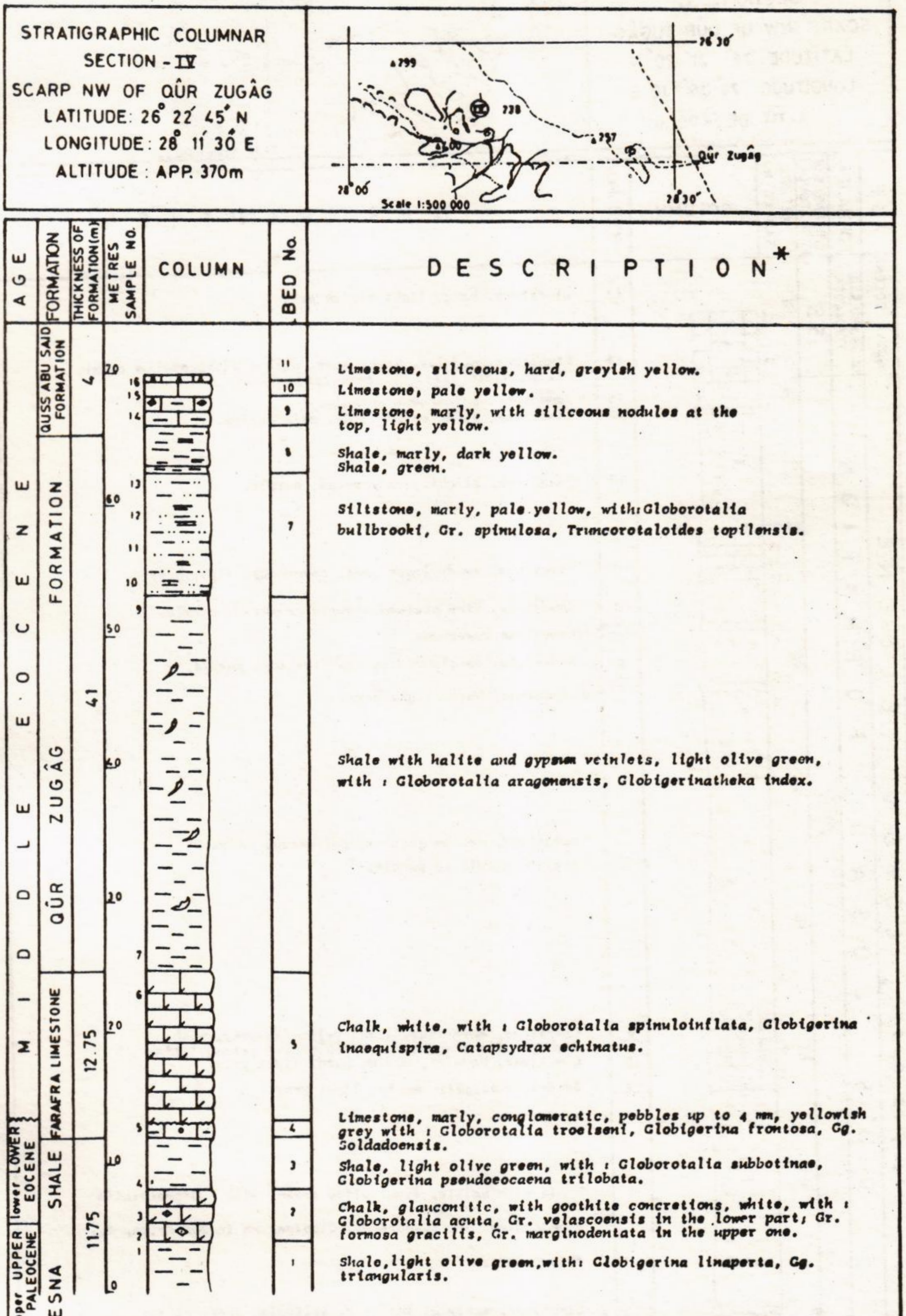
STRATIGRAPHIC COLUMNAR
SECTION-III
PLATEAU NE OF QÛR EL MALIK
LATITUDE : 26° 09′ 15″ N
LONGITUDE : 28° 18′ 45″ E
ALTITUDE : 400 m





* : For complete faunal content see text. —— Unconformit

Fig.(5)



* For complete faunal content see text

~~~~ Unconformity
~~~~

Fig.(6)

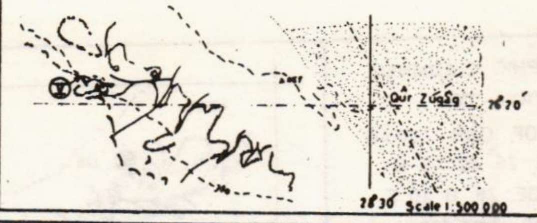
STRATIGRAPHIC COLUMNAR SECTION _ V

SCARP NW OF QÛR ZUGÂG

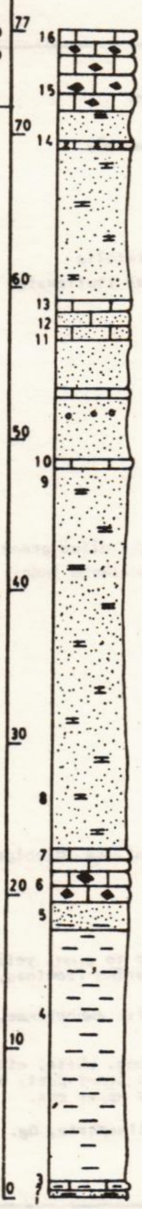
LATITUDE: 26° 21′ 20″ N

LONGITUDE: 28° 06′ 30′ E

ALTITUDE: 400 m



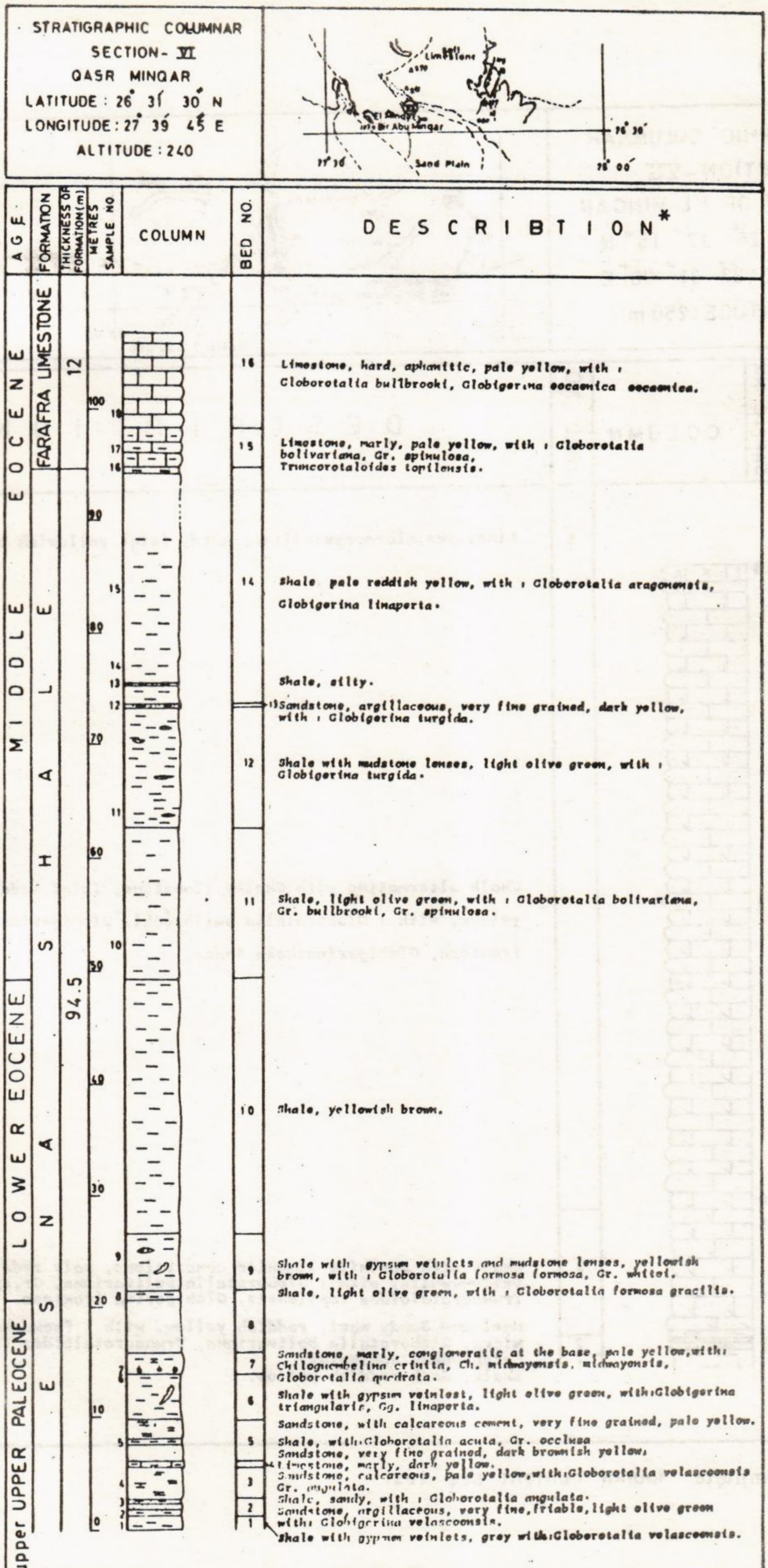
AGE	FORMATION	THICKNESS OF FORMATION (m)
MIDDLE EOCENE	QUSS ABU SAID FORMATION	5.5
upper LOWER EOCENE	QÛR ZUGÂG FORMATION	71.5



BED NO.	DESCRIPTION*
17	Limestone, hard, light bluish green.
16	Limestone, nodular, light grey, with : Globorotalia renzi, Gr. spinuloinflata, Gr. spinulosa.
15	Sandstone, calcareous, purple.
14	Limestone, hard, crystalline, pale yellow.
13	Sandstone, slightly calcareous, purple.
12	Limestone, sandy lower part, cavernous, light grey.
11	Sandstone, fine grained, poorly cemented, purple.
10	Limestone, cavernous.
9	Sandstone, conglomeratic near the top, purple.
8	Limestone, hard, light grey.
7	Sandstone, medium grained, calcareous cement, greyish purple to purple.
6	Limestone, cavernous, light yellowish grey, with: Globorotalia aragonensis, Globigerina triangularis.
5	Limestone, nodular, medium hard, light grey.
4	Sandstone, slightly marly, light grey.
3	Shale with halite, light olive green, with : Globorotalia planoconica, Gr. subbotinae, Globigerina inaequispira, Gg. triangularis.
2	Limestone, marly at the base, yellowish grey, with : Globorotalia broedermanni.
1	Shale, Sandy with gypsum veinlets, light olive green, with: Globorotalia aragonensis, Gr. formosa formosa.

* : For complete faunal content see text

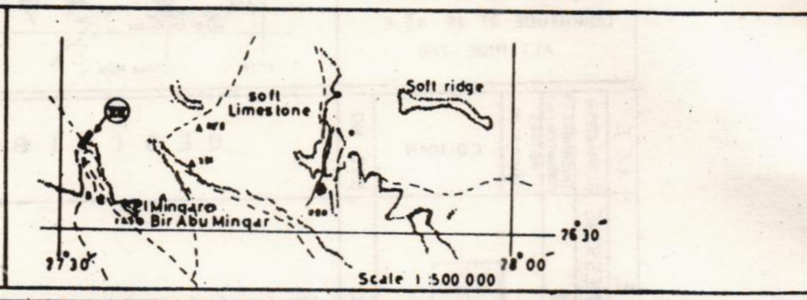
Fig.(7)



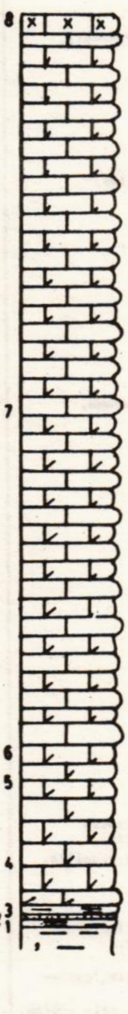
*. For complete faunal content see text

Fig.(8)

STRATIGRAPHIC COLUMNAR
SECTION-VII
SCARP NW OF EL MINQAR
LATITUDE : 26° 37′ 15″ N
LONGITUDE : 27° 31′ 00″ E
ALTITUDE : 250 m

