# TECTONO - STRATIGRAPHIC NET AND ECONOMIC MINERALS OF THE BLACK MOUNTAIN AREA OF THE MANSEHRA AND BATGRAM DISTRICTS, NWFP, PAKISTAN

A THESIS
SUBMITTED TO THE
NATIONAL CENTRE OF EXCELLENCE IN GEOLOGY
UNIVERSITY OF PESHAWAR
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF
PHILOSOPHY

**BY**

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*APRIL - 1995*

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## ACKNOWLEDGEMENT

I wish to express my sincere gratitude to Dr- Muhammad Rafiq for his kind advice and critical reading of the Manuscript.

I am also thankful to Dr. R.A. Khan TahirKheli for his valuable suggestions for improving the quality of work and critical review of the report.

The Teaching Staff of the N.C.E, Geology are thanked for their sincere teaching and guidance which has enabled me to complete this research work.

Sincere thanks are extended to Dr Farhat Husain Director General, GSP, for granting permission to carry out this research.

Gratitude is also extended to Arbab M. Sabir Hayat, Director, GSP, Peshawar for providing fullfledge field facilities during the field work.

Sincere thanks are extended to Mr. Rab Nawaz Khan, Deputy Director, GSP, Peshawar for his good advice regarding classification of the Mansehra granites and help in petrographic study of thin sections.

The Executive Engineer C&W Mansehra is thanked for providing accommodation facility. The people of the area are gratefully acknowledged for their friendly relationship and cooperation during the field work.

Mr. Riaz Hussain, Stenographer is thanked for typing of this report.

IN THE NAME OF ALLAH, THE GRACIOUS,THE MERCIFUL.

DO THEY NOT LOOK AT THE CAMEL, HOW IT IS CREATED?

AND AT THE HEAVEN HOW IT IS RAISED HIGH?

AND AT THE MOUNTAINS HOW THEY ARE SET UP?

AND AT THE EARTH, HOW IT IS SPREAD OUT?

ADMONISH, THEREFORE, FOR THOU ART BUT AN ADMONISHER.

( AL-QURAN, AL-GHASHIYAH)

## ABSTRACT

Geological mapping and mineral investigations were conducted in the Black Mountain and adjacent areas of districts Swat & Batgram, N.W.F.P. in order to establish its tectono-stratigraphic set up and study its related mode of mineralization. The area covers about 640 square Kilometres, stretching on both sides of the Indus River and is bounded by the main towns of Darband in the S, Oghi in the SE, Thakot in the N and Batgram in the NE.

The geological Formations exposed in the mapped area are the Salkhala Formation of Middle to Late Proterozoic, the Tanol Formation of Late Precambrian, and the Mansehra Granite of Early Cambrian age. These lithostratigraphic units are intruded by sills and dykes of amphibolites, dolerites and pegmatites.

The Salkhala Formation is dominantly composed of pelitic rocks consisting of garnet-muscovite schist, biotite and graphite schist, calcareous schist, along with flaggy quartzite and thinly bedded fine to medium grained crystalline limestone and marble.

The Tanol Formation is composed mainly of psammitic rocks which includes quartzites, quartzitic sandstone and quartzitic schist.

Sills, dykes and veins of amphibolite, dolerite, pegmatite and quartz are found throughout the Tanol Formation.

The Mansehra Granite covering large part of the mapped area

forms high peaks and ridges and is characterized by granitic gneisses, granites, pegmatites and aplites. The main mineral constituents are alkali feldspar, albite, oligoclase and quartz with small amounts of micas, accessory magnetite, apatite and sphene.

Tectonically the Black Mountain area reveals four major imprints of deformation (folds, faults, joints, etc) emanating from the following four regional phases, e.g.

i. The earliest one is associated with the Mansehra granitic magmatism that occured in Cambrian time.

ii. The second being more severe resulted from the collision of Indo-Pak Plate with the Kohistan Island arc, that took place in Eocene time.

iii. The third deformation imprint was associated with the formation of Hazara-Kashmir syntaxis,that occured in Post Mid-Miocene.

Iv. The last phase of deformation was resulted from anticlockwise rotation of the Indo-Pak plate after collision with the Asian plate which took place in post Miocene time.

Economic minerals and rocks associated with the Salkhala and Tanol Formations reveal several hydrothermal emanations where pyrite, arsenopyrite, and iron showings are commonly noticed. At present none of these minerals are commercially exploitable.

Among the non-metalic minerals marble, talc, feldspar, and graphite are the common ones and among them the first two mentioned are locally being commercially exploited.

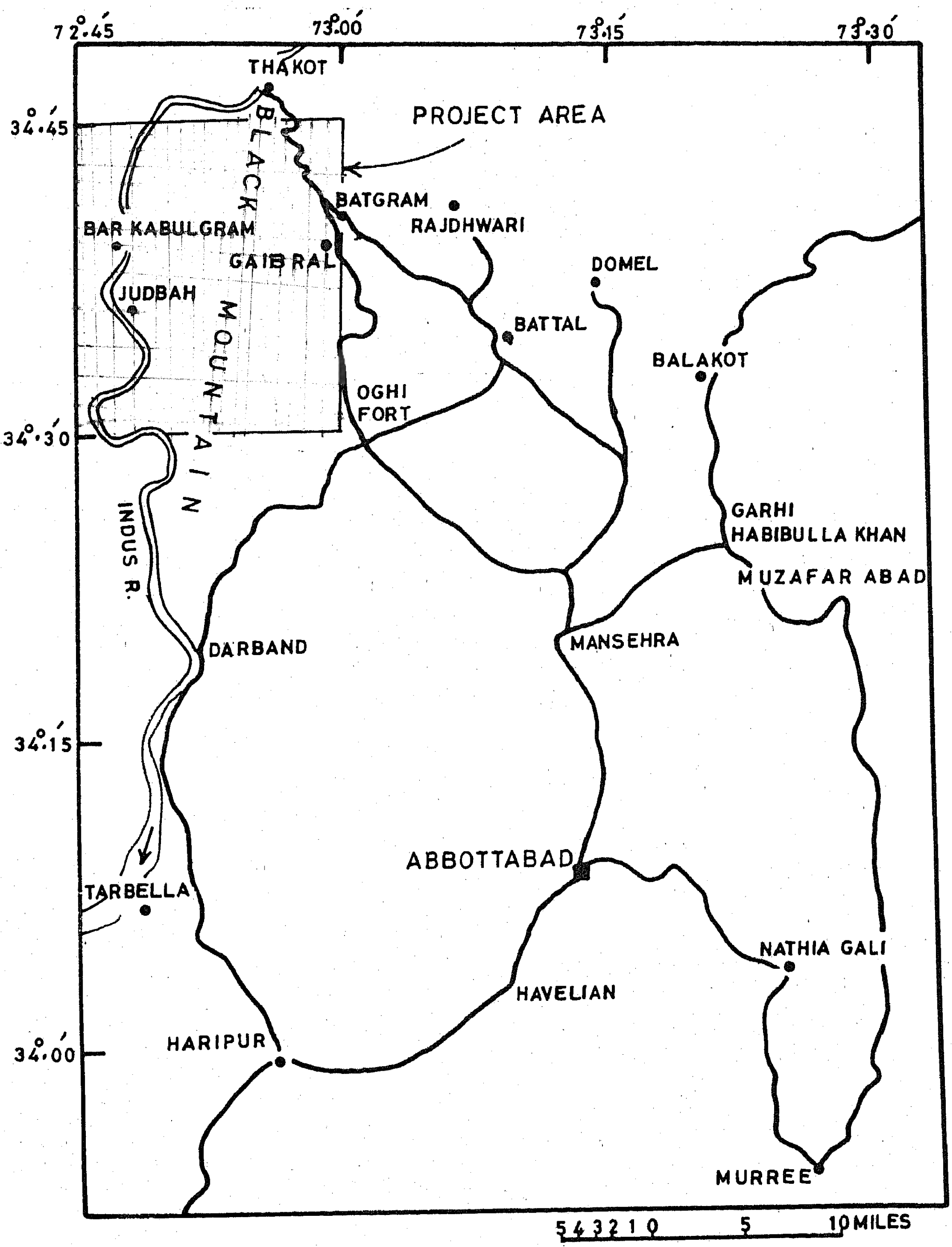



FIG.1 LOCATION MAP OF THE BLACK MOUNTAIN AREA.

# CHAPTER. 1

## INTRODUCTION

The Black Mountains received little attention during the past due to inaccessibility and administrative constraints. Middlemiss (1896) was the first geologist who paved the base in linelighting its geology and mineral resources.

The Black Mountain area was assigned to the author to geologically map it and appraise its tectono - stratigraphic set up and report on its mineral resources, as a part of the requirement for the award of the Degree of M.Phil. in Geology.

The area under investigation is about 640 sq. kilometres and is located along both the banks of the Indus River, the right bank of which falls under the civil administration of the District Swat and the left bank under the Batgram.

It is covered by topographic sheet No. 43 B/14 and lies between Latitude 34°. 30' and 34°. 45' N and Longitude 72°. 45' and 73°. E.

The area was mapped geologically on 1:50,000 scale and synthesized its geological, structural and mineral information.

### 1.i. Previous Work

Middlemiss (1896) produced first geological map and report on Hazara and Black Mountain. He did not delineat boundaries of granitic and metamorphic formations and showed them together. He drew up a stratigraphical table of formations and the corresponding part of which is reproduced below.

11. Infra-Triassic or Carbo-Permian.

1. Slate series-Age unknown.

Crystalline and Metamorphic Rocks.

| | |
|---|---|
| Paleozoic or older | b."Tanol"- Infra-Triassic in main.<br>a. Crystalline rocks- Equivalent of 1 and 11.<br>x. Intrusive gneissic granite.<br>y. Intrusive dyke rocks. |

In the text of his publication Middlemiss subdivided the granitic rocks on the basis of their structure as (A) foliated, (B) semi foliated (C) non foliated. According to him the Black Mountain constitutes Crystalline and Metamorphic Rocks of Paleozoic or older in age.

Wadia in (Pascoe 1929) introduced the name "Salkhala Series" to a sequence of quartz schist, marble, graphite schist, and quartzofeldspathic gneisses exposed in Kashmir and designated the type section at Salkhala village on the Kishanganga River, Kashmir.

Shams F.A. (1969) worked on the geology of Mansehra and Amb state which is located to east and south of the Black Mountains. In his report he mentioned that the area is dominated by semipelitic to psammitic schists and quartzites that have suffered regional metamorphism. These schists bound a large granitic complex composed of an older group of gneissic (the Susalgali gneiss) to granitoid rocks (the Mansehra granite and the andalusite granite, Karkala granite etc). In addition there are a large number of aplites and pegmatites.

Calkins et. al, (1975) reproduced the geological map (Fig-1.a) and report on Hazara which did not include the Black Mountain. In the Balakot and Mahandri areas, the unit (Salkhala Series of Wadia) was called as Salkhala Formation by them. They also studied the Tanol Formation previously called by Wynne (1879) as Tanawal Group and by Middlemiss (1896) as Tanol quartzites, in the Ghandghar range south of Tarbella and divided it into four units. The lowermost unit is Conglomerate which is followed upward by Lower quartzite, Quartz schists and Upper quartzite.

Tahirkheli et. al (1979) wrote first comprehensive account on the Kohistan arc and the associated suture zone in Jijal-Pattan areas located north of the Black Mountains.

Kazmi et. al (1984) published a detailed report on the extension of the Indus Suture Zone in the Mingora-Shangla areas of Swat which lie north of the Black Mountain.

Lawrence et. al (1985) appraised the tectonic geomorphology of the area located north and east of the Black Mountain between Thakot and Mansehra. Malik (1986) produced first geological report on the hydrothermal graphite deposits of Patlepani Mohriwali area, near Kel in Neelam valley, Azad Kashmir.

Coward et. al (1988) studied the folding and imbrication of the Indian crust during Himalayan collision i.e. in the northern margin of the Indo-Pak plate.

Dipietro (1991) has studied pressure - Temperature condition in the metamorphic domain of Swat, south of Main Mantle Thrust which lies north of the Black Mountain.

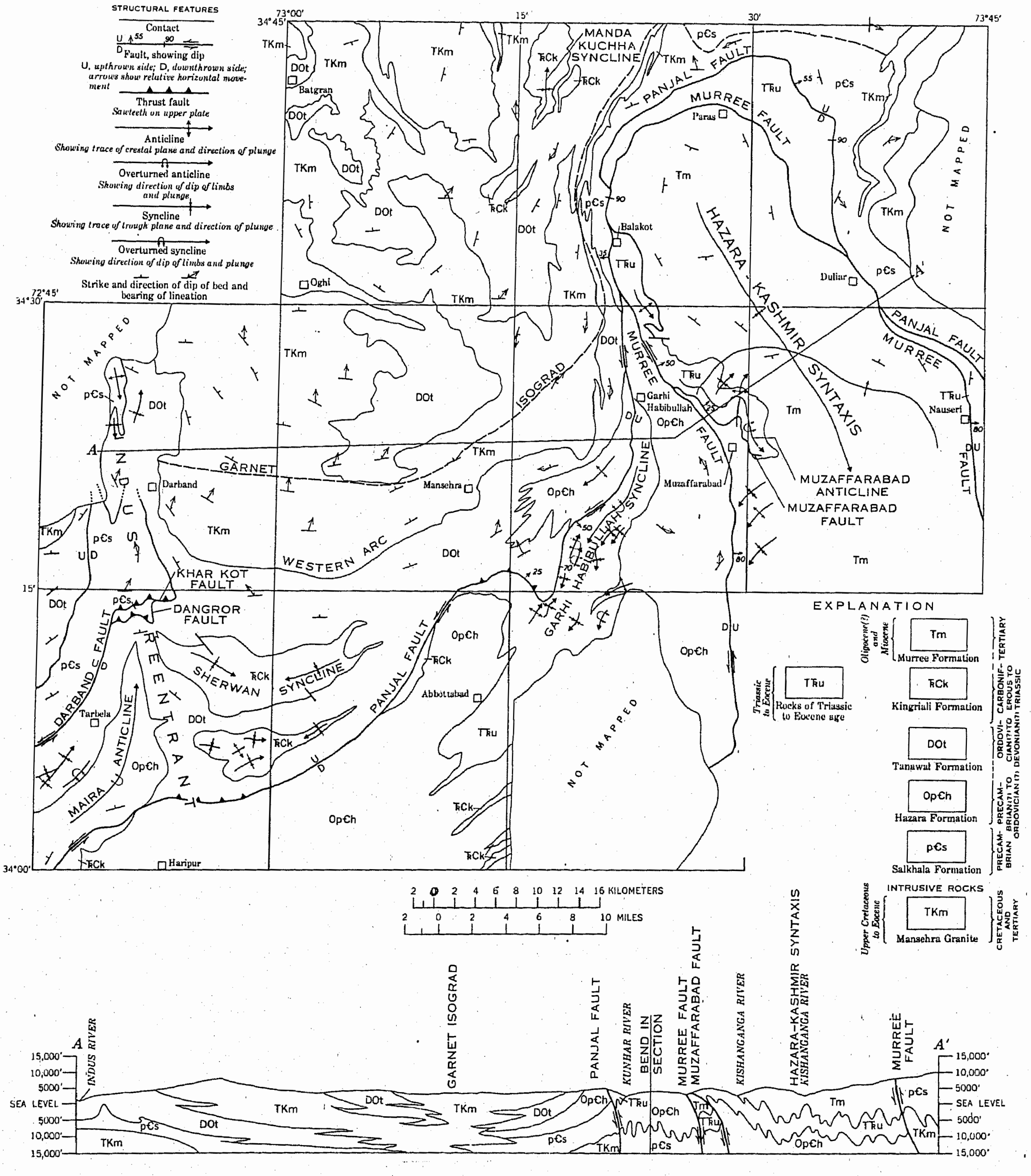



**Fig-1. Structure map of southern Hazara district, Pakistan and parts of western Kashmir. After Calkins, et. al. 1975.**

## 1.ii. Physiography.

The Black Mountain area constitutes north western Himalayas where the mountain ranges culminate to over 3000 metre with general north - south orographic trend.

