# GEOLOGY OF THE AREA AROUND UTTARKASHI, GARHWAL HIMALAYA (UTTAR PRADESH)

A DISSERTATION
*submitted in partial fulfilment of*
*the requirements for the award of the degree*
*of*
MASTER OF TECHNOLOGY
*in*
APPLIED GEOLOGY

UNIVERSITY OF ROORKEE CENTRAL
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1977

# C E R T I F I C A T E

Certified that the dissertation entitled "GEOLOGY OF THE AREA AROUND UTTARKASHI, GARHWAL HIMALAYA (UTTAR PRADESH)" being submitted by Sri J. FRANCIS LAWRENCE in partial fulfilment of the award of the degree of MASTER OF TECHNOLOGY in Applied Geology of University of Roorkee is a record of student's own work carried out by him under our supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

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# A C K N O W L E D G E M E N T

I am highly indebted to Dr. R. S. Mithal, Professor and Head, Department of Geology & Geophysics, University of Roorkee for providing the necessary facilities requisite for the present work.

It is very pleasant duty to express my deep sense of gratitude to Dr. V.K.S. Dave, Professor, and Sri R. S. Chaturvedi, Reader, Department of Geology & Geophysics, University of Roorkee, for sincere guidance and supervision of the present work.

Thanks are also due to Dr. A. K. Jain, Reader in Geology, for his help during field and laboratory investigations.

I would also like to extend my thanks to my friends Abjit Ray, Dhruva Ganguli, Samshuddin, Sambandam, Jeyaram and Sridhar for their help in the preparation of this dissertation.

I would like to express my gratitude to the Department and University for giving partial financial assistance during the course of field and laboratory investigations.

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# CHAPTER - I

# I N T R O D U C T I O N


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# CHAPTER - 1

# INTRODUCTION

The area under investigation lies in Uttarkashi District of Uttar Pradesh. It consists of approximately 50 sq.km. of Lesser Himalayan Terrain between latitude $30^{\circ}$ 40' and $30^{\circ}$ 50' and longitude $78^{\circ}$ 20' and $78^{\circ}$ 30' in the Survey of India toposheet Nos. 53 J/5 and 53 J/6. The Bhagirathi river, one of the two chief tributaries of the river Ganga in the Lesser Himalaya, flows almost north-south across the area. The town of Uttarkashi is the district headquarter and an important pilgrimage centre for Hindus. It is situated on its right bank of Bhagirathi River (Fig. No. 1).

## 1.1 Accessibility :

The nearest railway station for the area is Rishikesh from where an all weather road runs right upto Gangotri. Uttarkashi is 165 Km from Rishikesh by road. The road traffic is often dislocated on account of numerous landslides, particularly during the rainy season, i.e. between middle of June to end of August. Ordinarily, the traffic is confined during day time only.

## 1.2 Climate :

The climatic condition in the Lesser Himalaya is

an important governing factor in carrying out field work. The diverse type of climates limit the field season only to a few months in summer. During this season the valleys are hot and humid. The rainy season assumes the ferocity during 3rd week of June and continues till August. The winter season is very cold particularly from December to March, while light rains are common at only higher altitude, the heavy downpour is confined in the valleys during the winter. The temperature varies from - $3^{\circ}$ C to $30^{\circ}$ C. The maximum annual rainfall is about 250 cm.

1.3 Physiography and Drainage :

As in any part of the Lesser Himalaya, the topography is typically immature, rugged, hazardous with thickly forested slopes. The area is characterised by N.N.W. - S.S.E. and W.N.W. - E.S.E. trending predominant ridges. In the western part, some of the ridges trend more towards N-S and NW-SE. On the left bank of the Bhagirathi river, the major ridges are the result of dissection by Dhanari and Gamrigad streams.

The elevation of the area varies from about 920 mts in the Bhagirathi valley near Dunda to 2701 mts hill feature on Nagni Thank. The topographical map of the area shows many peaks which are more than 2500 mts in height.

The area is drained by the mighty, turbulent perennial Bhagirathi, tributary of the river Ganga. The Bhagirathi drainage system includes the following important streams.

(i) Dhanari Gad flowing in a general north westerly direction.

(ii) Rano Gad, Sialam Gad and Kaldi Gad flowing towards south and draining a part of northern region near Uttarkashi,

(iii) Baragadi Gad flows in a north westerly direction, South of Uttarkashi.

In the north, the Bhagirathi river flows almost east to west between Uttarkashi and Nakuri for about 10 Kms. At Nakuri, the river takes a sharp turn and changes its course in a N $10^{\circ}$ E - S $10^{\circ}$ E direction for about 20 Km upto Dharasu. The east-west trend of the river between Uttarkashi and Nakuri is peculiar to the area as it is characterised by broad 'U' shaped valley in comparison to typical 'V' shaped valley elsewhere. Jain (1971) attributes a part of the east-west segment of the river to correspond to a thrust delineated by him.

1.4 Flora and Fauna :

The thick forest cover over the rugged mountainous

terrain is an important element in the landscape of the area. The flora is characterised by the presence of Shisham (Dal bergia sisson), Saal (Shorea robusta), Tun (Ecoratona) and are common at about 1200 mts. Chir (Pinus Longifolia) forests are most common in the area between 1000 and 2000 mts and yield much of the forest revenue. At higher elevations deodar (Cidrus deodara) and bairuj (Rhododendron arborcum) forests beautify the landscape.

In the valleys the main crops are wheat, rice, and ragi. In vegetables potato is commonly grown in higher regions in addition to tomato, cabbage, chillies etc.

The fauna is now reducing in number due to unauthorised hunting. The big animals like Bear, Leopard and Tiger are rarely seen. Other wild animals are pig, wolf, Jackal, Langaur, Fox, Spotted deer etc. Snakes and Scorpions are common in the valley. Some of the beautiful birds like Cuckoo, Golden eagles, Peacocks are also present in the valley regions.

## 1.5 Purpose, Scope and Method of Investigation :

The Department of Geology & Geophysics, University of Roorkee has been engaged in carrying out geological investigation in Garhwal and Kumaun Himalaya, since the department came into existence. Until now some parts of the

area in Garhwal and Kumaun Himalaya have been worked out by M. Tech. students of the department, in the past.

This time the interior parts of Garhwal and Kumaun Himal aya, were alloted to five students of this department. The present area around Uttarkashi was undertaken in order to have a detailed petrographic studies of the metabasics and related rocks.

The field work was carried out for a total period of 32 days spread over nearly 7 months. Preliminary field work was carried out from 2nd June to 15th June, 1976. Later detailed geological investigations were carried out from 29th September to 15th October 1976, and area was again visited from 5th January to 12th January 1977, for final field checks.

The geological and structural mapping was carried out on a part of Survey of India toposheet Nos. 53 J/5 and 53 J/6 on 1:50,000 scale. The various mappable lithological units were established during the field work supplemented by later laboratory work. The detailed structural mapping was carried out in which the structural data in respect of bedding, foliation and joints was collected during the various field visits. However, due to inaccessibility of some of the areas, the thick soil and vegetation cover; the entire area could not be mapped in detail. Thus only traverse mapping

was taken along road cuts, mule tracks, and nallah and river cuttings. About 110 representative rock specimens from various lithological units were collected for the detailed petrographic studies in the laboratory. Laboratory work included the study of about 45 thin section of rocks, four polished sections were studied under ore microscope to assess the extent and nature of mineralisation of pyrite in the metabasics. The structural data were plotted on the map and also on Schmidt's equal area net. The interpretations regarding the structure of the area have been made on the basis of graphical analysis of structural data.

1.6 Previous Work :

Garhwal, a region situated in the Lesser Himalaya was first investigated geologically by Middlemiss in 1887. The classic work on the "physical Geology of British Garhwal" carries a geological map on 1" = 4 mile scale.

Griesback (1891), who took traverses in the Upper Bhagirathi valley that is in Harsil area, classified the rocks into Vaikrita and the Haimanthas.

Auden (1935) carried out preliminary work in this area. However, later Auden (1938) grouped the rocks around Uttarkashi under the name Barahat series but later Auden (1949) renamed it as Garhwal group.

Dhoundiyal and Ali (1967) investigated the area around Dharasu and named the tectonic contact between the 'Simla Slates' and the 'Garhwal series' as Nalupani Fault and considered the possibilities of extension of Tons thrust. Tiwari (1970) has taken traverses in Harsil area and considered the contact between the metasedimentaries and granites of Gangotri as a tectonic one. Chatterji and Agarwal (1971) worked in Seansu-Dharasu area and disputed the extension of Tons thrust in Bhagirathi valley. Saklani and Pande (1970) and Saklani (1971) described the geology of the area adjoining Pratap Nagar.

1.61 Jain (1971) carried out detailed geological mapping in 1:50,000 scale and classified the lithology into the following lithostratigraphical units.

| | | | |
|---|---|---|---|
| (i) | Laluri Formation | : | Slate, Quartzite, and Phyllitic-Slate. |
| (ii) | Chandpur Formation | : | Alternating Phyllite and Quartzite. |
| (iii) | Nagthat Formation | : | Schistose Quartzite, Sericite Quartzite, Arkose etc. |
| (iv) | Dharasu Formation | : | Slates, Phyllites, Argillaceous Quartzite. |
| (v) | Bangoan Formation | : | Dark greyish black limestones. |

1.7 It would appear that the area under investigation has been variously described by earlier ~~writ~~ workers to belong to Garhwal group of rocks. A sincere attempt has now been made to establish the various lithostratigraphical units according to their characters so that it forms a simple formation.

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| (v) | Bangoan Formation | : | Dark greyish black limestones. |

(vi) Garhwal Group : Quartzites, Limestones, Dolerites, Slates, Phyllites, Metabasics, etc.

1.62 Agarwal and Kumar (1973) worked in the Upper Bhagirathi valley and classified the lithology as follows :

Nagni Thank Formation →

Pujargoan Meta Volcanics :

Green amygdaloidal Schist with amygdules of quartz and Zeolite, occasionally with porphyroblast of Chlorite.

Gamri Quartzite :

White to purple medium to coarse grained, massive current and graded bedded with occasionally lentiform conglomerate on basal part.

Kot metavolcanics :

Green amygdaloidal schist with thin bands of quartzite and slate.

Shyalaa Formation →

Limestone and dolomite, massive bluish grey to black, light green at places cherty and pelletal, stromatolitic with subordinate slate and quartzit

Uttarkashi Formation →

Sartali Slate :

Banded, grey, green purple slate and interbedded quartzite.

Natala Quartzite :

White to buff coloured fine grained, current bedded quartzite and interbedded slate with lentiform limestone.

1.7 It would appear that the area under investigation has been variously described by earlier workers to belong to Garhwal group of rocks. A sincere attempt has now been made to establish the various lithostratigraphical units according to their characters so that it forms a simple formation.

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# CHAPTER - II

# STRATIGRAPHY AND REGIONAL GEOLOGY

# C H A P T E R - II

## STRATIGRAPHY AND REGIONAL GEOLOGY

2.0 The area under investigation forms a part of the extensive area mapped early by Griesbach (1891) who took traverses as early as 1885 in Central Himalaya. He made a general classification of the major lithologic units and named the metamorphics, as Vaikrita. He grouped the Gangotri granite and other metamorphics under this category. He further named all the sedimentaries as Haimantha and included the phyllites, Quartzite and other sedimentaries under this category.

2.1 Auden (1935) broadly outlined the structural features and grouped the rocks around Uttarkashi as Barahat series. Auden (1936) summarised his traverses to Gangotri in General report of Geological Survey of India as follows :

> "The rocks encountered along Bhagirathi river as far as Sini (N 30° 46'; E 78° 35') consist of three groups in the following sequences :
>
> The top - Schistose phyllite resembling Chandpur, a thick series of quartzite and bottom slates and limestones. The Quartzite are well exposed from 78° 36" eastward to Sini and show a striking resemblence to those seen at Chamoli. Along this part of valley, there are basic intrusives, which extends upto Alakananda. There is a sudden change in lithology from sheared quartzite to overlying schists and gneisses at Sini".

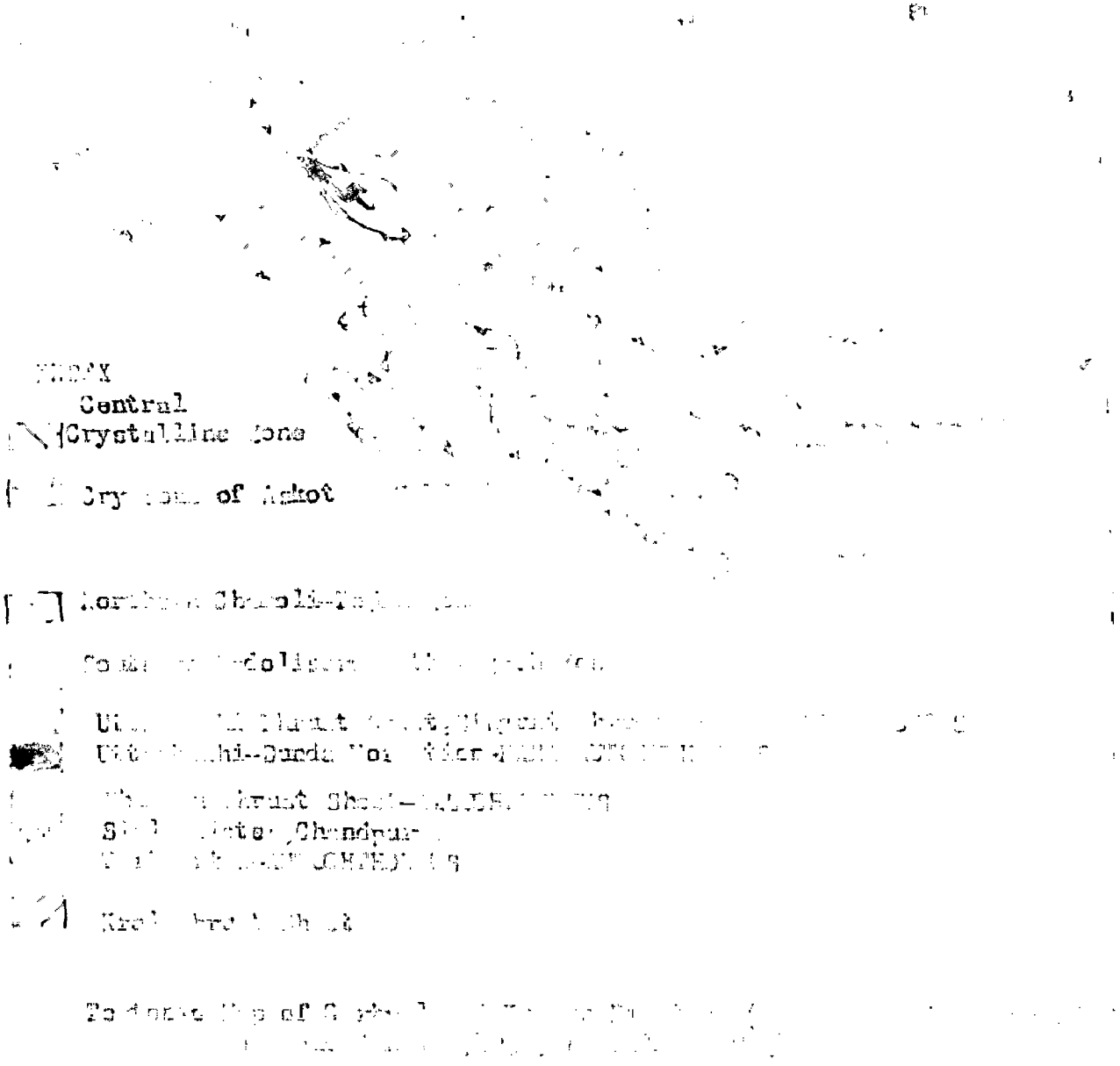



Fig. 2

GEOLOGICAL MAP OF PART OF BHAGIRATHI VALLEY


FIG. 3

2.2 Auden (1938) considered that Vaikrita actually consists of "Mesograde garnet - biotite granulites, garnet - biotite schist, Staurolite schist and Kyanite schist and are partly, if not wholly the metamorphic equivalents of epigrade Haimanta" exposed in the Siam and Jalandra Valley. He thought the Haimantha to be lithologicall y idential to the 'Simla Slates' and Chandpur. Auden (1935, 1938, 1949) broadly outlined the structural features and recognised one major tectonic unit in the north. (Fig. No. 2).