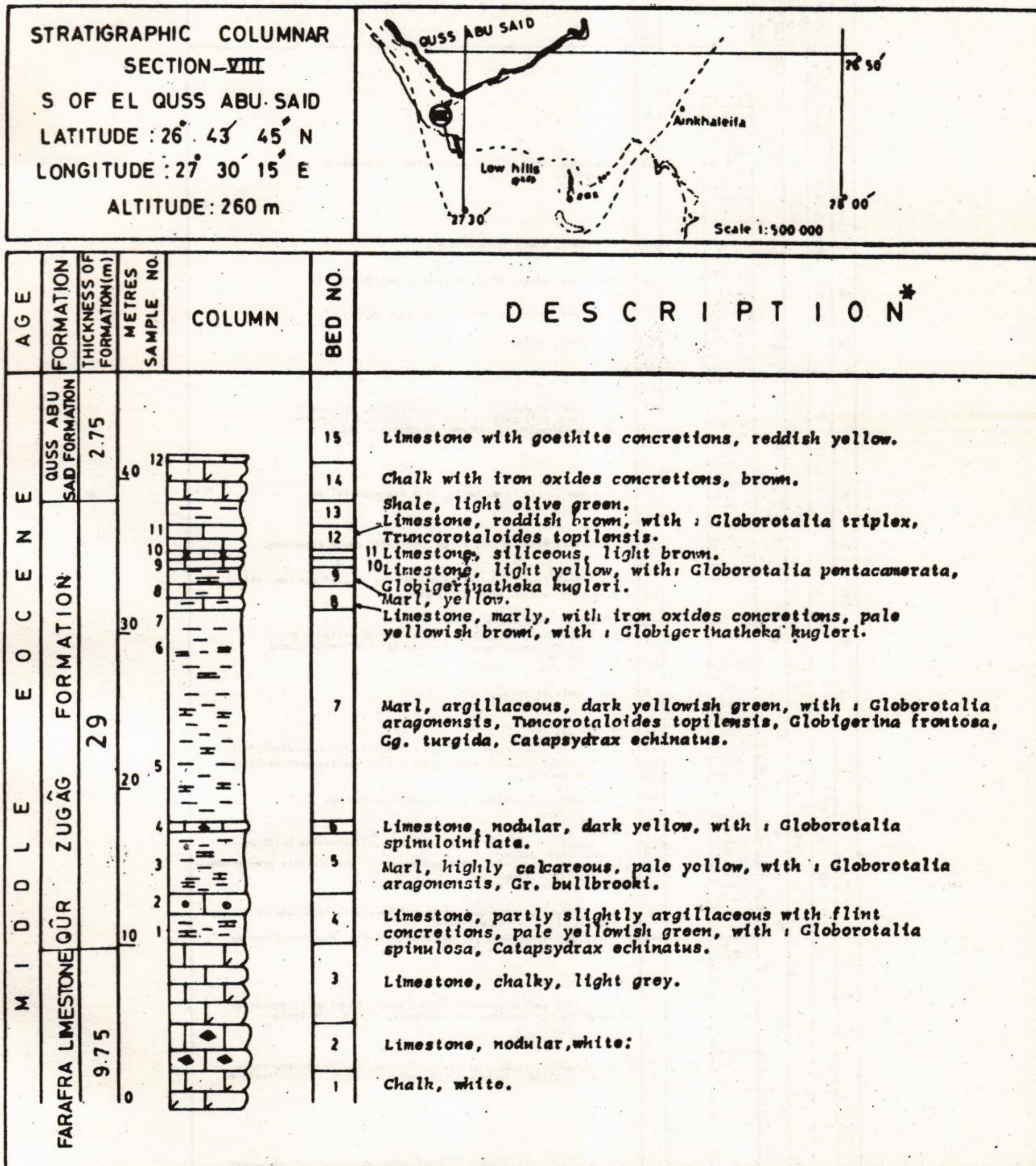


AGE	FORMATION	THICKNESS OF FORMATION(m)	METRES	SAMPLE NO.	COLUMN	BED NO	DESCRIPTION*
MIDDLE EOCENE	FARAFRA LIMESTONE	49	50	8		5	*Limestone, microcrystalline, hard, faint yellowish brown.*
			30	7			*Chalk alternating with Chalky limestone, faint reddish yellow, with : Globorotalia bullbrooki, Globigerina frontosa, Globigerinatheka index.*
			10	6, 5, 4		3	*Chalk with goethite-limonite concretions, pale reddish yellow-white, with : Globorotalia bolivariana, Gr. spinulosa, Truncorotaloides topilensis, Globigerina frontosa.*
				3, 2		2	*Marl and Sandy marl, reddish yellow, with : Pseudohastigerina micra, Globorotalia bolivariana, Truncorotaloides topilensis, Catapsydrax echinatus.*
	ESNA SHALE	2.5	0	1		1	*Shale, dark reddish yellow.*



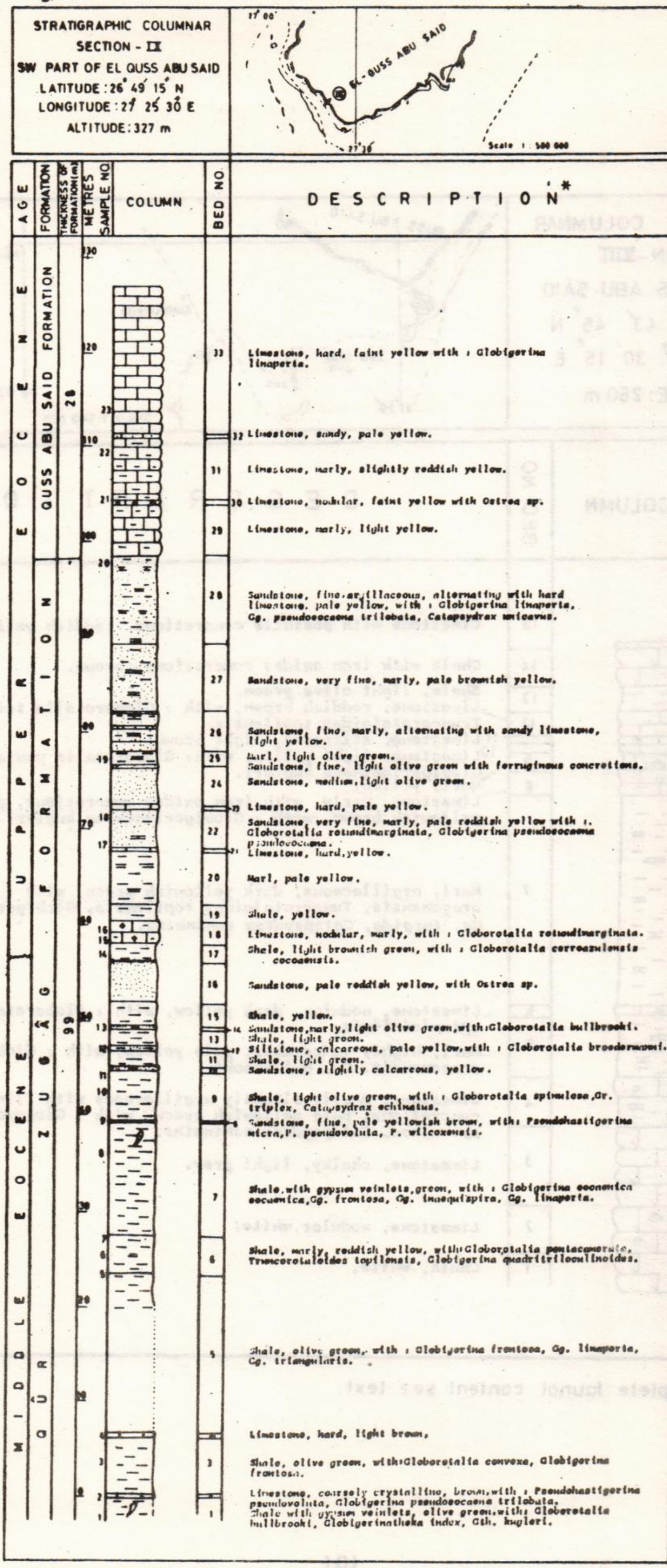
* : For complete faunal content see text

Fig(9)



* : For complete faunal content see text.

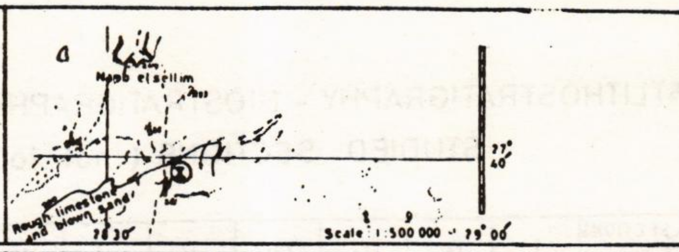
Fig.(10)

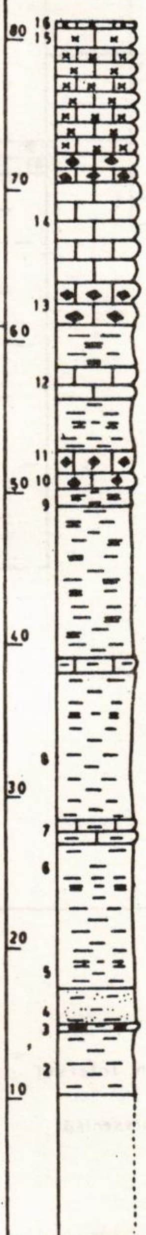


* For complete faunal content see text —— Unconformity

Fig. (11)

STRATIGRAPHIC COLUMNAR SECTION-X
S OF NAQB EL SELLIM
LATITUDE : 27° 37′ 15″ N
LONGITUDE : 28° 34′ 45″ E
ALTITUDE : 261 m





AGE	FORMATION	THICKNESS OF FORMATION (m)	BED NO	DESCRIPTION*
MIDDLE EOCENE	QUSS ABU SAID FORMATION	20	19	Limestone, crystalline, siliceous, hard, light bluish grey.
			18	Limestone, Crystalline, light grey to yellowish grey.
			17	Limestone, nodular, faint grey.
			16	Limestone, irregularly bedded near the top, yellowish grey.
			15	Limestone, nodular, greyish yellow.
	QÛR ZUGÂG FORMATION	61	14	Marl, argillaceous, greyish yellow to dark yellow.
			13	Limestone, highly fossiliferous, white, with : Pseudohastigerina pseudovoluta, Catapsydrax echinatus.
			12	Marl, highly argillaceous, yellowish grey to yellow.
			11	Limestone, nodular, yellowish grey.
			10	Marl, pale yellow.
			9	Shale, marly, pale reddish yellow.
			8	Limestone, marly, yellowish grey.
			7	Shale, slightly marly, green, with : Globorotalia bolivariana, Gr. bullbrooki, Gr. spinuloinflata, Gr. spinulosa, Truncorotaloides rohri, Catapsydrax echinatus.
			6	Limestone, marly, pale yellow, with : Globorotalia formosa formosa.
LOWER EOCENE			5	Shale interbedded with marl, yellowish grey, with : Globorotalia pseudotopilensis, Gr. quetra, Globigerina linaperta.
			4	Shale, silty to finely sandy, olive green, with: Globorotalia irrorata, Gr. tribulosa, Globigerina eocaenica eocaenica.
			3	Marl, yellow, with : Globorotalia planoconica, Gr. subbotinae.
			2	Shale, green, with : Pseudohastigerina wilcoxensis, P. pseudovoluta, Globorotalia broedermanni, Gr. formosa gracilis, Gr. marginodentata, Gr. subbotinae, Gr. wilcoxensis, Globigerina frontosa.
			1	Limestone, crystalline, hard, light grey, with: Globorotalia aequa, Gr. convexa.

*: For complete faunal content see text

Fig.(15) LITHOSTRATIGRAPHY - BIOSTRATIGRAPHY AND AGE OF THE STUDIED SECTIONS (not to scale)