The main towns in the area are Oghi, Darband, Thakot and Batgram which are accessible by metaled roads.

Across the Indus River along both the banks, the area is rugged and is only accessible by foot paths. The main drainage of the area is captured by the Indus River through several tributaries, some of these (Bakrai, Kotlai, Judbah and Kulash Khwar) originate from Hazara, and other (Pai Khwar, Langarai Khwar, Karagar Khwar and Kabulgram Khwar) originate from Swat.

Cultivation is mostly done on the valley sides, slopes and in the flood plain of the Indus River.

The highest peak is Dandai Sar with an altitude of about 3500 metre. All the high altitude areas are covered by thick forests of pines and receive snow fall in winter.

The area is inhabited by the Tribes of Yousufzai and Hasanzai and are short of basic needs of life such as health, education, communication and electricity.

# CHAPTER. 2

## Regional Geology

The Black Mountain area is situated in the north western part of Hazara and makes a geographical border with the Swat District, located in the west.

The geological formations exposed in the area under investigation are as follows:

iii. Mansehra Granite of Early Cambrian.

ii. Tanol Formation of Late Precambrian.

i. Salkhala Formation of Middle to Late Proterozoic.

The Salkhala Formation is composed of carbonates, graphite schist, talc schist, quartz schist, quartzite and quartzofeld-spathic gneisses. The Salkhala Formation is overlain by the Tanol Formation and the contact is faulted.

The Tanol Formation is mainly composed of quartzite, quartz schist, garnet-mica schist and metapelites. The Metasediments of both the Salkhala and the Tanol Formations are intruded by the Mansehra Granite and has intrusive contact with them.

The Mansehra Granite is light brown in colour, medium to coarse grained and is composed of alkali feldspars, albite, oligoclase and quartz. Le-Fort (1980) has given it a Cambrian age.

These geological formations are extension of some of the well established geological units, exposed in the south eastern Hazara and Kashmir. These are also extended to Swat where the Tanol Formation is called as Chamla Quartzite (Tahirkheli et. al. 1977) al. 1977) and the Salkhala Formation as Alpurai schist and Saidu schist (Kazmi et. al. 1980).

The Mansehra Granite is extended to Swat where it is called as the Swat Granite.

Grade of metamorphism is higher in the contact zone between the granite and the country rocks and along the highly tectonized zones in the north.

Structurally the area is folded into a series of anticlines and synclines with their axial trends in N-S direction. These are followed by N-S trending strike slip faults, called the Oghi shear located to the east and the Indus shear occurring to the west in the mapped area. It is also bounded to the north by the Main Mantle Thrust and to the south by the Mansehra Thrust. Thus the area is rolled like a ball between the various tectonic zones which have been originated as a result of collision between the Asian Plate in the north and the Indo-Pak Plate in the south.

Trelaor (1989 a, b) has recognized six major nappes in the internal zone (Fig 7). Each nappe is stratigraphically distinct from that adjacent to it.

The Besham nappe is dominated by the gneisses of the Precambrian Besham Group which includes both granitic and biotite rich orthogneisses, together with a sequence of metasedimentary gneisses, schist, marbles and amphibolites. The Besham nappe is overlain to the west by the Swat nappe. This nappe, the base of which is marked by a ductile shear zone termed the Alpurai Thrust, is constituted by the Precambrian Manglaur crystalline schists which are intruded by the Swat Granite (Kazmi et. al. 1984), and which are unconformably overlain by the calcareous schists, marbles and amphibolites of the Alpurai Group (Lawrence, et. al. 1989).

The Hazara nappe which is separated from the Besham nappe by the mylonitic Thakot shear zone, is largely constituted by the metapelites and metapsammites of the Precambrian Tanol Formation (Calkins et .al .1975). These are intruded by the Early Cambrian-Mansehra Granite (Le-Fort et. al. 1980) which may be correlable with the Swat Granite.

Two nappes, the Lower and Upper Kaghan are separated from the Hazara nappe by the Balakot shear zone. The rocks with in the nappes contain a series of pelitic sediments belonging to the Salkhala Formation (Calkins et. al. 1975). This stratigraphy has been redefined and divided into two Groups (Ghazanfar and Chaudhry, 1986) the Sharda Group(Upper Kaghan nappe) to the N of Batal Thrust which includes calcareous garnet-kyanite bearing schist, marbles and amphibolites and the Kaghan Group (Lower Kaghan nappe) which is dominated by pelitic rocks of the Salkhala Formation.

A final nappe, the Banna nappe contains a series of chlorite bearing slates, interbedded with limestone with characteristically brittle deformation features, and which belong to the Banna Formation. These low grade rocks are separated from the underlying high grade rocks of the Hazara nappe by a major extensional Thrust, shear related folds parasitic on which imply N or NW sense of displacement (Fig. 7).

# CHAPTER. 3

## STRATIGRAPHY.

During the present investigation the author established the following stratigraphic sequence in the Black Mountain area.

iii. Mansehra Granite of Early Cambrian.

ii. Tanol Formation of Late Precambrian

i. Salkhala Formation of Middle to Late Proterozoic.

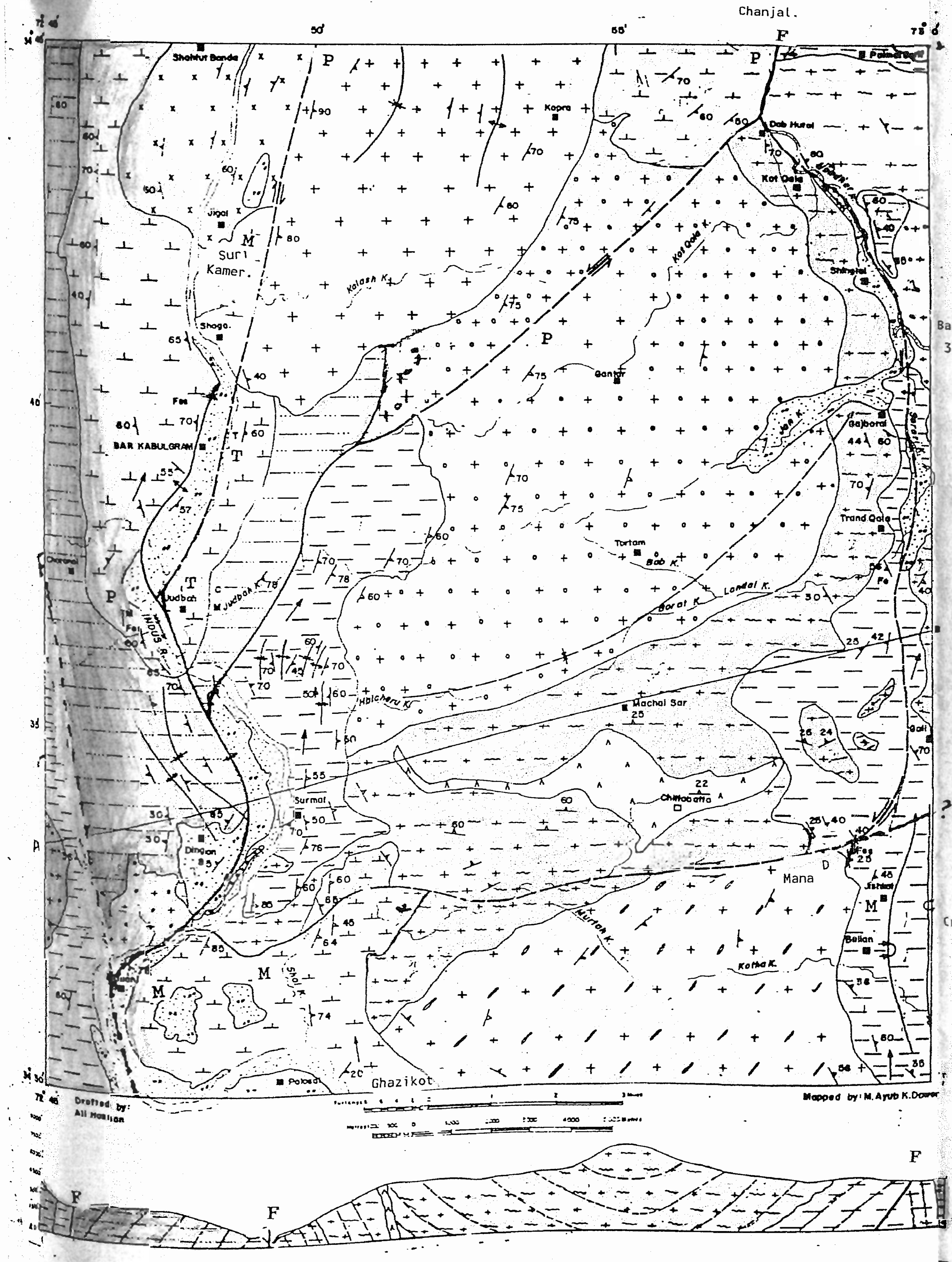
The Salkhala Formation occupies the core of anticline, the axial plane of which runs parallel to the Indus River, between Ghazikot in the south and Suri Kamer in the north (Fig. 2). The Formation consists dominantly of pelitic and graphitic schists with subordinate quartzites and carbonates. The pelitic schists include garnet muscovit schist, biotite schist, staurolite schist and calcareous schist. The graphite schist is mainly composed of graphite with minor quartz, disseminated as minute grains. The carbonate includes crystallized limestone and marble.

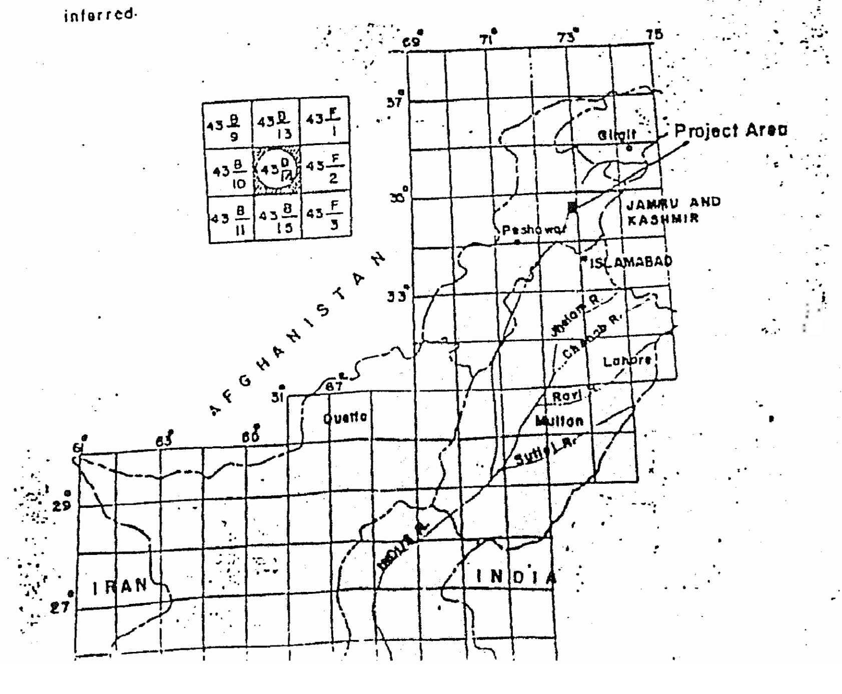
The Salkhala Formation is intruded by the acidic and basic dykes and sills. Among the former pegmatites, aplites and veins of quartz are common whereas dolerite, and amphibolite are common among the basic suite.

The Tanol Formation crops- out along Oghi-Batgram road and in the flanks of anticline along the Indus River (Fig. 2). In Oghi area the Formation is composed of red clay, silt and shale at the base followed upward by garnet-mica schist and less metamorphosed sandstone and quartzite at the top. At more tectonized sections Kyanite and sillimanite bearing schists are also developed. Dykes and Sills of amphibolites, dolerites and veins of quartz are abundant throughout the formation. The contact with the underlying Salkhala Formation is faulted. The formation has been assigned Late Pre-cambrian age, (Latif 1972 and Rushton (1973).

The Mansehra Granite occupies the central part of the mapped area. It is of light gray colour, medium to coarse grained and is characterized by megarcrysts of alkali feldspar. The main mineral constituents are alkali feldspar, albite, oligoclase and quartz with small amounts of biotite and muscovite. Accessory magnetite, apatite, and sphene are also present. Some granite contains tourmaline and is called tourmaline granite.

Le Fort et. al. (1980) from Rb/Sr whole rock isotope analysis, dated the Mansehra Granite at 516+16Ma which is considered to be its intrusion age (Early Cambrian).




## LEGEND

| | | | | |
|---|---|---|---|---|
| QUATERNARY | SUB RECENT RECENT | Alluvium | Qal | Gravels, silt, pebbles and cobbles. |
| | | Alluvial fan | Qaf | Clay, silt and gravels. |

**Mansehra granite gneisses**

| | | | | |
|---|---|---|---|---|
| CAMBRIAN | EARLY | Dykes & sill | | Aplite, pegmatites and dolerites. |
| | | Massive granites | | Homogeneous granite with no deformation. |
| | | Porphyritic granite gneisses | | Granite gneisses with megacryst of feldspars. |
| | | Augen gneisses | | Gneisses with augens of feldspar. |
| | | Mylonitic gneisses | | Highly deformed gneisses with relict of little or no feldspar augens. |
| | | Migmatites | | Banded light brown mixed quartzite and granites. |

**Swat granite gneisses**

Augen gneisses — Consists of biotite quartz and feldspar.

**METASEDIMENTS**

| | | | | |
|---|---|---|---|---|
| Proterozoic. | M-L. L. | Tanawal form. | | Quartzites, quartzitic schist, quartz garnet, mica schist, quartz garnet mica, sillimanite schist, sandstone, clay and shale. |
| | | Salkhala form | | 2 Quartzites, quartzitic schist, garnet, mica schist and quartzofeldspathic gneisses. |
| | | | | 1 : Dolomitic limestone, marble, graphitic schist, calcareous schist, arenaceous schist and amphibolites. |

Prospects showing mineral commodities.

