GEOLOGICAL REPORT ON SOME TRAVERSES ALONG BHAPKUND–SOMNA AND MALARI–NITI SECTIONS DISTRICT CHAMOLI (U.P.)

DISSERTATION
IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF
M. Sc. Tech. DEGREE IN APPLIED GEOLOGY

SUBMITTED BY
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ROORKEE (U.P.)
1967

C E R T I F I C A T E

Certified that the dissertation entitled "Geological Report on Some Traverses along Bhapkund-Somna and Malari - Niti Sections, District Chamoli, U.P." being submitted by Shri Bakhtawar Singh Rawat in part fulfillment for the award of the DEGREE OF M.Sc. TECH. in Applied Geology of University of Roorkee, is a record of student's own work carried out by him under my 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 take this opportunity to express my sincere gratitude towards Prof. R.S.Mithal, Head of Department of Geology and Geophysics, University of Roorkee, Roorkee, for suggesting the problem and offering valuable guidance. His keen interest in making all necessary arrangements in the field and laboratory could make it possible to complete the work.

My sincere thanks are due to Dr. V.K.S. Dave for constant guidance and help while carrying out the field and laboratory studies. I am greatly indebted to the B.R.T.F. authorities for their hospitality, accommodation and transport facilities during the investigations in the field.

I acknowledge my thanks to Dr. R.K. Goel for his help in palaeontological studies. Thanks are also due to Shri M.V.A. Shastri, Chief Palaeontologist, Geological Survey of India, Palaeontological Laboratories, Calcutta, for the determination of the fossils.

It is my pleasant duty to thank Dr. K.K. Singh, Dr. V.D. Choubey and other members of the teaching staff of the Department of Geology and Geophysics for frequent help and encouragement avail during the present study.

I owe my thanks to my colleague Shri B.K. Singh for his company in the field for most of the time. Furthermore, thanks are due to all other colleagues for their assistance in various ways.

I also remember thankfully, the S.P.F. Personnels and all other persons who have contributed to my comforts and convenience during the field investigation in that difficult area.

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DATE : 6th of May, 1967.

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CHAPTER I

INTRODUCTION

THE AREA

Location and Extent

The region included in the present work is situated between the North latitudes 30° 40' to 30° 50' and East longitudes 79° 50' - 80° 05' covering parts of Survey of India 1 : 50,000 toposheets numbering 53 N/14, N/13, R/1 and R/2, forming a tract of Chamoli district of Uttar Pradesh, Bhapkund (latitude 30° - 40' longitudes 79° 50' 30''), a place 53 kms. from Joshimath makes the starting point of the area. The distances covered were Bhapkund-Malari 12kms, Malari - Somna 21 kms and Malari - Niti 17 kms.

Access

The last point in the area approached by a motor vehicle is Malari, which is connected with Joshimath with a motorable road. The road is not yet open for public traffic. Places beyond Malari can be reached through tracks and bridle paths only. Most important amoung them are the Malari - Somna tracts and the Malari - Niti bridle path. The former, passing along the steeply sloping gorges, is difficult and dangerous especially after 8 kms. from Malari. The later, Malari - Nitti bridle path, is comparatively easy.

Joshimath is a town on Rishikesh - Badrinath pilgrimage motor road 272 kms from Rishikesh. The road is subjected to frequent road blocks in the rainy season.

Climate

The region varies in altitudes from 3000 m and high. As might be expected at such hights, Alpine type of climate prevails over the area. The summer mean temperature is below 18° C while the winter mean is below the freezing point. Precipitation is chiefly in the form of snow. Rains are not torrential but in the form of drizzling. Whole of the area gets covered with snow during the winters. In the lower portion the snow is melted by the end of March but the peaks of the mountains remain under perpetual ice cap.

Vegetation

In accordance with the climate, the vegetation in the area is of Alpine type. Three zones of vegetation can be demarcated. The portions below the altitude of 3000 metres are represented by the forests of Deodar (Cedrus deodar) and Bhujpatra (Betula alnoides) between 3000 metres and 3400 metres mixed and above this upto 4000 metres only grass and shruby bushes are found. Beyond the altitude of 4000 metres no vegetation is present and the area assumes a barren, rugged, wind-swept and frost bitten character.

Inhabitants

Niti is the last Indian village in the valley. All the inhabitants of this area who live in villages in the valley have to migrate along with their cattles to the lower places during the winter. The main but bare occupation of the people now is sheep forming agricultural crops of barley, Kota and potato are grown only in small favourable plots in the valley, but the yield is quite poor.

PREVIOUS WORK

There is no published record of geologic work in the area proper. However, a good account of geology of the adjoining areas is available. These areas include the Gori-ganga Valley and Kalinadi Valley in the Kumaon, Laptal-Sang-chamalla track, along the Kauri pass, Almora-Karamprayag track and Alaknanda Valley. The important works in these areas are due to MIDDLE MISS (1887), GRIESBACH (1891, 93), BURRARD and HAYDEN (1934), AUDEN (1935, 39), HEIM and GANSSER (1939) and GANSSER (1964). The contribution of Heim and Gansser who have taken intensive traverses in the areas lying in East, South and North-West is deserves special mention. Gansser (1964) has compiled, all the available though scanty information to complete in map.

PRESENT WORK

The geological traverses in the area were undertaken with a view to study the geology, structure and stratigraphy of Himalaya north of main axis. The engineering aspect of the geological factors affecting the road alignment, construction and stability were also studied.