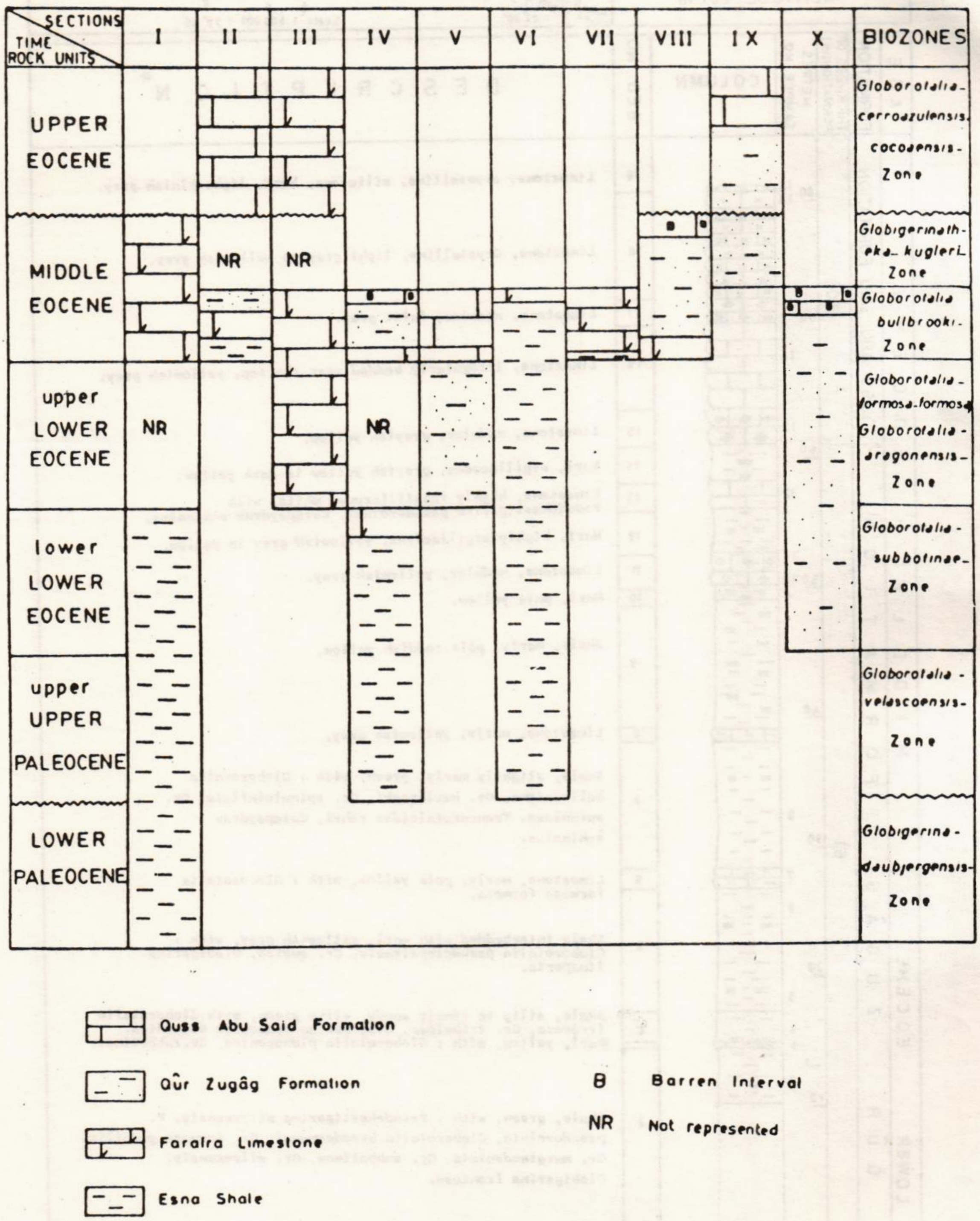


Fig.(14) COMPARISON BETWEEN PALEOCENE - EOCENE BIOZONES

F O R A M I N I F E R A

SYSTEM	SERIES	STAGE	SUBSTAGE	EGYPT: PRESENT STUDY	EGYPT: SAID & SABRY (1964) GEBEL AWEINA	EGYPT: KRASHENINNIKOV & PONIKAROV (1965) NILE VALLEY	EGYPT: EL-NAGGAR (1966) NILE VALLEY	EGYPT: BECKMANN et al. (1969) EGYPT	EGYPT: KRASHENINNIKOV & ABD EL RAZIK (1969) QUSEIR	EGYPT: VIOTTI & EL DEMERDASH (1969) W. NUKHUL	EGYPT: FAHMY et al. (1969) EGYPT	EGYPT: ANSARY & FAHMY (1971) EZZ EL ORBAN AREA	EGYPT: YOUSSEF & ABD EL AZIZ (1971) FARAFRA OASIS	EGYPT: EL DAWOODY & BARAKAT (1972) QUSEIR DESTRICT	EGYPT: ABD EL MALIK et al. (1978) W CENTRAL SINAI	EGYPT: HASSAN et al. (1978) LUXOR	EGYPT: BASSIOUNI et al. (IN PRESS) GULF OF SUEZ	EGYPT: MANSOUR et al. PERSONAL COMMUNICATION KHARGA OASIS	O…: BOLLI (1957 a,b) TRINIDAD	O…: LOEBLICH & TAPPAN (1957) USA	O…: BOLLI & CITA (1960a) ITALY	O…: BANDY (1964) WORLD WIDE
TERTIARY	EOCENE	UPPER EOCENE	upper	GR CERROAZULENSIS; COCOAENSIS				GR DANVILLENSIS; GR CERROAZULENSIS		GR CERROAZULENSIS	GR CERROAZULENSIS						GR CERROAZULENSIS; COCOAENSIS		GR COCOAENSIS			GR CERROAZULENSIS GR INCREBESCENS
			lower					G SEMI INVOLUTUS		G SEMI INVOLUTUS	G SEMI INVOLUTUS						G SEMI-INVOLUTUS		G SEMI-INVOLUTUS			GR CERROAZULENSIS G SEMI INVOLUTUS
		MIDDLE EOCENE		GTH KUGLERI; GR BULLBROOKI				T PSEUDODUBINS; P MEXICANA; GR LEHNERI; G KUGLERI; GR BULLBROOKI		R TOPILENSIS; T PSEUDODUBINS; NOT RECOGNIZED; GR BULLBROOKI	R ROHRI; GR LEHNERI; GR. BULLBROOKI: G KUGLERI SUBZONE, H ARAGONENSIS SUBZONE	GR BULLBROOKI					R ROHRI; GR LEHNERI; GR. BULLBROOKI: G. KUGLERI SUBZONE, H ARAGONENSIS SUBZONE		R ROHRI; P MEXICANA; GR LEHNERI; G KUGLERI; H ARAGONENSIS		H ARAGONENSIS GR A KUGLERI; H ARAGONENSIS	GD GD PSOUDODUBIA; P MEXICANA; R TOPILENSIS; Gg FRONTOSA
		LOWER EOCENE	upper	GR FORMOSA FORMOSA / GR ARAGONENSIS		GR ARAGONENSIS A PENTACAMERATA; GR SUBBOTINAE		GR ARAGONENSIS; GR FORMOSA FORMOSA	GR ARAGONENSIS A PENTACAMERATA; GR SUBBOTINAE	NOT RECOGNIZED PROBABLY GR ARAGONENSIS	GR. PENTACAMERATA: A PENTACAMERATA / SUBZONE; GR. ARAGONENSIS: GR ARAGONENSIS; GR MARGINODONTATA SUBZONE	ZONE N; GR MARGINODONTATA		—?—?— GR ARAGONENSIS		BARREN ZONE; N PLANULATNS; OP ITBYCA; GR FORMOSA / FORMOSA / GR ARAGONENSIS	GR ARAGONENSIS GR PENTACAMERATA; GR FORMOSA /		GR PALMERAC; GR ARAGONENSIS; GR FORMOSA / FORMOSA		GR FORMOSA / FORMOSA / GR ARAGONENSIS	GR PALMERAC
			lower	GR SUBBOTINAE	GR REX	GR SUBBOTINAE	GR WILCOXENSIS	GR SUBBOTINAE	GR SUBBOTINAE		GR. SUBBOTINAE: GR SUBBOTINAE SUBZONE		GR REX	GR SUBBOTINAE	GR REX	GR REX GR FORMOSA / FORMOSA /	GR REX		GR REX	GR REX	GR REX	GR REX
	PALEOCENE	UPPER PALEOCENE	upper	GR VELASCOENSIS ** ?	GR VELASCOENSIS	GR VELASCOENSIS	GR. VELASCOENSIS: GR AEQUA / GR ESNAONSIS SUBZONE	GR VELASCOENSIS	GR VELASCOENSIS		GR. VELASCOENSIS: GR VELASCOENSIS	GR VELASCOENSIS	GR. ACUTA: AEQUA SUBZONE	GR VELASCOENSIS	GR VELASCOENSIS	GR PSOUDOMONARDII GR VELASCOENSIS		GR VELASCOENSIS	GR VELASCOENSIS	GR VELASCOENSIS	GR VELASCOENSIS	GR VELASCOENSIS
			lower		GR PSOUDOMONARDII		GR PSOUDOMONARDII SUBZONE	GR PSOUDOMONARDII			GR PSOUDOMONARDII	GR PSOUDOMONARDII	GR PSOUDOMONARDII		GR PSOUDOMONARDII			GR PSOUDOMONARDII	GR PSOUDOMONARDII	GR. UNCINATA: ACUTA / SPIRALIS / SUBZONE	GR PSOUDOMONARDII	GR PSOUDOMONARDII
		MIDDLE PALEOCENE			GR PUSILLA; GR UNCINATA	GR ANGULATA; A UNCINATA	GR. ANGULATA: GR PUSILLA; GR UNCINATA	GR ANGULATA; GR UNCINATA	GR ANGULATA; A UNCINATA		GR ANGULATA; GR UNCINATA		GR PUSILLA PUSILLA; GR UNCINATA UNCINATA		GR PUSILLA PUSILLA; GR UNCINATA			GR UNCINATA; GR UNCINATA	GR PUSILLA PUSILLA; GR UNCINATA	GR. UNCINATA: GR PSEUDOBULLOIDES SUBZONE	GR PUSILLA PUSILLA; GR UNCINATA	GR PUSILLA PUSILLA; GR UNCINATA
		LOWER PALEOCENE		** ? Gg DAUBJERGENSIS	Gg DAUBJERGENSIS GR PSEUDO BULLOIDES	GR TRILOCULINOIDES GR PSEUDOBULLOIDES	GR COMPRESSA Gg DAUBJERGENSIS	GR TRINIDADENSIS; GR PSEUDOBULLOIDES	GR TRINIDADENSIS GR PSEUDOBULLOIDES; Gg (DOG) EOBULLOIDES		GR TRINIDADENSIS GR PSEUDOBULLOIDES; Gg EOBULLOIDES		GR COMPRESSA		Gg DAUBJERGENSIS GR PSEUDOBULLOIDES			Gg PSEUDOBULLOIDES Gg DAUBJERGENSIS	GR TRINIDADENSIS	GR COMPRESSA Gg DAUBJERGENSIS	GR TRINIDADENSIS Gg DAUBJERGENSIS	GD DAUBJERGENSIS

A: *Acarinina* C.: *Catapsydrax* Cr.: *Cribrohantkenina* Eog.: *Eoglobigerina* G.: *Globigerapsis* Gc.: *Globoconusa* G…

O.: *Orbulinoides* Op.: *Operculina* P.: *Porticulasphaera* Pr.: *Planorotalia* Ps.: *Pseudogloboquadrina* T: *Truncorotalo…*

* (1) CARIBBEAN: BOLLI 1957, 1966, 1970; BOLLI & BERMUDEZ 1965, BOLLI & PREMOLI SILVA 1973. (2) ITALY: BOLLI & CITA 1960; LUTERBACHER 1964, 197… (3) SYRIA: KRASHENINNIKOV 1971. (4) CRIMEA - CAUCASUS - TRANSCAUCASUS: SUBBOTINA 1947, 1953; SHUTSKAYA 1956; 1960; MOROZOVA … (6) N. ATLANTIC - BOREAL EUROPE: HANSEN 1968, BERGGREN 1972

IN EGYPT AND OTHER PARTS OF THE WORLD.

L B I O Z O N E S

OTHER PARTS OF THE WORLD

COMPILED BY KRASHENINNIKOV ACCORDING TO BOLLI & KRASHENINNIKOV 1977**

Source	Zones (top to bottom)
LUTERBACHER (1964) CENTRAL APENNINES	(hatched); GR BULLBROOKI; ?—?—?; GR ARAGONENSIS; ?—?—?; GR FORMOSA / FORMOSA /; GR AEQUA; GR VELASCOENSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR UNCINATA; GR TRINIDADENSIS; GR PSEUDOBULLOIDES; Gg ENGUBINA
BOLLI (1966) WORLD WIDE	GR CERROAZULENSIS; G SEMIINVOLUTUS; R ROHRI; P MEXICANA; GR LEHNERI; G KUGLERI; H ARAGONENSIS; GR PALMORAE; GR ARAGONENSIS; GR FORMOSA / FORMOSA /; GR REX; GR VELASCOENSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; GR UNCINATA; GR TRINIDADENSIS; GR PSEUDOBULLOIDES; Gg ENGUBINA
SAMUEL & BYSTRICKA (1968) SLOVAKEI	Gg OFFIAINALIS; A INDEX; R ROHRI; GR CERROAZULENSIS; GR ARAGONENSIS CRATER; GR; SUBBOTINAE; MARGINODONTATA; GR ACQUA; GR PUSILLA PUSILLA; TU (A) INCONSTANS; PRAECURORIA; Gg COMPRESSA; (hatched)
MOHAN & SOODAN (1970) INDIA	C UNICARES R ROHRI; O BECKMANNI; GD KUGLERI Gg FRONTOSA; H ARAGONENSIS; (hatched)
OLSSON (1970) NEW JERSEY	(hatched); GR SUBBOTINAE; GR VELASCOENSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; GR UNCINATA; GR TRINIDADENSIS; Gg EDITA
TOUMARKINE & BOLLI (1970) ITALY	GR CERROAZULENSIS CUNIALENSIS; GR CERROAZULENSIS; GR COCOAENSIS; GR CERROAZULENSIS CERROAZULENSIS POMOROLIS; GR CERROAZULENSIS POMOROLI; GR CERROAZULENSIS; POSSAGNOONSIS; GR CERROAZULENSIS FRONTOSA; (hatched)
POSTUMA (1971) WORLD WIDE	GR CERROAZLENSIS; G SEMIINVOLUTUS; R ROHRI; O BECKMANNI; GR LEHNERI; G KUGLERI; GR BULLBROOKI; GR FORMOSA / FORMOSA / GR ARAGONENSIS; GR REX; GR VELASCONSIS; GR PSOUDOMONARDII; GR ANGULATA; GR UNCINATA; Gg DAUBJERGENSIS
MEHROTRA & BANERJI (1972) CAUVERY BASIN	(hatched); GR VELASCONSIS GR WHITEI; GR PSOUDOMONARDII GR PUSILLA LACVIGATA; GR UNCINATA; GR PSEUDOBULLOIDES
KARAM (1973) JORDAN	(hatched); GR FORMOSA / FORMOSA / GR ARAGONENSIS; GR REX; GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA; GR UNCINATA; GR TRINIDADENSIS GR PSEUDOBULLOIDES; Gg DAUBJERGENSIS Gg COMPRESSA
POMEROL (1973) WORLD WIDE	Gg GORTANTI; GR CERROAZULENSIS; G SEMIINVOLUTUS; R ROHRI; P MEXICANA; GR LEHNERI; G KUGLERI; H ARAGONENSIS; GR PALMORAE; GR ARAGONENSIS; GR FORMOSA / FORMOSA /; GR AEQUA GR SUBBOTINAE GR REX; GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; GR UNCINATA; GR TRINIDADENSIS; GR PSEUDOBULLOIDES Gg DAUBJERGENSIS; Gg EUGUBINA
DORREEN (1974) PAKISTAN	LIMESTONE; GR CERROAZULENSIS; G KUGLERI; G CHAMBLEI; H ARAGONENSIS; GR REX; GR VELASCONSIS; GR ANGULATA; GR PSEUDOBULLOIDES
EL-KHAYAL (1974) SAUDI ARABIA	(hatched); G KUGLERI; GR BULLBROOKI; GR FORMOSA / FORMOSA / GR ARAGONENSIS; GR SUBBOTINAE; GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; (hatched); PRAECURSORIA; GR PSEUDOBULLOIDES; Gg EUGUBINA
STAINFORTH et al (1975) WORLD WIDE	GR CERROAZULENSIS S.L; GTH SEMIINVOLUTUS; R ROHRI; O BECKMANNI; GR LEHNERI; GTH SUBCONGLOBATA; H ARAGONENSIS; GR PENTACAMERATA; GR ARAGONENSIS; GR FORMOSA FORMOSA; GR SUBBOTINAE; GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; GR UNCINATA; GR TRINIDADENSIS; GR PSEUDOBULLOIDES; Gg EUGUBINA
SALAJ et al (1976) TUNISIA	(hatched); GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; PRAECURSORIA GR UNCINATA GC KOZLOWSKI; GR TRINIDADENSIS: PR PRAECURSORIA, Gg COMPRESSA, GR PSEUDOBULLOIDES SUBZONE; GC TAMRICA
CARIBBEAN -1-	GR CERROAZULENSIS S.L; GTH SEMIINVOLUTUS; R ROHRI; O BECKMANNI; GR LEHNERI; GTH SUBCONGLOBATA SUBCONGLOBATA; H ARAGONENSIS; GR PALMORAE; GR ARAGONENSIS; GR FORMOSA / FORMOSA; GR SUBBOTINAE GR EDGARI; GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; GR UNCINATA; GR TRINIDADENSIS; GR PSEUDOBULLOIDES; Gg EUGUBINA
ITALY -2-	GTH SEMIINVOLUTA, GR CERROAZULENSIS: GR CERROAZ, GR CERROAZULENSIS COCOAENSIS, GR CERROAZULENSIS; R ROHRI: GR CERROAZULENSIS POMOROLI; O BECKMANNI: GR CERROAZULENSIS CERROAZULENSIS POMOROLI; GR LEHNERI: GR LEHNERI; GTH SUBCONGLOBATA: POSSAGNOONSIS, GR CERROAZULENSIS; H ARAGONENSIS: FRONTOSA; GR PENTACAMERATA; GR ARAGONENSIS; GR FORMOSA / FORMOSA /; GR SUBBOTINAE; GR VELASCONSIS; GR PSOUDOMONARDII; GR PUSILLA PUSILLA; GR ANGULATA; GR UNCINATA; GR TRINIDADENSIS; GR PSEUDOBULLOIDES; Gg EUGUBINA
SYRIA -3-	Gg CORPULENTA: GR CUNIALENSIS, GR COCOAENSIS, G SEMIINVOLUTUS; R ROHRI; H ALABAMONSIS; A ROTUNDIMARGINATA; GR BULLBROOKI: G KUGLERI, H ARAGONENSIS; H ARAGONENSIS: A PENTACAMRATA, GR ARAGONENSIS; GR MARGINODONTATA; GR SUBBOTINAE; GR VELASCONSIS; GR PSOUDOMONARDII; GR ANGULATA: A CONICOJRUNCATA, GR ANGULATA; A UNCINATA; GR PSEUDOBULLOIDES GR TRINIDADENSIS; Gg TOURICA; ?
CRIMEA-CAUCASUS-TRANSCAUCASUS -4-	Gd CONGLOBATUS: GR CUNIALENSIS, GR COCOAENSIS, GTH SEMIINVOLUTUS; Gg TURCMONICA; H ALABAMONSIS; A ROTUNDIMARGINATA; A CRASSAFORMIS: G KUGLERI, H ARAGONENSIS; GR ARAGONENSIS; GR MARGINODONTATA; GR SUBBOTINAE; A ACARINATA; A SUBSPHAERICA; A TADJIKISTANESIS; A CONICOJRUNCATA; GR ANGULATA; A UNCINATA; GR PSEUDOBULLOIDES GR TRIVIALIS; Gg TOURICA; Gg EUGUBINA
NEW ZEALAND -5-	GR BROVIS; Gg LINAPERTA; GR INCONSPICUA; GTH INDEX; PS PRIMITIVA; GR CRATER CRATER; GR WILCOXENSIS; Gg TRILOCULINOIDES; Gg PAUCILOCULATA
NORTH ATLANTIC-BOREAL EUROPE -6-	Gg ANGIPOROIDES; Gg LINAPERIA; Gg GALAVASTA; NO RECORD; INDEX; A DONSA; GR FRONTOSA; Gg PATAGONICA; Gg TRIANGULARIS; NO RECORD; ANGULATA; NO RECORD; GR PSEUDOBULLOIDES; NO RECORD