T : Talc. C : Graphite.
M: Marble. D: Dolerite.
P: Pyrite.

## GEOLOGICAL SYMBOLS

Contact — Contact, dashed where approximately located

Arrow — Arrow show direction of lineation

Syncline — Syncline, showing trace of trough plane, dashed where inferred.

Overturned Syncline — Overturned syncline, dashed where inferred.

Inclined — Vertical — Strike and dip of foliation

Fault — Fault, dotted where inferred arrow show relative horizontal movement

Anticline — Anticline, showing trace of crestal plane and direction of plunge, dashed where inferred

Overturned Anticline — Overturned anticline, showing trace of crestal plane and direction of plunge.

GEOLOGICAL MAP OF THE BLACK MOUNTAIN AREA, DISTT. MANSEHRA, HAZARA N.W.F.P. PAKISTAN.

## 3.1 SALKHALA FORMATION

### 3.1- i. Previous Work:

Wadia (in pascoe, 1929) introduced the name "Salkhala Series, to a sequence of slate, phyllite, schist, quartzites with dominant carbonaceous materials exposed in Kashmir.

Offield and Abdullah (in Calkins et, al 1969) adopted the same name with changed nomenclature as "Salkhala Formation".

The type section of the Sakhala Formation is located near Salkhala village in the Neelam (Kishanganga) valley, Azad Kashmir. The Salkhala Formation occupies an extensive area in Kashmir and Hazara (Lesser Himalayas). The Salkhala predominates in flaggy quartzite, quartz schist, garnet mica schist, talc schist along with consistent beds of medium crystalline limestone and marble.

The Salkahla Formation extends from Pirpanjal in Kashmir, to the apex of syntaxis near Balakot in Hazara which gradually peters out along it's western flank.

According to Calkins et. al (1969) the formation occupies both sides of the Indus River between Tarbela in the south and Darband in the north. Marble, graphite schist, quartz schist and quartzofeldspathic gneisses are the main lithologies of the formation in Hazara. Eastward in the Kashmir region the formation is intensely folded and consists mainly of schistose rocks with minor calcareous and psammitic beds.

3.1- ii. <u>Present Investigation</u>:

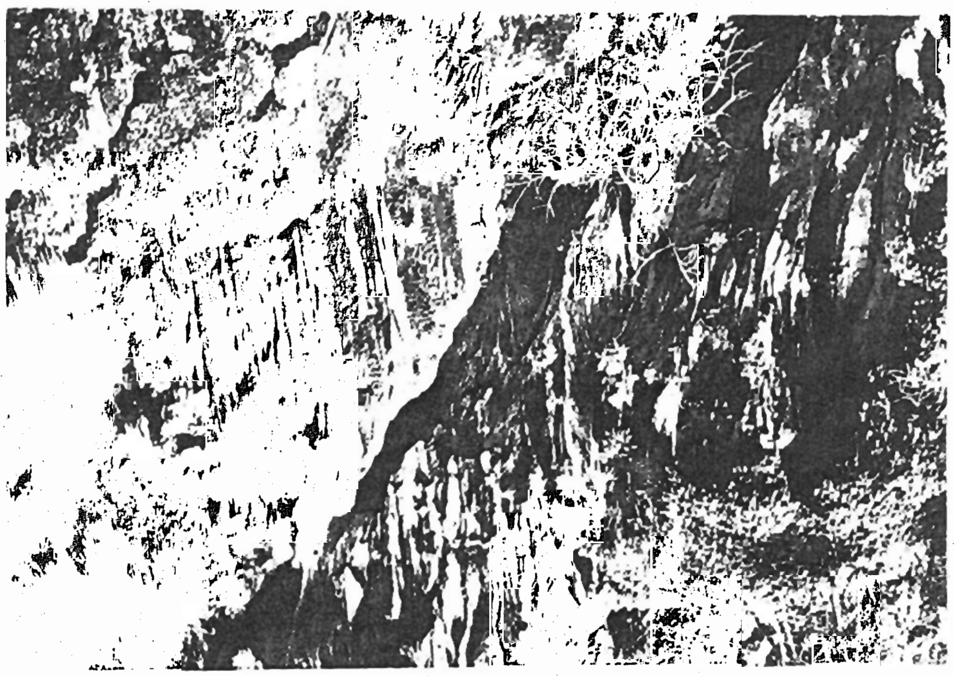
In the mapped area the Salkhala Formation is exposed on both sides of the Indus River from Ghazikot in the south to Suri Kamer in the north and along the Road in the vicinity of Chanjal, between Batgram and Thakot (Fig. 2). The formation is mainly developed in the core of an anticline with its axial trend along the Indus River . On the basis of lithological characteristics the formation can be divided into the following two units:

b. Upper Siliceous Unit:
- Quartzofeldspathic rocks.
- Quartzites :<
  - Ferruginous quartzite.
  - Thin bedded pure quartzite.
- Schist :<
  - Quartzitic schist.
  - Garnet, muscovite schist.

a. Lower Calcareous Unit :<
- Arenaceous schist.
- Calcareous schist.
- Graphitic schist.
- Marble.
- Crystalline limestone.

a . <u>Lower calcareous Unit</u>:

Limestone is green to dirty green thin bedded and medium grained. It occurs in the form of lenses and is full of pits and furrows which are filled with sulphur and pyrites. The limestone exposed at Judbah area shows pinching and swelling characters which is attributed as boudinage structures resulting from extension. Since this bed was more resistant than the overlying-schist, therefore due to extension broke into series of elongated bodies and overlying schist being very incompetent, flowed in between the broken bodies. At places where rate of strain did not exceed the rate at which the limestone was to behave in ductile manner, the boudinage failed by necking. It is due to this phenomenon that the limestone at Judbah occurs in the form of lenticular or tabular bodies. The limestone exposed on the right side of the Indus River is medium bedded and shows stalactitic and stalagmitic features, (Photo.1).



Photograph. No. 1, Taken at Karegar Khwar showing stalactitic and stalagmitic features.

Marble: Moving upward from the axis of the antiform, the limestone is followed by marble which is greenish white in colour. It is thin bedded and fine to medium grained. It is about 20 metre thick. It also contains thin lenses of interbedded talc.

At Suri Kamer, the marble is of white colour fine to medium grained and massive. The rock shows flowage structure. The thickness of the marble is 61 metre. It is also exposed at Kabulgram, Biyar, Bimbal, and at several other localities along the Indus River. It contains grains of pyrite and arsenopyrite. Talc is also associated with it.

Graphitic schist: It is dark gray to black in colour, soft and flaky. It occurs in the form of thin lenses and is associated with limestone and marble. It is of both amorphous and crystalline varieties and contain melanite variety of garnet crystals at some places. At Chanjal the graphitic schist is highly sheared and as a result, pyrite and arsenopyrite have higher concentration along the fracture zones. Its other exposures are found at Ghazikot, Bimbal, Dewal, Judbah, Kabulgram and Shagai.

Calcareous schist: It is associated with carbonate and is derived from it by regional metamorphism. This low grade schist consists of calcite as dominant constituent along with subordinate amount of quartz, feldspar, micas, chlorite and magnetite.

The fabric is marked by parallel arrangement of micaceous and prismatic minerals. At some places the texture is banded and consists of alternating fine and coarse grained carbonate layers which at some places are rich in mica, chlorite and amphibole.

__Arenaceous schist__: It constitutes parallel thin lenses alternating with graphitic, calcareous schist and carbonate. It is greenish gray in colour and medium grained and weathers to sandy and clayey materials. The schist is of gray colour and sili-ceous. Its thickness measured at Judbah is 1100 metre.

b. __Upper Silliceous Unit__:

In the upper silliceous unit, schists are found through-out the formation and on the basis of the mineral constituents, they have been divided into the folloiwng sub units.

The Garnet muscovite schist shines bright due to the abun-dance of muscovite. The muscovite is in the form of augens and is distributed uniformly throughout the rock by which it can be separated from rest of the rock unit. Its measured thickness is 1220 metre.

The quartzitic schist is brownish gray in colour and contains predominantly quartz, feldspar. It is comparatively hard and occurs mostly in well defined planar structures although at some places the rocks are less fissile and schistose due to the presence of a very little amount of flaky minerals.

The quartzites are exposed near Chanjal along Thakot to Batgram road and at several places along both flanks of the Indus River. Based on mineral constituents and fabrics the quartzite is divided into two categories;

__Thin bedded pure quartzite__: It is exposed near Chanjal along fault and is developed in the form of vertical cliffs. It is of light brown colour fine to medium grained. It is hard and highly jointed and breakes into parallel slabs. It predominantly contains quartz with minor amount of ferromagnesian minerals, and micas.

The ferruginous quartzite: It is found throughout in the Salkhala Formation. It is banded and of greenish gray and fine grained. It contains pyrite both in the form of veins and disseminated grains. It is very hard and dense and breakes into conchoidal fractures. The quartzites at some places have been feldspathized and chloritized.

Quartzofeldspathic gneisses: These are medium to coarse grained and are made up of quartz, feldspar (microcline and albite, oligoclase). biotite, muscovite and chlorite. At places it is pegmatitic. The rock has a layered structure and a granitic texture, the texture being modified by foliation and cataclasis. Augens of feldspar are characteristics. Some augens are subhedral crystals as much as 4 centimetre long and more are less than 2.5 centimetre long and have become rounded and crushed by shearing movements.

The author is of the view that this unit is a part of the Mansehra granite gneisses which has intruded the Salkhala Formation in the form of small isolated lenses. These are offshoots of the Mansehra granitic complex which have been metamorphosed along with the country rocks.

Besides this, the Salkhala Formation has well foliated conformable sheets and layers of amphibolite interbedded with carbonate, graphite and schists which belong to para- amphibolite type. Ortho- amphibolite is also found in the formation which occur in plug shaped bodies and lacks mineral orientation.

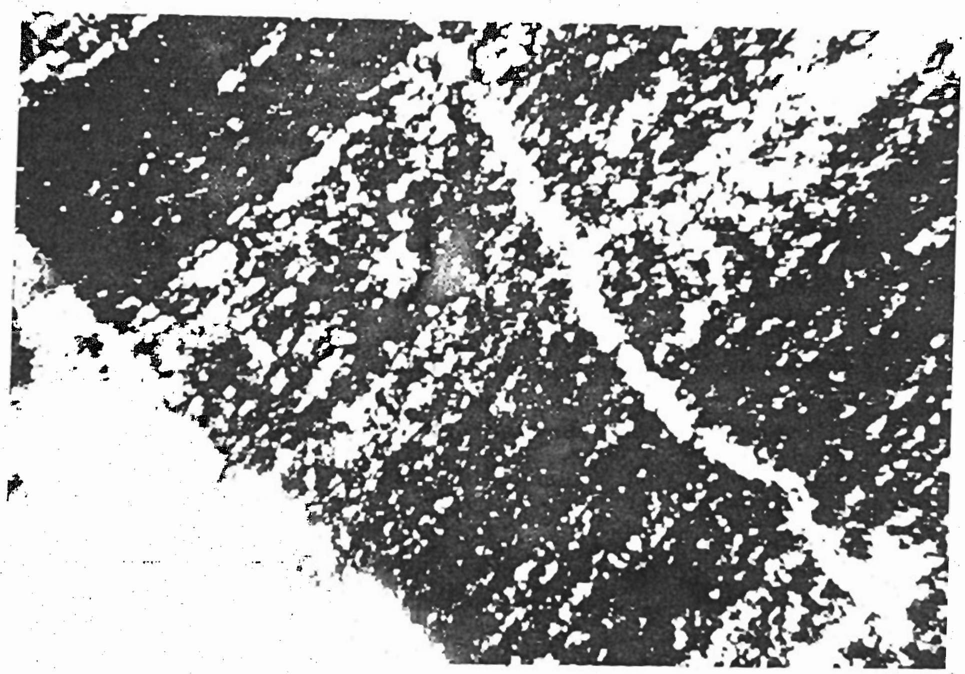
2.1- iii Thickness, Contact relationship and Age:

According to Shah (1977), the Salkhala Formation is from 1,800 to 3,000 metre thick in Kashmir and becomes thicker in the vicinity of Nangaparbat.

In the mapped area, the formation is about 4000 metre thick and has faulted contact with the Tanol Formation and intrusive contact with the Mansehra granitic gneisses.

At the type locality the Salkhala Formation is overlain by Dogra Slate" which is considered equivalent to the Hazara Formation. The Dogra Slate in turn is overlain by the limestone of Wadia (1928) which is correlated with the Abbottabad Formation of Hazara and on the basis of Cambrian fossils found in the overlying Hazira Formation, is assigned Middle to Late Proterozoice age to the Salkhala Formation. The Salkhala Formation extends to Tarbella in the south and to Besham in the north, located on both the flanks of the Indus River. The formation has been observed at several places on road from Besham to Swat where it is involved in the Main Mantle Thrust and is developed along the footwall zone of the Thrust.

Kazmi et. al (1984) has named various units of the Salkhala as Alpurai schist and Saidu schist in the Swat area.



Photomicrograph 1. Grapite schist cut by veins of quartz and feldspar proving the graphite schist to be of early in age than the adjacent magmatic rocks.

| Age | Formation | Columnar Section | Thikness in feet | Character and Distribution |
|---|---|---|---|---|
| PRECAMBRIAN | SALKHALA | | 60' | Calcareous schist |
| | | | 18' | Amphibolite |
| | | | 60' | Calcareous schist |
| | | | 3' | Quartz vein |
| | | | 6' | Calcareous schist |
| | | | 20' | Amphibolite |
| | | | 18' | Graphite schist |
| | | | 12' | Amphibolite |
| | | | 18' | Calcareous schist |
| | | | 15' | Limestone and Marble |
| | | | 15' | Calcareous schist |
| | | | 12 | Arenaceous schist |
| | | | 2' | Graphite |
| | | | 2' | Amphibolite |
| | | | 7' | Arenaceous schist |
| | | | 3' | Amphibolite |
| | | | 4' | Graphite schist |
| | | | 3' | Amphibolite |
| | | | 40' | Graphite schist |

90 feet
75
60
45
30
15
0
Scale.

FIG. 3. COLUMNAR SECTION OF PART OF SALKHALA FORMATION AT JUDBAH.

## 3.2. TANOL FORMATION

### 3.2.i. Previous work:

Wynne (1879) described the rocks of this formation as "Tanawal Group" Middlemiss (1896) called these as "Tanol quartzites" and considered them to form the lower part of the overlying Infra-Triassic, now named as Abbottabad Formation and on fossils basis placed them in the Lower Cambrian. Marks and Ali (1962) and Latif (1970) named the rocks as "Tanawal Formation". Calkins et. al (1969) mapped these rocks in detail and used the name Tanawal Formation for this unit of rocks. According to these workers the Tanawal Formation (Tanol) consists mainly of quartzose schist, quartzite and schistose conglomerate.