The non-availability of the base maps of suitable scales had been a major handicap in detail mapping. About 200 specimens were collected and structural data were obtained in the field. More than 40 thin sections of the rocks were stu-

CHAPTER II

G E O M O R P H O L O G Y

died under the polarising microscope. The fossils collected were studied and some favourable shales examined for micro-fossils.

The geological mapsand sections were prepared (Fig. 1 to 9) and possible structures of the area delineated.

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CHAPTER II

G E O M O R P H O L O G Y

The area under investigation lies partly in the Central Himalayan and partly in Tethys Himalayan belts. Naturally, the erosion by wind and rivers is further accentuated by the frost weathering and ice. The geological action of ice had a profound impact in shaping the present physiography and the presence of moraines, evidences of river damming and avalanche fall at relatively low levels prove that ice was a very important agent in geologically recent past. Although, at present times the snow line has gone a little higher and most of the area remains free of snow during a greater part of the year, the high peaks in the area still remain snow bound through-out the year.

Frost action is a very important factor to cause the physical disintigration and although it assumes importance during winter season, it has to be taken into account as it has a great bearing while considering the road alignments. The avalanche and water are also important agents in shaping the surface features.

Gravity by virtue of great height and steep slopes is of great help to other agents in the action by bringing down the loose material to the valleys. Glacier in upper reaches and rivers in general are the most important agents of erosion and hence the general geomorphology is controlled by drainage pattern. Retrend of strike and

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A brief summary of the drainage pattern therefore, has been described in the following pages and an attempt has been made to show other factors have modified the physiography.

River Dhauli Ganga which is a tributory to river Alaknanda and its tributory river Girthi Ganga are the two main rivers flowings in this region. The rivers have cut very deep vallyys and are joined by several streams in their entire run. At various confluence points the rivers are joined by streams almost at right angle. The smaller side streams also as channels through which glacier decend during winter and it not rare to find some of these glaciers persisting to the river level even during the summers. The profile of valleys is generally asymmetrical and convex inward. The valley side is gentler on the higher elevations but become vertical at the base which indicates the accentuation of erosion by uplifting in the recent geological past (Profiles in Fig plate No. 3a,b,c,d).

RIVER DHAULI

The River Dhauli has nearly North-south trend below Bhapkund where the valley is parallel to the strike of the formations. The western slope being gentler while the Eastern one is steeper. At Bhapkund we find a huge avalanche fall from the North-west blocking the river course in the past, which has given rise to gravel deposits just above it. The river course is still not completely cleared of the avalanche debris. Here the boulders bridging the rivers serve as passage to cross the river in summer. Hot springs are reported below the Bhapkund shops just at the river level which are covered by the rock boulders and hence could not be seen. The name of this locality as Bhapkund (Bhap = steam, Kund = small water body) has its origin for the same reason.

While moving up stream the river valley is in the form of deep gorge trending North-east between Bhapkund and Malari. This is because the river here cuts across the strike of the ingected granitised Biotite quartzite. Still the valley wall on the South-east that is on Bamkosa side is comparatively less steeper than the other side which is in the form of cliff.

At Bhujgarh the valley opens into the open Malari Bowl. In this rugged and mountainous rettain the Malari and adjoining area is wide open in the form of a bowl, base is filled by glacial material mostly from the Eastern mountain slope and gravel terraces below Kailashpur. The village Malan is situated over the glacial deposits which gently slopes down. It is slightly compacted and cemented may be due to calcareous matter present in it. The stream coming from the same valley now has cut it clearing its way to the river. The eroded flanks of the glacial material display beautifully the Earthen pillars each capped by a rock boulder, which has protectected it from being totally washed down. This open space can probably be due to the fact that the thick and hard metapsammites in the south are traversed only by a narrow gorge and on the N and NE the various overlying formations are very much crushed and disturbed due to tectonic movement against the hard metapsammites, making them easy to be eroded away creating this wide open space.

The Eastern slope of Malani village is occupied by extensive soil-boulder deposit with collapsed brecciated limestone and shale boulders standing out prominently. The slope is covered by grass and thorny bushes. The ridge in the North of Malari above the confluence of River Dhauli and Girthi, shows a major land slide zone. The steeply dipping perfect joints in the shales (Martoliseries) have been responsible for providing the planes of easy sliding. It seems to have dammed the river at confluence in the past which has now been cleared but the gravel deposits, wide gravel filled valleys and slighty changed river courses just above it are the signes still present.

At village Kailashpur and on both sides of it the ground slope is having considerable thickness of glacial deposits derived from the mountain slope above.

River Dhauli before meeting the River Grithi below Kailashpur has a wide near East-west course parallel to the strike of metapsammites. upto Bampa village. Then again cutting the metapsammites through a North - south gorge. At Bampa huge old glacial deposit fills the valley brought mainly from the side valley coming from North -west (NW). It has now been dissected by that valley stream and River Dhauli. On the other side of the gorge lies the village Niti, the last Indian village in the valley. From there again the river valley is nearly parallel to the strike. The South-western flank of the valley is the dip slope of metapsammites and other one which is steep partly of metapsammite the lower half and rest of the overlying formations. At Niti the valley is wide but of lesser dimensions as compared to that at Malari.