2.3 The area on a regional scale forms a part of the north eastern portion of the Simla-Krol belt but mainly lies within the Deoban - Tejam zone of Ganssar (1964). Garhwal group of rocks forms the major portion of the present area.

2.4 Jain (1971) carried out detail geological mapping in this area (Fig. No. 3) and considered that the region comprises four major structural and stratigraphic unit bounded by large scale thrust. The major stratigraphic and tectonic units established by him are briefly described as follows :

2.41 Tectonic Sequence of Uttarkashi

| Tectonic Unit | Stratigraphic Unit | | Equivalents |
|---|---|---|---|
| Krol Thrust Sheet | Nagthat Formation | | Nagthat |
| | Chandpur Formation | | Chandpur |
| | Laluri Formation | | Mandhalis |
| Dharasu Thrust Sheet | Dharasu Formation | | Morai-Chakrata beds or Simla slates. |
| Allochthonous zone (Singuni-Uttarkashi Thrust sheet). | Dichli Dolomites | Garhwal Group. | Gangolihats |
| | Gamri quartzite | | Berinags |
| Para-autochthonous zone (Dunda-Uttarkashi window) | Dunda-Uttarkashi Formation | | Shalis, Nagthats Chandpur-Mandhalis |

After Jain (1971)

2.42 Garhwal Group

The Garhwal group in the north west is thrust upon by the Central Crystalline Groups along the Main Central Thrust and in south west by the Dharasu Formation along the Dharasu Thrust.

2.43 Dunda Formation :

Dunda formation comprises of thick lime stone, slate and micaceous quartzite. The formation has been sub-divided into three lithostratigraphical members.

Khaltukhal Limestone :

The oldest Khaltukhal Limestone member of Dunda formation occurs as three linear detached out crops. They are thick variably bluish, grey black, cherty, very fine grained and thinly bedded limestone. It also has the intercalations of chert and thin slate.

Dhanari Slate :

The slate is well exposed in road section of Uttarkashi – Tehri road. It conformably overlies khaltukhal limestone. It consists of alternating purple and greenish grey, fine grained quartzite and purple grey black slate in the lower part and yellowish brown-purple-olive green-grey banded slate in the upper part.

Dunda Quartzite :

It is arenaceous and well exposed on Dunda-Uttarkashi road. It is medium grained, thickly bedded and has cross bedding in the lower part.

2.44 Uttarkashi Formation :

A thick succession of Quartzite, limestone, slate and phyllite occur along the lower elevations of Bhagirathi river around Uttarkashi.

Netala Quartzite :

It is dominantly arenaceous with buff-grey-green thinly bedded quartzite and phyllite.

Lower Uttarkashi Limestone :

The quartzite member is conformably overlain by greyish, friable limestone containing many thin yellowish quartzite and grey phyllite intercalations.

Pokhri Slate :

The slate is greenish, grey-black, friable, laminated and thinly bedded. It is well exposed in the following areas : (i) between Hinna and Naid, (ii) between Gargoli-Jurain and (iii) between Matli and Sada.

Upper Uttarkashi Limestone :

It is blackish to bluish grey, fine grained, thinly bedded limestone. Frequently intercalated with thin greyish black slate and phyllite.

Bargti Quartzite :

It is the upper most member of Uttarkashi formation. Predominantly arenaceous with minor slate, limestone and metabasic occurrences. It is of medium to fine grained with argillaceous intercalations. It is well exposed in Uttarkashi-Lambgaon Road. The associated metabasic is exposed near Pata.

2.45 Gamri Quartzite :

The Gamri Quartzite occupies more than half of the Garhwal Group exposure in northern belt around Uttarkashi between Jagaldi-Manpur-Dhauntri-Nakuri and Southern belt lying south of Singuni hills. The formation comprises buff-white, massive and thickly bedded medium to fine grained quartzite. Near the thrust zone it is highly schistose and metamorphosed to quartz-schist.

2.46 Dichli Dolomite :

In the southern part, the Gamri Quartzite is conformably overlain by the Dichli Dolomite which is exposed near junction of Dichli Gad and Bhagirathi river. The formation consists of pinkish, massive, hard and fine grained dololirtite, sometimes intercalated with purple green cale slate.

2.47 Dharasu Formation P

The Dharasu formation comprises olive green and greyish black thinly laminated slate, and greyish green thinly bedded quartzite. Purple quartzite is mainly exposed along Nagon Gad. The contact with Garhwal group is impersistantly marked with schistose metabasic near Soman and Ulya. The Dharasu formations are further intruded by metabasic sill at Rari.

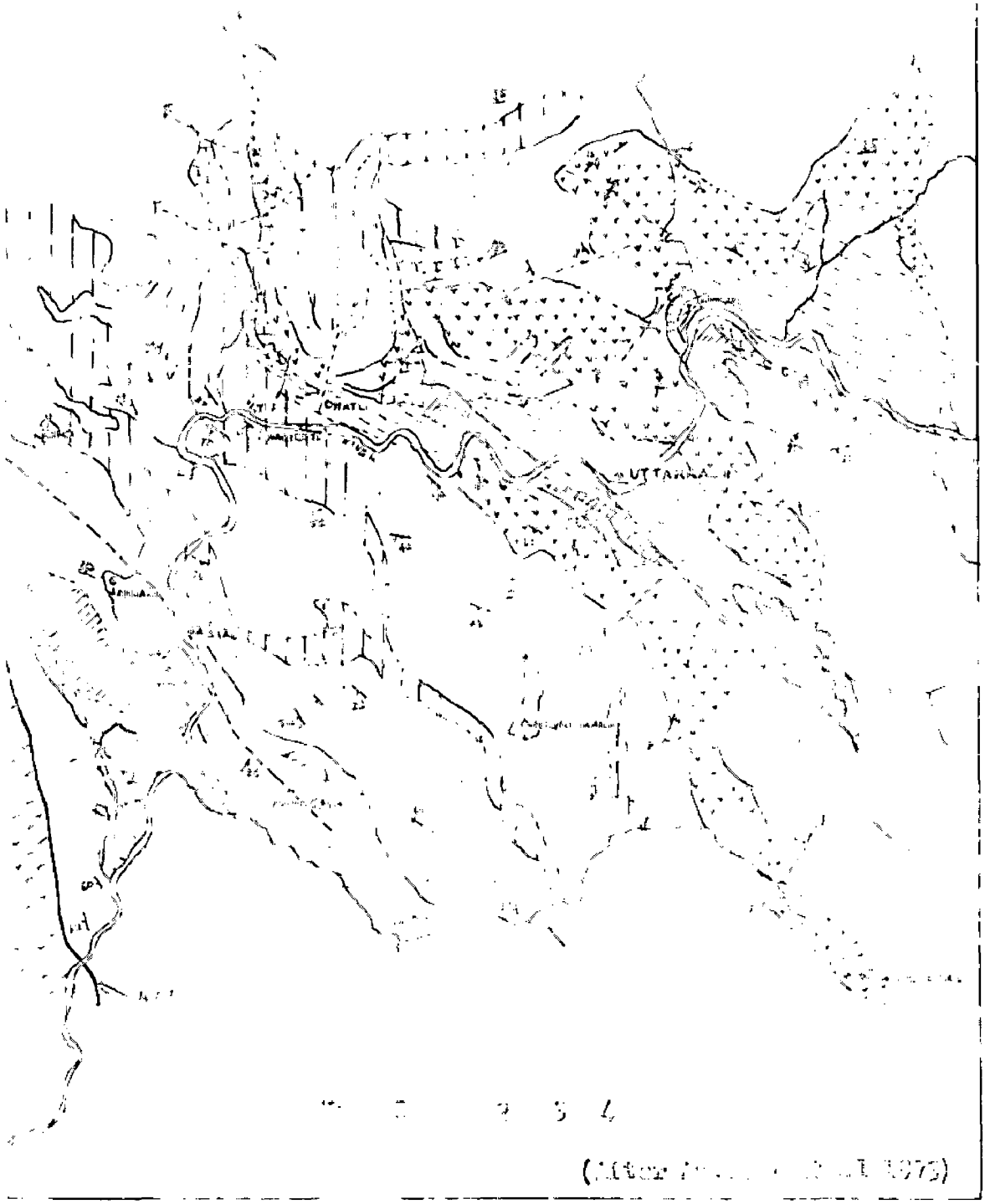
2.48 Laluri Formation :

This formation comprises of thick slate, phyllite and quartzite and are well exposed between Chapra and Cham on the right bank of Nagon Gad and Bhagirathi river. It is underlain by the Chandpur formation but separated from Underlying Dharasu formation by the Tons thrust. Litho-stratigraphically they are subdivided into Laluri A, Laluri B and Laluri C.

2.49 Chandpur formation :

A very thinly laminated greenish black phyllite and greenish grey quartzite sequence of Chandpur formation resembling well known Chandpur phyllite is mainly exposed in a 1.5 to 2 Km wide NW-SE trending outcrop between Andhiari and Basul. Another exposure of this formation is met within south west bank of Aglar Nadi.

# Geological Map Of Part Of Uttarkashi District.



2.50 Nagthat Formation :

The Nagthat formation, overlying the Chandpur, comprises thick succession of buff grey thinly bedded Quartzite, greyish green sericite quartz schist and schistose quartzite with intercalations of schistose phyllite. The dark grey shenny schistose phyllite intercalations distinguish the Nagthats from the Gamris.

The change from underlying argillaceous Chandpur Formation to predominantly arenaceous Nagthats is abrupt without any gradation at the contact which appears to be a thrust plane. An abrupt increase in metamorphic effect in the Nagthats also noticed by him.

2.60 Agarwal and Kumar (1975) mapped the area around Uttarkashi and ahead of Uttarkashi towards Gangotri (Fig. No. 4). They have worked the following stratigraphic units Central Crystalline, Martali Formation, Dudatoli Group and Garhwal Group, each of their units is separated by a major fault. The north Almora Thrust and the main Central Thrust separate the Garhwal groups from the Dudatoli GROUP IN the southwest and the Central Crystalline in the north east respectively. It appears that Tons thrust appears to die out in the Bhagirathi valley, and the rocks equivalent to the Tiuni Formation grade into the Chandpur formation of the

Dudatoli group with no apparent break. Agarwal and Kumar (1973) divided the Garhwal group into three formations; the Uttarkashi, Shyalana and Nagnithank, which occur in normal stratigraphic order and has been subjected to at least two tectonic episodes. These three formations have been recognised by Agarwal & Kumar (1973) in Garhwal Group exposed between Nalupani in South and the Sainj in the north in the Bhagirathi Valley. They also correlated the lithostratigraphy with Jain's classification.

2.6.1 Uttar Kashi Formation :

Jain, (1971) proposed the Uttarkashi formation includes the Netala Quartzite, Lower Uttarkashi Limestone, Pokri Slate, Upper Uttarkashi Limestone and Bareti Quartzite. Agarwal and Kumar (1973) on the basis of their work recognised in this formation only the Netala Quartzite and the Sartali Slates (Dhanari and Pokri Slates of Jain, 1971).

2.62 Shyalna Formation :

Jain (1971) assigned various outcrops of limestone and dolomite to three stratigraphic horizons, the lower Uttarkashi limestone and the Khattukhal Limestone occurring below the Pokri and Dhanari Slates respectively, and the Upper Uttarkashi Limestone above the slates. Agarwal and Kumar (1973) have, on the basis of their field work, postulated that all these outcrops constitute one and the same horizon.

2.63 Nagni Thank Formation :

This formation is extensively well developed around Nagni Thank after which the formation has been named (Agarwal and Kumar 1973). It is characterised by Quartzite and penecontemporaneous basic flows with intrusion of dolerite metamorphosed to epidorite.

2.70 Agarwal and Kumar (1973) attempted to correlate the various members of the formations established by them with those given by Jain (1971). The correlation is shown in the form of Table No. 2.71.

They have further attempted to correlate these formations with various fofmations in Eastern Kumaun Himalaya, which is given in Table No. 2.72.

2.71 LITHOSTRATIGRAPHY OF GARHWAL GROUP IN BHAGIRATHI VALLEY OF UTTARKASHI DISTRICT.

| Formation | Agarwal and Kumar (1973) Classification | Jain (1971) Classification |
|---|---|---|
| | Pujargaon Metavolcanics :<br><br>Green amygdaloidal schist with amygdules of quartz and Zeolite, occasionally with porphyroblasts of chlorite. | |

| | | |
|---|---|---|
| Nagni Thank Formation | Gamri Quartzite :<br><br>White to purple, medium to coarse grained, massive, current and graded bedded with occasional lentiform conglomerate in basal part.<br><br>Kot Metavolcanics :<br><br>Green, amygdaloidal schists with thin bands of quartzite and slate. | Gamri Quartzite and Dunda Quartzite. |
| Shyalna Formation | Limestone and Dolomite, massive bluish grey to black, light grey, at places cherty and palletal, stromalolitic with subordinate slate and quartzite. | Part of Lower Uttarkashi limestone, Upper Uttarkashi limestone, Khattukhal Limestone and Dichli Dolomite. |
| Uttarkashi Formation | Sartali Slate :<br><br>Banded grey, green, purple slate and interbedded quartzite.<br><br>Netala Quartzite :<br><br>White to buff coloured, fine grained, current bedded quartzite and inter-bedded slate with lentiform limestone. | Bokri and Dhanari Slate.<br><br>Netala quartzite Bareti quartzite Part of Lower Uttarkashi Limestone |

After Agarwal and Kumar (1973)

2.72 CORRELATION OF DIFFERENT FORMATION OF GARHWAL GROUP OF UTTARKASHI REGION WITH THOSE OF EASTERN KUMAUN HIMALAYA.

| Uttarkashi area (After Agarwal and Kumar 1973) | Dobri-Chamoli Pipalkoti Section (After Mehdi et al 1972) | Ghat Pithoragarh (After Mehdi et al and Valdiya 1962) | Askot Section Valdiya personnel communication |
|---|---|---|---|
| Not developed | Gwanagarh Formation | Not developed | - |
| Nagni Thank Formation | Chamoli Formation | Berinag Formation | Berinag Quartzite |
| Shyalna Formation | Lameri and Pipalkot Formation | Pithoragarh Formation | Gargolihat Dolomite |
| Utterkashi Formation | Rudraprayag Formation | Saryu Valley Formation | Rautgara Quartzite. |

(After Agarwal & Kumar 1973)

2.80 METABASICS AROUND UTTA-RKASHI :

Metabasics occur mainly as silts and occasionally as silts in Garhwal group of rocks of Uttarkashi area. Auden (1938) recognised the occurrence of intrusive rocks of various parts of Garhwal and Kumaun Himalayas.