### Type Section:

The Type Section of the Tanol Fomation is located in the western part of Hazara between Haripur in the south, Mansehra in the east, Darband in the west and Thakot in the north. The area is inhabited by the Tanol tribe after which the name of the area is derived.

### Regional Lithological description:

The Tanol Formation as described is composed of quartzose schist, quartzites and at places lenses of conglomerate. South of the Mansehra Granite and in the Garhi Habibullah area the Tanol Formation consists mainly of medium grained quartzite and thinly laminated fine grained mica-quartz schist of low to medium metamorphic grade. Various combination of the main mineral constituents and slight differences in metamorphic grade from place to place result in a variety of rock types. These range from white fine grained quartzose schist or unmetamorphosed quartzite with little mica, to dark biotite quartz schist and phyllite containing large amount of mica. Between these extrems are micaceous quartzite, micaceous quartzose schist, siltstone, brown weathering spotted biotite quartz schist, greenish biotite quartz schist, quartzose muscovite or sericite schist, brown phyllite and other related rock types. Near the contact with the Hazara Formation the Tanol Formation consists of alternating layers of mica_quartz schist and black slate indicating a transitional sedimentary contact. Two miles south of Tarbela, schistose conglomerate marks the base of the Tanol Formation and indicates an unconformable relationship with the Hazara Formation. Within the Mansehra Granite and northward in the Battal and Balakot areas the Tanol Formation is more highly metamorphosed than it is in the south of the granite. Garnet, biotite, muscovite, quartz schist as well as andalusite and staurolite- schists form the bulk of the Tanol Formation in these areas. Sillimanite schist also is found in the Rajdawari area.

3.2.ii. Present Investigation:

In the mapped area the Tanol Formation is exposed inconsistently along the Oghi-Thakot Road and in the flanks of anticline along the Indus River (Fig. 2).

In Oghi area, the Tanol Formtion is exposed in an overturned anticline and constitutes the following lithological units.

iv. Quartzites.

iii. Sandstone with intercalation of quartzite and clay.

ii. Garnet- mica schist.

i. Red clay, silt and shale.

The red clay which occurs at the base is of brick red colour with intercalation of silt and greenish shale. The shale contains crystals of garnet of peanut size. The thickness of this unit is about 44 metre.

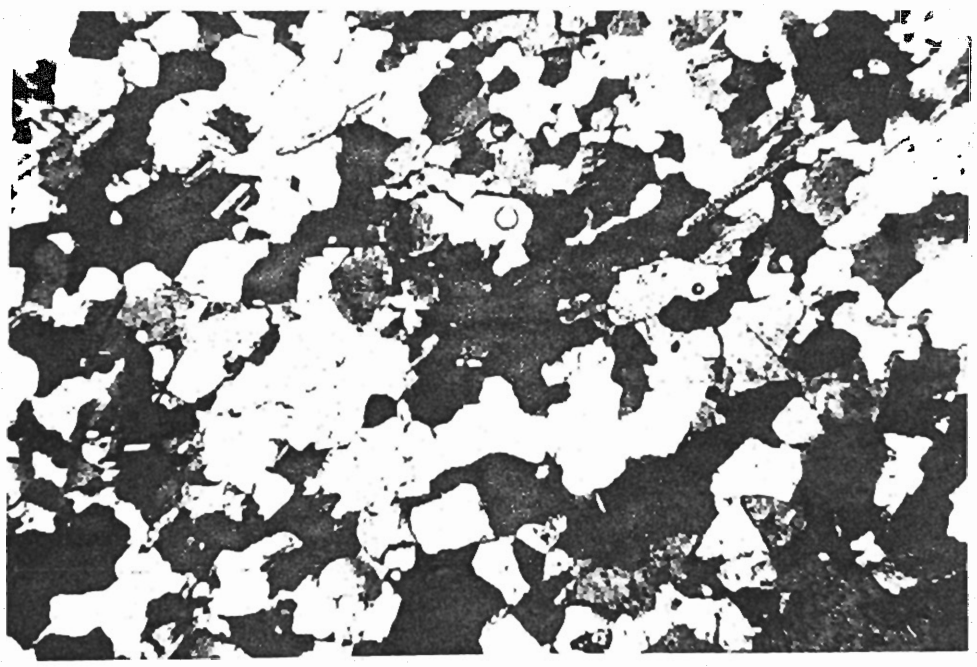
The Garnet- mica schist overlies the clay bed and is well foliated and of red colouration. It is chloritic and constitutes about 35 percent garnet crystals. It is also interbedded with clay . The thickness of this unit is 42 metre.

The sandstone overlying the schistose unit is of red to purple colour. It is poorly cemented and contains garnet crystals. It is 48 metre thick.

The quartzite which occures at the top of this succession is of light brown colour on weathered surface and greenish white on fresh surface. It is hard and flaggy. It,s thickness is about 12 metre (Fig.4). This lithological succession extends to north - west where it is encountered with granitic rocks. The Tanol

Formation exposed at Shahtut, close to the granitic contact and the tectonized zone is composed of quartzites with pink garnet crystals, andalusite schist, sillimanite schist and thin bedded fine grained quartzites.

The formation also contains thin lenses of sugary white marble.It is fine to medium grained thin bedded. It is rich in pyrite and arsenopyrite and is exposed in the form of desiccated lenses. It's exposures are found at Shahtut and Chanjal.



(2) Photomicrograph of quartzite.

(3) Photomicrograph of sillimanite schist.

Photograph No. 2, showing Marble (the white in the picture) at Shahtut.

In the Indus River area the Tanol Formation contains quartzites as the most dominent unit. It,s approximate thikness is 1500 metre. The Tanol Formation is intruded by Dykes and Sills of Dolerites and Amphibolites. The grade of metamorphism is higher in the north close to the tectonized zone as compared to the south as is evident by the gradual development of low grade metamorphic minerals in the south and high grade in the north of the mapped area.

3.2.iii. Thickness and Contact relation:

The thickness of the Tanol Formation is not known with certainity due to structural complications. Wynne (1879) suggested a minimum thickness about 6100 metre, whereas Ali (1962) estimated the thickness as 1,666 metre. The author measured the formation at Oghi picket which is about 152 metre thick. At Surmal it,s thickness is about 1500 metre. East of the Hazara Kashmir Syntaxis, the Tanol Formation is missing and the Hazara slate (Dogra slate) is overlain unconformably by a thick calcareous bed which is considered equivalent to the Abbottabad Formation. The Tanol Formation underlies the Abbottabad Formation and overlies the Hazara Formation in the area between Abbottabad and the Indus River. The contact between the Abbottabad Formation and the Tanol Formation in various sections in this area is marked by an unconformity which is represented by a boulder bed known as Tanakki conglomerate as reported by Calkins et. al, (1969). He also mentioned that between Abbottabad and Garhi Habibulla the lower contact is marked by only a lithological change from slate to quartzite which in places is gradational with the underlying Hazara Formation. In the north eastern part of southern Hazara the Tanol Formation directly overlies the Precambrian Salkhala Formation with an unconformity.

In the mapped area the Tanol Formation has faulted contact with the Salkhala Formation and intrusive contact with the Mansehra Granite.

3.2.iv. Age and Correlations:

Since the Tanol Formation is devoid of fossils therefore it has been assigned the age on the basis of its stratigraphic position with respect to the adjacent rock formations.

Wadia (1928) has pointed out a conformable passage of the Tanol Formation into the Agglomeratic slate of Jured in Kaghan where it is a part of the Pirpanjal Volcanics of Permian-Triassic age.

Fuchs (1975), described a section north west of Sach Pass in the western Himalayas where the Tanol Formation interfinger with the Syringothyris limestone.

In an other section between Sach Pass and Dolhousi, a sample collected by Gupta (1971) from the lower part of Psammitic bed, considered equivalent to Tanol Formation was examined by him, which yielded Lower Devonian Conodonts. Martin et. al (1962) while working in Swabi and lower Swat, encountered dominantly psammitic rocks called Swabi and Chamla Quartzites representing Tanol Formation which interfinger with fossoliferous dolomites of Siluro-Devonian age.

Therefore it has been concluded that according to previous workers the Tanol Formation has been assigned Devonian to Early Carboniferous age.

Latif (1972) and Rushton (1973) discovered Hyolothids at the top of Abbottabad Formation near its contact with the Hazira shale and confirmed a Cambrian age for the Hazira Formation. The Hazira Formation conformably overlies the Abbottabad Formation of an Early Cambrian age which unconformably overlies the Tanol Formation. Therefore on the basis of this contact relationship the Tanol Formation has been assigned a Late Precambrian age.

Moreover Le Fort et. al. (1980) from Rb/Sr whole rock isotope analysis, dated the Mansehra granite at 516+16 Ma, which is considered to be its intrusion age. As the Tanol has been intruded by the Mansehra Granite therefore it confirms a Precambrian age for the Tanol Formation.

The correlation of the Tanol Formation and their equivalents in the Indo-Pakistan subcontinent, based on the past and present researches (Tahirkheli & Majid, 1977) is as shown below:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Hazara | Kashmir | Simla | Garhwal | Spiti |
| Tanol Quartzites | Muth Quartzites | Bawar Qtz. Jaunsar.Bed | Naghat Series | Muth Qtz. |

| 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|
| Swabi | Buner | Khyber | Chitral | Nepal |
| Qtz. | Chamla Qtz. | Qtz at Bara ghat section (Tirah) Spinragh Qtz. of Jamrud. | Charun Qtz. | Qtz. in Chilos&Thulo Bheri Valley |

3.2.v. Depositional Environment.

The Tanol Formation comprises part of the Lesser Himalayan sequences in Hazara. They represent the Tethyan facies which were deposited after the shrinkage of the geosyncline in which the great slate series; Hazara Slates, Dogra Slates, Manki Slates, Simla Slates and Landikotal Slates were deposited (Tahirkhali and Majid,1977).

Before the commencement of deposition of the Tanols, a ridge called the "Himalayan Ridge", (Fuchs, 1975) was created in the central Himalayas which extended to the north west and coin-cided with the Tanol Zone.

North of this ridge was the Tethyan basin where the Tanol sedimentation was taking place, whereas on the south, this ridge bordered Indian subcontinent as evident by occurrence of the Gondwana Flora in the Agglomeratic Slate with which the Tanol have kinship and existence of Upper Paleozoic glacial boulder bed. Whatever may be the causes of the shallowing of the Tethyan Basin, the character of the Tanol shed ample light on the rapid fluctuations during the deposition of the Tanols, which have effected the grain size. Thus in the Tanols, beside pelitic interfingerings which is frequent in the north west, the quartz grains also show great variations in size ranging from fine grain to gritty.

From the mineral assemblage in the Tanol Quartzites, such as quartz, feldspar, biotite, tourmaline, sphene and ores, it is apparent that the source area was underlain by the igneous rocks where acidic igneous suite predominated.

In the Tanol sequence, in the south western Tanol, the top and bottom are comparatively more sandy and gritty, whereas the finer pelitic bands frequent in the middle part. Thus during early and late periods of deposition of the Tanols,shallow and agitated conditions prevailed whereas during the middle period the deposition was comparatively in deeper water which remained oscillatory (Tahirkhali and Majid.1977).

In Oghi area the Tanol Formation contains red clay, silt, greenish shale at the bottom and sandstone, quartzites at the top which show deposition ranging from deep to shallow marine conditions.

The Tanol Formation overlies the Hazara Slates and is underlain by the Abbottabad Formation and both the lower and upper contacts are unconformable and are marked by conglomeratic beds.

Table-1. Modal composition of metamorphic rocks of the Tanol Formation, from the Black Mountain.

| Location & | Ghanian. | Shahtut. | Belian. | Kamatch |
|---|---|---|---|---|
| Sample.No. | 2 | 5 | 8 | 48 |
| Minerals. | % | % | % | % |
| Alkali feldspar. | 25 | – | 30 | 20 |
| Albite. | – | – | – | 10 |
| Quartz. | 60 | 20 | 10 | 40 |
| Sillimanite. | – | 10 | – | – |
| Biotite. | 8 | 20 | 40 | 12 |
| Muscovite. | – | 15 | 6 | 10 |
| Garnet. | 5 | 30 | 10 | 5 |
| Ore. | 2 | 5 | 4 | 3 |
| Total. | 100 | 100 | 100 | 100 |
| Rock Type. | Garnet-mica schist. | do. | do. | Garnet qtz.schist. |