Gd.: Globigerinoides Gg.: Globigerina Gr: Globorotalia Gth: Globigerinatheka H.: Hantkenina N: Nummulites

...aloides Tu.: Turborotalia — Zone boundary — Time boundary ~~~ Unconformity ** Zonal boundary indeterminate

Boundary not exposed or zone absent

...975; CITA et al 1968; BAUMANN 1970; PROTO DECIMA & BOLLI 1970; TOUMARKINE & BOLLI 1970.

... 1959, 1960, NEVZOROVA 1971, KRASHENINNIKOV & PTUKHYAN 1973 (5) NEW ZEALAND: JENKINS 1971.

Fig.(13) BIOSTRATIGRAPHIC CORRELATION BETWEEN THE STUDIED SECTIONS

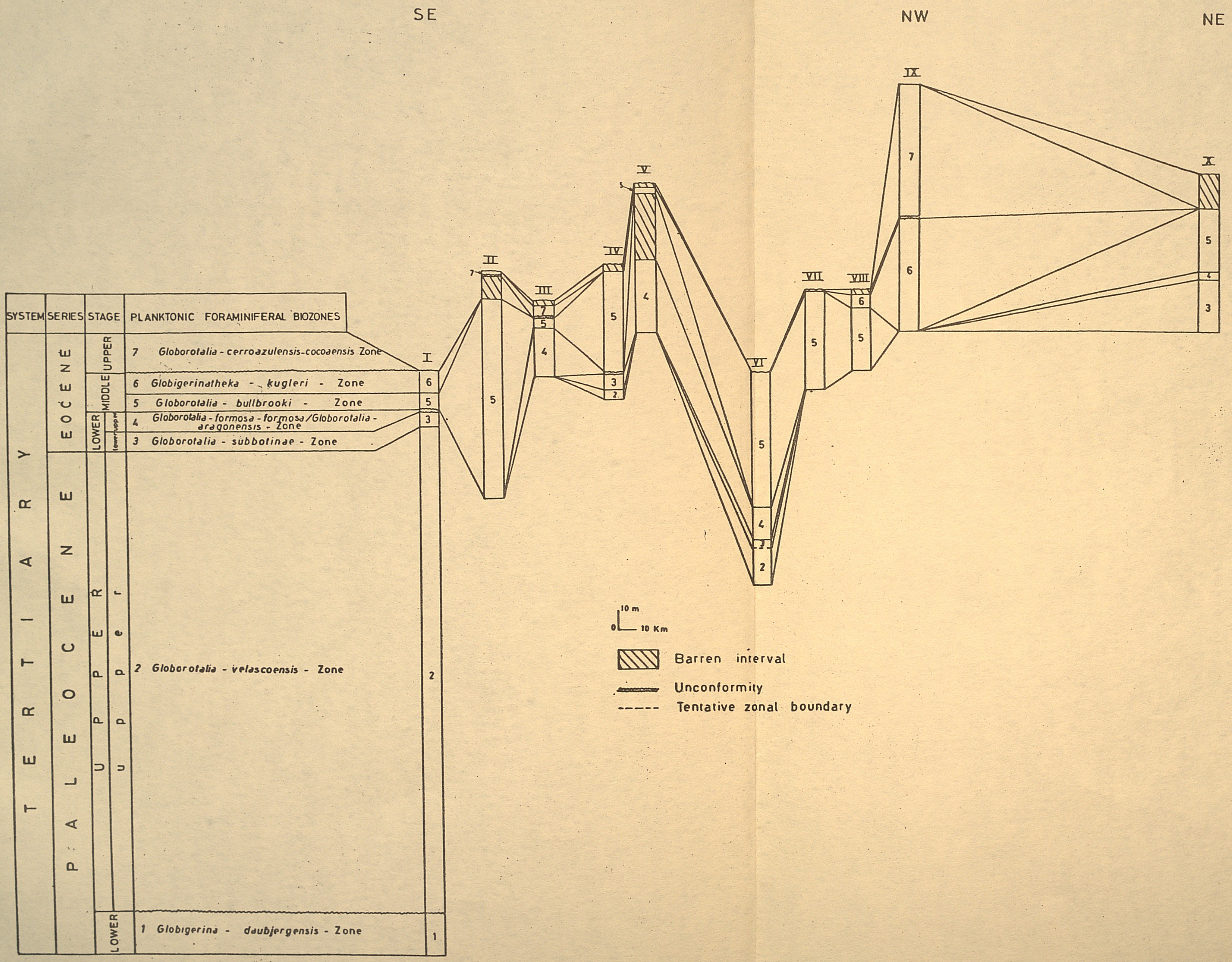
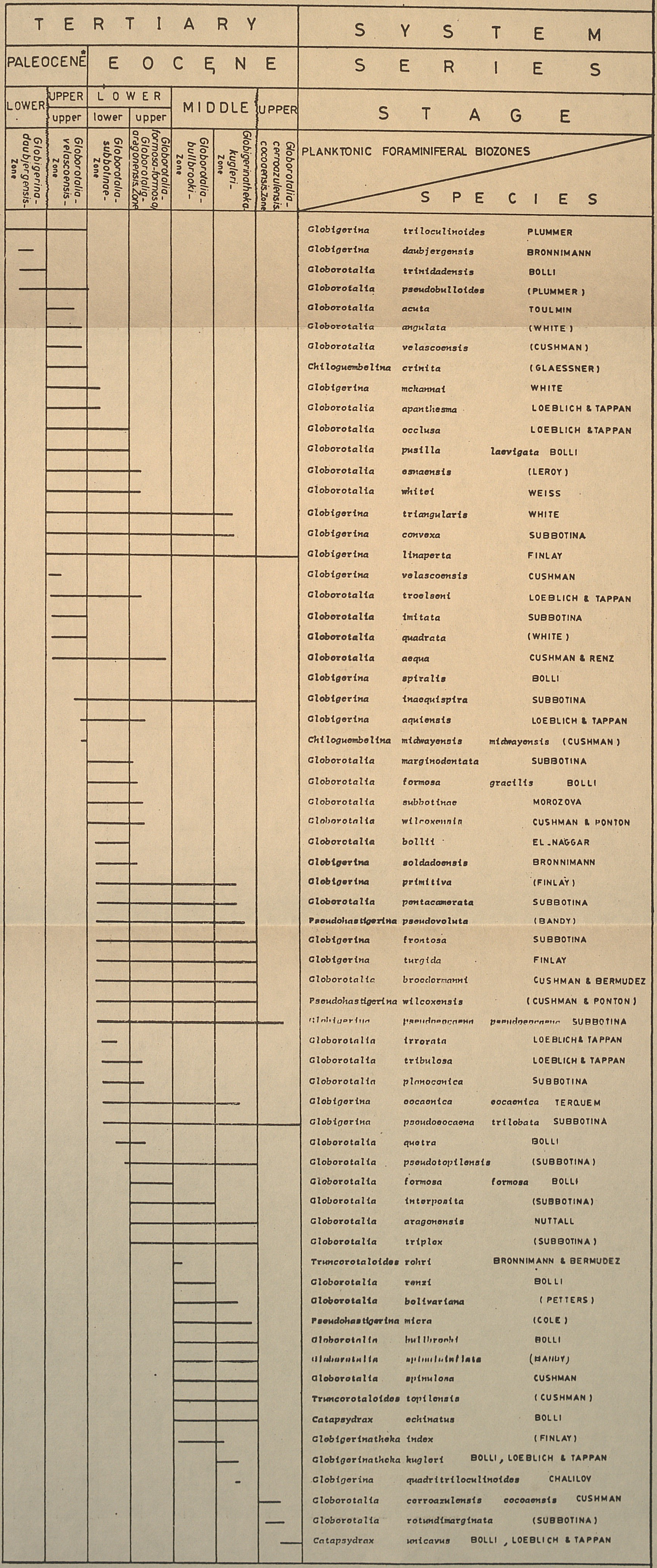


Fig.(12) RANGE OF THE IDENTIFIED PLANKTONIC FORAMINIFERAL SPECIES IN THE STUDIED SECTIONS



* Middle Paleocene is not represented in any of the studied sections.

— Unconformity

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

SOME RECENT CONTRIBUTIONS ON THE MESOZOIC STRATIGRAPHY OF BALUCHISTAN

BY

A.N. FATMI[1]

ABSTRACT :–The Upper age limit of Windar group and the age of Sembar Formation are redefined on the basis of recent paleontological evidences in the Axial Belt region of Southern Baluchistan (Kanrach - Windar Nai Section). The Windar group is dated as Bajocian/ Toarcian in its Upper age limit while the lower limit may extend into the Late Triassic.

Nearly 2/3 of the disconformably overlying Sembar Formation which has yielded an abundant Cephelopod fauna is dated as Late Jurassic. The Jurassic/Cretaceous boundary lies fairly high in this sequence. Most of the Middle Jurassic (Post Bajocian) sediments are missing in Southern Baluchistan either depositionally or erosionally.

A new Triassic (Early and Late) section with abundant Lower Triassic Cephelopods is recorded in the Gowal - Khanozai area of Northern Baluchistan for the first time.

The Stratigraphic problems of Mesozoic rocks are discussed in an attempt to draw attention of the geologists for a better stratigraphic planning of the area.

Stratigraphic and paleontological studies of the Windar group of contended Jurassic – Triassic age and of the Sembar Formation of contended Early Cretaceous age (Hunting Survey Corporation, 1960) in the Axial Belt region of Southern Baluchistan (Kanrach – Winder Sections) indicate that the Upper age limit of Windar group in Southern Baluchistan including Gadani area does not extend beyond lower most Middle Jurassic (Bajocian) and in some areas suggest an Early Jurassic (Toarcian) age.

The Bajocian Cephelopods occur in a condensed top most rusty brown weathering bed in Kanrach and Sund areas and has yielded typical, widely distributed species of ammonoid genera like *Docidoceras Emileia, Stephanoceras (Skiroceras), Witchellia, Sonninia* etc. Which establishes a correlation with Europe, Hungary, Iran and Turkey etc.

The Toarcian ammonoids occur a few meters (5 – 30) below this top bed and consist of widely occuring species of the genera, *Bouleiceras, Protogrammoceras.* Fuciniceras and *Dactylioceras* etc. A great thickness of marine sequence of limestone and calcareous shale and marl occur below the Toarcian horizon of Windar group and suggest that in southern Baluchistan Pre – Toarcian Jurassic rocks unlike that of Potwar are marine and that this area offers one of the few Pre-Toarcian marine sections for study. Although Pre Toarcian fauna is not yet fully discovered and studied but it is likely that the Jurassic – Triassic boundary in this section may be comformable occuring near the lower sandy unit of the Windar group. The Triassic/Jurassic boundary in potwar and Kalachitta is however, disconformable.