RIVER GIRTHI

The genmal trend of River Girthi is east-west. But before joining River Dhauli its course has a accute shape, its convesity towards North-west. In this part the valley is wider and gravel filled. Then the valley becomes normal narrow and asymmetrical. The Southern flank that is the left side of river is being dip slope is gentler and is covered with scree material. Other flank is near vertical. Beyond 8 kilometres from Malari the valley becomes deep and gorgeous the climax is reached near Girthi dobla where the river has cut a vertical gorge more than 500 metres deep. River Girthi is joined from North by R. Kaiogad at Girthi dobla. This comes from laptal Somna side and cuts the steeply dipping limestone and shales, through a deep gorge (Photo No. 1).

Beyond Somna R. Kaiogad has its Southern slopes gentler mostly due to the dip slope and soft black shales formations.

At Somna the R. Yonggad coming from Rimkhin side meets the Kiogad. The western valley slopes of R. Yong-gad is gentler (dip slope) and covered with scree material

CHAPTER III

GEOLOGICAL SETTING

The rocks encountered in the area are biotite-quartzites with quartz-biotite schist bands showing extensive granitization and tourmaline - pegmatite tykes are overlain by various types of sedimentary rocks, metamorphosed to various degrees and bälonging to different geological horizons. Some of the upper sedimentary formations, that is limestone and shales are fossiliferous to varying extents. The fossils in the most of the cases are inidentifiable except the upper most black shales which has rich Triassic fossil assemblage. A complete lithological succession with possible age correlation is given below :

Succession

Series	Lithological Units	age
	Glacial and river gravel deposits -	Pleistocene to Recent.
	~ Unconformity ~	
Black shales	Black shales with limestone bands	Triassic (Muschekalk)
	~ Unconformity ~	
Muth Series	Snow white quartzite Red Calcareous Quartzite	Devonian

Somna Series	Nodular limestones with subordinate bands of green shales and fossiliferous limestones (probably crinoidal limestone) Pink shales with subordinate limestones White to grey thinly-bedded marls with distinct shaly bands Green limestones with subordinate shales	Silurian
	~ unconformity ~	
Shiala Series	Red and Green shales and limestone showing perfect pencil fractures and crushing towards upper part	Ordovician
Garbyang Series	Dark ferruginous arenaceous limestones Brown arenaceous limestone (fossiliferous) Phyllitic slates Brown weathering buff dolomite with bands of weathered yellow clayey material Orange spotted greenish quartzites (pyritiferous) Greenish and purple quartzites with basal Ralam conglomerates	Cambrian
	~ unconformity ~	

Martoli Series	Black arenaceous phyllitic slates with thin brown ferruginous bands Green phyllitic slates with sub-ordinate quartzitic bands, (pyritiferous).	Pre-Cambrian (Algonkian)

~ Unconformity ~

Biotite Meta-psammites	Granitised Biotite metapsammites — Biotite - quartzites with bands of quart - biotite schist showing granitisation and pegmatite veins and dykes	Archean

LITHOLOGY

THE BIOTITE META-PSAMMITES

The rocks belonging to the metapsammite series are mainly thick biotite-quartzites with quartz biotite schist bands showing a varying degree of felspathisation. The original bedding planes of quartzites are rather faithfully preserved, although no other sedimentary structures could be seen. These are locally folded and occasionally faulted but their general character is same between Bhapkund-Malari-Niti sections. At places in situ alteration, thick soil mantle over them is present in the lower reaches but are bare on the peaks. The biotite seems has been formed out of the original suitable sedimentary minerals constituents by the progressive regional metamorphism. It shows preferred orientation parallel to the bedding but due to less in amount schistosity is not markedly developed in quartzites. At some places, it has also been observed that a white flaky and fibrous mineral having a resinous lustre has also developed, particularly along certain shear planes. This mineral, appears like kyanite in the thin sections.

These meta-psammites are continuations of the augen gneiss and quartzites belonging to the central crystalline series of Heim & Gansser (1939) which is thrusted upon the younger limestones, slates and quartzites at Helaung (6 miles SW of Joshimath) and which are taken as pre-Cambrian, equivalent of Jutog series. The rocks show, a general felspathization and have been traversed by tourmaline-pegmatites dykes and veins with occasional crystals of beryl (rare). The pegmatites dykes are not very large or extensive as far as their dimension is concerned, the largest encountered in the area having a width of about 3 m. very coarse quartz, feldspars, muscovite and tourmaline are the main main mineral constituents of these pegmatites. Small quartz-tourmaline veins are also common, particularly the lower horizons.

The rocks show local intense folding, particularly in biotite rich zones, but the quartzite do not show any intense folding. The general dips vary from 20° due N 20 E near Bhapkund to 35° - 40 due E near Malari. Below Malari Dak Bungalow the dips are 45° due S 80° E (local) but at Kailashpur, the dip changes to 49° due N. These are highly jointed and some small movement along some joint planes has also taken place. The vertical joint planes across the formations are the controlling factor for the formation of Malari Bhapkund gorge.

The meta-psammites series is overlain by Martoli series and near the contact the intense granitisation is very characteristic. The contact plane shows crushing of both the formations and runs approximately N-S through Malari Kailashpur and Niti villages. The marked difference in grade of metamorphism; the strike and dip of the meta-psammites and Martoli formation and crushing points not only towards their being of two different ages but considerable relative movement, Martolis having moved over the meta-psammites. The plane of movement being approximately parallel to the bedding of meta-psammites. The felspars near the contact have been Kaolinised, quartz develops corrugated margins and greyish blue crystals of tourmaline become conspicuous. The granitisation is not seen in the Martolis, some quartz veins, however, are continuing in them.