2.81 Jain (1971) postulated that in this part of Garhwal, most widespread metabasics are developed in thrust zones of Dunda-Uttarkashi thrust separating underlying Dunda-Uttarkashi formation from the overthrust Gamri quartzite. The Dunda thrust is characterized by mainly 100 - 600 metre thick north easterly dipping metabasics, brings southwestly dipping Gamri Quartzite over the underlying formations. He also inferred from his field work that the metabasics are emplaced along a zone of dislocation during the overthrusting of Gamri Quartzite.

2.82 Agarwal and Kumar (1973) recognised three types of basic rocks in Bhagirathi valley, viz., (i) Kot metavolcanics, (ii) Pujargoan Metavolcanics and (iii) Epidiorite.

Kot metavolcanics :

It occurs as a persistant basal horizon of Nagni thrust formation and comprises basic flows. The

massive varieties occasionally show structures similar to pillow and are amygdaloidal, the cavities generally filled with epidote and Zeolite.

Pujargaon Metavolcanics :

The youngest basic flows in the area out crop around Pujargaon. It extends from near Koti to about 1.5 Km north of Dunda where it appears to pinch out within Gamri Quartzite. It differs from Kot metavolcanics in being highly amygdaloidal, the amygdules being of Zeolite and Quartz and at places contain porphyroblasts of chlorite.

Epidiorite :

The epidiorite showing intrusive relationship, is restricted mainly to the Nagni Thank Formation . Occurring as sill and dykes, it appeared to be low grade metamorphic derivative of possibly dolerite.

2.83 Age of Metabasic

Since basic and metabasic rocks of Garhwal and Kumaun are associated with the unfossilliferous Precambrian-Mesozoic formation, it is difficult to postulate their exact age. Precambrian to Lower Palaeozoic age for metabasics and metatuffs is implied if these are considered penecontemporaneous with sedimentation of the Berinag Quartzite and

calc zone of Pithoragarh (c.f. Gansser, 1964; Valdiya, 1965; Misra and Banerjee, 1968). Pilgrim and West (1928), Bisaria (1967) and Kanwar (1968) favoured Precambrian age for hornblende schist of Jutogh Series while Auden (1934) postulated Tertiary age for the dolerite intrusives in the krol series. However, Jain (1971) favours upper Cretaceous age for metabasics and concludes that the basic rocks in the Uttarkashi region are tectonically controlled and emplaced along the thrust planes. Agarwal and Kumar (1978) have indicated a Precambrian to early Ordovician age to the Garhwal group of rocks and have suggested the same age for the metabasics.

2.90 Regional Structure :

Jain (1971) inferred four large scale tectonic units bounded by large scale thrusts. The important thrusts are (i) Singuni Thrust, (ii) Dunda-Uttarkashi Thrust (iii) Dharasu thrust and (iv) Tons thrust.

2.91 Singuni Thrust :

The southern Gamri Quartzite belt is thrust over the underlying Dunda Formation along NNW-SSW and NW-SW trending and southerly dipping Singuni Thrust. This thrust conceals the Khattukhal anticline axis in northwest and Dhanari slate-Khattukhal limestone members on southern limb of this anticline.

2.92 Dunda-Uttarkashi Thrust :

The Dunda thrust limits the Gamri Quartzite (north of the metabasics) in the south and is demarcated by nearly 100-600 m thick northeasterly dipping metabasic which separates the overlying southwesterly dipping quartzite from Dunda Formation.

The NW-SE trending sinuous Uttarkashi thrust is also outlined by metabasic occupying the thrust zone. Generally it dips $30^{\circ}$ in a north-easterly direction between Naid and Hinora but is sinuous in north west upto Hill 2153 mt. where it attains the regional NW-SE strike. After a short turn near Hinna, the thrust crosses Bhagirathi river at longitude $78^{\circ}30'$ and trends NNW-SSE between Iwain and Manpur. In the south, the Uttarkashi thrust dips nearly $20^{\circ}$ SW between Sada and Dilsod. This thrust is folded into symmetrical anticlinal domal structure with subordinate warping.

2.93 Dharasu Thrust :

The Dharasu thrust demarcates the northern boundary of Dharasu Formation. It separates the Dharasu Formation from underlying rocks of Garhwal Group. It runs for nearly 40 Km through Hill 2339 m, Mason, Matli, and Baldogi, It takes a northerly swing between Pujargaon and Malli and then changes to NW-SE further south east. Between Malli and Khalsi, the underlying Dichili dolomite is highly disturbed and deformed. Jain (1971) considered

Dharasu Thrust synonymous with the Nalupani Fault of Dhoundial and Ali (1967), the major tectonic unit of Auden (1938) and the Dharkot dislocation of Saklani (1970).

2.94 Tons Thrust :

The Tons Thrust demarcates the northern boundary of Laluri Formation and southern boundary of Dharasu Formation. New Nagon Gad the thrust dips due south. The Ton Thrust is well exposed at Chapra, Kiari, Laluri Khand and Kandi.

Jain (1971) postulated the following other regional structural features in the area under investigation: (a) Uttarkashi thrust sheet, (b) Singuni Thrust sheet, (c) Uttarkashi Window and (d) Dunda window.

2.95 Uttarkashi Thrust Sheet :

The characteristic occurrence and opposite dipping metabasic along Dunda Thrust and along the southern trace of Uttarkashi Thrust indicate that the latter extends underneath the Gamri Quartzite to form a folded allochthonous thrust sheet.

2.96 Singuni Thrust Sheet :

The southern Gamri Quartzite belt with Dichli Dolomite has been considered by Jain (1971) to have over ridden the Dunda Formation along southerly dipping thrust and constitutes allochthonous thrust sheet, the Singuni thrust sheet.

2.97 Uttarkashi Window :

Jain (1971) named the window after the town Uttarkashi where it is exposed. The window is outlined by a persistant metabasic girdle along the Uttarkashi thrust.

2.98 Dunda Window :

The anticlinal Dunda Window exposes various members of the Dunda formation beneath over thrust Gamri Quartzite and is bounded by NE-dipping metabasic along the Dunda Thrust and SW-dipping Singuni thrust as its northern and southern margins. He also observed the extension of this window in Yamuna valley also.

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Quartz Sericite schist.

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shed Chandpur phyllite; friable carbonaceous
tamorphism; typical of other thrusts in foot

shed and powdered material.

(After Jain 1971)

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t mentioned

2.99 Jain (1971) correlated various important Thrusts of Garhwal Himalaya.

CHARACTERS OF SOME IMPORTANT THRUSTS IN GARHWAL, U.P.

| | | | | |
|---|---|---|---|---|
| | North (Dainj) | Deoban-Tejam Zone | Main Central Thrust | Impersistent chlorite schists; increase in metamorphic effects towards top of Gamri Quartzite near Thrust, development of foliation, mica lineation and Quartz Sericite schist. |
| | | | Uttarkashi Thrust | Persistent metabasics; metamorphic effects maximum wherever metabasics are absent, development of foliation, mica lineation and schistose quartzite. |
| Probable Shallowing of Thrusts | | | Dunda Thrust | Persistent metabasics, metamorphic effect minimum whereever metabasics are thick. |
| | | | Singuni Thrust | Impersistent mylonites; increasing metamorphic effect towards the sole of thrust on Gamri Quartzite development of foliation, mica lineation and quartz schist. |
| | | | Dharasu Thrust | Impersistent metabasics; increased metamorphic effects in Dharasu Formation along thrust zone, crushing of rock. |
| | South (Rajpur) | Simla - Krol belt | Tons Thrust | Fault breccia and crushed slate; lack of metamorphism. |
| | | | Basul Thrust | Sericite Quartz schist and schistose quartzite in thrust zone increase in metamorphic effects; development of foliation and mica lineation. |
| | | | Krol Thrust | Fault breccia, crushed Chandpur phyllite; friable carbonaceous matter, lack of metamorphism; typical of other thrusts in foot hills. |
| | | | Main Boundary Fault | Fault breccia, crushed and powdered material. |

(After Jain 1971)

Agarwal and Kumar (1973) have, however, denied the existence of Dunda-Uttarkashi thrusts of Jain (1971) on the basis of their field work, but have not mentioned

# CHAPTER - III

## GEOLOGICAL SET UP AND STRUCTURE OF THE AREA

# C H A P T E R - III

## GEOLOGICAL SET UP AND STRUCTURE OF THE AREA

3.0 The area has been mapped on 1:50,000 (2 cm = 1 Km) scale and a detailed geological map has been prepared (Fig. No. 5 ). The various mappable units were identified on the basis of the diagnostic lithological and other characters. Where the variation in rock types were frequent, the rocks have been grouped together. The structure of the area was established and that of the various lithological units confirmed. The lithostratigraphical units thus established were compared with those given by earlier workers which led to the conclusion that the rocks belong mainly to Garhwal group. The lithostratigraphy has been correlated with that given by earlier workers in table No. 3.15.

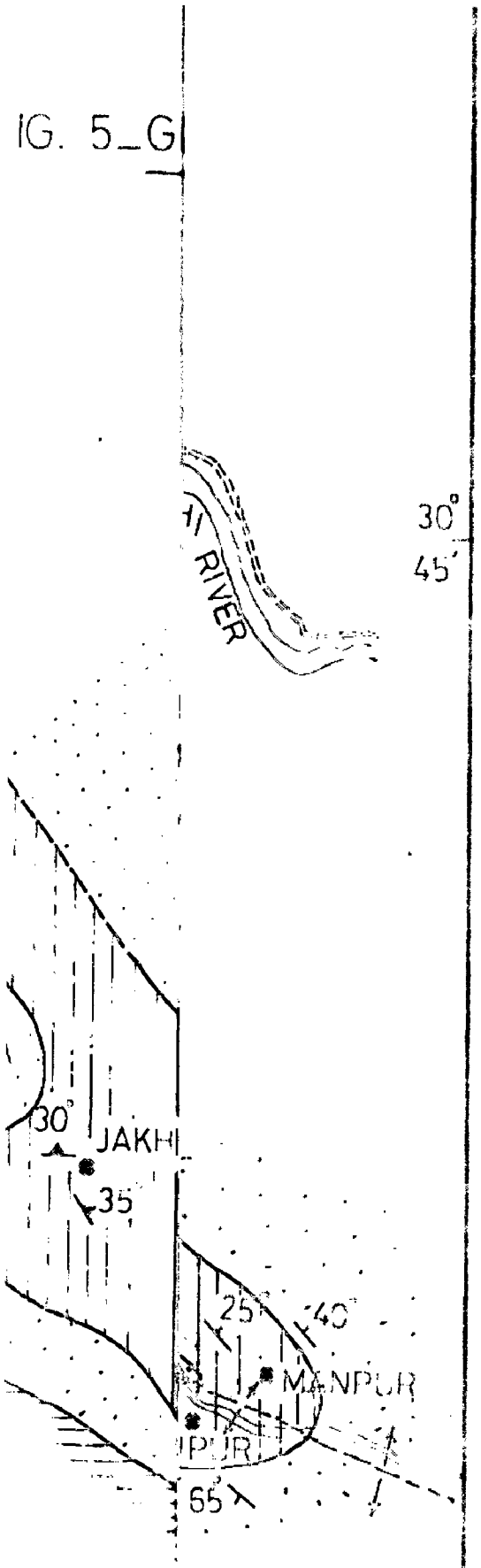
3.10 In the area under investigation, three mappable lithological members have been identified. They are, according to their stratigraphical position as follows :

I. Quartzite member

II. Variegated slate and slaty limestone member

III. Massive Limestone member

IG. 5_G


N
LEGEND
METAQUARTZITE
QUARTZITE MEMBER
VARIEGATED SHALE AND SLATY LIMESTONE MEMBER
LIMESTONE MEMBER
BEDDING PLANE
FOLIATION
JOINTS
ANTICLINE
SYNCLINE
RIVER
ROAD
MULE TRACK
BENCH MARK
CAVE
MAPPED BY J. P. LAWRENCE
RIVER
30°
45'
30°
JAKHI
35'
25'
40'
MANPUR
65'
75°

IG. 5_GEOLOGICAL MAP OF AREA AROUND UTTARKASHI, U.P.