The disconformably overlying thick marine sequence

1. Geological Survey of Pakistan, Quetta.

of Sembar Formation over the Windar group in Windar – Kanrach Sections consist of silty shale with rusty brown weathering siltstone and cherty interbeds. The Sembar Formation in some areas includes a unfossiliferous sandstone unit in the lower part while the upper part becomes calcareous and is gradational (with the inclusion of argillaceous limestone beds) into the overlying Goru Formation. The lower 2/3 of the Sembar Formation has yielded a rich Late Jurassic (Kimmeridgian – Tithonian) fauna (in manuscript) and indicate that nearly 2/3 of Sembar is of Late Jurassic age and Jurassic/Cretaceous boundary lies in southern Baluchistan. The ammonoids include various species of widely occuring genera like *Taramelliceras, Hybonoticeras, Aspidoceras, Idoceras, Orthaspidoceras, Katroliceras, Pachysphinetes, Physodoceras, Glochiceras, Glochiceras, Phylloceras Lytoceras* etc. in the lower – middle part of the sequence. Higher up in the Sembar Formation *Blanfordiceras, Blanfordiceras, Virgatosphinctes Spiticeras* and some *Phylloceratids* occur indicating a Tithonian age. This rich Upper Jurassic fauna, is the first recorded occurance from this area and will prove of great importance in regional and inter regional correlation. It estabiishes correlation with Cutch, potwar – Kohat, Hazara, Southern Germany, Madagascar and South America etc.

Stratigraphic and paleontological studies of structurally complicated Mesozoic section South of Gowal – Khanozai in the Axial Belt region of Northern Baluchistan, 50 Kms north east of Quetta has resulted in the discovery of a fairly rich Lower Triassic Cephalopod fauna occuring in grey, green, purple (variegated) friable shale with intercalated limestone interbeds wedged in between the faulted outcrops of the Cretaceous Pargh group. These Triassic out crops have not been previously mapped and included in the Cretaceous Parah group (Hunting Survey Corporation, 1961; Allemann in Geodynamics of Pakistan, 1979).

The Lower Triassic sequence in the Gowal section consists of a moderately deep marine variegated fine clastic rocks with subordinate grey, partly brecciated to conglomeratic micritic limestone interbeds. The limestone becomes a dominant lithology in the upper part. These shale and limestone are overlain by Upper Triassic well bedded silty shale and fine grained sandstone of grey to flashy colour and has yielded *Halobia – Dianella* bivalve fauna in the lower part. The contract between the Upper and Lower Triassic is discomformable marked by chert bearing limestone boulder bed or grit. The whole Triassic sequence is faulted both inthe upper and lower limits.

The lower Triassic fauna (in manuscript) is of Middle – Upper Scythian age and include world wide species of ammonoid general like *Meekoceras, Owenites, Aspenites, Anakashmirites, Dienaroceras, Xenodiscoides,* etc. followed by a second horizon of *Arcto-prionites, Durgaites, Anasibirites Preflorianites.* The fauna is correlative with the Upper – Middle Mianwali Formation of Kalachitta and Salt Range but differ in the Sedimentary facies of these areas. It is also correlated with Afghanistan, China and Greeland, America etc. The intra Triassic discomformity spotted in this area differs from that of Salt Range and Kalachitta where no such discomformity exist. Similarly Afghanistan Middle Triassic fauna is known to occur.

It is, therefore concluded that the Mesozoic rocks of Baluchistan particularly those of the Axial Belt Region which have a great economic potential (lead, Zinc, Barutes, Flourite etc.) require a detailed geological study. These sediments show a great variability in depositionaly environment, ages, facies changes resulting from the northward plate or plates movements during the Mesozoic times. These movements may have initiated the development of geanticlinal structure in the Axial Belt region at the close of Early Jurassic time. The Middle Jurassic Sediments are generally missing as contrasted to the adjoining areas of Sulaiman – Kirthar and Kohat – Potwar Provinces where shallow water carbonate deposition continued during the Middle Jurassic till the emergence of the whole area at the close of Early to Middle Callovian. A major transgression took place in the Late Jurassic (Late Oxfordian). The other major sea transgression in Pakistan is believed to be of Toarcian in age connecting most of the Jurassic areas of Pakistan.

The geological knowledge of the Mesozoic rocks of Baluchistan is still very limited and offers a great challenge to our biostratigraphers and sedimentalogist whose immediate attention is required to interpret these changing patterns of deposition, uplift or erosion and in defining the Permian/Triassic, Triassic/Jurassic, Jurassic/Cretaceous and Cretaceous/Tertiary boundaries in Baluchistan.

REFERENCES

Arkell, W. J. et al. 1957, Treatise on INVERTEBRATE PALEONTOLOGY (R.C. Moore Edt.) Part L, Mollusca 4 Cephalopoda (Ammonoidea) *Geol. Soc. Am* and University of Kansas Press.

Diener, C, 1906, Notes on an Upper Triassic fauna from the Pishin District Baluchistan *Geol. Surv. Ind. Mem.* Vol. 34, p. 12–21.

Fatmi, A. N., 1972, Stratigraphy of the Jurassic and Lower Cretaceous rocks and Jurassic ammonites from northern areas of West Pakistan : *British Mus. Nat. Hist. Bull, (Geol).* Vol. 20 no. 7, pp. 299–380.

1973, Lithostratigraphic units of the Kohat Potwar Province, Indus Basin, Pakistan: Pakistan *Geol. Surv., Mem.*, v. 10. 80 p.

1977, Mesozoic of Pakistan in Stratigraphy of Pakistan (Shah Ibrahim Edt). *Mem. G. S. P.* Vol. 12, pp. 29–56.

Vredenburg, E. W. 1904. On the occurence of a species of Haloritı in the Trias of Baluchistan : Ibid., *Recs. G. S. I.*, v. 31, pt. 3, pp. 162–166.

Vredenburg, E. W., 1909 b, Report on the geology of Sarawan, Jhalawan, Makran and the State of Lasbela: Ibid., Recs. v. 38, pt. 3, pp. 189–215.

Williams M. Dean; 1959, Stratigraphy of the Lower Indus Basin West Pakistan World Petroleum Congress 5th New York. Proc. Sec. 1, Paper 19, p. 337–390.

XX Time of Emplacement of the Zhob Valley Ophiolites and Bela Ophiolites, Baluchistan. (Preliminary Report) in Geodynamics of Pakistan (A. Farah and K.A. De jong editors) P. 217–218.

A PLATE TECTONIC MODEL FOR NORTHWEST HIMALAYAS[4]

BY

M. NAWAZ CHAUDHRY[1]

MUNIR GHAZANFAR[2]

M. ASHRAF MIAN[3]

INTRODUCTION

Plate tectonic models for the collision of India with Asia have been forwarded by a number of scientific workers (Dewey and Bird, 1970; Crawford, 1974; Powell and Conaghan, 1973; Sillitoe, 1975; Gansser 1974). but most of these concern the central and eastern Himalayas. Tahirkheli, Mattauer Proust, Tapponnier, 1979; have presented some thoughts on the sequence of events in the northwest Himalayas. They have indicated an initial ocean-ocean collision leading to the formation of an island arc in the north of the Indian plate. Later, according to these authors, this area was sutured to the south with the Indian and to the north with the Asian continents, and that the sequence of rocks constituting this island arc system is now located between two major thrusts, the Main Mantle Thrust (MMT) in the south and the Northern Suture Zone or the Main Karakoram Thrust (MKT) in the north. They have called it the Kohistan Island Arc sequence.

In the following pages a different model is postulated which is based on the situation of the rock types as they actually exist on the ground. This model partially developed before (Butt, Chaudhry and Ashraf, 1980) uses petrotectonic approach which is considered best since various petrotectonic regimes represent distinct tectonic environments. The fact that extensive thrusting and large scale transportation of chunks of rocks have juxtaposed unrelated rock units makes little difference since petrological studies on such blocks help in establishing their natural places in a plate tectonic model.

TWO ISLAND ARCS SANDWICHING A CENTRAL MASS OF OCEANIC LITHOSPHERE.

A generalized section from Shewa in the south to Chitral in the north represents a fairly symmetrical succession of rock types which from south to north occurs as follows. (The substance of this section is based on the mapping and work carried out in the region previously by Chaudhry, Jaffery and Saleemi 1974; Chaudhry, Mahmood and Shafiq 1974; Chaudhry M. N. and Chaudhry A. G. 1974; Chaudhry, Kausar and Lodhi 1974; Chaudhry M. N. Mahmood and Chaudhry A. G. 1974; Chaudhry, Ashraf and Hussain 1976; Chaudhry, Ashraf and Hussain, 1980; Chaudhry, Ashraf and Hussain 1980, 1981):

Indian marginal zone	**Indian continent**
Southern sedimentary-volcanic zone	**Southern island arc**
Southern trench zone **Southern melange zone.**	**Southern obducted melange**
Central layered intrusions	**Tethys oceanic lithosphere**
Northern melange zone **Northern trench zone**	**Northern obducted melange**
Northern sedimentary-volcanic zone	**Northern island arc**
Asian marginal zone	**Asian continent**

As can be seen from the above sequence of rock types two separate island arcs juxtapose Indian and the Asian continents. Further these two island arcs are in contact with two separate trench melange sequences which in turn

1. 2. Institute of Geology, Punjab University, New Campus, Lahore, Pakistan.

3. Institute of Applied Geology, Azad Jammu and Kashmir University, Mazaffarabad.

4. Read at the international Seminar on the stratigraphy of Pakistan on 21-2-83 at the institute of Geology, Punjab University, Lahore.

sandwich a central thick layered sequence of oceanic lithosphere. The rocks comprising this oceanic lithosphere were described as part of the Kohistan island arc sequence in the past (Tahirkheli, Mattauer, Proust, Tapponier 1979) while the present writers consider these too basic to represent an island arc. To us their composition and structure represent a typical oceanic lithosphere. Below we give a detailed description of the petrotectonic units enumerated above.

INDIAN MARGINAL ZONE

This zone comprises Precambrian and Palaeozoic metasediments (and granites) which have suffered polymetamorphism and show up to four lineations (Shams, 1961; Shams and Rehman, 1966; Shams, 1969). These rocks have been intruded by younger granites like Malakand granite, Chail Sar granite, Karka granite, etc. and contain large numbers of dykes (Shams, and Ahmad, 1968) representing passages from basic to intermediate volcanic eruptions. All this activity seems to be connected with southward underthrusting by the Tethy's oceanic lithosphere under the Indian continental mass.

This continental marginal zone is also intruded by a northeast-southwest extending zone of alkaline intrusions, feldspathoidal syenites, nordmarkites, alkali granites (Ahmad, Khan, Shah and Ullah, 1969), porphyries and carbonatites (Ashraf and Chaudhry 1977, Ahmad and Ali 1977), with associated fenites. These rocks appear to have been emplaced along roughly en echelon weak planes of tension. The associated normal acidic rocks (first described by Chaudhry et al., 1982) developed during periods of compression. The zone as a whole thus appears to have suffered alternate compression and tension.

SOUTHERN SEDIMENTARY VOLCANIC ZONE

The zone is present south of the Main Mantle Thrust (MMT) near Shangla, Char Bagh, Mingora, Murghzar and extends into Bajaur and even beyond. This zone contains basic to intermediate and even acidic volcanics and equivalents and associated metasediments. These metasediments are younger and low grade compared to the older and higher grade metamorphics of the nearby Indian marginal zone. These rocks represent southward thrusted fault blocks and sliced-off remnants of a southern island arc.

SOUTHERN TRENCH ZONE

This is the zone of high pressure, low temperature metamorphism. This again manifests block faulting. Blueschists are found in this zone near Shangla (Shams 1979; Shams, Jones and Kempe 1980; Shams, 1980; Shams and Desio; 1980).

SOUTHERN MELANGE ZONE

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

On the southern side close to the MMT these are cut by acid porphyries and probable volcanics near Bandagai, Ziarat Talash and Shahi in Dir (Gansser, 1974). For a different interpretation of these rocks see Jan, 1980; Jan 1980a.

CENTRAL LAYERED INTRUSIONS

The norites, noritic gabbro complexes represent tholeiitic magmas of the Tethyan oceanic lithosphere. The norite and noritic gabbros represent deeper; water poor, intrusions which contain olivine-pyroxene cumulates. The sequence is quite similar to part of the present day oceanic lithosphere. For olivine cumulates see Shams, 1975; Shams and Shafique, 1979.

NORTHERN MELANGE ZONE

This zone comprises amphibolites with slices of eclogites and ultrabasics.

THE NORTHERN TRENCH ZONE

Conclusive evidence of this zone has not been found so far but is likely to be found.

NORTHERN SEDIMENTARY-VOLCANIC ZONE

In Dir it is represented by a thick sequence of quartzites with substantial volcanic element and marls, shales and limestones with interbedded volcanics. This sedimentary-volcanic sequence extends into Swat-Kohistan and beyond. The volcanics belong to the andesite-dacite-rhyolite sequence. A part of the volcanic activity was subaerial. The sedimentary-volcanic sequence has undergone greenschist facies metamorphism. The pile is cut by a number of acid plutons. The environment throughout its extent is suitable for porphyry deposits all along and close to this sequence. The area is also suitable for stratiform-stratabound ore deposits.

ASIAN MARGINAL ZONE

The Asian continental edge consists of a series of metamorphics, gneisses and granites of Palaeozoic age. They are cut by acid to intermediate rocks of Cretaceous-Upper Tertiary age. There is also volcanic activity of andesite, dacite, rhyolite type. The magmas and lavas were most probably generated by partial melting of subducting Tethyan plate and of intermingled continental crust.

MINERALIZATION

There is a distinctive suite of ore mineralization related to each particular tectonic unit. The younger acidic rocks on both the continental plate margins show beryl, mica, and metals such as lead, zinc, molybdenum and uranium etc.

The alkaline rocks in the Indian marginal zone are associated with rare earths, uranium, thorium, neubium and phosphorous.

The island arcs contain stratiform-stratabound deposits and have indicated possibilities of porphyries.

The ultrabasics and melanges show chromite, nickel and platinum mineralization.