MARTOLI SERIES

The name Martoli Series was proposed by Heim and Gansser (1939) to include less metamorphosed "calcareous and non-calcareous phyllites, with quartzite layers" which are "joined to the underlying crystalline series not only by a passage in decreasing metamorphism upwards, but also by some of the last pegmatite dykes". In the present area the series of green and black phyllite slates with subordinate and quartzite bands whibh come in direct contact of the meta-psammites are taken to represent the Martoli Series. The nature of the contact between the two series has already been described and it is thought that due to the movement the lower and upper members of the Martoli series are not visible in the area. The fact that Martoli Series is overlain by Ralam conglomerates and quartzites of Garbyang series, the position of Martoli Series is more or less well defined as in Kumaon Himalaya. Since, both the Ralam Conglomerate and quartzites of Garbyang series contain certain characteristic lithological units, which have been found in this area also, the author has taken the green and black phyllitic slates with subordinate quartzite as representatives of Martoli Series in this area.

The stratigraphic position of black arenaceous slates exposed at 8.5 km from Malari towards Girthi dobla due to faulting have also been placed at the top of Martoli Series for the reasons of their dip (40° due N40 W) and the overlying Ralam conglomerates. The quartzites are also greenish with varing amounts of argillaceous contents. The quartzites shales and slates are pyritiferous. The shales showing yellow encrustation at many places. Quartz veins are also quite common in these formations.

The Martoli Series shows minor folds. The plunge of the fold axes varying between 12° due S 15° E to 21° due S 15° W. Minor fault along joints is quite common. Several shear zones are also developed. Six to seven sets of joints are usually present, which because of their close spacing and perfect nature have resulted into the smooth angular fragmentation of the rocks. The total thickness of Martoli formation in this area is not more than 200 m. being thinner near Niti village.

Garbyang Series

The Martoli series is overlain unconformably by the Garbyang series with basal Ralam conglomerate. A greater part of the Garbyang series was earlier described by Heim and Gausser (1939) as Ralam series and it included the basal conglomerate with quartzites and dolomites. Garbyang series was thought to lie conformably over the Ralam series by them (op. cit.) Gansser (1964), however, does not regard the unconformity of the Ralam conglomerate very significant "in spite of its interesting stratigraphic position (p.117). During the present investigation the latter view was found to be correct as the Ralam conglomerate show frequent lateral and upward variation. Some times these are deep purple conglomerates with purple, buff, white and greenish quartzite boulders, 5 cm. to 30 cm. in diameter, in a greenish or purple matrix. But at other times the gradation is through greenish conglomerate into greenish quartzites. But at all the places they overlain by pyritiferous orange spotted quartzites. It has been therefore decided to include the conglomerate as the basal part of Garbyang series. But as the conglomerates, when present, mark a distinct horizon it was decided to keep the nomenclature of the conglomerates as Ralam conglomerates. The maximum thickness of the conglomerates in this area is about 100 metres but pinches out in Nitti area, which may be due to tectonic reasons also

The Garbyang series is separated from Martoli series by a clear unconformity marked by Ralam conglomerate at most of the places, but also by the orange spotted quartzites near Niti village. The plane of unconformity has acted as the plane of movement in which conglomerates have moved over the Martolis which is evident from the crushing the latter along this contact.

The dip of the conglomerates varies between 28° to 35° due N 55° - 80° E. At some places however dip changes between 30° to 80° due E, particularly after the fault at about 6 km. E of Kailashpur.

The Ralam conglomerate series is conformably overlain by a succession of brown spotted quartzites, brown-weathering bluish dolomite, limestones, with subordinate shales, phyllitic slates red calcareous sandstones (fossiliferous) and thinly bedded dark ferruginous limestone forming a thick conformable succession.

In Niti area, where Ralam conglomerate series has pinched out the orange-spotted quartzites rest over the Martoli slates which themselves have thinned out in this region. This thick succession of rocks has been taken to belong to Garbyang series following Gansser (1964). The Garbyang formation have been described by Heim and Gansser (1939) as north dipping monoclines of 4.5 Km thickness in Kali section and 1.5 Km. thickness in Gori valley. The regularity of dips in the above section had led them to believe this thickness to "correspond about to the original thickness" (p. 203).

These rocks show many small and minor folding and are major Monocline (Girthi Monocline - Photo. Nos. 1 and 2, Fig. Plate No. 4). Some small normal faults doubly plunging folds and slicken sides are also present. One important observation noted in the field was that the north - dipping limbs are fairly uniform and extend through out the ridges upto top, but the anticlinal arches are visible generally towards the higher top of the ridges. It is, therefore quite possible that the monoclinal structure seen be Heim and Gansser (1939, Gansser 1964), in Kali and Goriganga sections are probably similar folds, with their tops eroded and hence folding being rendered inconspicuous. Summerising, it can be said that the enormous thickness of the Garbyang series is less than that postulated earlier may be of the order of 1000 m.