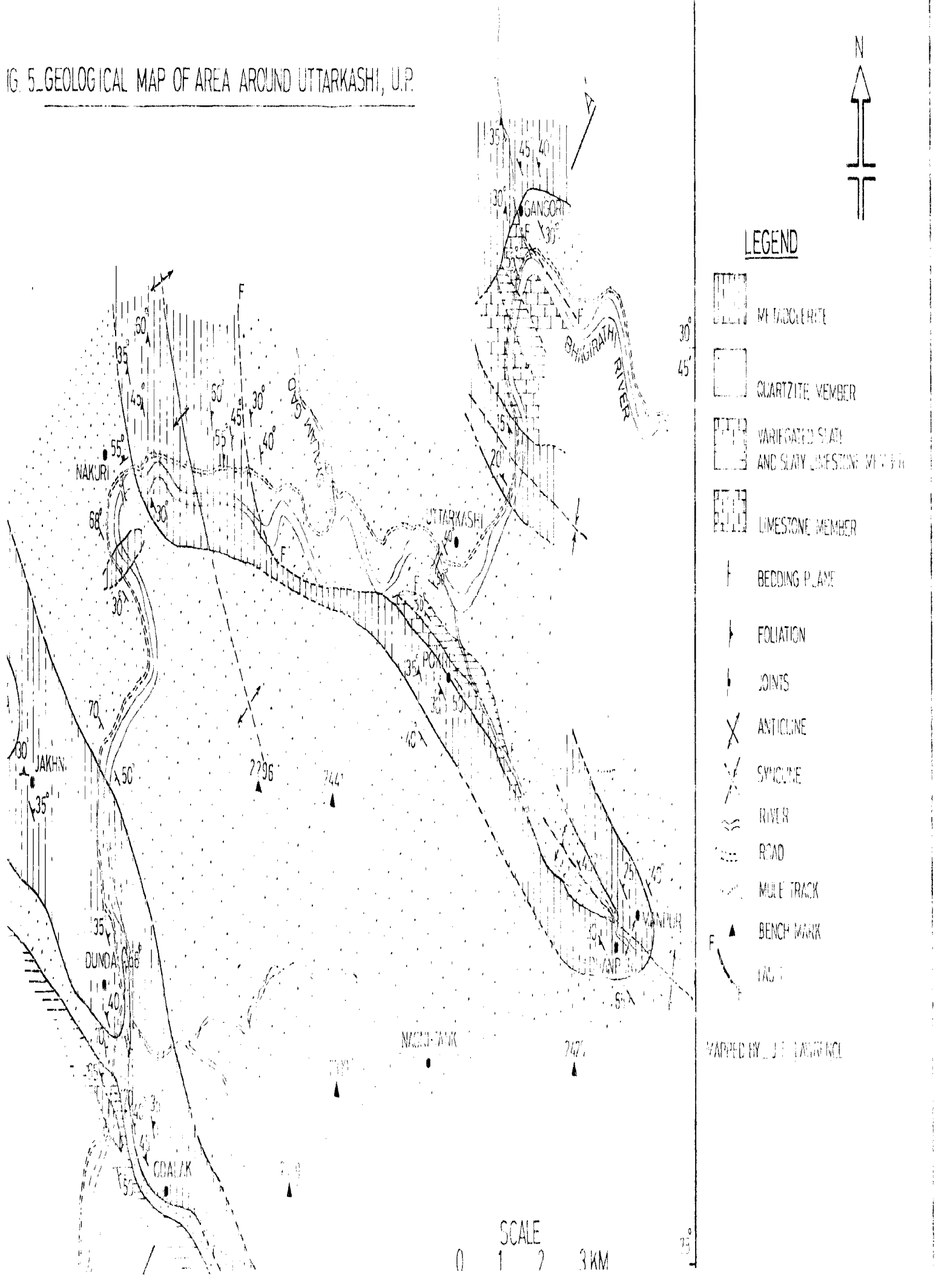
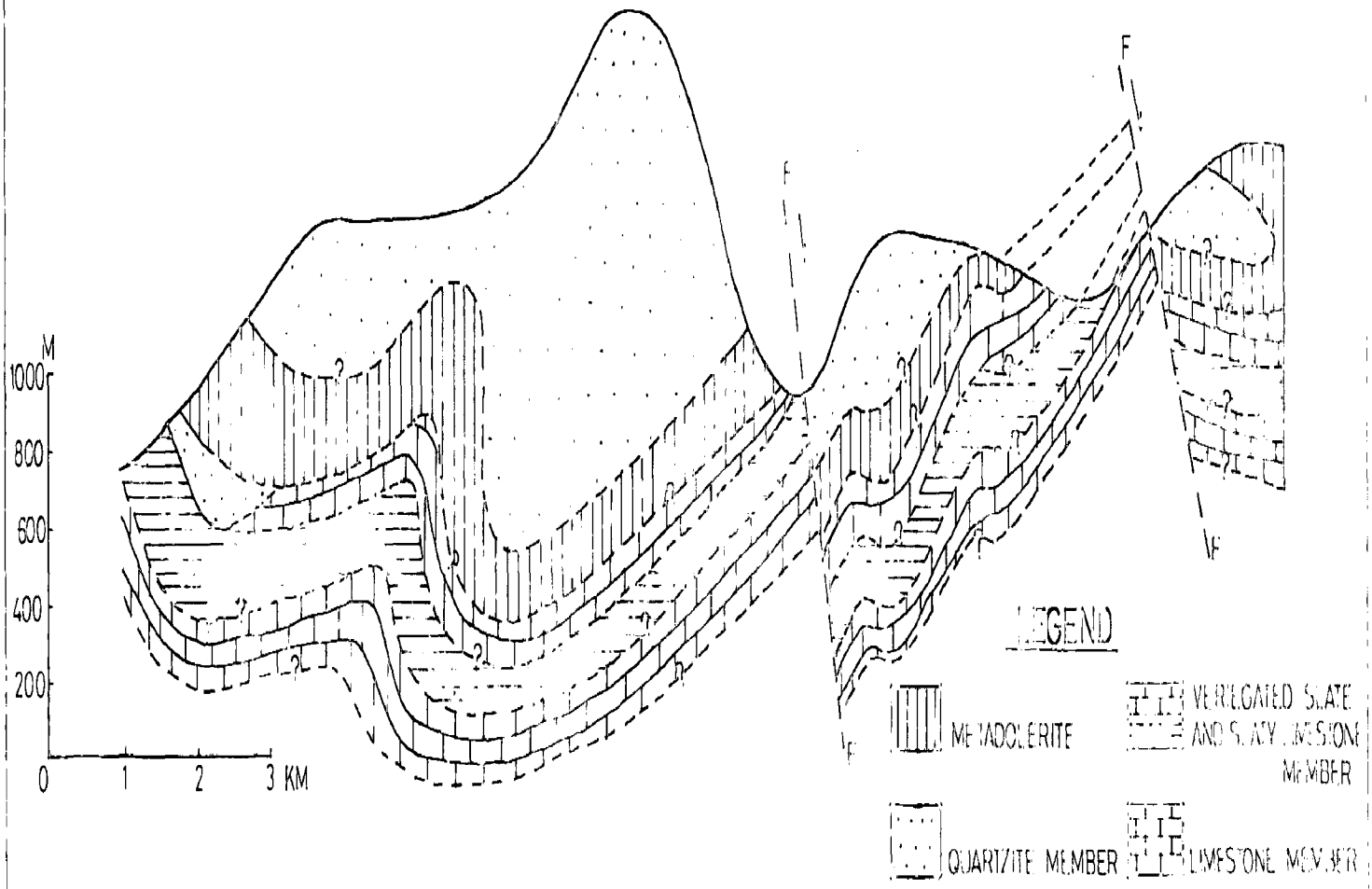


FIG.6_GEOLOGICAL SECTION ALONG A--A'



These members are repeatedly exposed at various locations due to folding and faulting during the successive stages of Himalayan Orogeny. These members show minor local variations in physical characters like change of colour, grain size, etc. The characteristic structural elements exhibited by various members have been recorded and discussed later.

As far as the stratigraphy is concerned, the limestone member is the oldest and followed by variegated slate member. The variegated slate grade into a slaty limestone which resembles the older limestone member. Quartzite member is the youngest member of the formation.

3.11 Massive Limestone Member :

The limestone member is exposed at three different localities due to folding and faulting. Two of these localities form part of the area under investigation while the third lies south of the area and has been recognised as "Khattukhal Limestone" by Jain (1971).

(i) The grey to greyish black argillaceous limestone with slate and quartzite intercalation, is exposed in Uttarkashi-Gangotri road section. The slate has a gradational contact with the overlying slaty limestone and the underlying limestone member. The slate typically

resembles with the variegated slate member. The same limestone is also exposed on the other bank of Bhagirathi river where it dips $45^{\circ}$ to $55^{\circ}$ in a south-westerly direction. It is massive and occasionally jointed at places. Due to weathering it shows characteristic rugged surfaces.

(ii) The grey to black coloured, fine grained, thinly bedded, slaty limestone with rugged surface is exposed in Uttarkashi-Pokri road section near the village Pokri. Unlike other limestone outcrop, it exhibits many minor folds and puckers which plunge towards South West. The slaty limestone has a regional dip of $45^{\circ}$ towards South West. Generally it is highly jointed and at places joint spacing is as close as 3 cm to 5 cm.

While Jain (1971) distinguishes this limestone member as two separate lithostratigraphic units and assigns them the name of "Upper Uttarkashi Limestone", Agarwal and Kumar (1973) consider them as some limestone member.

On the basis of the present investigation, it is not possible to distinguish between this two limestones. The slaty nature of the limestone overlying the variegated slate member is very typical and the calcareous content is noted to increase from the typical slate to slaty limestone. Occasional massive interbeds of limestone have also been noted.

3.12 Variegated Slate and Slaty Limestone Member :

The variegated slate member of the formation has been established on the basis of slate exposed at three different localities in the area under investigation. The variation in colour is noticeable in all localities but it is not possible to identify these on the basis of distinctive colour. It has been observed that this variegated slate is overlain by a slaty limestone which is a part of this member.

Jain (1971) has described the slates exposed in Uttarkashi-Gangotri Road and near Pokri as Pokri Slates and has distinguished it from Dhanari slates exposed near Odalak Village. In contrast, Agarwal and Kumar (1973) consider both these slates as the same lithostratigraphic unit and have called it as "Sartali Slate".

The present investigation reveals the slates exposed on Uttarkashi-Gangotri road and near Pokri and near Odalk belong to the same lithostratigraphic unit.

However, it is exposed at different localities, on account of folding and faulting.

(i) The slate exposed near Odalk village overlies the Khattukhal limestone according to Jain (1971). It is also exposed in Tehri-Uttarkashi road on the other bank of the Bhagirathi river. This slate shows variation in colours

from olive green to purple grey. The olive green slate is characteristically exposed near its contact with the underlying limestone. In the immediate vicinity of the contact, the state shows development of authigenic pyrite.

The pyrite cubes range in size from about 1 mm to 3 mm. The slate shows a gradual change in colour from olive green to purple colour. The purple slates are characteristics by minor intercalations of quartzite. Generally, it is thinly bedded with prominent slaty cleavage and is occasionally carbonaceous.

Near the upper contact of slate alternate dark and light colour banding were noted in slates which approximately coincide with the slate and quartzite contact. This feature is observed in Dunda-Odalak mule track. The slates have a conformable contact with the overlying quartzite. The gradational contact is clearly observed at a number of places viz. Tehri-Uttarkashi road section, Dunda-Odalak mule track in Odalak village. Intercalations of slate within the quartzite are seen on the left bank of Bhagirathi river. A lensiod shape intrusive body 0.5 Km long and 0.25 Km wide is seen within the slate. This is best exposed near the village Odalak. The dolerite intrusive body is having discordant relation with the slate. The dolerite is massive and typically unmetamorphosed and unaltered.

(ii) Greyish and partly greenish grey, thinly laminated slate marked by strongly developed slaty cleavages is exposed in Uttarkashi-Pokri road section. These variegated slates are also well exposed at Pokri village, where these are quarried for use as roofing material. Characteristically this slate is rarely carbonaceous while those near Odalak occasionally have carbonaceous bands. The contact relationship with adjacent slaty limestone part of the member is typically gradational, marked by interbeds of limestone and alate.

The general dip of the slate, as noted on the basis of colour banding, is $30^{\circ}$ in south-westerly direction. At places, the spacing of bedding plane varies from 2 cm to 5 cm.

Megascopically similar slate is exposed in Uttarkashi Gangotri road where it is underlain by limestone and overlain by slaty limestone part of the member.

3.13 Quartzite Member :

This is the youngest member of the Uttarkashi formation and also the most extensively developed member. This member is exposed repeatedly in the area due to folds trending NW-SE direction. At different localities this member shows change in character like difference in grain size, schistosity, colour etc. This member is exposed at four different localities.

(1) Buff to green coloured schistose quartzite exposed between Gangori and Netala villages, is dominantly arenaceous and shows thinly bedded character. At places it exhibits sedimentary features like current bedding, graded bedding and faint ripple marks, all of which indicate the right way up. The dips are $30^{\circ}$ to $35^{\circ}$ in North Easterly direction. The contact between this quartzite and adjacent massive limestone member at this locality has been established as a fault. The following field evidences have been used to establish the fault contact.

(i) The general strike trend in the quartzite has an angular discordance with the strike of the massive limestone member.

(ii) Crushing is observed nearly all along the contact along with evidences of slickan slides.

(iii) Geomorphologically, the Bhagirathi river takes a sharp turn along the contact of the two members.

(2) Greyish to buff schistose quartzite member with argillaceous intercalations are extensively exposed between Nakuri and Uttarkashi and also further South-East upto Dhanpur. It is fine grained and has abundance of mica which gives it a schistosd character. The schistosity

decreases further eastward and around Uttarkashi only faint schistosity is noted. It has a general regional strike of N 160° with dip of 25° to 40° in a North-Easterly direction.

East of Nakuri the metadolerite has a fault contact with the adjacent quartzite member. Just at the contact the metadolerite is entirely converted into chlorite schist. Under thin section, the quartzite also show cataclastic texture.

Near the Pokhri village, the contact of quartzite member with adjacent variegated slate and slaty/ limestone member is marked by a fault.

There is an angular discordance of 30° between the strike of slates and quartzites. The crushed zone close to the fault is well exposed near the pumping house in Langaon-Uttarkashi road cutting.

(3) White to buff coloured, medium to coarse grained quartzite is exposed south of Nakuri village upto Dunda. Further Northward and Southward, this quartzite is terminated by the metadolerite while along the strike direction it extends in a north west south east direction.

The quartzite has three widely spaced sets of joints and as a result of which rectangular blocks averaging

about 0.5 - 1.0 $m^3$ are obtained. It also exhibits sedimentary features like cross bedding, ripple mark, graded bedding etc., which indicate the right way up. It has a general regional dip of $35^\circ$ to $70^\circ$ in South West direction.

(4) White to light greyish green medium grained massive quartzite, overlies the variegated slate member and is exposed in left and right banks of river Bhagirathi; in Tehri-Uttarkashi road section and along the Dunda-Odalak mule track. It is thinly bedded showing graded bedding, colour banding and ripple mark (Plate No. 1) pree persistently indicating the right way up. At places the local movement within quartzite is observed, which is marked by zones of crushing.

The general strike of the quartzite is N $170^\circ$ with dips varying between $50^\circ$ to $60^\circ$ in a north-easterly direction.

3.14 The lithostratigraphical units, which are established on the basis of present, correlated with the work of the earlier workers in Table 3.15.

RKASHI DISTRICT.

| ARWAL AND MAR (1973) | PRESENT WORK |
|---|---|
| gni Thank-rmation | Quartzite member |
| yalna Formation | Variegated Slate with slaty lime-stone member |
| tarkashi rmation | Limestone member |

3.15 CORRELATION OF LITHOSTRATIGRAPHY OF GARHWAL GROUP IN BHAGIRATHI VALLEY, UTTARKASHI DISTRICT.

| GRIESHBACH (1891) | AUDEN (1938) | JAIN (1971) | AGARWAL AND KUMAR (1973) | PRESENT WORK |
|---|---|---|---|---|
| VAIKRITA (Gangotri granites and other metamorphics) | VAIKRITA (Mesograde granite-biotite granite, Garnet biotite schist, staurolite schist, Kyanite schist) | | | |
| HAIMANTHA (Phyllites, Quartzites and other meta-sedimentaries) | HAIMANTHA (Phyllite and other SEDIMENTARIES) | ~~Dlic~~ Dichli Dolomite<br>Gamri Quartzite<br>Dunda-Uttarkashi formations | Nagni Thank-Formation<br>Shyalna Formation<br>Uttarkashi formation | Quartzite member<br>Variegated Slate with slaty lime-stone member<br>Limestone member |

## 3.2 Chlorite Schist :

Chlorite schist occurs all along the contacts of metadolerite and metasedimentaries. The chlorite schist exhibits sedimentary character like lithological layering and enclosure of quartz pebbles under thin sections.

The chlorite schists generally exhibit schistose character. The chlorite schist which occur along the contact of quartzite and metadolerite in Dunda village encloses quartz pebbles of size range from 0.25 cm to 0.5 cm. These pebbles are randomly oriented.

The chlorite schist which occur along the contact of quartzite and metadolerite south of Nakuri village exhibits lithological layering in thin section. It contains pyrite grains along the foliation plane.

In other localities also chlorite schist occurs along the contacts.

This chlorite schist shows the same foliation directions as that of the metadolerites. It is evident that the foliation is of the same generation.

## 3.3 BASIC INTRUSIVES :

Basic intrusives, now metamorphosed to metadolerite, and amphibolite, occurs in narrow linear belts trending NW-SE direction in the form of lens shaped bodies. There are two linear belts ranging from 10 to 15 Km in length in the area under investigation. One NW-SE trending belt of metadolerite is exposed between Pokhri and Odalak villages while the other belt starts from Nakuri village and extends beyond Manpur in a south easterly direction. A few lens shaped bodies occur in between Dunda and Nakuri and Uttarkashi and Gangari. The southern boundary of another metadolerite body was traced north of Gangori. The extension of various metadolerite belts was established by traverse mapping across their strike lengths. These intrusive bodies clearly show evidences of moderate metamorphism. Schistosity is invariably clearly developed in all the metadolerites.