Although no detailed work has so far been carried out on the central oceanic lithosphere there are showings of the metallic deposits usually associated with the layered marine tholeiites.

SUMMARY AND CONCLUSIONS

The petrotectonic zones in the section between Shewa to Chitral and adjoining areas are more or less symmetrically disposed on either side of the central layered intrusions which represents oceanic lithosphere. There are southern and northern melanges, southern and northern volcanic-sedimentary zones (arcs), and the high pressure low temperature rocks (trench zone) which have so far been discovered only on the southern side.

The southern trench is located in the north of the southern island arc sequence and therefore indicates an initial subduction of Tethyan plate under the Indian continent. This is contrary to what is normally postulated viz. northward directed subduction.

The central layered intrusions represent oceanic lithosphere as against the, idea that they form lower part of the so-called island arc sequence (Tahirkheli et al. 1979). The huge succession that has previously been called the Kohistan island arc actually comprises four distinct units or petrotectonic provinces viz. from south, southern melange zone, central layered intrusions, northern melange zone and the northern island arc of Asian plate affinity.

The term Kohistan island arc may be kept but should be used only for a narrower zone south of the MMT i.e. between the Indian continental margin and the MMT and not for rocks north of the MMT, as originally envisaged.

One problem with the present model which envisages initial southward subduction under the Indian plate margin is the southward vergence (northward dip) of the rock units and contacts. More work is needed to explain this phenomenon but one possibility is later back folding of the rocks and tectonic contacts as the collision continued and suturing progressed.

REFERENCES

Ahmad, M., Ali, K.S.S., Khan, B., Shah, D.A., and Ullah, I., (1969). The geology of Warsak area, Peshawar, W. Pakistan, *Geol. Bull. Univ. Pesh.* Vol. 4, pp. 44-78.

Ahmad, R., and Ali, S.T., (1977) Occurrence of phosphate in Loe Shalman carbonatite. *Geol. Surv. Pak. I. R.* No. 101, p. 19.

Ashraf, M., Chadhry, M.N., (1977). A discovery of carbonatite from Malakand. *Geol. Bull. Punjab Univ. No. 14, pp. 39-44.*

Ashraf, M, Chaudhry, M. N. and Hussain, S.S., (1979). General geology and economic significance of Lahore granite and rocks of southern ophiolite belt in Allai-Kohistan area. *Proc. Inter. Commit. Geodyn* Group 6, Mtg., Peshawar, pp. 207-213.

Ashraf, M., Chaudhry, M. N., and Hussain, S.S., (1980). Molybdenum mineralization associated with igneous metamorphic rocks in Kohistan-Swat districts along Karakoram Highway. *Pak. Metallurgist., Vol. 2.*

Ashraf, M., Chaudhry, M. N., and Hussain, S.S., (1980). Magnetite deposits of Lower Kohistan District, Hazara Div., *Pak. Metallurgist*, Vol. 2.

Chaudhry, M. N., and Chaudhry, A.G (1974). Geology of Khagram area, Dir Dist., *Geol. Bull. Punjab Univ.* No. 11, pp. 21-43.

Chaudhry, M. N., Jaffery, S.A., and Saleemi B.A., (1974). Geology and Petrology of the Malakand granite and its environs. *Geol. Bull. Punjab Univ.* No. 10, pp. 21-42.

Chaudhry, M. N., Kausar A.B , and Lodhi, S A.K., (1974). Geology of Timurgara-Lal Qila area, Dir Dist, N.W.F.P. *Geol. Bull. Punjab Univ.* No. 11, pp. 51-73.

Chaudhry, M. N., Mahmood, A. and Chaudhry, A. G., (1974). The ortho-amphibolites and the para-amphibolites of the Dir Dist. NWFP *Geol. Bull. Punjab Univ.* No. 11 pp. 89-96.

Chaudhry, M. N., Mahmood A, and Shafiq, M., (1974). Geology of Sahibabad-Bibior area, Dir Dist., N.W.F.P. *Geol. Bull. Punjab Univ.* No. 10, pp. 73-85.

Chaudhry, M. N., Ashraf, M., Hussain, S.S., and Iqbal, M. (1976). Geology and petrology of Malakand and a part of Dir (toposheet 38 N/14). *Geol. Bull. Punjab Univ.* No. 12, pp. 17-39.

Chaudhry, M. N., Ashraf, M., and Hussain, S.S (1980). Preliminary study of nickel mineralization in Swat Dist., N.W.F.P. *Contr. Geol. Pak.* Vol. 1, pp. 9-26.

Chaudhry, M. N., Ashraf, M , and Hussain, S.S., (1980). Petrology of Koga nepheline syenites and pegmatites of Swat Dist. *Geol. Bull Punjab Univ.*, Spec. issue.

Chaudhry, M. N., Ashraf, M and Hussain, S.S., (1981). Lead and zinc mineralization of Lower Kohistan District, Hazara Division, N.W.F P., Pakistan. *Kashmir Jour. Geol.* Vo. 1, No. 1 (This Volume).

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

Chaudhry, M. N. and Shams, F.A., (1982). Petrology of Shewa porphyries and associated metasediments. Special Volume on Granites of Himalayas, Karakoram and Himdukush.

Crawford, A.R., (1974). The Salt Range, the Kashmir syntaxis and the Pamir arc. *Earth and Planet. Sci. Letters*, Vol. 22, pp. 371-379.

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

Gansser, A., (1974). The ophiolite melange, a world wide problem on Tethyan example. *Eclogae Geol. Helvetia.* Vol. 67, pp. 479-507.

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

Jan, M. Q., (1980). a Petrology of the obducted mafic ultramafic metamorphites from the southern part of the Kohistan Island Arc sequence. *Proc. Inter Commit. Geodynamics,* Group, 6 spec. issue, *Geol. Bull. Univ. Peshawar.* Vol. 13, pp. 95-108.

Powell, C. McA and Conaghan, P.T., (1973) Plate tectonics and the Himalayas. *Earth and Planet Sci. Letters,* 20, pp. 1-12.

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

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

Shams, F.A, and Ahmad, Z., (1968) Petrology of the basic minor intrusives of the Mansehra-Amb State area, N.W. Pakistan. Part I, The dolerites. *Geol. Bull Punjab Univ.* No. 7, pp. pp.43-58.

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

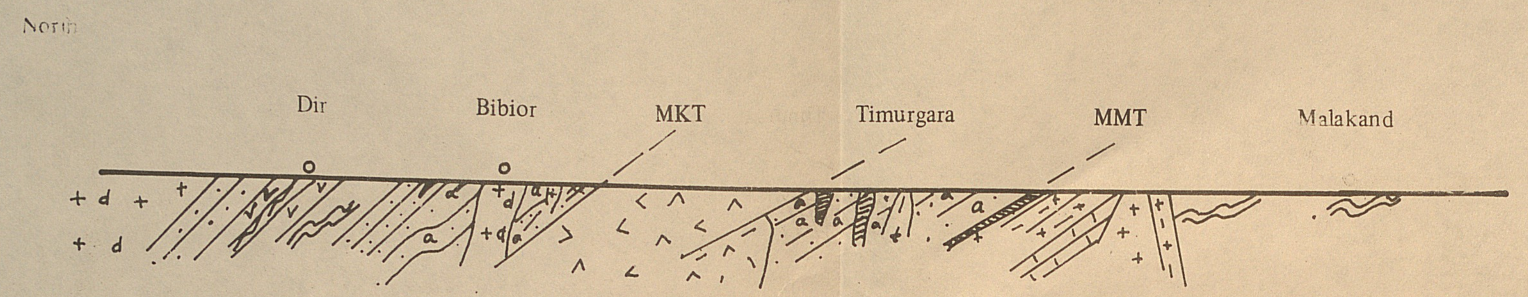
Shams, F.A, (1975). Petrology of the Thak valley igneous complex, Gilgit Agency, Northern Pakistan. *Proc. Italian Acad. Sc., Milan.* Vol. 53, pp. 453-464.

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

Shams, F.A., and Shafiq A., (1979). The petrochemistry of the Thak valley igneous complex, District Diamer, Northern Pakistan. *Pak. Jour. Sci. Res.* Vol. 31, pp. 145-150.

Shams, F.A., (1980). Origin of Shangla blueschists, Swat Himalaya, Pakistan. *Geol. Bull. Pesh. Univ.*, Vol. 13, pp. 67-70.

Tahirkheli, R.A.K., Mattauer, M., Proust, F. and Tapponier, P., (1979). The India -Eurasia suture zone in northern Pakistan; Synthesis and interpretation of data at plate scale, *Geodyn. Pak. Geol. Surv. Pak.* pp. 125-130.



Slightly generalized geological section between Malakand and Dir

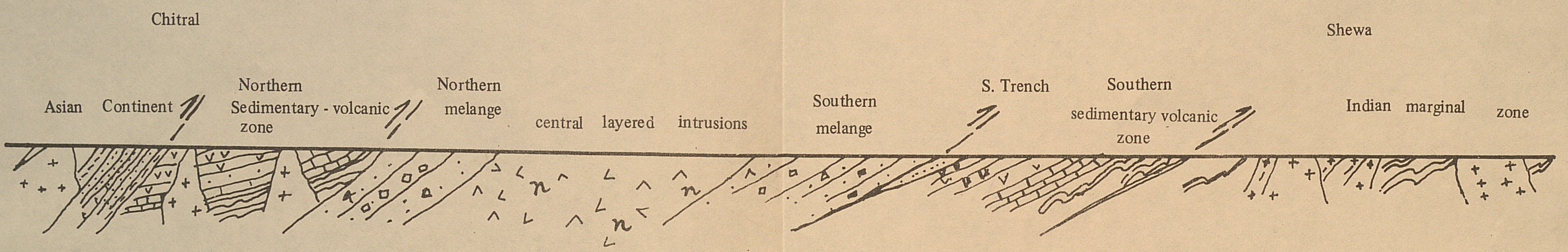
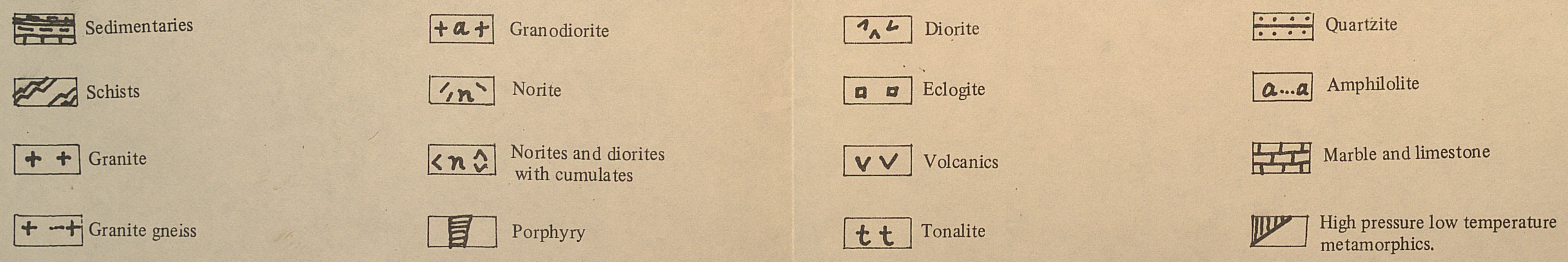


Fig. 1 Genralized and idealized geological Section between Shewa and Chitral



MINERAL SECTOR GETS ADDED EMPHASIS IN SIXTH 5 - YEAR PLAN

By

Nasim Hussain Chattha [1]

Nazir A. Butt [2]

INTRODUCTION

The importance of mineral sector and the contribution it can make for the overall industrialization process of Pakistan have duly been recognized in the Sixth Pla. Vast mineral resources, most of which untapped so far, will need an accelerated exploration programme to upgrade the knowledge on the mineral resource potential of the country. Added emphasis will be placed on rapid and systematic development of mineral projects for the already delineated ore bodies to meet domestic industrial and agricultural demands of minerals, increase imports substitution and earn foreign exchange through export of minerals not used locally.

Major emphasis has been placed on minerals that increase self-reliance in energy and supply of raw-material for PAK-STEEL; the imported raw material component mainly metallurgical coal, iron ore and manganese account for nearly 50 percent of the cost of production of basic steel produced at this Mill. There is an urgent need to use coal in place of oil (most of which is imported) in the process industry and the substitution of gas by coal to generate electricity. Similarly household use of gas could be replaced by briquettes to conserve the former for use in fertilizer and chemical industries.

The Sixth Plan envisages substantial increase in financial outlays in public mining sector. Other financial measures will also be enacted to increase direct participation of financial institutions for equity and credits. Adjustments in policy priorities, special stress on private sector and re-organization of public sector are proposed to make mineral sector more dynamic. Joint ventures with transnational firms, provision of infrastructure for mining areas and training of technical manpower are also stipulated.

FIFTH PLAN REVIEWED.

In Public sector, certain major minerals such as copper (Saindak), coal (Lakhra), rock phosphate (Hazara), iron ore (Nokundi), gypsum (Mianwali), emeralds (Swat) and magnesite (Abbottabad) were identified and investigations have advanced to project development stage. Mine development for these minerals is either assured or likely to be achieved in the near future.

Resource Development Corporation (RDC) has identified mineral resources of 412 million tonnes (mt) of copper and associated valuable minerals like gold, silver, etc., at Saindak. The viability of this project to a large extent, has reportedly been proven and the feasibility studies completed. It has been proposed to implement Phase – I of the project (blister copper and sulphuric acid production) at an estimated cost of US $ 330 million. For Phase - II, that is, the steel billets, the technical viability needs to be verified. This project will be included in the special development programme for Baluchistan. Because of heavy foreign exchange component and the need for modern technology to implement this project, the RDC is trying to get foreign financial participation.

Pakistan Mineral Development Corporation (PMDC) increased its production capability of coal from Makerwal colleries by 150 percent, installed a coal washing plant at Shahrigh and raised rock salt production by about 45 percent with some rock salt being exported to India and East Africa. Gemstone Corporation (GEMCP) functioning since 1979 has increased the production of emeralds and rubies and discovered new deposits. Pakistan Industrial Development Corporation (PIDC) upgraded as proven 30 mts of iron ore reserves (technically suitable for PAK-STEEL) at Nakkundi, and 11 mts of magnesite for refractory industry.