The orange brown- spotted quartzites contain crystals of pyrite and the orange spots are due to the alteration of pyrite into limonite. These are chiefly chlorite sericite quartzites with clots of argillaceous matter. The brown-weathering dolomite (= Girthi Dobla dolomite) is the thickest horizon in Garbyang series. It is a bluish buff ~~arenaceous limestone~~ with ferruginous impurities and is slightly dolomitic. The weathering of this limestone lead to the formation of limonite which occur either as leaching or as a brown cover over the rocks. On both sides of Girthi Dobla there are several large pockets of limonite rich clays, which have naturally been resulted due to alteration of these dolomitic limestones. The brown colour is often so much overwhelming that the bluish buff character of limestone is rendered insignificant. These limestone contain several thin slaty bands which are slightly chloritic in nature. The anticlinal part of these thick dolomites after the core materiol is removed by weathering have formed small caves at Girthi-Dobla and facilitate the overnight stay in the area. The overlying phyllitic shales are characteristic as they separate the thick dolomites from the fossiliferous red arenaceous limestone which are fairly bedded with frequent quartz and calcite veins traversing along joint planes. Their general dip varies from 35 to 40° due N 48°E. Local flexures and small folding are also present but the major structure is the same monocline (Photo. Nos. 1, 2). The current bedding in some more arenaceous bands indicates a normal sequence. These rocks are highly jointed and some places form dip slopes (Photo. No. 12).

The whole series is traversed with mineralised quartz veins but these are more prominent in the conglomerates and quartzites dolomite (Photo. No.   ).

Shiala Series

The Garbyang series is conformably overlain by red and green shales with subordinate calcareous bands. The rocks are highly jointed and fractured especially the shales which show pencil fracturing. On the basis of their shaly nature and straitigraphic position, these shales are supposed to correspond to Shiala series of Heim and Gansser (1939). These formations have general dip of 40° due N 40° E and show minor folding and warping. Some calcite veins are present along the joint and fracture planes, some times with traces of chalcopyrite.

Somna Series

The name Sómna series is proposed for a series of greenish limestones, gray fossiliferous limestones with thin shale lenticular, white, yellowish and pink shales and fossiliferous dark gray nodular limestone with subordinate green shales. The entire series overlies conformably the Shiala series. The upper limit of Somna series is clearly demarcated by the overlying red calcareous quartzite and white quartzites having unmistakable affinity with Muth series. The name "Somna" series has been proposed as the rocks are very well developed around Somna. The necessity of proposing a new name arose chiefly because the equivalent formation of these series in other areas was called by Griesbach (1891) & Pascoe (1959) as "Red crinoidal limestone", by Heim and Gansser (1939) as "variegated silurian" and by Krishnan (1960) as "Variegated series". Gansser (1964) has not given any name for these rocks, except mentioning the fossiliferous red crinoidal shaly limestone (pp.107, Fig 65). In Somna region it was observed that the shales of various colours form different horizons. The limestone bands in shale are fossiliferous but towards the top the limestone form comparatively thicker bands, show dark grey colour and acquire nodular character. All the rocks are conformable, but have unconformable contact with the overlying Muth series. The author has, therefore, grouped all the rocks between greenish limestones and dark grey nodular limestones in one group as Somna series. This also confirms the belief of Heim and Gansser (1939) who regarded the nodular limestone found on the top of Mangshang pass forming the Tibetan border and at Dung as "more probably, a special north facies of Silurian" (pp. 204) in contrast to Griesbach who regarded it "tentatively as Devonian" (Heim and Gansser, op. cit.). The so called red crinoidal limestones were also found to be brown-weathering bluish grey limestones.

The contact between Shiala series and Somna series could not be studied in the field due to inaccessible exposures. But as in contrast to ENE dips of the Shiala series, the rocks of Somna series dip at 10° - 32° due NW, the latter may be taken to rest over the Shiala series with slight angular unconformity. Just near the upper contact with Muth quartzites these are intensely deformed and minor drag folding has developed. The total thickness of Somna series is apploximately 600 metres.

Muth Series

Muth series consists of a basal red calcareous quartzite with overlying white quartzite and rest unconformably over the Somna series. The exposures are first met with at about 3 Km from Sumna towards Laptal. These red quartzites are fairly bedded, well jointed and highly crushed at lowr contact with rocks of Somna series. This contact is very sharp (Photo. 10).

The white quartzite is thickly headed, highly jointed and distinct even from a distance for its snow white colour. The joints have given rise to perfect blocks (Photo.No. 9). The Muth quartzites being hard are not thrown into minor folds. The average dip of these quartzites is 20° N 70°E. The total average thickness is nearly 150 metres. These rocks correspond to the Muth quartzites of Spiti (Pascoe, 1959) and hence have been correlated together.

Black Shales with limestone Bands

The Muth quartzites are overlain by crumpled and folded black shales with black limestone bands in Somna area. At places these have aquired slaty cleavage. These on weathering give greyish black soil. The limestone bands are having a white encrustation on the surface and give a almost continuing step like appearance (Photo. No). In other areas like the top of Kailashpur hill in NNE the grey black shales are directly overlying. The limestones and shales as seen from Malari. The white quartzite is not seen here. It can, therefore, be concluded, as also reported by previous workers that the black shales and limestones are unconformably overlying all the lower formations.

Both black shales and limestones are fossiliferous but the former is richer in fossil contents. The fossils include many varied forms, the ammonites being predominating. Fossils collected in a black shales horizon a little higher than the lower contact with Muth quartzites, at about 6 Km. short of Rinkhim comprised mainly of well preserved and fragmentary ammonites. These were identified as follows and form the part of Himalayan Muschel-Kalk fossil assemblage.

Sp.No. 4/183	<u>Meekoceras affine</u> Mojsisovics
Sp.No. $4/183^{A}$	<u>Ptychites cf. rugifer</u> Oppel
Sp.No. $4/183^{B}$	<u>Ptychites sumitra</u> Diener
Sp.No. $4/183^{C}$	<u>Orthoceras cf. Campanile</u> Mojsisovics
Sp.No. $4/183^{D}$	<u>Orthoceras</u> species

Palaeontological determination were made by the courtesy of G.S.I. Palaeontological Laboratories, Calcutta.