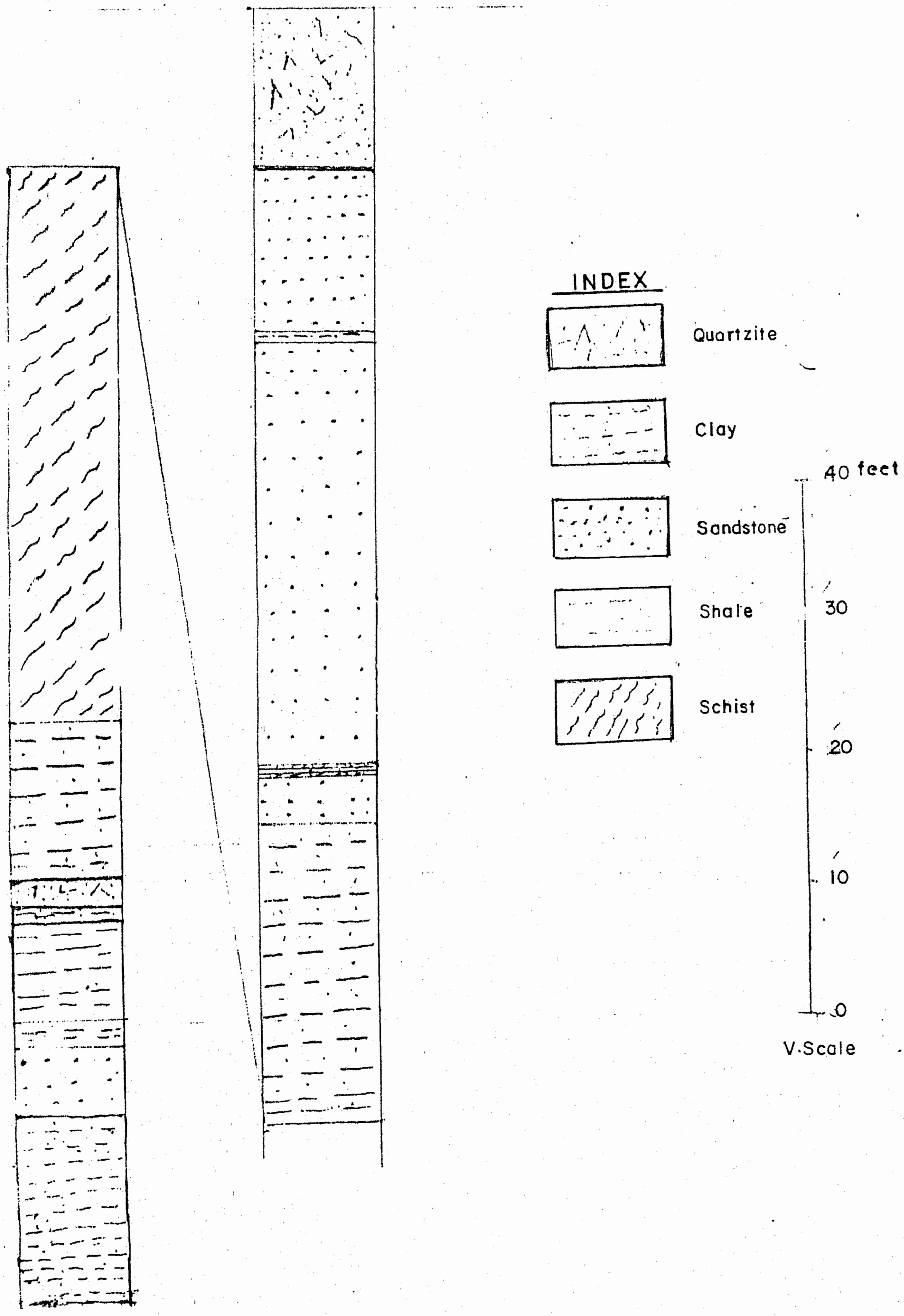


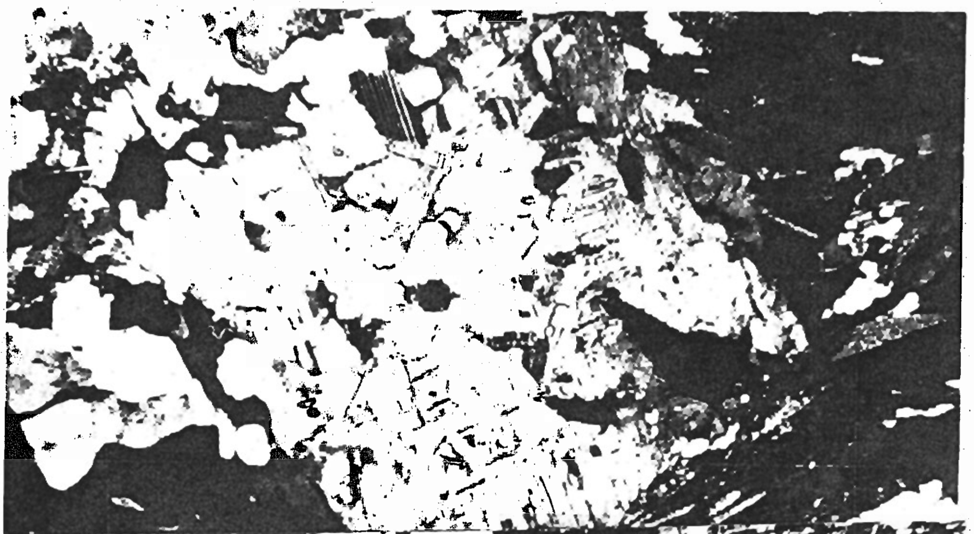

**Fig.4. Columnar Section of the Tanol Formation at Oghi-Picket.**

## 3.3. The Mansehra Granite

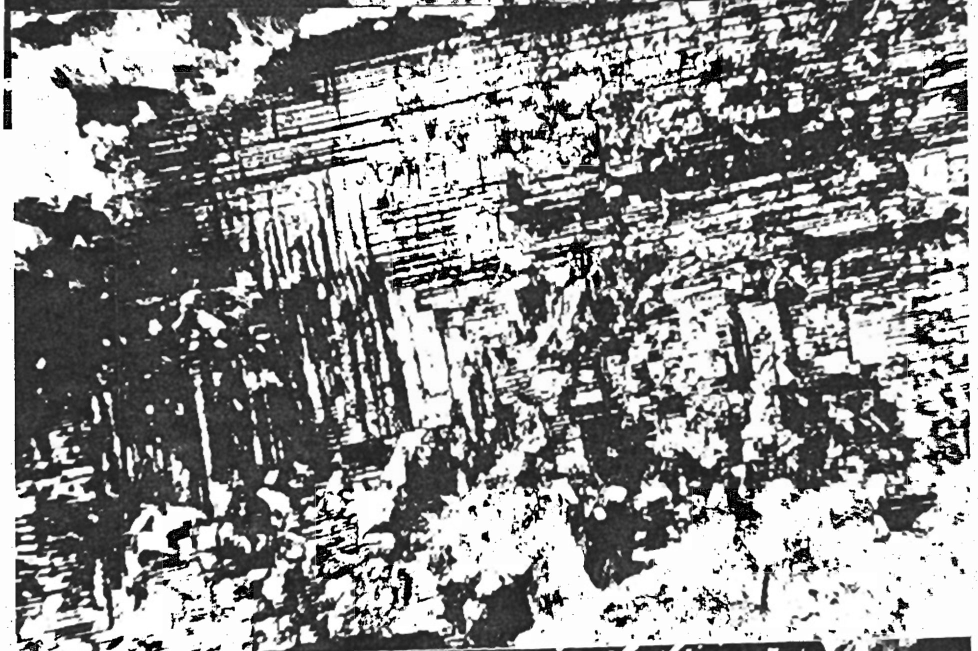
The Central part of the area under study is underlain by a huge body of granitic complex which is an extension of the Mansehra Granite from the south east, Swat Granite gneisses from the west and Besham Migmatites from the north. The granites make steep ridges and cliffs rising upto 3000 metres at Dandai Sar. It has intruded the metasediments of the Salkhala and Tanol Formations and has followed the general trend of the country rocks. At the contact no chilling and backing effects were preserved due to high deformation and only a lithological change between the plutonic and the country rocks was seen. The granitic rocks are generally foliated and their contacts with the adjacent country rocks are sharp and concordant with foliation. Although general concordance is the rule, in places the contact is marked by the presence of seams and stringers of granitic rocks and by inclusions of the adjacent rocks in the granite. There is no doubt about the intrusive character of the granite.

The granite is light coloured, medium to coarse grained and is characterized nearly every where by phenocrysts of alkali feldspar some as much as 15 centimeter long. The main mineral constituents are alkali feldspar, albite, oligoclase and quartz with small amounts of biotite, muscovite and accessory magnetite, apatite and sphene. Quartz content ranges from 15 to 50 percent (Table.2).

4.



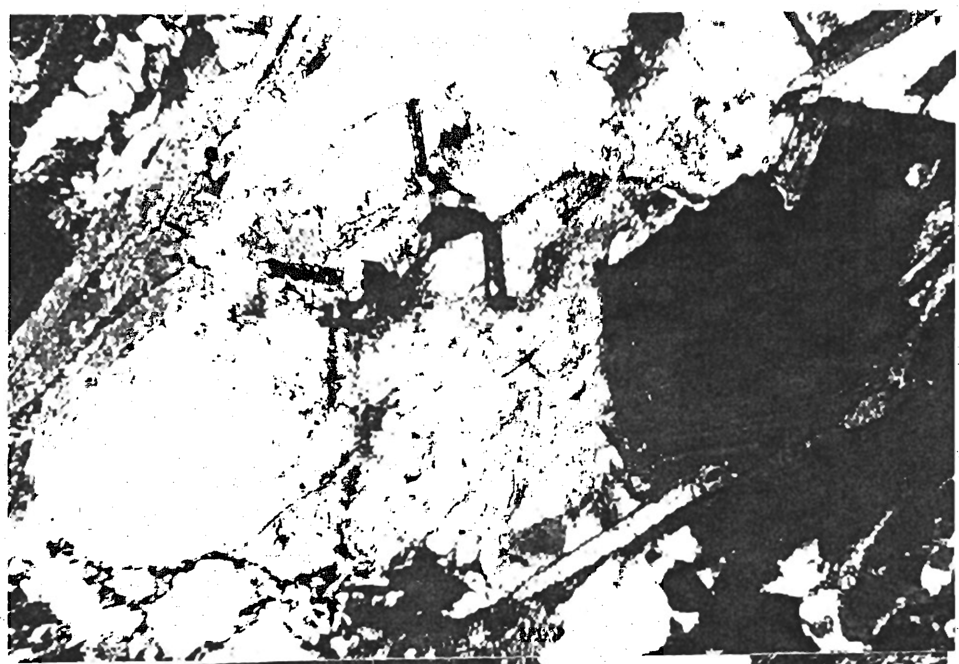
5.



6.

Photomicrographs 4, 5, 6. showing Alkali feldspar.

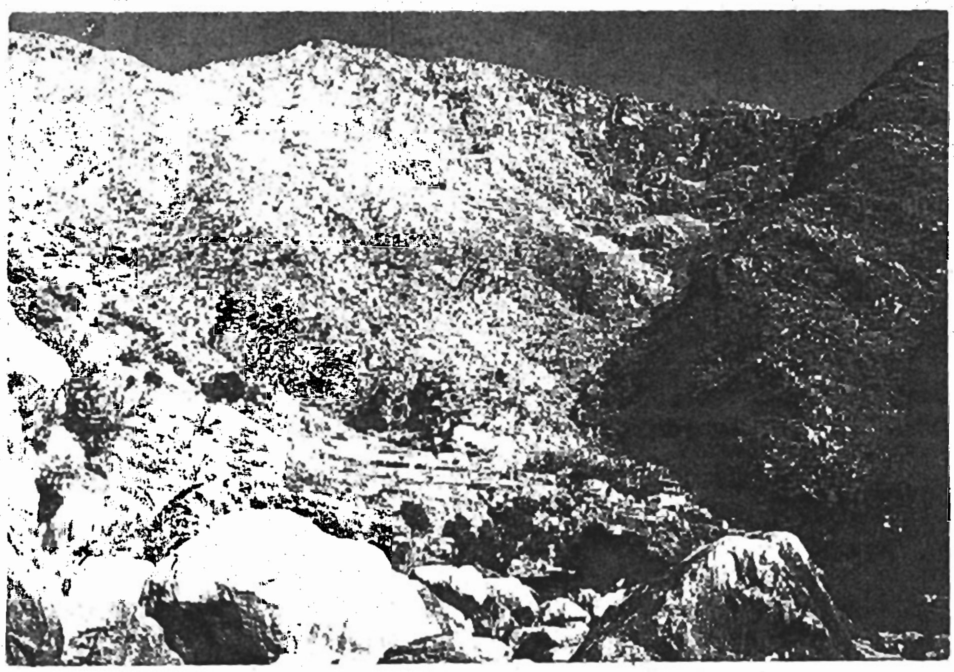
7.



8.

Photomicrographs 7, 8. showing Plagioclase.

The metamorphic rocks dipping under the granite (Photo.4) suggest that the granite is sheet like in form and that it has been folded with the metamorphic rocks. Homogeneity of structure in the granite and the surrounding rocks indicate the deformation of layered sequence of which the granite was a part,(Shams.1967).



Photograph.4. Taken at Garyar along the Indus River showing contact between the granite above and the metasediments below.

### 3.3.i. Subdivision of the Mansehra Granitic Complex.

Middlemiss (1896) subdivided the Mansehra Granitic Complex on the basis of their structure as:

i. Non foliated,

ii. Semi foliated,

iii. Foliated.

Shams F.A. (1969) subdivided the granitic complex into the following categories.

(2) Younger Tourmaline Granites.

- Hakale granites.
- Kaskala granites
- Sukal granite.

(1) Older Granites and Gneisses.

- Susal gali granitic gneiss
- Mansehra granites
- Andalusite granites
- Associated acid minor bodies.

He has also subdivided the granites into sheetlike form, mushroom like form and laccolith and sills.

In the area under investigation, Middlemiss has not marked boundaries between metamorphic rocks and the granites and has shown all together.

Shams has worked a lot of on the Mansehra Granitic Complex but has not touched the Black Mountain area which may be due to it's tribal position and unaccessibility.

The author of the present report, subdivided the granitic complex of the Black Mountain after detailed field work, on the basis of mineral assemblages and deformation of feldspar crystals in to the following units.

6. Pegmatites and aplites.
5. Massive granite.
4. Porphyritic granite.
3. Augen gneisses
2. Mylonites.
1. Migmatite.

1. <u>Migmatite:</u>

It is exposed on both sides of the Indus River at Jigal and is originated as a result of admixture of quartzite and granite. The rock is light gray fine to medium grained and gneissose in texture.It is in banded form and contains large clots of biotite.

2. <u>Mylonites:</u>

The Mylonites are exposed in the Shear zone along Oghi-Thakot road in an area of about 6 kilometer in width. The gneiss-es and the host rocks are highly sheared and mixed with one and other. The phenocrysts of feldspar and quartz if present are preserved very loosely.

Near Oghi, at Gali the rocks are so intensely sheared that they have last their original characteristics and changed into soft-clayey soil. At some places the mylonites are hard enough and show Crenulation and mineral lineation trending nearly in north-south direction (Table.3).

3. Augen gneisses:

The augen gneisses are inconsistently exposed along Oghi-Thakot road, and at Darbani and Dewal in the Indus River area. The rock is characterized by eye shape porphyroblasts of feldspar or quartz, wrapped by flaky minerals such as micas etc.

4. Porphyritic granite gneisses:

The porphyritic granite gneisses are well developed in the south eastern part of the mapped area and are extension of the granites exposed at Mansehra. They are coarse grained and characterized by megacrysts of alkali feldspar (microcline) upto 15 centimeter long.

5. Massive granite:

This type of granite is exposed in the northern part of the area east of Jigal on left bank of the Indus River. It is milky white, fine to medium grained and massive. It contains grains of pyrite. It is followed by granite of brownish and greenish white colour containing grains of hornblende.

6. Pegmatites and aplites:

In the granitic complex, pegmatites and aplites are sporadically distributed and are developed in zones of shears and joints.

At Belian, west of Oghi Muscovite and Tourmaline granitic pegmatites have been developed. The tourmaline is black and fractured. It is developed in the form of columns, packed together and are embedded in the granitic matrix. The muscovite flakes range in size from one centimeter to ten centimeters and are in the form of sheets. At Chittabatta on way to Machai Sar dyke of aplite is developed. It is sheared and foliated. It is of white sugary colour and contains fragments of biotite and tourmaline. It is fine to medium grained and of anhedral texture. It run along the fault zone and is exposed for about 3 kilometer trending in east- west direction.

3.3-ii. Intrusions of Dolerites & Amphibolites:

The dolerites and amphibolites which are closely associated are found throughout in the metasediments. They occur in the form of sills and dykes. At Mana Sar these rocks occur along contact zone between the Mansehra Granite and the metasediments and extend to Gidari on Oghi Road. Its approximate thickness would be 60 metre. The dolerite is dark black in colour fine to medium grained and massive. The amphibolites are of greenish and of rusty brown colour. Both the rocks are enriched in iron and magnesium.

### 3.3.iii. The Swat Granite gneiss:

It is exposed at Dewal on right bank of the Indus River and is composed dominantly of feldspar, quartz and biotite. It is in the form of sheets and the feldspar crystals are in the form of augens in the granitic rocks. It is similar to the augen gneisses of Mansehra.