1-2 Department of Mining Engineering, Engineering University Lahore.

Similarly, Federally Administered Tribal Areas Development Corporation (FATADC) and Azad Kashmir Mineral and Industrial Development Corporation (AKMI DC) have identified many minerals of economic value along with mining of *llimonite, mica and yellow ochre* in Azad Kashmir. Geological Survey of Pakistan (GSP) prepared geological maps for 4500 Sq. Km. area – 28 percent of the envisaged targets in the Fifth Plan – and undertook five exploration studies in Baluchistan. As a result, potential deposits of porphry copper, lead, zinc and flourite were identified.

The provincial mineral development agencies made their contributions as well. Sarhad Development Agency (SDA) in collaboration with British Mining Consultants (BMC) have established 3.2 mt (proven) and 3.0 mt (indicated) reserves of rock phosphate in Hazara. The Kakul rock phosphate mines are being developed to produce 67,000 tonnes annually for use at the National Fertilizer Corporation (NFC). SDA has further established 6 billion tonnes of Nepheline syenite at Kaga (Malakand – Mardan) and collected sufficient data showing promising results of lead, zinc and molybednum in Kohistan area. Punjab Mineral Development Corporation (PUNJMIN) has undertaken thirteen investigation and development schemes for minerals including gypsum, dolomite, silica sand, fire clay and coal, and has earned substantial revenue through sale of its products. The Baluchistan Development Agency (BDA) continues mining of quartzite, fluorite Barites and chromite minerals.

As against an allocation of Rs. 770 million for public sector in the Fifth Plan, the likely expenditure is expected to Rs. 478 million.

As far private mining sector, it has confined itself to mining of non-metallic deposits that occur on or near the surface and which can readily be marketed without any further processing. Coal, limestone, silica sand, fire clay, soap stone, gypsum etc. fall in this category.

SIXTH PLAN : OBJECTIVES AND PRIORITIES :

The major objectives include :

accelerated exploration and upgrading information of the country's mineral resources,

rapid and systematic development of viable mineral projects to meet local industrial and agricultural needs,

increase in foreign exchange earnings through export/ import substitution (especially of coal and iron for PAK-STEEL).

These objectives are planned to be achieved through :

expansion in the quality and extent of the activities of GSP.

participation of entrepreneurs in prospecting and development of mineral resources through a reform of mining laws and regulations.

re-structuring and re-defining the role and functions of public corporations and agencies engaged in mineral resource development so as to demarcate the areas between the public and private sector.

concentrating, at least in the initial years, on mining of minerals (except copper) that could be utilized locally. It is considered necessary because of the special features of financing, location, transportation, returns, marketing of products and the state of mining industry in Pakistan in general.

changes in the system of publication of information about mineral resources and procedures for obtaining certificates of approval, prospecting and mining leases,

formation of a national mineral policy (to be announced shortly) defining the roles of public as well as private sectors, and also dealing with proprietary rights, tenure, role of banks and other physical and regulatory incentives,

providing safeguards against wasteful exploitation of country's mineral wealth.

development of suitable courses/training programme by the universities and institutions,

preparation of a directory of minerals including gradation, specifications of ores etc., to be used as a reference material by investors, institutions and policy makers,

emphasis on public enterprises like PMDC to strengthen their technical advisory and project preparation services to provide help to private sector in mineral exploitation and development. Portfolios of variable projects based on comprehensive pre-investment and investment feasibilities will be prepared by the PMDC for inviting private sector participation.

THE ROLE OF GOVERNMENT AND PUBLIC ENTERPRISES

In the initial years GSP was responsible for geological maping and exploration and the Federal Bureau of Mines provided advisory and promotional services; the provincial governments issued prospecting and mining leases. With frequent change over and distribution of subjects from Federal to Provincial Governments and vice-versa, and the changes in the nature of their functions there has been a proliferation of laws, regulations and directives. This has obviously affected the direction and pace of mineral sector.

At present there are 17 public corporations both federal and provincial engaged in one or other type of mining operations. The activities of these corporations/ agencies and their charters sometimes overlap and duplicate each other's efforts and responsibilities. With the exception of GSP whose responsibility has been, and still is, to explore and map geologically promising areas, others have extended their operations in areas which at times overstretch their financial managerial and technical resources. Completion for already scarce public funds and shortage of technical manpower available in the country have obviously affected the performance of mineral sector.

It is, therefore, proposed in the Sixth Plan that for proper management and co-ordination of exploration and development policies for coal and its use for electricity generation or substitution of other energy resources, a National Coal Authority (NCA) will be set up at the federal level. Its functions, among others, will be to ensure continuous policy development and to co-ordinate planning, exploration, research and development and financing.

A Mineral Co-ordination Board in existence since 1973, focuses on the problems faced by mining industry. Its functions include co-ordination of activities of various agencies, review of annual programmes and progress, resolution of any differences and advice to governments on mineral policy matters.

The Sixth Plan will also actively examine through a study of needs and scope the need for :

reducing the number and streamlining the functions of public corporations,

creating a Mineral Development Bank or Fund,

establishing a public agency for prospecting and development of coal for coal based industries and power generation with possible participation of WAPDA and KESC as well as provincial governments on joint venture or equity basis.

FINANCIAL OUTLAY AND PHYSICAL TARGETS.

For investment funds allocations during the Sixth Plan period, those categories of minerals which have been explored and have reached development/production stage, get higher priority and hence major allocation of public funds. These minerals include coal; copper; gold and silver; rock phosphate, iron ore, gypsum, gemstones, china clay and refractory materials, and marble and onyx. For other minerals, investigations will be carried forward to warrant further evaluation of the size and quality of reserves available. These include antimony, lead, zinc, nickel, manganese and china clay.

The Sixth plan envisages a financial outlay of Rs.5,000 million in the public sector for various on-stream projects. The biggest allocation of Rs. 2140 million goes to the development of indigenous coal deposits (estimated to be more than one billion tonnes), followed by Rs. 650 million for Saindak Integrated Mineral Project. Hazara rock phosphate gets Rs. 372 million whereas Nukundi Iron ore project will receive Rs. 500 million in this plan period.

Development of gypsum quarries at Daudkhel gets Rs.470 million. Other allocations include Rs. 100 million each for rock salt and magnesite mines development, and Rs.300 million for the exploration of uranium minerals. A sum of Rs.900 million has been earmarked for other surveying and investigations, research and development and minor projects including infrastructure.

It is estimated that among other things, these financial allocations will help to achieve planned physical targets. Productions levels of minerals already being exploited in the country will be raised – in some cases upto 300 percent of the last Plan's achievements. Other projects which have reached development stage will be rapidly developed to start productions.

It is estimated that 5.4 mt. of coal per year will be produced by the end of the Sixth Plan as against 1.8 mt. at the end of the last plan period. Rock Salt target has been set at 1 mt as against 600,000 tonnes. Similarly gypsum is expected to touch 2 mt mark with 502,000 tonnes previously, limestone 11 mt from 3 mt, marble 110,000 tonnes from 81,000 tonnes and chromite 60,000 tonnes from 3,000 tonnes. Rock phosphate and iron ore projects will be developed to produce 271,000 tonnes and 544,000 tonnes respectively. Gemstones are expected to fetch Rs. 400 million. Further, GSP will undertake regional geological mapping on 1:50,000 scale to cover an additional 44,000 sq. kilometers.

INFRASTRUCTURE, MANPOWER AND SAFETY.

To alleviate transport problems of mining areas thereby improving efficiency and raising production levels, it is proposed to provide more than 150 miles of roads in coal, barite, soapstone, marble and chromite mining areas.

For the implementation of the Sixth Plan, a variety of manpower requirements have been estimated. There will be an additional demand for 184 geologists and 276 Mining Engineers. Other manpower requirements include 165 other engineers and technical staff, 2390 para-engineering staff and 5730 unskilled workers. Arrangements will be made for the in-service training of para engineering and geological staff. A training mine near Choa-Saiden Shah will be developed for this purpose. Mine Rescue and Safety Stations are also proposed to be set up in all provinces (one at Khushab is already functioning) for the safety and in service training of miners and other staff.

Thus it is through a combination of enhanced public fund allocations, re-defining and streamlining the role of public corporations/agencies and changes in priorities and policy re-adjustments that the Sixth Plan proposes to achieve the goals set for mineral sector of Pakistan.

CHRONOSTRATIGRAPHIC POSITION OF PANJAL FORMATION IN AZAD KASHMIR A STRATIGRAPHIC DISCREPANCY

By

Nasir Ali Bhatti[1]

ABSTRACT.– Reported occurrence of Permo-Carboniferous fauna from the Panjal Formation and an interbedded nature of the Panjal Formation within Sirban Formation of Cambrian age in Azad Kashmir is in discrepancy. This is only explainable in the event of two isolated phases of volcanic activity. However, re-examination of the contact relationship between the two units – the Panjal Formation and Sirban Formation may finally clarify this discrepancy.

There has been a stratigraphic controversy because of the lack of the fossil evidence over the age of the sequence consisting of the Kakul Formation, Sirban Formation, and Tarnawai Formation. The sequence of these formations was named Abbottabad Group by Marks and Ali (1961, p. 48), but Calkin and others (1975) did not recognize the group status. However, on the basis of the Tanakki Conglomerate which was lithologically correlated with the fossiliferous Permian Talchir Boulder Bed of Salt Range and the overlying rock unit, the Datta Formation of known Jurassic age – the Abbottabad Group has been regarded to be of Permo-Triassic age.

In 1972, Latif reported the discovery of the pteropod Hyolithes (*Circotheca ? and Linevitus ?)* and specules of the Heterectinellid sponge *Chancelloria* Walcott from the glauconitic sediments of Tarnawai Formation and as such he suggested a Lower Palaeozoic, possibly a Cambrian age, for the Abbottabad Group. Rushton (1973, p. 142) cited the occurrence of *Chancelloria* from the Middle Cambrian of North America and from the Lower Cambrian in England, and therefore he finally confirmed a Cambrian age for the Tarnawai Formation (which he called Hazira Shale).

A Pre-Devonian age for the Sirban Formation is supported by Tiechert (written communication, 1965, in Calkin and others, 1975, P. C. 13) who reported that in the area west of Hazara, the rocks of similar lithology and stratigraphic position contain conodonts no younger than Late Devonian. Calkin and other (1975, pl. 2) have mapped a volcanic metamorphic unit-the Panjal Formation – as interbedded with the Sirban Formation in the area east of Hazara in Azad Kashmir, (Holland (1956, p. 8) reported the occurrence of a fauna of Late Carboniferous to Permian age in the Panjal Formation. This age determination is in conflict with the interbedded relationship of the Panjal Formation with the Sirban Formation as mapped by Calkin and others (1975, pl. 2). However, regardless of the above discrepancy a Cambrian age for the Sirban Formation is well accepted.

The volcanic assemblages equivalent to the Panjal Formation marking a regional strike continuation in the occupied Kashmir and further east has been assigned varying age depending on their relative position of the formations with which these volcanics are associated (Gupta, 1978). A late Paleozoic time interval for these volcanic activities appears to be well accepted by the Indian workers. But closest in time to the Panjal Formation appear to be the volcanics of Mandi-Drang-Dharamsala area in the east of Azad Kashmir which have been considered to be of Precambrian age by Srikantia (1977).

In the context of above, our present state of knowledge suggests that the outcrop which yielded Permian to Carboniferous fauna (Holland 1956) represents a later phase of volcanic activity than depicted by the volcanic interbeds of Sirban Formation in Azad Kashmir. However, a re-examination of interbedded nature of the Panjal

1. Geological Survey of Pakistan, Punjab Regional Office, Lahore.

Formation and its contact relationship with the Sirban Formation may further clarify the discrepancy.

REFERENCES

Calkin, J. A., Offield, T. W., Abdullah, S. K. M., and Tayyab Ali, S., (1975). Geology of the Southern Himalaya in Hazara, Pakistan, and adjacent areas. *U. S. Geol. Survey. Prof. Pap.* p. 716–C. Pt. 2.

Gupta, V. J., Kanwar, C. R., and Kapila, S. P., (1978). Late Paleozoic Volcanics of the Punjab and Kumaun Himalaya. *Contributions to Himalayan Geology. Hindustan Pub. Corp.* p. 25.

Holland, T. H., (1956). Lexique stratigraphique international, v. 3, Asie, Fascicule 8a, India, Pakistan, Nepal, Bhutan, Paris. *International Geol. Cong. Stratigraphie, Centre Natl. Racheche Sci.*, p. 4–281.

Latif, M. A., (1972). Lower Paleozoic, Cambrian hyolothids from the Hazira shale, Pakistan; *Nature phys. Ści.* vol. 240, p. 92.

Marks, P., and Ali, C. M., (1961). The Geology of the Abbottabad area, with special reference to Infra-Trias. *Geol. Bull. Punjab Univ.* No. 1, p. 47–55.

Rushtan, A. W. A., (1973). Cambrian fossils from Hazara : *Nature Phys. Sci.*, vol. 243, p. 142.

Srikantia, S. V., (1973). The tectonic and stratigraphic position of "Panjal Volcanics" in the Kashmir Himalaya – A reappraisal. *Himalayan Geology,* vol. 3, p. 59, 71.

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

MINERAL DEPOSITS OF AZAD JAMMU AND KASHMIR – A REVIEW

BY

S. TAYYAB ALI [1]

MOHAMMAD ASHRAF [2]

RASHID H. MALIK [3]

ABSTRACT : The territory of Azad Jammu and Kashmir lies between Pakistan (on its west) and Indian occupied main land mass of the disputed State of Jammu and Kashmir (on its east). The total area of Azad Jammu and Kashmir is about 12,000 sq.kms. It has a fairly rugged mountainous topography.