Along the contact of metadolerite and quartzite chlorite schist is developed with well defined schistosity. Within the metadolerite, the rock is generally non-foliated and coarse grained.

The various metadolerite bodies mapped in the area are discussed below :

3.31 Linear metadolerite body from Jakhni to Odalka :

The village Jakhni itself is located right on the metadolerite. The contact of the metadolerite shows a discordant relationship with the quartzites. Near the contact of the metadolerite, it occasionally shows crushing while in the middle it is dark greenish, compact and coarse grained. At places the metadolerite exhibits spheroidal weathering. The foliation strikes N 85° with a dip of 25° in N 355°. The same belt continues south east of Dunda village where it is well exposed both in the river cutting and the road sections. At the river cutting it is observed that metadolerite encloses a 0.25 m wide and 3 m long quartzite, clearly indicating that the intrusive is post quartzite in age (Plate No. 2).

The same belt extends further south east upto Odalak. At Odalak it is metanocratic, medium grained foliated and has a discordant relation with the Quartzite. Just at the contact the rock is fine grained and in the middle it is coarse grained and massive. This is clearly the chilling effect of dolerite intrusive in the pre-existing meta-sediments.

The foliation has a general strike trend of N 340° with dips varying between 30° to 40° in N 70° direction.

The main mass of metadolerite has been variously metamorphosed to metadolerite and amphibolite stages.

3.32 Linear belt from Nakuri to Manpur and further south-east.

Metadolerite having a discordant relation with quartzite is exposed in Dunda-Uttarkashi road at Km stone 6 from Dunda. Close to the contact it is fine grained. This belt continues in the east upto Uttarkashi as a narrow belt and follows almost along the course of the Bhagirathi river. The metadolerite is faintly foliated with strike trending due east and dips varying between $30^{\circ}$ to $45^{\circ}$ in N $270^{\circ}$ direction. South of Uttarkashi, near Pokhri, the metadolerite is well exposed. Here the metadolerite is medium grained, pale green colour with clearly marked foliation. However, it is compact and non-foliated in the middle of the body. The metadolerite here is highly weathered. The contacts are having discordant relation with limestone and quartzite respectively. The strike of the foliation is N $310^{\circ}$ with dips of $30^{\circ}$ in N $220^{\circ}$.

It is further exposed towards south east upto Dhanpur and Manpur. On the road section metadolerite is exposed near Dhanpur and Manpur. Megascopically, this metadolerite is similar to the Uttarkashi metadolerite.

3.33 LENS SHAPED METADOLERITE IN DUNDA-UTTARKASHI ROAD :

Megascopically it is dark coloured, medium to coarse grained, sparsely pointed, and generally non-foliated. The width of the body is about 0.5 Km and it is about 3 Km long. It has a discordant relation with the quartzite country rock.

METADOLERITE IN UTTARKASHI-GANGOTRI ROAD SECTION :

Megascopically, dark greenish grey coloured, medium to coarse grained, foliated metadolerite has discordant relation with the country rock. The width of the body varies from 0.5 Km to 1 Km and is about 1.5 Km long. The foliation within the metadolerite is synclinally folded.

3.40 STRUCTURE OF THE AREA :

This part of the chapter deals with the various structural elements present in the area under investigation. The following structural elements have been discussed.

(a) Planar Structures

(b) Folds and Joints and

(c) Linear Structures

3.4.1 PLANAR STRUCTURES :

The Planar Structural elements are divided as $S_0$, $S_1$, $S_2$ etc. with respect to the generation of the structure.

Bedding Plane ($S_o$) :

It is observed in various metasedimentary units. Bedding plane is observed in Limestone, Slates and Quartzites in the area. It is identified on the basis of colour banding, graded bedding an d ripple marks. The bedding planes in Limestones have been identified on the basis of colour banding both at Pokhri village and in the Gangotri-Uttarkashi road section.

The general strike trends of Limestone in the area are as follows :

(i) Limestone near the village Pokhri has a strike of N 125° and dips 45° in N 215° direction.

(ii) Limestone in the Gangotri-Uttarkashi road has a strike of N 130° and dips 55° in N 220° direction.

The bedding plane of the variegated slates are established on the basis of colour banding. The structural trends of the variegated slate units is as follows :

(i) Variegated slates at Odalak village has a strike of N 120° and dips vary between 30° and 35° in N 210° direction.

The bedding planes of the quartzite member have been identified on the basis of colour banding, graded bedding and ripple marks.

The structural trends of quartzite member at different localities are as follows :

(a) Near Dunda Village it strikes in N 170° direction and dips vary between 50° to 70° in N 80° direction.

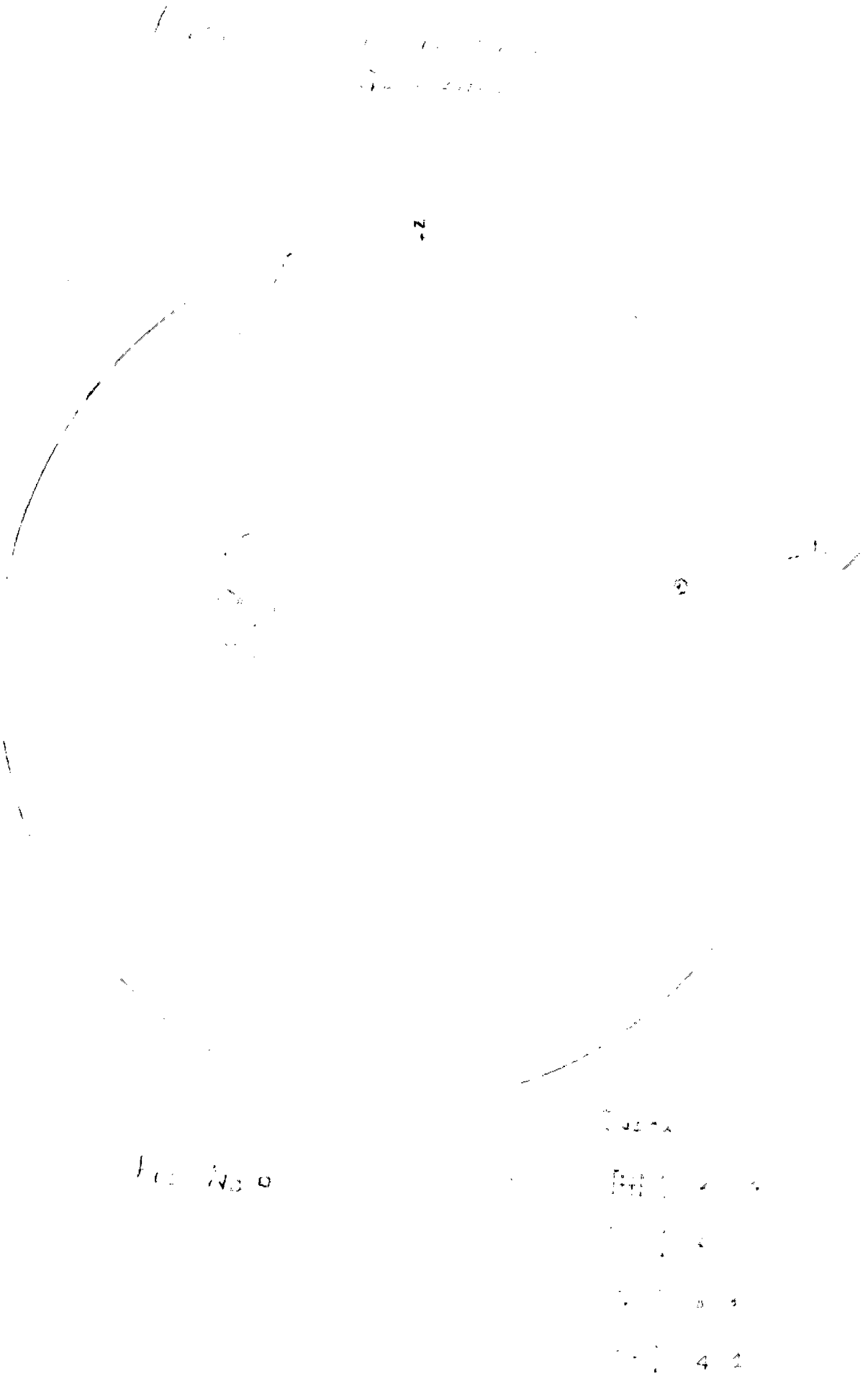
(b) Quartzites between Dunda and Nakuri villages strikes in N 140° direction with dips varying from 35° to 60° in N 230° direction.

(c) Quartzites around Uttarkashi strike in N 175° direction with a dip of 50° in N 85° direction.

(d) Quartzites between Gangori-Netala villages strike in N 110° direction with a dip of 30° in N 20° direction.

3.42 PRIMARY FOLIATION : (Schistosity) $S_1$

Schistosity is observed mainly in metadolerite and Quartzite. Due to metamorphism micaceous quartzites are converted into schistose quartzites and schistosity is also developed in metadolerite. Poles of $S_1$ foliation in metadolerite and schistose quartzite occuring east of Nakuri



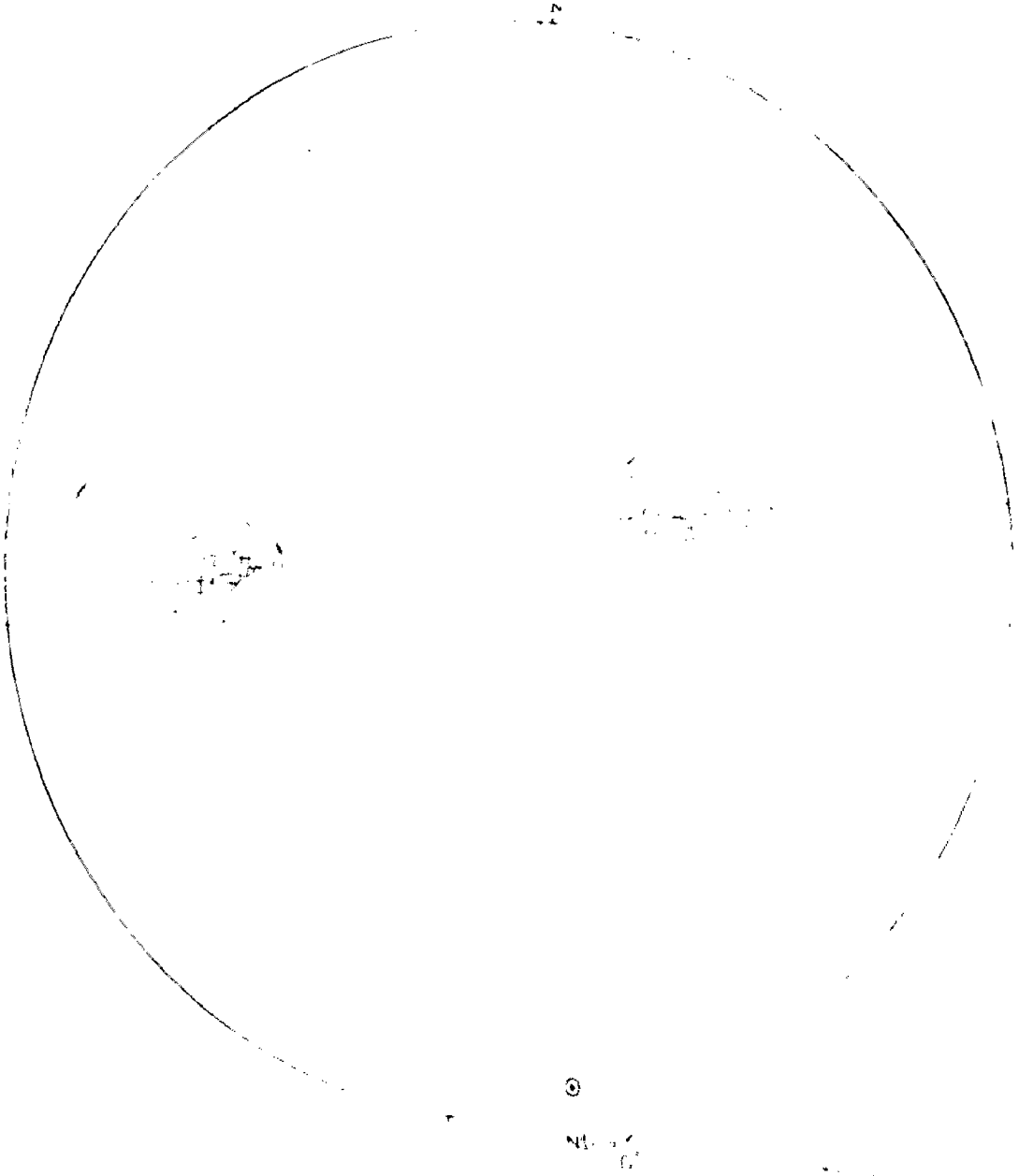


Fig No 9.

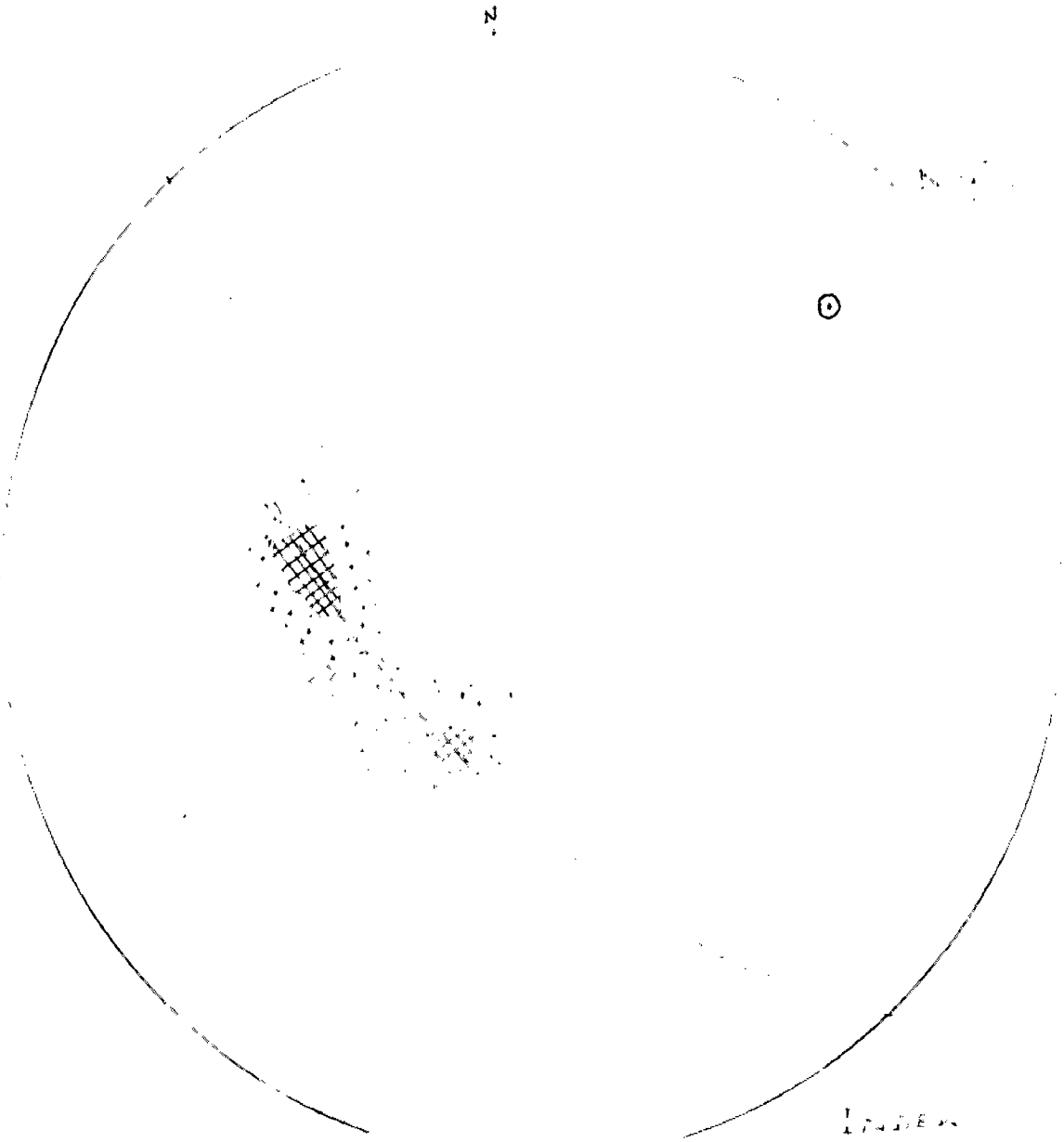



Fig No 10

are plotted in Schmidts' equal area net. It indicates that the foliation is of the same generation in both the metadolerites and schistose quartzite. The generalised dip direction of foliation from the plot is $30^{\circ}$ N $72^{\circ}$ (Figs. No. 7 and 8).