Le Fort et.al (1980) from Rb/Sr isotope analysis, dated the granite at 516+16 M.a.

### 3.3.iv. Phenomena associated with the Granitic-Metamorphic Contact zone.

The Granitic complex is closely associated with the metasediments of the Salkhala and Tanol Formations and some important phenomena have been observed with in the Granitic-Metamorphic Contact zone which have been found to have important bearing on the origin of the Hazara Granitic complex and similar complexes elsewhere in the Himalayas (Shams.1969).

#### 1. The thermal effects.

The thermal effects observed at contact zone between the country rocks and the intrusives in the Oghi, Peshora area could-be explained in the following few lines.

i. The hardening effect: There is a prominent change in hardening of the country rocks (schist and quartzites) as compared to the same rocks located away from the contact zone. In addition to this, there is development of pink garnet, well cemented in the matrix of the country rocks, (quartzitic schist). All these show very early signs of thermal effects leading to hardening of the country rocks. This appears to have happened due to loss of hydroscopic water and textural interference of constituent minerals to produce an interlocking fabric,(Shams,1961). There was slight increase in the grain size although no new mineral had developed in the rocks.

ii. Mica porphyroblasts. Muscovite and hornblende porphyroblasts, were observed in the large granitic pegmatites along Oghi Thakot Road and at Gavi near the Indus River. These pegmatites containing the porphyroblasts are sporadically distributed throughout in the granitic complex and make disconcordant contacts with the country rocks. These are also deformed and sheared along the fault zones. This marks the next stage of thermal metamorphism and is recognised by the appearance of the porphyroblastic pools of muscovite flakes.

iii. Formation of Fibrolites: At Shahtut, the contact zone between the country rock and the granite, fibrolite, a variety of sillimanite was developed. This appears to have been initiated just after the growth of andalusite. At this stage garnet of the schists also show evidence of having suffered thermal effects which cause its break down and release of rods and granules of black ore.

## 2. The structural effects:

Along the contact between the granite and the country rocks, the prominent structural effects developed are columnar joints and the shear foliation with micaceous layers wrapped around augen shaped areas of feldspar and/or quartz as are observed at Gali (Oghi). Near the contact the structure become almost mylonitic (Photographs 6,7 ).In the case of metamorphic rocks,the important structural effect is intense refolding of the primary schistosity giving rise to a strain slip cleavage, the later have offered a new set of planes for tectonic slippage and minerals reorientation. These effects have produced small scale folds, puckers and fine crenulations on schistosity planes of the rocks related to intense slickensiding with attendant lineation. It is notable that the superimposed structures in the contact zone between the granitic and the metamorphic rocks such as lineation, crenulation and microfolds etc. are mutually conformable as well as parallel to the nearby contact planes.The structural effects are also suffered by aplitic and basic minor intrusives leading to their shearing and tear faulting.It is also important that many of these minor bodies had suffered movements along such a set of joint system which is mostly oriented diagonal to the nearby contact planes. Such a disturbance was post-thermal and is proved by disrupted bedding of hornfelsed schist, (Shams, 1967).

3.3-v. DISCUSSION

The variety and nature of various phenomena, as recorded within contact zones of the Mansehra granitic complex and the associated metamorphic formations, show the following sequence of events.

1. Pre-granitic regional metamorphism of the geosynclinal argillaceous, arenaceous sediments, causing recrystallization of original minerals and growth of new minerals of Barrovian type sequence (Shams, 1967).

2. Thermal metamorphism of the metasediments forming new minerals, causing thermal break down of older minerals and destroying to variable degree the primary fabric of the metasediments.

3. Upwelling and expansion of the granitic body producing marginal shear structures such as slickensides,striations and microfolds are observed by the author in Shahtut, Darbani and Shagai areas.In addition to this,quartz pegmatite, feldspar pegmatite and mica pegmatites are also developed at several places with in the granitic complex.

The pegmatites which are younger than the parent granitic body also show deformation.

3.3-vi. Age and Correlation of the Mansehra Granite.

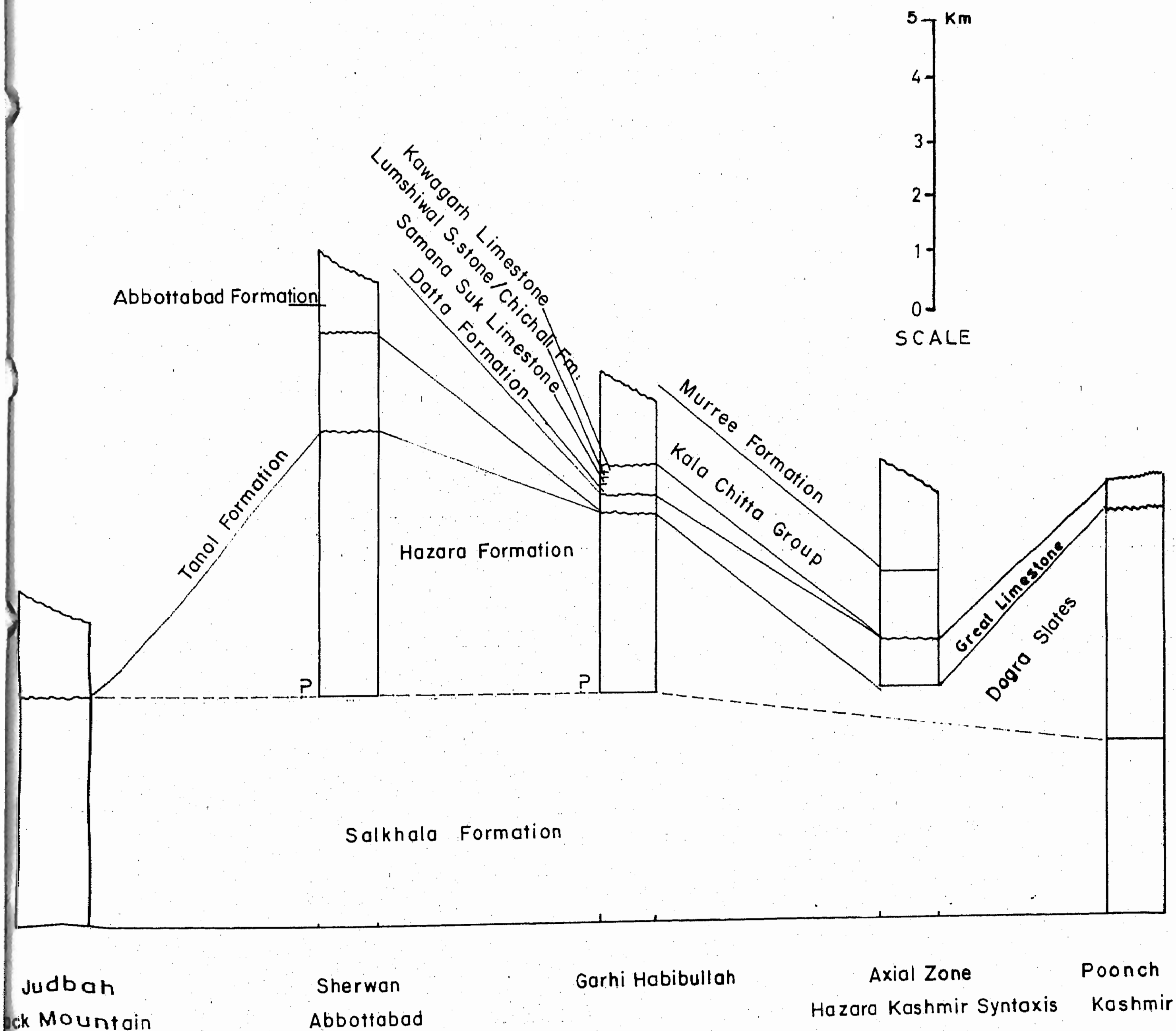
On the basis of mineral assemblage and other considerations, Le Fort. et al (1980) gave a well defined 150 chrome age of 516+16 m.y. Since the Mansehra and Swat Granitic gneisses intrude the metasediments of Pre-Cambrian age therefore they are one and the same body and the age of these granitic complex would be of Early Cambrian.

Table.2. Modal composition of granitic gneisses of the Black Mountain area.

| Location & | Bakrai Khwar. | Dab Khwar. | | Dewal. | Kander. | Itai Khwar |
|---|---|---|---|---|---|---|
| Sample.No. | S1 | 7a | 7b | S11 | S22 | S30 |
| Minerals. | | | | | | |
| Alkali feldspar. | 30 | 45 | 40 | 40 | 25 | 55 |
| Albite. | - | 2 | 7 | 10 | 40 | - |
| Quartz. | 50 | 23 | 40 | 20 | 15 | - |
| Biotite. | 10 | 20 | 10 | 15 | 15 | 20 |
| Muscovite. | 10 | 10 | 3 | 10 | 5 | 20 |
| Garnet. | - | - | - | 2 | - | 2 |
| Ore. | 3 | - | - | 3 | - | 3 |
| Total. | 100 | 100 | 100 | 100 | 100 | 100 |
| Rock. | Granite gneiss. | do. | do | do. | Granite. | gneiss. |

Table:3. MODAL COMPOSITION OF MYLONITE FROM THE BLACK MOUNTAIN

| Location | Gali S-No.I | Shalun Khwar S.No.17 |
|---|---|---|
| Alkali feldspar | 15 | 45 |
| Albite | 2 | 5 |
| Quartz | 30 | 20 |
| Biotite | 30 | 15 |
| Muscovite | - | - |
| Kyanite | 13 | - |
| Zircon | - | 2 |
| Ore | 10 | 3 |
| Total: | 100 | 100 |




.5 : CORRELATION IN THE FIVE STRUCTURAL BLOCKS OF THE BLACK MOUNTAIN, SOUTHERN HAZARA AND PARTS OF KASHMIR. (THICKNESSES ARE APROXIMATE)

# CHAPTER. 4

## STRUCTURAL SET UP.

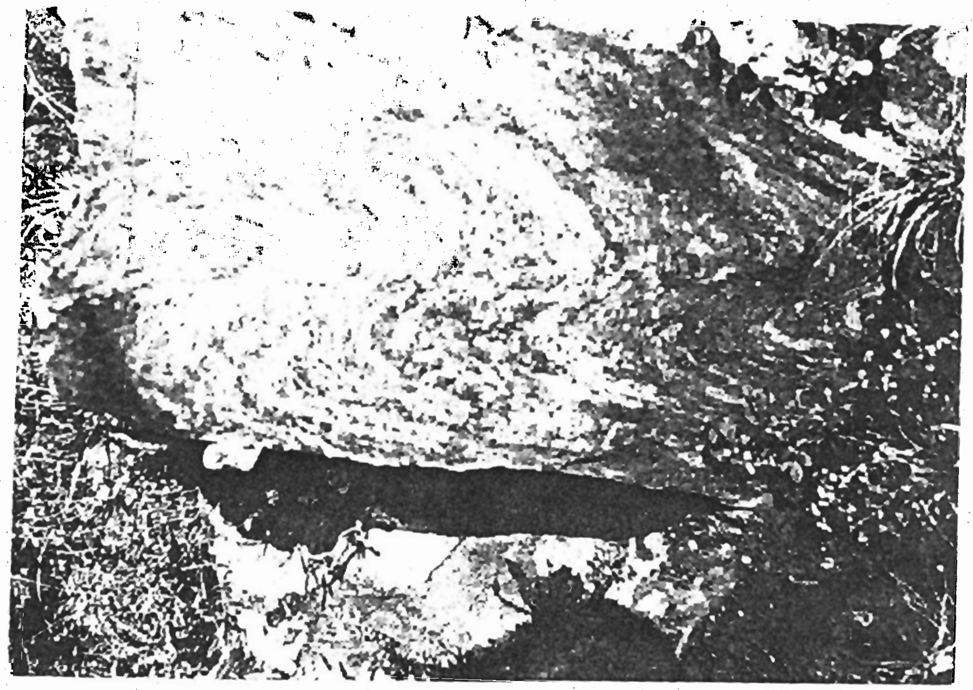
The structural set up of the Black Mountain may either be thought to be a westward extention of the Hazara-Kashmir Syntaxis here called, the Indus reentrant (Calkins et.al,1975 Fig.2), or the Besham Nappe (Trelaor,et. al.1989b,Fig.7). Whatever may be the nomenclature, the area is dominated by folds, faults, joints, foliations and lineations which may be described briefly in the following few lines.

### Folds:

Two generation of folds (early and late) have been recognized in the area under study. The early generated folds trend in north- south direction and the later trend in east-west direction cutting across the former (Fig.2). The former folds are located along the Indus River in the west and along Oghi-Batgram Road in the east, while the later folds are located in the central part of the mapped area,(Fig.2). Among the former an anticline is developed along the Indus River ,the axial plane of which follows the course of the River with a northward plunge. It's flanks are refolded into small scale synclinal and anticlinal structures forming anticlinorium. In Oghi area, an overturned anticline and syncline, plunging to north and south respectively are developed. Moreover small scale domal folds are developed throughout the Oghi terrain. Among the later folds, an anticline is developed along Bakarai Khwar in the south followed by syncline in the north with their axial trends in east-west direction cutting across the former folds (Fig.2).

4 5

Photographs No.4, 5. Taken at Kotqala, along Batgram-Thakot Road showing Folds with in the granite and quartzite.



Photograph No. 6. Taken at Gali,Oghi showing ptygmatic folding in mylonite.

Faults:

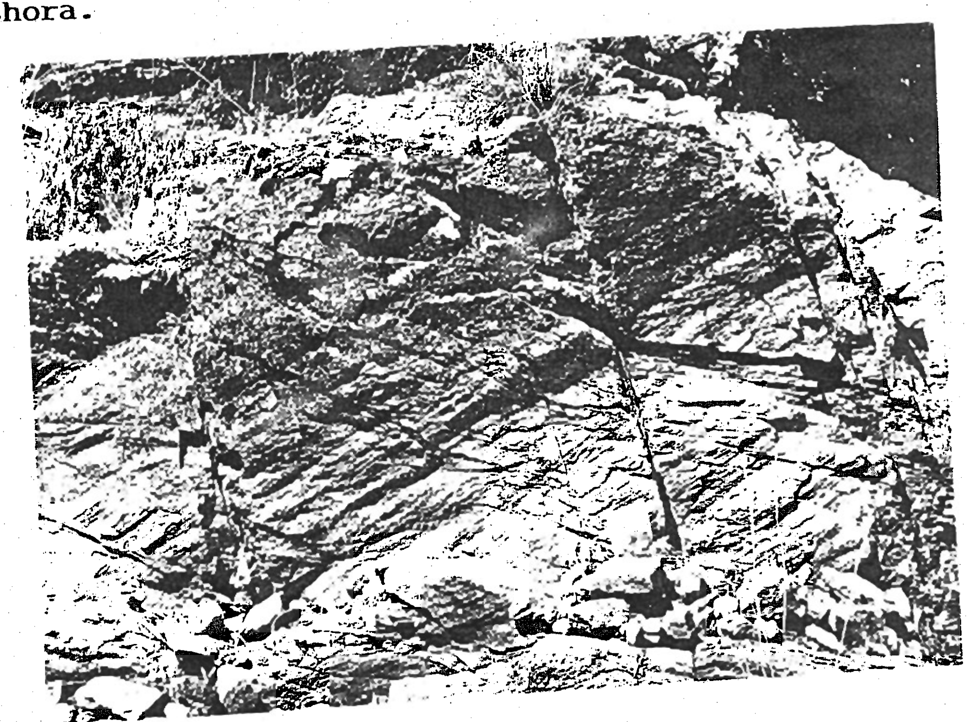
Since the area lies close to the M.M.T,and hence it has been severely deformed and a series of strike slip faults have been developed.A strike slip fault also called the Oghi Shear is developed in the eastern part of the mapped area (Fig,2} The block on right side of the fault plane has moved anticlockwise while the block on its left side has moved in a clockwise direction suggesting it to be a dextral fault as is evident by rotation of the garnet along the fault plane (Photomicrograph.9.10) Similarly strike slip fault along Shalmano Khwar has been observed. The rocks on the right side of the fault plane have moved to the north while the corresponding rocks on it's left side have moved opposite to it (Fig 2. Photo. No. 11). An other strike slip fault along the Indus River has been demarkated by remnants of slicken-sides and striations trending in north- south direction. This-fault follows the course of the Indus River (Fig.2,Photo-graphs.No.9,10).