Geology is simple and well exposed . Almost all the rock units are of sedimentary origin, ranging in age from Precambrian to Recent. Acidic and occasional small basic intrusive bodies are present in the Neelam Vally. Large scale regional metamorphism is encountered in the northern half of the State. The major tectonics are controlled by the collision of the Indo-Pak Plate with the Eurasian Plate north of the Nanga Parbat, the fourth highest mountain peak in the world. One of the most important tectonic features in this area is the Syntaxial bend of the Himalayas just around Muzaffarabad, the capital town of the State of Azad Jammu and Kashmir.

Major metallic mineralisation has not been met with uptill now, however, workable deposits of bauxite, bentonite, coal, dolomite, fireclay, graphite, gypsum, limestone, marble, mica. quartzite, silica sand. slates, soapstone, and volcanic ashes are well established as a result of numerous exploratory surveys carried out by various concerned agencies. Reported occurrences and showings include phosphate, gemstones, feldspar, iron ores, lead. oil, gas. Pozzulana materials, gold, barite, and rare earths. The possibilities of discovering minerals like scheelite, ilmenite, monazite and zircon exist.

1-2 Institute of Applied Geology, Azad Jammu and Kashmir University, Muzaffarabad.

3. Azad Kashmir Mineral and Industrial Development Corporation, Muzaffarabad

MINERALOGY PETROLOGY & ECONOMIC GEOLOGY WITH EMPHASIS ON MINERAL DEPOSITS OF BESHAM – LAHOR AREA SWAT KOHISTAN

By
Anwar Jawaid [1]
Arshad Javed [2]
Mohammad Pervaiz [3]

ABSTRACT.– Igneous and metamorphic rocks of the project area (longitude (E) 72° 50' to 72° 54', latitude (N) 34° 54' to 34° 58') represent the leading edge of the Indian continent unaerthrusting the Kohistan Island Arc? The mineralization described in this work are related to igneous and metamorphic rocks. Granites/pegmatite and metamorphic rocks make up the bulk of Besham-Lahor area. The Lahor granite/pegmatite complex are of Pre-Cambrian .age. Metamorphics of the area are correlated with Salkhala Formation, Tanawal Formation and poorly defined Thakot metasediments.

In mapped area metamorphism of pelitic rocks ranges from chlorite to biotite grade, and rocks are named as biotite-chlorite-graphite schist, while quartzite and amphibolites are also present. They are folded metasediments and uplifted due to stresses during Himalayan orogenies. Sequence of folded metasediments was followed by the intrusion of Lahor granite/pegmatite.

The Lahor granite/pegmatite has been assigned a mixed origin and is a result of the processes of intrusion, anatexis and palingenesis of the country rock. The formation of this granite involves more than one phase of magmatic activity and granatization of the country rocks.

Oxides (magnetite, haematite) and sulphides (galena, sphalerite, molybdenite, pyrite) mineralization are associated with Lahor granite/pegmatite complex and metasediments. Oxides occur in skarns which were originated by the igneous/metamorphic activity (metasomatism). Late stage hydrothermal activity formed disseminated and vein mineralization of sulphides.

The study covers the petrographic and ore-microscopic aspects. The evaluation of petrographic and ore-microscopic data of Besham-Lahor area, shows its economic importance.

1-3 Institute of Geology, University of the Punjab Lahore.

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

MINERALOGY PETROLOGY & ECONOMIC GEOLOGY OF LAHOR PAZANG AREA, SWAT KOHISTAN

By

Syed Ali Naqvi [1]
Haroon M. Ahmed [2]
Ahsan Muneer and [3]
Abdul Qayyum [4]

ABSTRACT.– Detailed geological mapping was carried out in the Besham and allied areas on the toposheet 43 B/13 of the survey of Pakistan. The mapping has revealed the following rock units in the project area; granites, pegmatites, skarns, metamorphics of the Thakot and Salkhala groups, and a number of amphibolite dikes.

The granites and metamorphics of the area depict the varying types of conditions which affected the rocks of the area probably in precambrian time. The granites of the area have both granular and microprophyritic textures. The two kinds have been assigned different origins.

Greater emphasis has been paid to the study of the skarn bodies. These skarns contain significant amounts of magnetite, sphlerite, galena and molybdenite. The skarn bodies have developed by the interaction of granite with the surrounding metamorphics. Som› mineralization has also resulted through a hydrothermal action. The hydrothermal min‹ ral veins are of hypothermal to mesothermal type. Disseminated sulphide are also occurs ‹‹ ithin the altered granite.

1-4 Institute of Geology, University of the Punjab, Lahore.

Kashmir Journal of Geology, *Vol. 1, No. 1, 1983*

CATHODOLUMINESCENCE STUDY OF THE DOLOMITIZED PHOSPHATE OF HAZARA

By

Nasir Ali Bhatti[1]

ABSTRACT.– Petrological examination of some of the Mg bearing phosphate rock of Hazara exhibits an illustrative relationship of the Phosphate deposition and the dolomitization process. MgO is an undesirable impurity in the phosphate ore and its higher values than the permissible limitations render the ore uneconomical.

Cathodoluminescene refers to the emission of light during electron bambardment. Enervy levels of the light thus emitted are characteristics of the individual material and correspond with the chemical compositional and textural changes. These changes within a material itself, which are not otherwise discernable, become distinguishable under cathodoluminescence and are seen as variation in the intensities of the luminescence.

Different concentrations of Mg produce different colours and intensities in the phosphate rock. These colors and intensities are helpful in tracing the flow direction of the Mg bearing ions which in turn can be utilized in delineating the phosphate ore bodies of the low Mg content.

Cathodoluminescence can be an useful tool in locating the phosphate ore bodies of the desirable composition.

1 Geological Survey of Pakistan, Punjab Regional Office Lahore.

GRANITES OF HIMALAYA, KARAKORUM AND HINDU KUSH

Editor : Professor F. A. Shams

This is a very welcome book of unique nature published on the core-lithologies of the three magnificent mountain belts of the area, namely Himalays, Karakorum and Hindu Kush. The Book is a compilation of 24 papers by 32 front-line researchers, belonging to 9 countries including Pakistan, who had spelled out their thinking on the origin, emplacement and tectonic mobilization of complexes of granites and granitic gneiss. In relation to this topic, stratigraphy, petrology, structure, geophysics and mineralizations associated with such complexes have been discussed in detail. The array of papers covers many controversial topics with different directions of approach and giving indicators for future research. The Book is loaded with data and diagrams in support of ideas expressed by authors of the papers. The Book is hard bound with beautiful Jacket, composed of 456 pages including 48 photographs, 29 drawings, 62 tables of data, 102 interpretation diagrams, 36 geological sections and 40 maps including the latest geological colour Map of the Mount Everest origin. Lot of data are new and of fundamental importance. The Book fulfils the urgent need for mono-topic publications in the background of Geological Survey of Pakistan publication of Geodynamic of Pakistan in 1979. It is a must for all those who are interested to know the current status of research and problems for future work. The publication upholds tradition of leading works always produced by the Institute of Geology, Punjab University. It will also bring honour to the University.

Address all correspondence to Professor F. A. Shams, Director, Institute of Geology, Punjab University. New Campus, Lahore -20

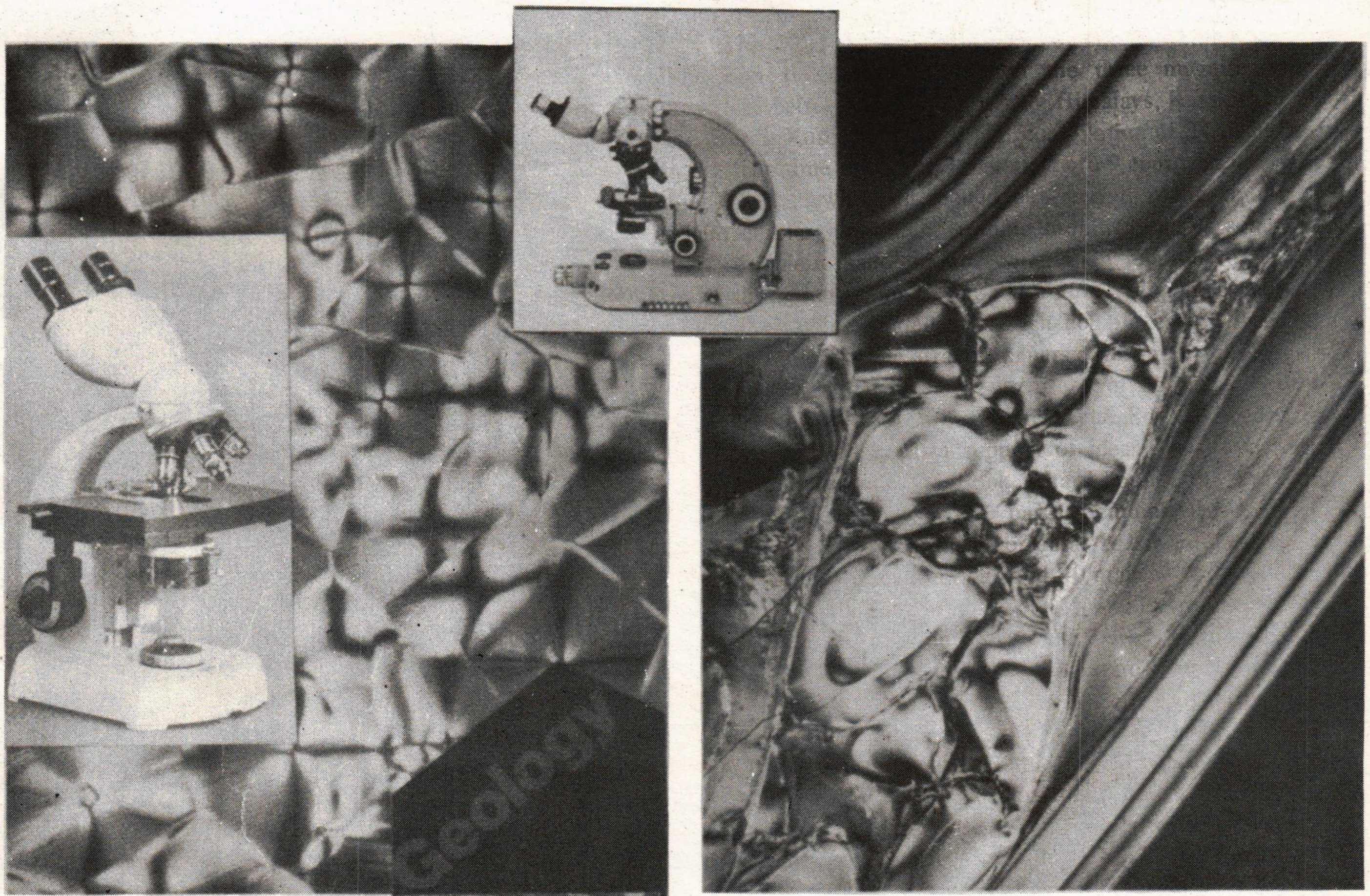
Published by: The Institute of Geology, Punjab University, Lahore. 1983. Price : Rs. 400. US $ 50.00

Editors

Zeiss has the complete microscope program.

ZEISS

West Germany



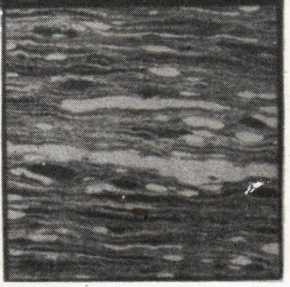


Fig. 1
Polyamide spherulites
Transmitted light
Polarizer and analyzer crossed
Universal microscope
Achromat 10/0.2 Pol
MC 63 attachment camera
9x12 cm format
Magnification of original 100x
Magnificiation of reproduction ca. 110x

Fig. 2
Unfused granules in a polyamide piece
Transmitted light
Polarizer and analyzer crossed
Standard 18 microscope
Planachromat 1/0.04 Pol
MC 63 attachment camera
9x12 cm format
Magnification of original 8x
Magnification of reproduction ca. 9x

Sole Representatives:

SCIENTIFIC EQUIPMENT SUPPLY COMPANY

Grams : SESCOM
Phone : (042) 301236, 304236
Address : 22-MIAN CHAMBERS
3-HAMEED NIZAMI ROAD
(TEMPLE ROAD)
LAHORE-4 PAKISTAN

A-45
BLOCK 2
GULSHANE IQBAL
KARACHI-47
Grams : SIEMSSENIO
Telephone:
(021) 468780

INSTRUCTIONS TO THE AUTHORS :

The Kashmir Journal of Geology is devoted to the publication of original research in the field of geology including geophysics, geochemistry, geomorphology and paleontology. Review articles, short papers and abstracts are welcomed. The articles should deal with some aspects of the geology of Pakistan or should pertain to significant advancement of geological knowledge of international importance.

The authors are solely responsible for the facts and opinions stated in their papers and the correctness of the references.

The articles should be written in English accompanied with adequate abstracts, type written (doubl- [illegible] side of the fullscape paper, with wide margin and should be sub- [illegible] rations (figures, diagrams, and maps) should be drawn in black [illegible] with allowance for reduction in final print. Letttering should be preferably [illegible] 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 far as possible. In all maps and illustrations linear scale should be used. The maximum length of the articles generally should be around 20 fullscape pages. including diagrams. One copy [illegible] 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 microplaeontology of the Gali's Group of Hazara, Pakistan. *Geol. Bull. Punjab Univ.*, No. 13, p. 1p. 1-65.

Shams, F.A., (ED. 1983). Granites of the Himalayas, Karakorum and Hindukush. Centenary Publication : Institute of Geology, University of the Punjab, New Campus, Lahore, Pakistan.

25 Reprints of each article will be provided to the author free of charge. Additional copies should be ordered at the time of submitting articles.

The Journal is edited by an Editorial Board. It is published by the Institute of Applied Geology, University of Azad Jammu and Kashmir, Muzaffarabad, Azad Kashmir (Pakistan).

SYNTAXIAL BEND OF THE HIMALAYAS

NEW CAMPUS SITE OF THE UNIVERSITY OF AZAD JAMMU AND KASHMIR MUZAFFARABAD