The orientation diagram of 40 readings of $S_1$ i.e. foliation in metadolerite east of Nakuri village are plotted in Schmidt's equal area net (Fig. No. 9). The $\pi$ pole of the gridle of the anticlinal fold shows that the fold plunges with $8^{\circ}$ in N $168^{\circ}$ direction.

About 45 readings of $S_1$ i.e. foliation in metadolerite between Dhampur and Manpur villages are plotted in Schmidt's equal area net (Fig. No. 10). The $\pi$ pole of the gridle of the anticlinal fold shows that the fold plunges with $25^{\circ}$ in N $51^{\circ}$ direction.

3.43 FOLDS AND JOINTS :

The rocks in the area under investigation exhibit megascopic folds of both the small scale and those of regional scale which have been inferred after interpretation of structural data.

The following types of folds are observed in the area under investigation.

(i) SYMMETRICAL PLUNGING FOLDS :

Limestone south of Uttarkashi shows megascopic symmetrical plunging folds. These folds have plain limbs with a gently rounded crustal region. The folds show a plunge of 20° to 25° in N 210° direction.

(ii) ISOCLINAL FOLD :

Slate near the village Pokhri shows isoclinal fold. Both the limbs are dipping about 45° in N 210° with their fold axis plunging 25° in N 130°. (Phote Plate No. 3).

3.44 JOINTS :

Joints are observed in Quartzite, Limestone metadolerite and slates. The Quartzites south of Dunda has two dominant sets of vertical joints and a horizontal joints. Limestone which occur south of Uttarkashi, has closely spaced horizontal joints with joint spacing ranging from a few cms to as much as 20 cms or so. Metadolerite occuring in Odalak-Dunda mule track is also jointed (Plate No. 4). In Dunda Singuni mule track, closel y jointed slates are exposed. Orientation readings of joints in quartzite (Plate No. 5) were plotted in lower hemisphere of Schmidt's equal area net. From a study of the plot

of joints (Fig. No. 11). It is clear that there are two sets of prominent joints whose generalised trends are as follows :

| | Strike | Dip | Dip direction |
|---|---|---|---|
| $J_1$ | N 326° | 40° | N 236° |
| $J_2$ | N 190° | 45° | N 100° |

3.50 REGIONAL STRUCTURES :

3.51 BARAGADI FAULT :

The contact between the quartzite around Uttarkashi and slates near Pokhri is clearly a fault. The trend of the fault is NW-SE. The following field evidences have helped in establishing the existence of this fault. This fault has been recognised by Agarwal and Kumar (1973) who have called it Baragadi fault.

(a) The strike of these two units have a angular difference of 30° to 35°

(b) The crushing is seen in both the lithological units near their contact, specially near the pump house road cutting. The fault divides the rock into two blocks and the N-W block is the downthrough block.

(a) There is a remarkable angular difference between the strikes in the quartzite and massive limestone members.

(b) Crushing has been observed all along the contact for a distance of nearly 1 Km.

(c) The Bhagirathi river, which flows in a NE-SW direction NE of Gangori village suddenly takes a sharp turn from North of Gawana village along the fault and flows for about 2 Km in a NE SE to NW direction and near Gangori, it ggain reers around to a NE-SW direction.

This fault divides the whole rock body into two blocks, the North Eastern block is down thrown block.

3.60 LINEAR STRUCTURE :

Lineation is defined as "The descriptive and non-genetic terms for any kind of linear structure within or on a rock". Mineral lineation and slickenslide are main linear structure observed in the area under investigation.

3.61 LINEATION :

Mineral lineation is commonly observed in Schistose quartzite which occur near the village Nakuri. The mineral lineation is defined by the preferred orientation of elongated quartz grains.

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3.52 NAKURI FAULT :

The contact between the schistose quartzite and metadolerite has been established as a fault.

(i) The contact of both the lithological unit is highly crushed. Schistosity has developed both in quartzite and metadolerite. Schistosity dies out on moving away from the contact.

(ii) Under thin section, the quartzite shows cataclastic texture and has been identified as the rock cataclasite.

Jain (1971) considers this contact as a thrust contact, whereas Agarwal and Kumar (1973) recognise this as the extension of Baragadi Fault.

3.53 NETALA FAULT :

The contact between the Quartzite member occuring between Gangori and Netala and the massive Limestone member occuring North of Uttarkashi has been established as a fault which has a strike of the following evidences have helped in establishing the faulted nature of the contact. This fault has neither been recognised by Jain (1971) nor by Agarwal and Kumar (1973). It is being named as Netala fault.

(a) There is a remarkable angular difference between the strikes in the quartzite and massive limestone members.

(b) Crushing has been observed all along the contact for a distance of nearly 1 Km.

(c) The Bhagirathi river, which flows in a NE-SW direction NE of Gangori village suddenly takes a sharp turn from North of Gawana village along the fault and flows for about 2 Km in a NE SE to NW direction and near Gangori, it ggain reers around to a NE-SW direction.

This fault divides the whole rock body into two blocks, the North Eastern block is down thrown block.

3.60 LINEAR STRUCTURE :

Lineation is defined as "The descriptive and non-genetic terms for any kind of linear structure within or on a rock". Mineral lineation and slickenslide are main linear structure observed in the area under investigation.

3.61 LINEATION :

Mineral lineation is commonly observed in Schistose quartzite which occur near the village Nakuri. The mineral lineation is defined by the preferred orientation of elongated quartz grains.

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3.62 SLICKEN-SLIDE :

It is produced due to the movement either within a rock unit or more commonly along the contact surfaces between two rock units. It has been observed that the slickenslides have strongly developed within the quartzites occuring between Dunda and Nakuri.

The general directions of movement is noted to be $70^{\circ}$ in N $300^{\circ}$, $85^{\circ}$ in N $290^{\circ}$ and $50^{\circ}$ in N $240^{\circ}$.

Slickenslides are also observed along the Baragadi fault contact and Netala Fault Contact. The following dominant directions are noted :

(i) Along Baragddi Fault :

$35^{\circ}$ in N $220^{\circ}$

(ii) Along Netala Fault :

$45^{\circ}$ in N $30^{\circ}$

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# CHAPTER - IV

# P E T R O G R A P H Y

# CHAPTER - IV

# PETROGRAPHY

4.0 This chapter deals with both megascopic and microscopic character of the representative specimens of various rock types exposed in the area under investigation. The various rock types have been grouped as three Members of Uttarkashi Formation as discussed in Chapter III. Two major groups of rocks have been identified and described herein. Both the group of rocks clearly show evidence of meta-morphism and have thus been discussed as :

(i) Metasedimentaries and

(ii) Metadolerites

## 4.1 Metasedimentaries :

The metasedimentaries, are being discussed under the following three Members, which have been established stratigraphically and structurally :

3. Quartzite Member
2. Variegated Slate with Slaty limestone member
1. Limestone member

4.11 QUARTZITE :

Slide No: D 28/278

Location : South of Dunda Village

Plate No : 15 = Slide No. D 28/278

Megascopic Character : It is pale greenish to grey coloured, medium grained moderatel; compact rock.

Microscopic Character : The rock is medium grained, while the grains are embedded in sericit matrix. The grains are sub angular Grain boundaries are slightly sutured. Muscovite flakes are bent, indicating diagenetic effect

Mineralogy : The rock is composed of quartz, plagioclase, orthoclase, tourmaline both blue and brown variety.

Quartz : It shows weak to moderately undulating extinction. Quartz with moderate extinction is less common.

| | | |
|---|---|---|
| Plagioclase | : | Subrounded grain with lamellar twin, having andesine composition. |
| Orthoclase | : | Occuring as subrounded grain with carlsbad twin. |
| Schrolite | : | Blue variety of Tourmaline mostly occur as subrounded grain. |
| Dravite | : | Brown variety of Tourmaline. Occurs as subrounded grains. |
| Muscovite | : | ~~Mainly-made-up-of~~ Occurs as flakes with occasional bending. |
| Matrix | : | Mainly made up of Sericite. |

The minerals occur in the following decreasing order of abundance :

| | | |
|---|---|---|
| Quartz | : | 55% |
| Plagioclase | : | 7% |
| Orthoclase | : | 3% |
| Muscovite | : | 2% |
| Others | : | 3% |
| Matrix with sericite | : | 30% |

4.12 MASSIVE QUARTZITE :

| | | |
|---|---|---|
| Slide No. | : | D 28/216, D 28/225 |
| Location | : | Between Dunda village and Nakuri Village. |
| Megascopic Character | : | It is white to purple coloured, medium to caarse grained rock. |
| Microscopic character | : | The rock is made up of medium to coarse grained with sutured grain boundaries. The grains are sub-rounded and embedded in silica matrix. |
| Mineralogy | : | Mainly made up of quartz with little heavy minerals. |
| Quartz | : | Occurs as sub-rounded grains with sutured grain boundaries. |
| Tourmaline | : | Brown variety of tourmaline occur as subrounded grains. |

Very little amount of Iron Oxide is present.

—

4.13 QUARTZITE :

Slide No: D 28/226

Location : Nakuri village

Megascopic Character : Purple coloured, coarse grained rock.

Microscopic Character : Very coarse grained texture with subangular to subrounded grains. Chlorite occur in vermicular shape. Detrital chert occur in little quantity. The grain boundary is generally sutured. Tourmaline occur in little quantity.

Quartz : It occurs as subangular to subrounded grains with interlocking grain boundaries. It shows mostly straight extinction and occasionally undulatory extinction.

Tourmaline : Blue variety of tourmaline with faint Pleochroism.

Chlorite : Green variety of chlorite occur in vermicular shape.

## 4.14 CATACLASITE :

Slide No. : D 28/233

Location : Between village Nakuri and Uttarkashi.

Plate No. : 12 = Slide No. D 28/233

Megascopic Character : Grey coloured, fine grained exhibits schistose character.

Microscopic Character : It shows cataclastic texture larger grains are surrounded by small grains. Grains are sub-rounded with sutured margin indicating action of pressure solutio It has mainly siliceous matrix.

Mineralogy : It is made up of quartz.

Quartz : They are of two varieties :

(i) Those show moderately undulating

(ii) Strong undulatory extinction Both uni and polycrystalline quartz are recognised.

| | | |
|---|---|---|
| Matrix | : | It is made up of Siliceous material. |
| Others | : | Tourmaline, Zircon and Iron Oxide. |

The minerals occur in the following decreasing order of abundance :

| | | |
|---|---|---|
| Quartz | : | 70% |
| Heavy minerals and Iron Oxide | : | 5% |
| Matrix | : | 25% |

—

4.15 QUARTZITE :

| | | |
|---|---|---|
| Slide No. | : | D 28/285 |
| Location | : | Near Village Gangori |
| Megascopic Character | : | White to buff coloured with medium grained, and moderately compact rock. |
| Microscopic character | : | Rock shows coarse grained texture where the grains are embedded in siliceous matrix. The grains are subangular to subrounded with straight margins with some grains showing sutured margin. A few grains are showing authegenic growth. |
| Mineralogy | : | It is mainly made up of quartz and orthoclase (little) . Siliceous matrix and brown variety of tourmaline mainly Dravite occur. |
| Quartz | : | Three varieties of quartz occur (i) showing weak undulatory extinction, (ii) moderate undulatory extinction, (iii) Strong undulatory extinction. Polycrystalline quartz are less common. |

| | | |
|---|---|---|
| Orthoclase | : | It occurs in more kaolinised stage. Occasionally with cleavage; |
| Tourmaline | : | They are subrounded to rounded. |

---

4.2 VARIEGATED SLATE :

| | | |
|---|---|---|
| Slide No. | : | D 28/245, D 28/220, D 28/219 |
| Location | : | D 28/245 South of village Odalak<br>D 28/220, D 28/219 near village Pokri. |
| Megascopic Character | : | Grey to Olive green, fine grained, with well defined slaty cleavage. |
| Microscopic Character | : | The rock is very fine grained. Difficult to identify even under high magnification. In D 28/220 the grain size is more fine.<br>D 28/219 is more shaly than the other two. |
| Mineralogy | : | Mineralogically the rock is made up of quartz, muscovite with little sericite. |
| Quartz | : | Subangular to elongated, showing parallel allignment with weak undulatory extinction. |
| Muscovite | : | The flakes are also parallely arranged, showing characteristic IInd order Inferference colour. |

## 4.3 LIMESTONE MEMBER :

Slide No. : D 28/262, D 28/287.

Location : D 28/262 - Uttarkashi-Gangotri road section.

D 28/287 - Near village Pokri.

Plate No. 14 : 14 - Slide No. D 28/262

Plate No. 15 : - Slide No. D 28/287

Megascopic Character : It is dark grey to greyish black in colour, fine grained with calcite veins.

Microscopic character : It shows fine grained texture with very micro-crystalline calcite matrix, with little argillaceous material. Slide No. D 28/287 shows slaty character.

Mineralogy : The main constituent is fine graine Calcite with minor amount of argillaceous material and fine grained microcrystalline matrix.

Calcite : Fine grained calcite, and it has been traversed by Calcite vein.

Matrix : It is composed of microcrystalline variety of calcite with little argillaceous matter.

## 4.4 CHLORITE SCHIST :

The chlorite schist is persistent all along the contact of metadolerites and metasedimentaries. Chlorite schist, which occur in the village Dunda contains quartz pebble Pyrite mineralization has been observed in the chlorite schist south of Nakuri village.

Slide No. : D 28/204, D 28/206, D 28/207 D 28/209, D 28/213.

Location : D 28/204, D 28/206, D 28/207, D 28/209 - In the village Dunda, just at the contact.
D 28/213 - South of village Nakuri

Plate No : 8 = Slide No. D 28/207

Plate No. : 9 = Slide No. D 28/213.