Joints:

Columnar joints are developed in the granitic rocks close to the contact with the metasediments as are observed at Shahtut and Peshora areas. The columns are in hexagonal form (Photo.7). The metasediments particularly the quartzite exposed in the Oghi area has two sets of joints which trend in a north -south and east-west direction indicating the direction of tectonic forces.

In the Indus River area conjugate joint systems have been developed in the granitic gneisses (Photographs.No.8).

Photograph No.7, showing columnar joints in granitic gneisses at Peshora.



Photograph No.8, showing conjugate joints in granites at Tarnao.

## Foliation and Lineation:

The foliation in the metasediments dip away from the axial zone of the anticline along the Indus River .They trend in north-south direction in the 1st order folds and east-west direction in the 2nd order folds. The lineations which result from elongation and stretching of minerals,ie.feldspar,quartz and other minerals trend in north -south direction. These suggest the general flow direction of the rocks to the north.

# CHAPTER. 5

## TECTONIC FRAME WORK

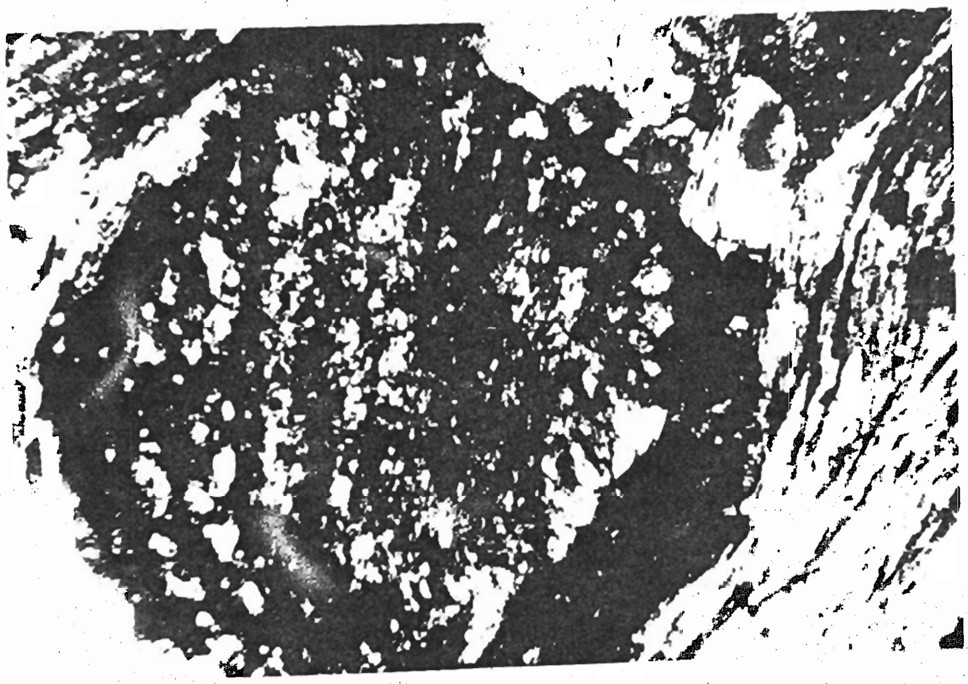
The Himalayan mountain chain evolved as a result of collision between the Eurasian and the Indian plates about 50 - 55 Ma ago, ie, Eocene (Trelaor.et.al 1990). The two plates are separated by the Kohistan-Ladakh Island Arc (Fig.6) developed above a north dipping subduction zone within which the Tethyan oceanic plate was consumed (Trelaor.et.al.1990).

The Island Arc was subducted under the Asian plate along the northern suture about 100 Ma ago and obducted over the Indian plate along the Main Mantle Thrust (MMT) before 50-55 Ma,(Trelaor.et,al.1989b,Fig.6).

The area under study is located on the northern fringe of the Indo-Pak plate and tectonically is influenced by the deformation initiated by the MMT (Fig 7). The second major tectonic episode which effected the area is related to Hazara- Kashmir Syntaxis which was initiated during Late Middle Miocene,ie.2.7-1.5 Ma ago and continued till to Early Pleistocene (Coward et.al, 1988). A major antiform is developed along the Indus River with a north ward plunge direction (Fig.2).Calkins et.al (1975) have called it the Indus reentrant and considered it to be an extension of the broad regional structure of the Hazara-Kashmir Syntaxis, (Fig.1.a). On the west side of the River Indus the structure swings south west and finally takes a westward course. The antiform in the area extends to Shagai in the north with its axis running parallel with the course of the Indus River (Fig.2).

The eastern part of the mapped area is deformed into a number of small overturn and domal folds with their axes trending in north-south direction.

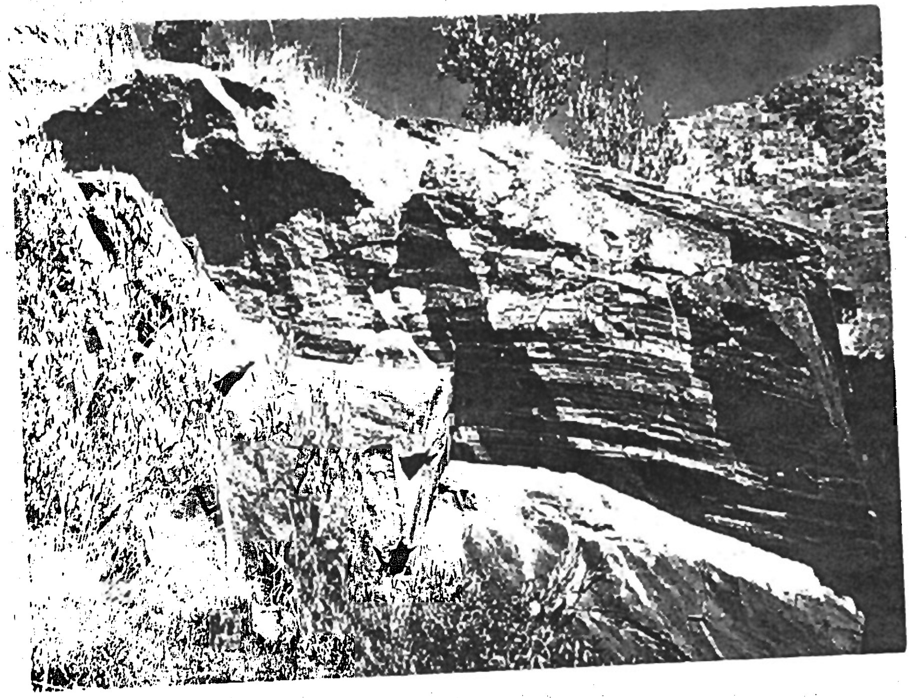
From these evidences it may be suggested that the area was subjected to east-west compression relating with the tectonic episode of Hazara- Kashmir syntaxis during Post Mid Miocene time. The east-west compression has resulted strike slip faults trending north south in Oghi,Chanjal areas and along the Indus River. In addition to field evidences,ie.shearing and mylonization of the rocks (Photographs.9, 10, 11 & 12), the strike slip fault at Shahtut, Oghi can be recognized by rotation of the garnet along the fault plane (Photomicrograph.9 & 10) At Belian on right side of the fault,the garnet shows rotation in a counter clockwise direction (Photomicrograph.9) while at Shahtut and Ghanian on left side of the fault plan the garnet is rotated in a clockwise direction,(Photomicrograph.10). This suggests a dextral movement along the fault. This strike slip fault is also called Oghi Shear by the earlier workers (Trelaor.1989). At Chanjal, an other strike slip fault has been observed along the contact between Salkhala and Tanol Formations. The left side of the fault has moved south westward and the right side has moved opposite to it as is observed along the Judbah Khwar where similar blocks have been displaced along the fault plane in opposite direction, (Fig.2 & Photo.11). Similarly fault lineaments with slickensides trending in a north south direction have been observed along the Indus River indicating that the Indus River follows the fault zone. The compression emanating from reactivation of the MMT, again changed the direction of the earlier fabrics to east-west (Fig.2.) From these structural patterns it can be deduced that the Indian plate was moving northward and after the collision with the Asian Plate resulted in folding and upheaving the area. The Indo-Pakistan plate first-collided with Asia in the north west Himalayas and then rotated anticlockwise with a total rotation of about 40 degree since 84 Ma ago and stricked with Asia in the North East Himalaya,(Patriate et,al 1989). As a result it compressed the strata once again but in a different trend, probably north-south direction as is observed from refolding of the previous structures (Fig.2).



Photomicrograph 9.showing anti-clockwise rotation of the garnet crystal in garnet-mica schist.

Photomicrograph 10. showing clockwise rotation of the garnet crystal in garnet-mica schist.

9.



10.

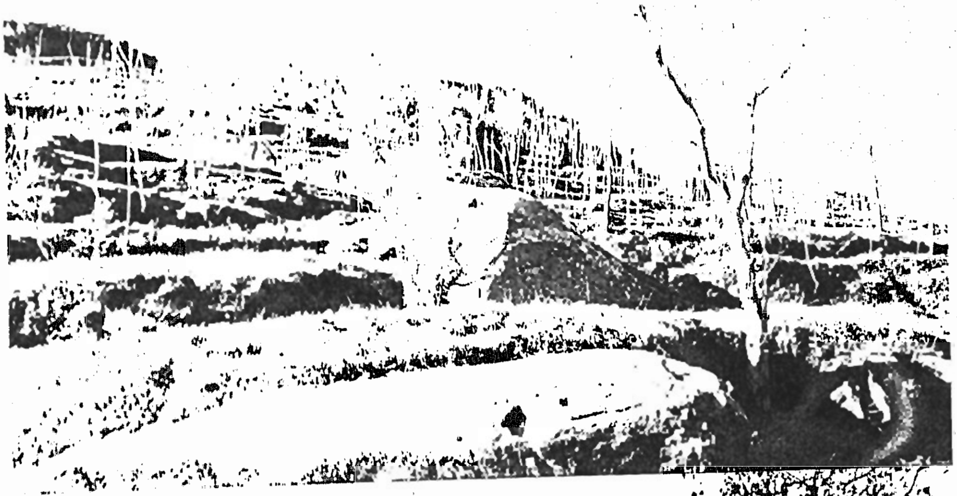
Photographs No.9 & 10. Taken at Bakarai and Garyar showing slik-en-sides trending in north-south direction.

Photograph No.11,Taken at Shalun Khwar showing vertical cliffs and spaces between beds.This block of rocks occur on left side of the Judbah strike slip Fault.

12.a

Photographs No.12 a. Taken at Churkalan showing mylonitic blocks.

12.b



12.c

12.d

Photographs No 12.(b, c, d) Taken at Chaprai, Shahtut and Oghi areas showing mylonitic blocks (b), Oghi Shear Zone (c) and a general view of the Oghi plain (d).

Phtograph No.13. Taken at Jigal showing strike slip Fault along the Indus River .

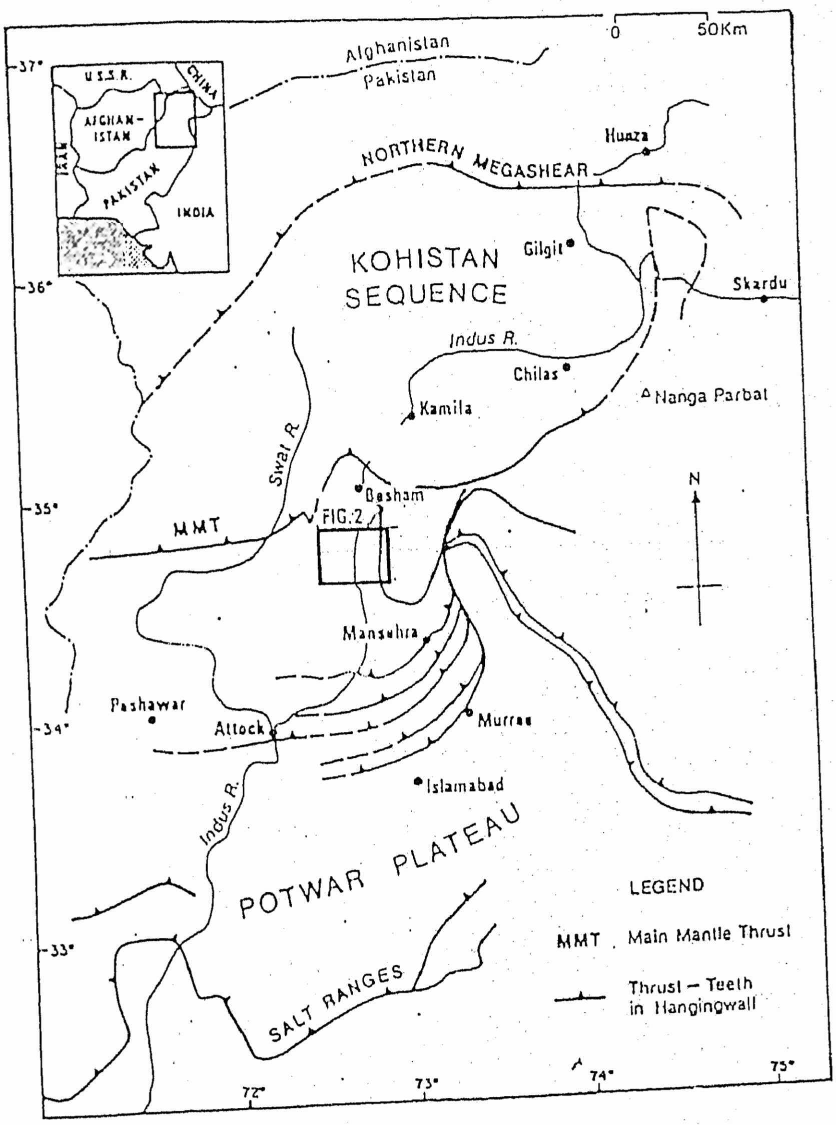



Fig.6. Outline map of Northern part of Pakistan to show the position of the Kohistan Island Arc between the Indo- Pakistan and Asian Plates: Some of the main thrusts of the Main Mantle Thrust(MMT),some of the main towns and the location of Fig.2. After Mathew P.William,1989.