The black shales were treated by different methods that is with Hydrogen - peroxide, 30% (20 volume), and sodium-carbonate in cold and also by boiling then crushed and sieved, to liberate microfossiles, if any. But inspite of the fact that such type of rocks are favourable for microfossiles, no foraminifera and ostracoda were found to be present. However, some siliceous sponge spicules and calcareous tubes were seen, which do not point to any definite age of the formations. The thin sections also does not show any section indicating the presence of microfossils. The absence may be due to the great paucity of microfossils especially the foraminifera in the triassic strata in all the parts of the world. This may also be due to the antipathy of foraminifera with sponges, of which an example is seen in the Cretaceous stratigraphy of NW Europe where the horizons rich in sponge material yield little or no foraminifera.

STRUCTURES IN OUTLINE

The rocks are in the area are of sedimentary origin, metamorphosed to varying grades and fall in a zone of strong compressional stresses. The structures of the area, therefore, are the reflection of all these factors. The important structural features will be described in these pages.

Regional Struscutres

The contact between the various formations of different series form the regional structure. The nature of the contacts have already been described in chapter along with the description of Geology and lithology except for the contact between the Garbyang and Shiala formations all are of unconformable nature. The strong compressive forces have moved up all the formations along these planes over the just underlying ones. Thus the movement is like that of reverse fault. The exact estimate of total movement can not be made but from the general observations it seems to be considerable. There is possibility of similar differential movement along some of the bedding planes but this could not be seen in the field due to other disturbing elements.

Major Folds

Girthi Monocline is the major local structure in the area. Its northern limb rises up steeply from the depth and becomes gently dipping from the hill tops, (Photo No. 2). The direction of the dip of both the limbs is same only the amount is different. Its axis is plunging with a low angle in the direction N35W. This is a major evidence of compressional forces in NE - SW direction.

<u>Minor Folds</u>

Minor folds are well developed in the dolomite in Girthi dobla area. All of them are plunging asymmetrical folds with northern lime dipping with an angle of 70° while the southern one with 10° (Photo. Nos. 4 ,5). These have been developed on the limbs of major monocline. Therefore, broadly conform with the geometry of the monocline. Their plunges very in amount from 10° to 15° in the direction N15° W to N 40° W. Some flexures are also present in these rocks (Photo. No. 6). At Somna the limestones and shales of Somna series have been folded into a asymmetrical anticline having the similar features as those in Girthi dobla area (Fig. 4). Doubly plunging and cross folds are also present in the Girthi dobla area. One such cross fold has its plunges 10° due N 70° W and 7° due S 25 E.

Minor folds are also present in the Martoli phyllitic slates and quartzites. One such fold is seen at 3 km. from Malari towards Girthi dobla. These are also asymmetrical with southern limb steeper and plunging with an angle of 20° due S 15 W. Some of the joint planes are also folded there by showing that these joints are pre-folding in age. The biotite schist bands in metapsammites are highly contorted and complexly folded. It is because of these are incompetent in comparison to the massive hard biotite quartzites (Fig. 7).

The point diagram of plunge of "b" lineation (Fig. No. 6) axes of the folds and puckering shows maximum concentration in the N to NW direction which shows that the major direction of latest force as at right angle to it. Other directions of maxima are in NNE, ENE and ESE but are not so conspicuous because of the less number of points plotted on the diagrams. There are a series of southerly dipping step faults met with in the area particularly between Malari and Girthi dobla i.e. in the Garbyang formations.

<u>Faults</u>

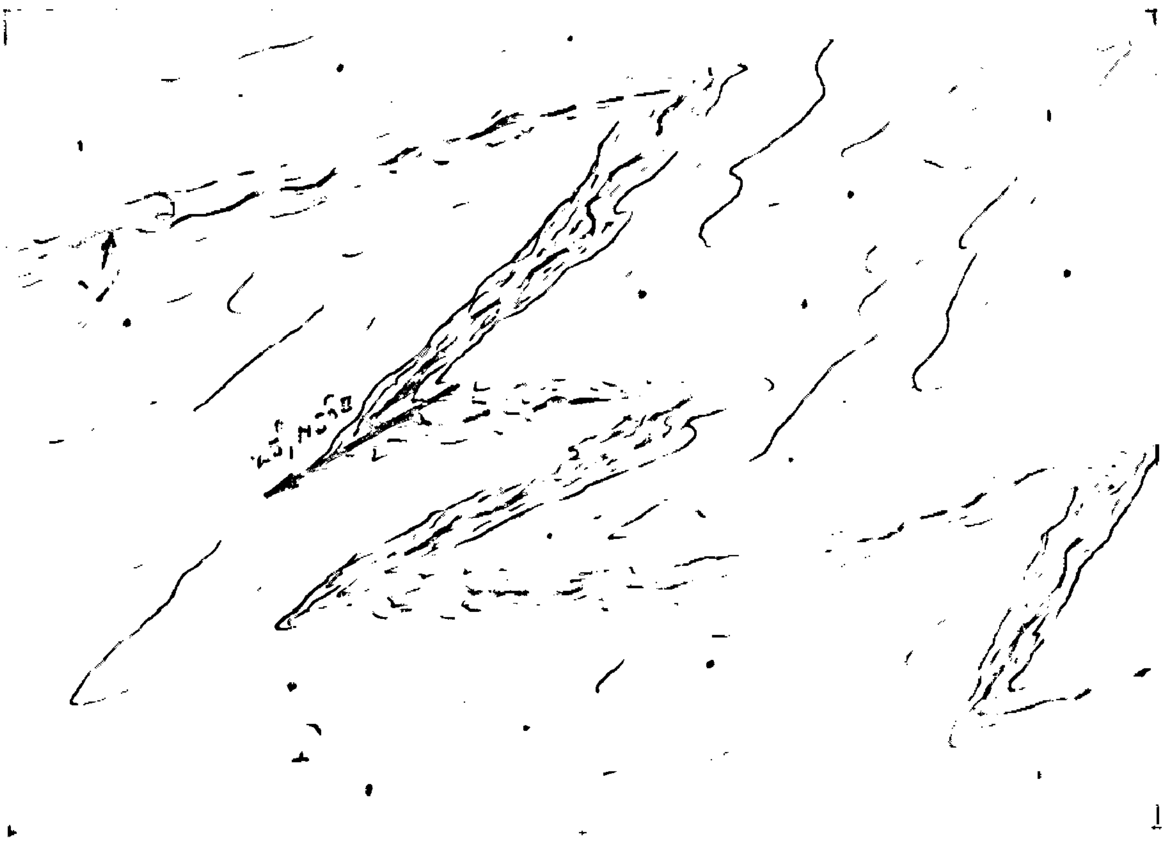
The fault planes have an average dip of 40 to 45°. The spacing among them is variable. The spacing between the faults and the amount of throw is small in the Girthi dobla area where these are best exposed on the limb of monocline in the gorge (Fig. 4), and also at 9 km. from Malari (Fig.5) Some almost horizontal fault planes are also present with hanging block moved forward.