Megascopic Character : Pale green to grey coloured, fine grained, foliated, moderately compact. Specimen D 28/207 has the subrounded quartz granular pebbles whose size range from 0.25 cm to 0.5 cm. Specimen D 28/213 has pyrite mineralization along the foliation plane.

Microscopic Character :

It is fine grained and the grains are oriented along a preferred direction. Section D 28/204 shows extremely fine grained cataclastic texture with marked schistocity. Section D 28/209 shows the contact between chlorite schist and metadolerite. Here chlorite schist occurs as a wedge surrounded by metadolerite. Section D 28/207 shows rounded to subrounded quartz pebbles, which are made up of polycrystalline quartz with serrated grain boundaries. Individual pebble is surrounded by a chlorite layer resembling the enveloping of an augen. Smaller grains show a radial growth of coarse grains similar to secondary cavity fillings. Section D 28/213 shows alternation layers of fine grained quartz and chlorite flakes. This could be due to the preservation of compositional layering. In this section pyrite mineralization is seen along the layers. A very few random grains of iron oxide are also seen in chlorite schists.

Mineralogy : Chlorite and quartz are the main mineral constituent. Generally there are two types of chlorite. One shows pale green and other shows pale yellow to green colour. Quartz grains are extremely fine grained. Ocassionally a few grains of pyrite and other opaque iron oxide are present.

Chlorite : It occurs in the form of aggregate fine flakes which impar t schistosity to the rock. Generally it is shows faint pleochroism. Two varieties of chlorite are recognised. It shows anomalous low order interference colour.

Prochlore : Prochlore : It shows faint pleochroism of pale yellow to colourless.

Pennite : It shows a pleochroism of pale green to bluish green.

In thin section No. D 28/204, chlorite ( Prochlore) occurs as veins. It is recognised by extremly low birefringence and anomalous blue interference colour.

Quartz : Quartz occur as fine grained crystals, along with chlorite or as alternate layers. It occurs as en-echelon veins or simple veins. The quartz pebble reported above consist of poly crystalline quartz with serrated grain boundaries and accompanied by strong undulatory extinction. At times quartz grains show a radial pattern producing a-cross due to selective extinction.

Iron Oxide : It occurs as brown to opaque grains.

Pyrite : Pyrite occurs as dark grains arranged parallel to foliation. Under the ore microscope it shows pale yellow, with high reflectivity and isotrophism. The pyrite could be an authigenic mineral of the original sediments.

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## PETROGRAPHY OF METABASIC ROCKS

4.5 The metabasic rocks, which occur around Uttarkashi, have been petrographically classified into following types : (i) Coarse grained metadolerite, (ii) Medium grained metadolerite and (iii) Amphibolite.

### 4.51 COARSE GRAINED METADOLERITE :

It occurs in the central part of the metadolerites

Slide No. : D 28/210, D 28/228
D 28/239. D 28/265

Location : D 28/210 - Dunda village
D 28/228 - South of Nakuri village
D 28/239 - South of Ranari village
D 28/265 - Between the villages Dhanpur and Manpur.

Megascopic Character : These rocks are dark green to greenish black in colour. They are very coarse grained.

Microscopic texture : Microscopically they show medium to coarse grained sub-ophitic to gabbroid, texture.

Mineralogy : The main mineralogical constituents are the augite, hornblende, plagioclase and minor amount of quartz with little iron oxide.

Augite : Unaltered Augite occasionally occurs as small aggregate. Generally it is uralitized. Such grains show alteration along the grain boundary within an unaltered core. Most of the grains entirely altered to uralitic hornblende as seen in thin section D 28/239

Horn Blende : Hornblende occur in variable amount. Generally it shows pleochroism Two varieties of horn blende are seen. One with brown colour which has an extinction angle of $32^{\circ}$, and pleochroic scheme as follows :

Absorption X < Y < Z

X = pale yellow

Y = Brownish yellow

Z = Brown.

The other show bluish green colour with extinction angle of $20^{\circ}$. The pleochroic scheme is as follows :

Absorption X < Y < Z

X = Greenish yellow

Y = Emerald green

Z = Greenish blue.

Occasionally, the latter is fibrous.

Plagioclase : It occurs in the form of laths The prominent plagioclase is labradorite - andesine altering to albite. However, at times it is completely Saussuritised leading to albite - epidote and other minerals. In thin section D 28/210 alteration is minimum.

Epidote : It ofcurs as tabular crystal with yellowish green colour with one set of cleavage.

Quartz : Little amount of quartz occurs as coarse grains with undulatory extinction.

Iron Oxide : It occurs as opeque to dark brown tabulaf crystals.

4.52 MEDIUMGRAINED METADOLERITE :

It occurs relatively towards the margins of the metadolerite bodies.

Slide No. D 28/201, D 28/203, D 28/205
D 28/208, D 28/212, D 28/214
D 28/215, D 28/218, D 28/220
D 28/222, D 28/230, D 28/231

Location : D 28/201, D 28/203, D 28/205
D 28/208 - Dunda Village.

D 28/212, D 28/214, D 28/215
- South of the village Nakuri.

D 28/218, D 28/220, D 28/222
- Near the village Pokri

~~D 28/218, D 28/220~~

D 28/230, D 28/231 - North of village Nakuri.

Plate No. 10 - Slide No. D 28/222

Plate No. 11 - Slide No. D 28/214

Megascopic Character : The rock is pale green to grey coloured, medium grained, non-foliated and moderately compact.

Microscopic Character : Microscopically the rock is medium grained. The rocks generally show blasto ophitic to blasto sub ophitic texture.

Mineralogy : The rock mainly comprises of relict Augites, Hornblende, albite epidote, biotite, chlorite, and with minor amount of quartz, and iron oxide occasionally illmenite in the form of skeletal crystal. Relict texture is seen in the following rocks
D 28/215, D 28/208 and D 28/222.

Augite : Occasionally it occurs as unaltered tabular crystal high relief with cleavage. In section D 28/205 relict augite is present. Augite generally alters to uralitic hornblende. Uralitised pyroxene is best seen in section D 28/230

Hornblende : It occurs as long bluish green prismatic crystal with pleochroism showing characteristic cleavage and uralitic hornblende are fibrous.

Pleochroic scheme

Absorption = X < Y < Z

X = Greenish yellow

Y = Emerald green

Z = Greenish blue

It shows an extinction angle of $20^{\circ}$. T

Albite : The prominent plagioclase is albite although occasionally the relict labradorite occurs. Albite seems to be the product of saussuritisation of calcic plagioclase and is associated with quartz, epidote etc.

Epidote : It occurs as tabular crystals with faint pleochroism and high birefringence.

Biotite : Biotite occur as flakes with deep brown to green pleochroism in minor amount.

Chlorite : It occurs as aggregate of tabular crystals with pleochroism of greenish yellow to colour less.

Quartz : Quartz occur as medium grains with moderate undulatory extinction

Opaque minerals : Brown, limonitic leaching is usually associated in the form of tabular crystal. Ilmenite occur as skeletal grains.

Mineralogic assembleges :

The general mineralogic assembleges are as follows :

Albite - Chlorite - Hornblende - Epidote - Quartz

Albite - Chlorite - Epidote - Biotite - Quartz

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4.53 AMPHIBOLITE :

Slide No. D 28/217

Location : North of Dunda Village

Megascopic Character : It is green to pale green in colour, medium grained, nonfoliated and moderately compact rock.

Microscopic Character : Microscopically it shows medium grained texture, it neither shows relict ophitic texture nor a well developed schistosity. Lack of blasto ophitic texture and presence of abundant hornblende distinguishe this rock from metadolerites described above.

Mineralogy : This rock is characterised by the assemblage.

Albite - Hornblende - Quartz - Chlorite and others in minor quantity.

Augite : It occur as short prismatic tabula crystal with cleavages. It is altered to uralite.

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Hornblende : It occurs as long prismatic crystal with pleochroism. A few grains are also altered to fibrous varieties. It has the extinction angle of wide range ϕfrom $20^{\circ}$ to $32^{\circ}$.

Pleochroic scheme

Absorption $X < Y < Z$

X = Pale yellow,

Y = Greenish

Z = Dark green

Plagioclase : Relict labradorite - andesine is seen. But they are usually saussuritised. Albite is the prominent plagioclase.

Chlorite : It occurs as flakes in minor amount with characteristic pleochroism of yellowish green to colourless.

Quartz : It occurs in minor quantity with weak undulatory extinction.

Other minerals : Opaque to deep brown iron oxide occur in very little amount.

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# CHAPTER - V

# D I S C U S S I O N

# CHAPTER - V

## DISCUSSION

5.0 In this chapter an attempt is made to correlate the findings of the present investigations with the salient features of the earlier work. An attempt is also made to discuss the metamorphic history of basic rocks and sedimentary history of the meta-sedimentaries present in the area under investigation.

5.1 Grieshbach (1891) and Auden (1938) broadly grouped the metamorphics and igneous rocks under the name 'Vaikrita' and grouped the Metasedimentaries under the name 'Haimantha'.

5.2 Jain (1971) recognised four major stratigraphic and structural units bounded by large scale thrusts. In the area under investigation, he recognised two formations viz. Uttarkashi Formation and Dunda Formation, each consisting of a number of lithostratigraphical members. Dunda Formation consists of Khattukhal Limestone, Dhanari Slate and Dunda Quartzite members and Uttarkashi Formation consists of Netala Quartzite, Lower Uttarkashi Limestone, Pokri Slate, Upper Uttarkashi Limestone and Bareti Quartzite members. He considers that the metadolerite occurs mainly along the thrust contact and occasionally along other weak planes.

According to Jain (1971) the long belts of Metadolerite occur along the contacts of two different formations which are emplaced tectonically during the Overthrusting of Gamri Quartzite against Dunda-Uttarkashi Formation. He favours Upper Cretaceous age for the metadolerites.

5.3 Agarwal and Kumar (1973) recognised three formations in Garhwal Group namely Uttarkashi Formation, Shyalna Formation and Nagni Thank Formation. According to Agarwal and Kumar (1973) Uttarkashi Formation includes Netala quartzite and Sartali Slates and Shyalna formation includes the limestone member and Nagni Thank includes Gamri quartzite with basic intrusives. Agarwal and Kumar (1973) have indicated a Precambrian to early Ordovician age to the Garhwal gropp of rocks and have suggested the same age for the metadolerites.

5.4 On the basis of present investigation, the litho-stratigraphic units have been grouped in a single formation which has been recognised in the area. It has been named as Uttarkashi Formation which differs from the Uttarkashi Formation of the earlier workers. It consists of the oldest Massive Limestone member, followed successively by Variegated slate and slaty limestone member and the Quartzite member. Their normal gradational contacts have been established and there is no reason to believe that these are parts of different formation. The structural setting also confirms the stratigraphic position.

Massive Limestone member, as defined here, includes upper Uttarkashi Limestone, Lower Uttarkashi Limestone and Khattukha Limestone of Jain (1971) since, megascopically and microscopically they have same characters and no distinction could be made. Variegated Slate and slaty limestone member includes the Dhanari and Pokri Slate of Jain (1971) and Sartali Slates of Agarwal and Kumar (1973). Quartzite member includes Dunda Quartzite, Gamri Quartzite, Bareti Quartzite and Netala Quartzite of Jain (1971) and Gamri and Netala Quartzite of Agarwal and Kumar (1973). The metadolerite which occur in the form of transgressive sills and dykes, appear to be post depositional but pretectonic. In Dunda village river cutting, the metadolerite encloses a quartzite body which indicates that these are post depositional. The quartzite band which extends northward upto Dunda village for about one Km further indicates that the metadolerites are younger to the metasedimentaries . In the present area the metadolerites commonly occur as dykes and occasionally as sill Discordant relationship has been noted in the following locations: (i) East of Nakuri village (Plate No. 6 and 7), (ii) South of Nakuri village, (iii) North west of Jakhni village and (iv) South of Gangori village. In remaining places, it occur as sills. On the basis of the present work, it is concluded that the intrusion took place along the lithological contact and other preexisting weak planes.

The existence of chilled margin can be explained, by the presence of medium grained metadolerite relatively near the contacts, with well defined foliation and gradual transition to coarse grained metadolerite with faint foliation in the middle. The foliations are caused by the regional metamorphism which took place during the Himalayan Orogeny.

Two stages of deformation, as a part of Himalayan Orogeny, are imprinted on some of the lithostratigraphical members in form of folds, faults and other structural elements.

## 5.5 SEDIMENTATION HISTORY TECTONIC HISTORY AND METAMORPHIC HISTORY.

In this section, Sedimentation has been discussed in brief along with tectonic history. A sincere attempt has been also made to discuss the metamorphic history of basic intrusives.

The area consists of metasedimentary rocks of Uttar-Kashi Formation and metabasic rocks in the form of meta-dolerite and amphibolite. To discuss the history of sedimentation with reference to the tectonic evolution one must know the possible mode of sedimentation and tectonic set up of each lithostratigraphic unit.

5.51 UTTARKASHI FORMATION :

It consists of Massive Limestone, Variegated slate and slaty limestone, chlorite schist and quartzite. The deposition probably started under the deep water condition when limestone followed by argillaceous members were deposited. The upper portion of the Uttarkashi formation is represented by Quartzite member. The argillaceous member started declining towards the top, it may be probably due to shifting towards a different condition, where quartzite was deposited.

The presence of bent mica flakes and puckering indicate that the deformation is post metamorphism. These rocks also show effects of multiple deformation, which may be due to different orogenic cycle. After the deposition of Uttarkashi formation of entire sequence along with basic intrusives was folded into different anticlines and synclines the axis of which are trending northwest and southeast, this implies that the stresses were acting from NE-SW directions.

5.5.2 METAMOR-PHIC HISTORY OF METABASIC ROCKS :

Metabasic rocks consists of mainly of metadolerite but include the coarse grained counterparts as well as amphibolite which have together undergone regional metamorphis

as indicated by the alteration of pyroxene and saussaritisation of plagioclase.

The metadolerites are little metamorphosed, since it exhibits relict texture, that is blasto ophitic to blasto subophitic associated with minor alterations including mineralogical and textural changes. The Hornblende - Plagioclase - Epidote - Chlorite assemblages, relict ophitic texture and absence of garnet indicates they have undergone regional metamorphism corresponding to the Green schist facies. Plagioclase is generally of labradorite composition, but it shows distinct changes with metamorphism Plagioclase which are formed as a result of metamorphism show a composition of albite.

The various mineral assemblages in the increasing order of metamorphism are :

1. Albite - Chlorite - Quartz
2. Albite - Chlorite - Actinolitic hornblende - Quart
3. Albite - Chlorite - Epidite - Hornbbende - Quarts
4. Albite - Hornblende - Epidote - Chlorite - Quartz

The presence of relict texture and of the original minerals suggest that the metamorphism was not complete and no equilibrium could be established. It is suggested, therefore, that this area has never gone beyond a temperature of 200° C 400° C and 2 - 9 Kb pressure corresponding to 6 - 30 Km depth.

# CHAPTER - VI

# SUMMARY AND CONCLUSION

# CHAPTER - VI

## SUMMARY AND CONCLUSION

The investigated area around Uttarkashi, U.P. forms a part of Garhwal Himalayas. Present investigation was carried out as a part of fulfilment of the M. Tech. (Applied Geology) course of University of Roorkee.