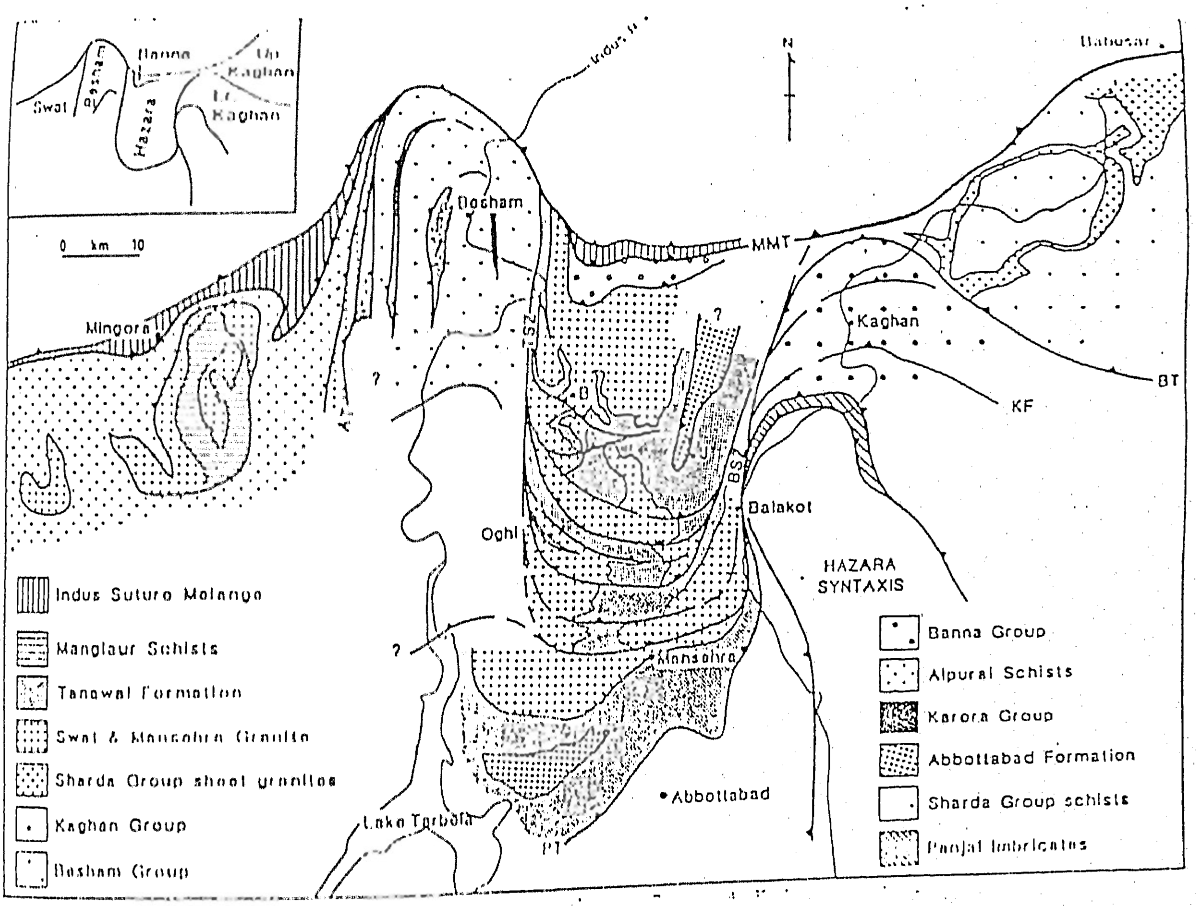



Fig.7. Map of the internal zone of the Indo-Pakistan plate underlying the MMT between Swat and the Kaghan valley, with an inset showing the boundaries of the j.jabori,AT.Alpurai Thrust, PT.Punjal Thrust, BT.Batal Thrust. After Mathew P.Williams,1989.

# CHAPTER. 6.

## Economic Minerals.

The mineral resources encountered in the area may be divided into two parts, those which occur as showings and those which occur in minable reserves and are exploitable. Among the former,chalcopyrite, pyrite, arsenopyrite, muscovite and graphite are associated with various magmatic and metamorphic horizones.

### Chalcopyrite, Pyrite and Arsenopyrite:

These are associated with the tectonized zones and are found in carbonates, quartzites and massive granites. The metallic minerals occur in disseminated, as well as in crystalline form. The mineralized zones are located at Chanjal, Kabulgram, Biyar, Ashario Kondao and Shahtut.

**Muscovite:** It is found in sillicic pegmatites mostly associated with the granitic intrusions and Occur as clusters about 5 centimetre in diameter. It is located at Peshora, Belian, Gavi and at several other localities in the mapped area.

**Graphite:** It is black soft and of both crystalline and amorphous varieties. The crystalline variety consists of thin black flakes while the amorphous variety occurs in dust like form. The graphite is closely associated with carbonates. The reserves are extensive and are found throughout in the metamorphic rocks of the Salkhala Formation. Its good exposures are found at Judbah, Dewal, Shagai, Kabulgram and Chanjal. Detail work is needed to appraise the Tenor of fixed carbon in the graphite.

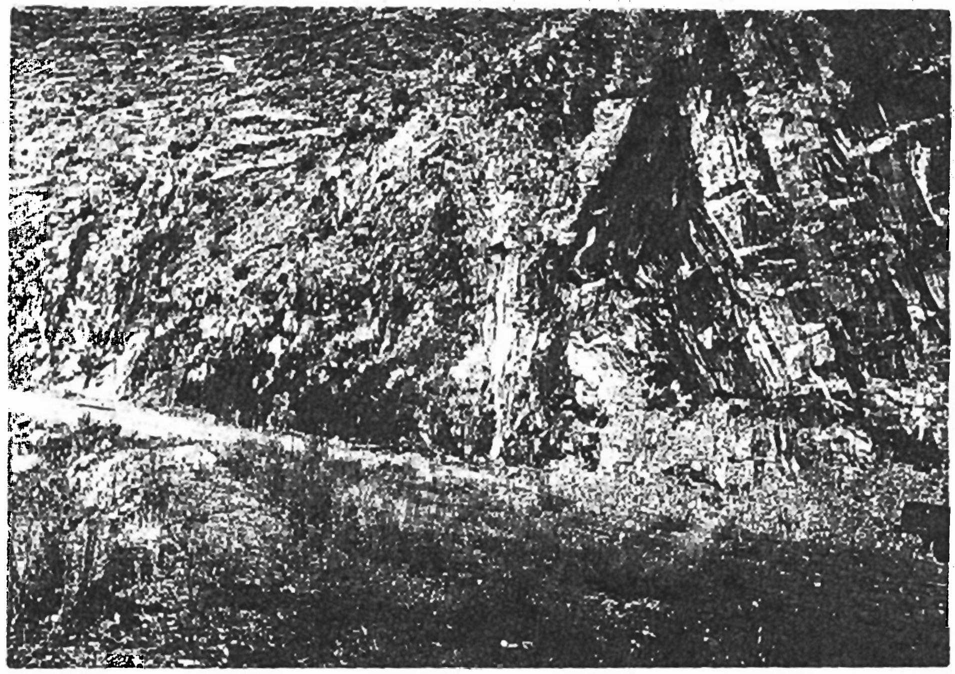
Among the exploitable minerals & rocks are marble, talc, and dolerite.

Marble: It includes recrystallized limestone which is suitable for building and decorative stone. Quite an extensive area is underlain by the marble bed and need infra-structure for its exploitation. Norange, Suri Kamer, Judbah, Shagai, Kabulgram and Bimbal sections have vast reserves.

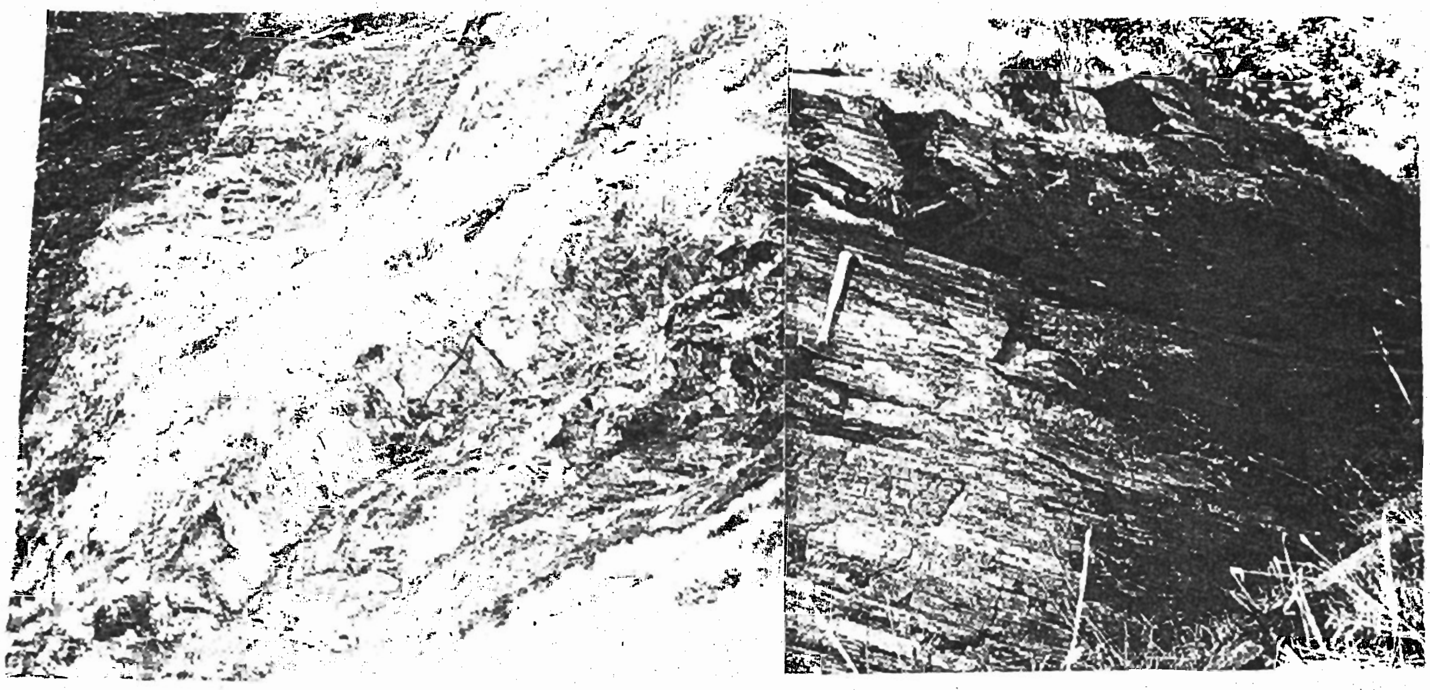
The marble exposed at Norange is of good quality. It is white, fine to medium grained and free from impurities. Its thickness is about 30 metre and is extended to about 100 Kilometres both to south and north, along the Indus River and occurs in the form of small isolated bodies .The marble deposite is located near road and therefore it is more economical. Marble found along the Indus River between Thakot and Darband has not been exploited due to the lack of road connection.

Talc: It is found at Norange, Judbah, Shagai, Sadu Khan and Kabulgram. At Norange it occurs at higher elevation and is exploited with great difficulty. Since it is near the road and the quality is good, therefore it is economical. It is transported from the mine with the help of lifts. The thickness of the bed is about 10 metre. It is extended in the south and is exposed at Sadukhan, Suri kamer, Shagai, Kabulgram and Judbah. It is found throughout in the metamorphic rocks of the Salkhala Formation. The talc is associated with carbonates in the form of thin lenses and pockets. It occurrs both in massive and fibrous forms. Its exposures found along the Indus River are unexploitable due to the lack of road linkage.

Dolerite: It is black, fine to medium grained and massive. At Mana it is exposed at the contact zone between the granitic rocks and the Tanol Formation. It is about 150 metre thick and is extended for several Kilometres but is burried underneath the alluvium. Its best exposure are found at Mana Sar, Gidari, and at several other places along the Indus River. Dolerite located at Mana is under exploitation.



Photograph No.14. Taken at Chanjal showing a Gossan. the white tree like structure indicates veins of pyrite and arsenopyrite.



PhotographsNo 15.16.Taken at Chanjal showing Graphite schist enriched in pyrite and arsenopyrite.

Photograph No 17.Taken at Jishkot showing marble enriched in pyrite & arsenopyrite.

CHAPTER. 7

## CONCLUSIONS

The Black Mountain constitutes a westward extension of the Lower Himalayas and is tectonically bounded by the Oghi Shear in the east, the Indus Shear in the west, Main Mantle Thrust (MMT), in the north and Mansehra Thrust in the south.

Following four tectonic deformational episodes have been observed in the area.

i. The earliest one is associated with the Mansehra granitic magmatism that occured in the Cambrian time when India was part of Africa (Le Fort et. al 1980).

ii. The second phase being more severe resulted from the collision of Indo-Pak plate with the Kohistan Islan arc that took place during Eocene ie, 50-55 Ma (Trelaor et. al 1990).

iii. The third deformational imprint was associated with the formation of Hazara-Kashmir syntaxis which occurred during Post Middle Miocene (Coward et. al 1988).

iv. The last phase of deformation was the result of anti-clockwise rotation of the Indo-Pak plate after its collision with the Asian plate which took place during Post-Miocene time and continued till to Early Pleistocene. These tectonic episodes have greatly deformed the stratigraphic set up of the area.

The following major stratigraphic units are differentiated In the area under study:

The SalKhala Formation forms the base of the unfossiliferous sequence of the Lower Himalayas. It is mainly composed of carbonates, calcareous schist, graphite schist, quartz schist and quartzites. It is of Middle to Late Proterozoic age. (Calkins. et. al.1975). In the area under study, the Hazara Formation is missing and the Tanol Formation directly overlies the SalKhala Formation with a faulted contact. It is characterized by pelites, psammites, quartz schist, garnet- mica- schist and quartzites. It has been assigned a Late- Precambrian age.

The Mansehra granite of Early Cambrian intrudes the metasediments of Salkhala and Tanol Formations and is of light coloured medium to coarse grained. It is characterized by large phenocrysts of twinned alkali feldspar. The main mineral constituents are alkali feldspar, albite, oligoclase and quartz. On the basis of deformation of felsic minerals particularly the feldspar and quartz the Mansehra granite may be divided in the following units:

vi. Pegmatites and aplites,

v. Massive granite,

iv. Porphyritic granite,

iii. Augen gneisses,

ii. Mylonites,

i. Migmatites.

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