There are other faults with relatively large throw. (Fig. 3, a, b, & c) one with largest throw is present at 8.4 km from Malari where the two glacier valleys meet the

HIGHLY FOLDED BIOTITE SCHIST BAND

IN META-PSAMMITES

(NEAR BAMKOSA)



SCALE - 1 cm = c 15 metre (APPROX.)

LEGEND

1. GARNETIFEROUS BIOTITE-QUARTZITE

2. BIOTITE SCHIST BAND

3- THIN QUARZO-FELSPATHIC BAND SHOWING PINCHING & SWELLING

FIGURE _ 7

Girthi River. The hanging block has moved down taking the Ralam conglomerated to deeper level and the quartzites abutting against the Martoli phyllites and quartzites (Fig. 4). These quartzites show drag folding near the plane of movement which also indicates that the hanging wall has moved down (Fig. 8). In an area of strong compression the faults with normal throw are quite interesting. The cause of their formation may be the released stresses after the main orogenic activity subsided.

At many places in the metapsammites minor movement has taken place along the joint planes (Fig. 9). Shear planes and zones are also quite common.

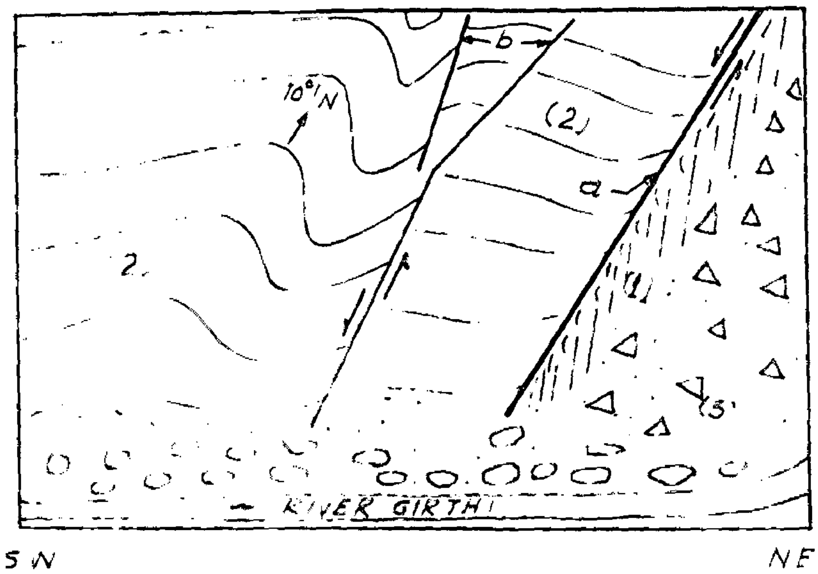
Slicken Side

The differential movement along the planes in faults and on the limb of folds is indicated by the slicken sides. One fine example of such slicken sides was seen at 2.5 km from Girthi dobla over the steeper limb of monocline with a plunge of 45° due N 30° and are accompanied by fine tranverse puckering (Photo No. 8).