Garhwal group of rocks are exposed in the present area. Geological and Structural mapping was carried out on 1:50,000 scale with special emphasis on Metadolerites.

The tectonic succession for the investigated area has been proposed as given below :

| | | |
|---|---|---|
| Uttarkashi Formation | 3. | Quartzite Member |
| | 2. | Variegated Slate with Slaty Limestone member |
| | 1. | Massive Limestone Member. |

The above succession has been intruded by Basic intrusives occurring as transgressive sills and dykes which are definitely pretectonic as they have been subjected to folding and faulting together with metasediments during various stages of Himalayan Orogeny. During the regional

metamorphism various sedimentary units are converted into metasedimentaries and basic intrusives are converted into metadolerite and amphibolite. The metamorphism did not go beyond the Green schist facies.

However, the fact is that the geology of Himalaya is not very simple. Various stratigraphic and tectonic units are yet to be assigned proper places in terms of Stratigraphic positions according to their age.

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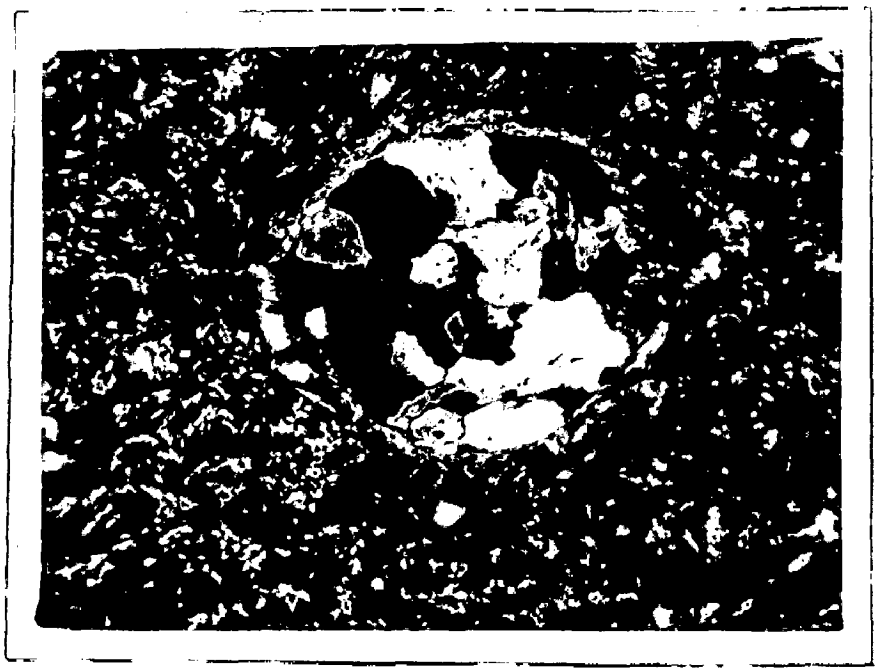
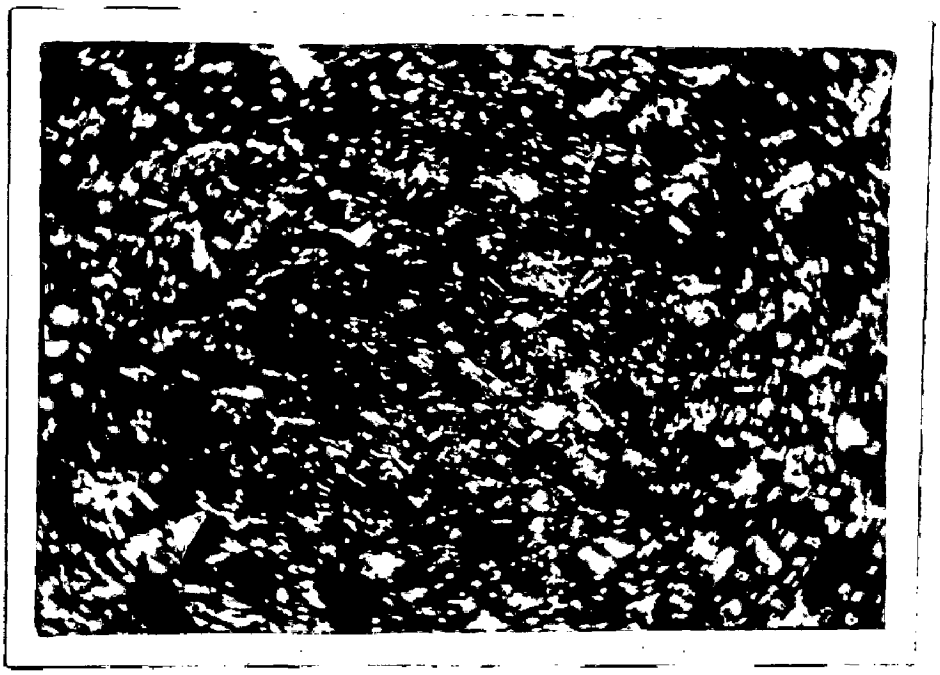
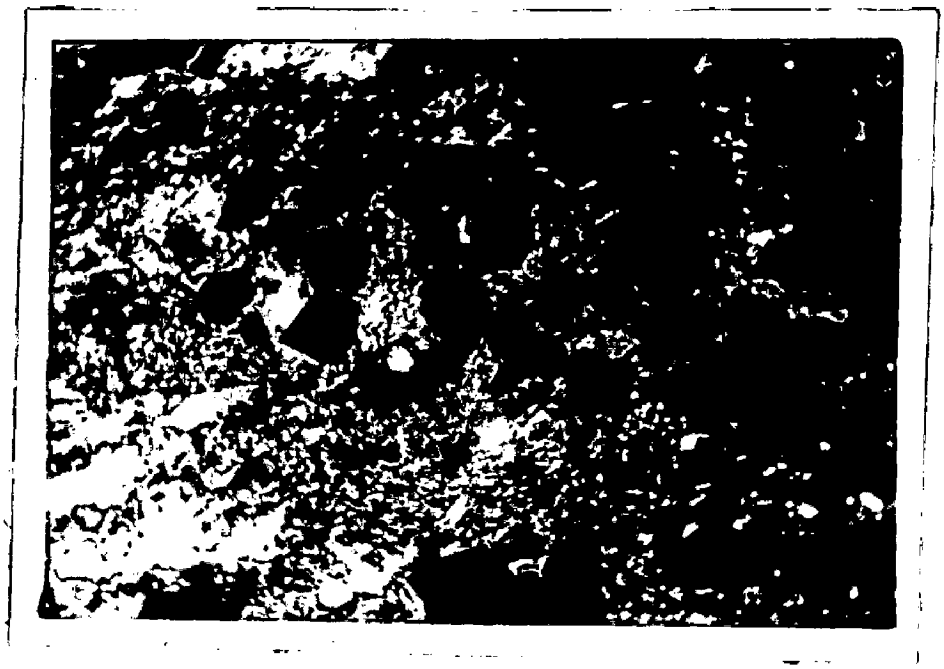
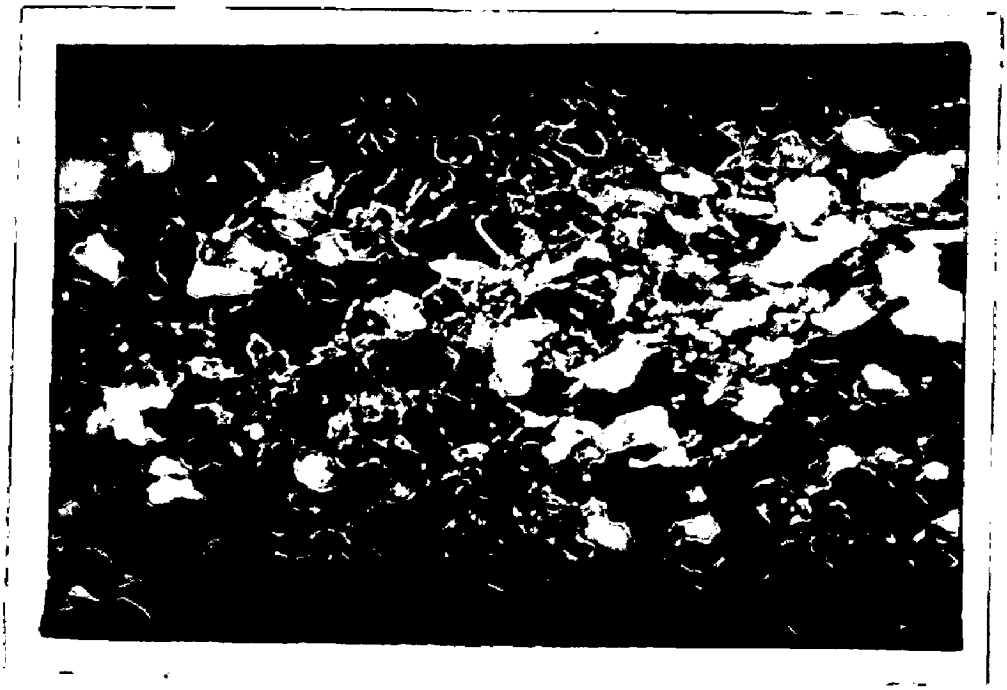
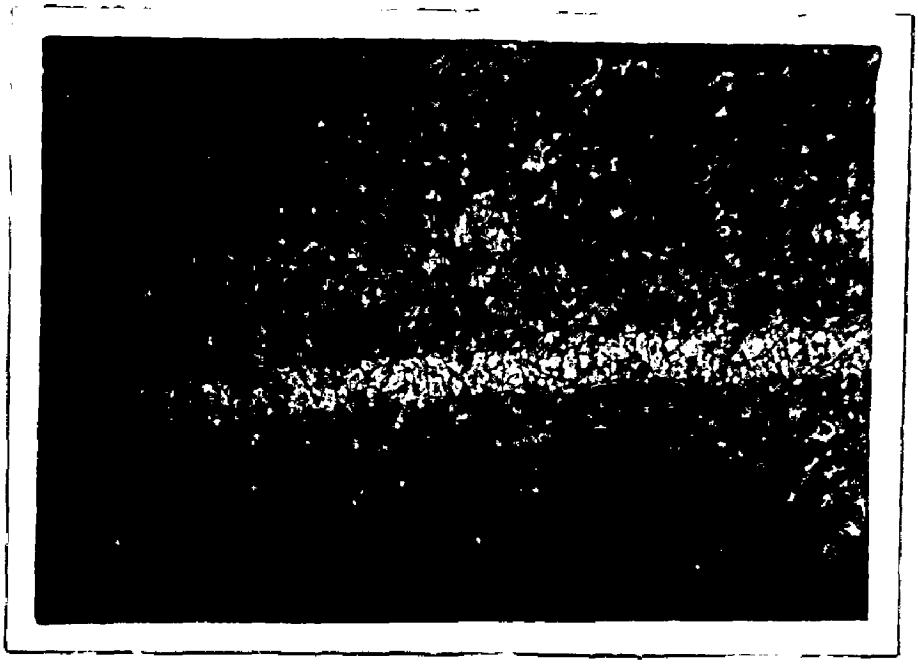
# PHOTOGRAPHS











| S. No. | Slide No. | Name of the rock | Location | Stratigraphic horizon | Description | Remarks |
|---|---|---|---|---|---|---|
| 1. | D 28/278 | Quartzite | South of Dunda village | Uttarkashi Formation | Pale greenish medium grained | Orthoquartzite |
| 2. | D 28/216 | Massive quartzite | | | | |
| 3. | D 28/225 | Massive quartzite | Between Dunda and Nakuri villages. | Uttarkashi Formation | White to purple coarse grained | - |
| 4. | D 28/226 | Massive quartzite | | | | |
| 5. | D 28/233 | Cataclasite | East of Nakuri | Uttar Kashi Formation | Grey, fine grained with schistose character. | Cataclasite occuring near fault. |
| 6. | D 28/285 | Quartzite | Near Gangori | Uttarkashi Formation | Buff coloured medium grained | - |
| 7. | D 28/245 | Variegated Slate | South of Odalak | Uttarkashi Formation | Grey to olive green, fine grained. | Shows variation of colour from Olive green to grey. |
| 8. | D 28/219 | Variegated slate | Near Pokri | Uttarkashi Formation | Olive green, fine grained with slaty cleavage | - |
| 9. | D 28/220 | | | | | |
| 10. | D 28/262 | Massive limestone | Between Uttarkashi-Gangori village | Uttarkashi Formation | Grey to bluish grey, fine grained | It has a calcite vein |
| 11. | D/28/287 | Slaty limestone | Near Pokri | Uttarkashi Formation | Dark greyish black fine grained. | - |
| 12. | D 28/204 | Chlorite schist | Dunda village | Younger than Uttarkashi Formation | Green to grey fine grained, well foliated. | - |
| 13. | D 28/206 | Chlorite schist | Dunda village | --do-- | --do-- | Quartz pebbles are present. |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 14. | D 28/211 | Chlorite schist | East of Nakuri | Younger than Uttarkashi Formation | Greenish grey foliated. | - |
| 15. | D 28/207 | Chlorite schist | Dunda village | --do-- | --do-- | Quartz pebbles are present |
| 16. | D 28/209 | Chlorite schist | Dunda village | --do-- | --do-- | Shows contact between chlorite and metadolerite. |
| 17. | D 28/213 | Chlorite schist | South of Nakuri | --do-- | Dark green with foliation | Pyrite is mineralised along the foliation. |
| 18. | D 28/210 | Coarse grained metadolerite | Dunda village | --do-- | Dark greenish grey coarse grained | - |
| 19. | D 28/228 | Coarse grained metadolerite | South of Nakuri | --do-- | Greenish grey coarse grained. | - |
| 20. | D 28/239 | Coarse grained metadolerite | South of Ranari | --do-- | Greenish grey coarse grained | - |
| 21. | D 28/265 | Coarse grained metadolerite | Between Dhanpur and Manpur village | --do-- | --do-- | - |
| 22. | D 28/201 | Medium grained metadolerite | Dunda village | --do-- | Pale green, medium grained, foliated. | - |
| 23. | D 28/203 | Medium grained metadolerite | Dunda village | --do-- | --do-- | - |
| 24. | D 28/205 | Medium grained metadolerite | Dunda village | --do-- | --do-- | Relatively unaltered |
| 25. | D 28/208 | Medium grained metadolerite | Dunda village | --do-- | ---do--- | - |
| 26. | D 28/212 | Medium grained metadolerite | South of Nakuri | --do-- | ---do--- | - |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 27 | D 28/214 | Metadolerite | South of Nakuri | Younger than Uttarkashi Formation | Greenish grey, medium grained. | - |
| 28 | D 28/215 | Metadolerite | South of Nakuri | --do-- | --do-- | - |
| 29 | D 28/218 | Metadolerite | Near Pokri | --do-- | Pale greenish, medium grained. | - |
| 30 | D 28/220 | | | | | |
| 31 | D 28/222 | Metadolerite | Near Pokri | --do-- | --do-- | - |
| 32 | D 28/230 | Metadolerite | North of Nakuri | --do-- | Greenish grey, medium grained. | - |
| 33 | D 28/231 | Metadolerite | North of Nakuri | --do-- | --do-- | - |
| 34 | D 28/217 | Amphibolite | North of Dunda | --do-- | Greenish grey to green, medium grained. | - |