Primary Sedimentary Structures

Among the primary sedimentary structures the current bedding and ripple marks are commonly seen in the area. Current bedding is seen in the brown spotted quartz-

CLIFF SECTION AT 8 KMS FROM
MALARI TOWARDS SOMNA



LEGEND —

3. MORAINE DEPOSIT

2 - SPOTTED QUARTZITES (GARBYANG SERIES)

1 - CRUSHED PHYLLITE (MARTOLI SERIES)

(a) MAJOR FAULT

(b) SMALLER FAULTS

FIGURE _ 8

MINOR FAULT SHOWING DISPLACEMENT ALONG JOINT PLANES IN META-PSAMMITES NEAR BHAPKUND

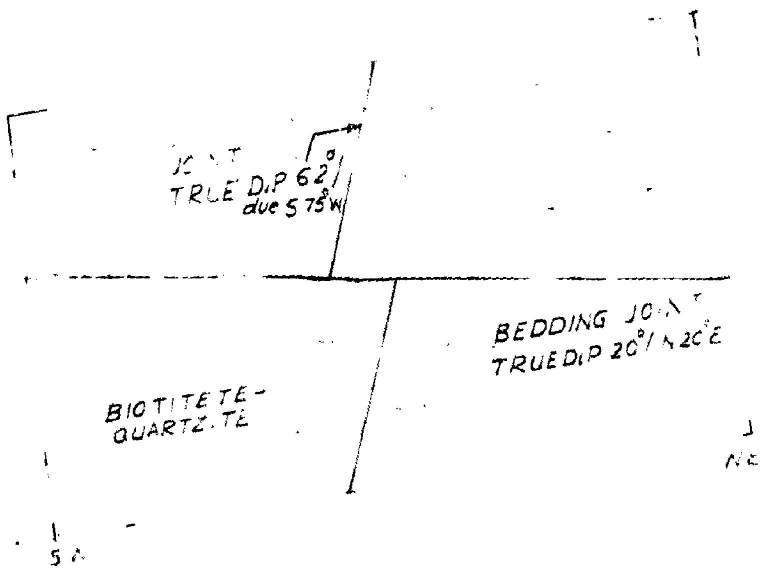


FIGURE – 9a

MINOR FAULTING ALONG MAJOR JOINT PLANE IN META-PSAMMITES, SHOWING DISPLACEMENT OF BIOTITE SCHIST BAND
(NEAR BAMKC5A

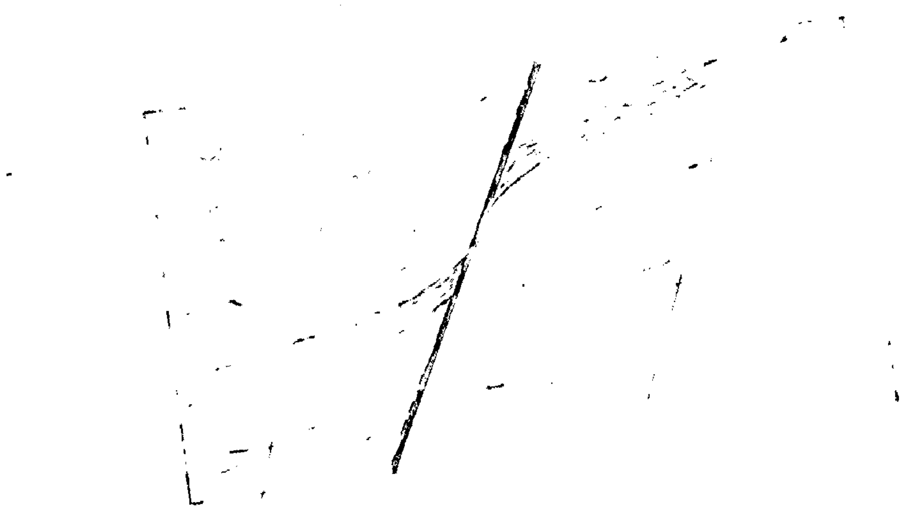


FIGURE – 9b

ites (at 7.9 km. from Malari) and the arenaceous limestones of Garbyang series. All these show the palaeocurrent direction towards the east and normal sequence that is right side up.

Ripple marks are quite common in the shaly limestones of Shiala and Somna series. These are of oscillatory nature.

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MINERALISATION

Mineralisation of copper, baryles and magnesite has been noted at certain places. The copper sulphide mineralisation is due to the hydrothermal fluids while baryles and magnesite were formed by the solution and precipitation mainly by meteoric waters.

Copper Sulphide Mineralisation

Copper is found in the form of sparsely dissemi-nated and filling of sulphides mainly chalcopyrite accompan-ied by pyrite along with quartz veins in the rocks of Garb-ynag series and other underlying formations. Dolomites and conglomerates are having relatively higher concentration. In the dolomites the sulphides are present in disseminated form and fracture filling, while in conglomerate fracture filling is more predominant. Some old copper working are also present in the conglomerates on both sides of river Girthi at 9 km from Malari and many other reported by the local people. The bluish leaching is very common phenomena. At times the calcite veins in limestones of Shiala series show a few chalcopyrite grains.

Barytes

Its insitu occurrence could not be found but rolled boulders are present, especially in the dolomitic scree just at nearly 7 kms. and glacial material at 8.4 km from Malari towards Suman. It is almost white and sometimes the boulders show sheared laminae.

<u>Magnesite</u>

Magnesite boulders are also found in the scree material. At one place nearly 500 metres from Malari on Topidunga track the colloidal magnesite deposition was seen in the fractures in phyllitic slates of Martoli series. The concentric thick rings one being more whiter and other translucent.

A few plates of a black metallic mineral are present in the quartz veins in the metapsammites and Martoli which is probably wolframite.

All these minerals are but of academic interest because of sparsely disseminated occurrence. Copper mineralisation of course may draw some interest from economic of view but the surface indication are not in encouraging. The under ground prospecting may lead to some discovery.

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CHAPTER IV

P E T R O G R A P H Y

INTRODUCTION

The rock types belonging to the different strati-graphic horizons have been found to show usually distinct characters, although at times a few of them resemble very much, particularly those belonging to the less metamorphosed sedimentary rocks of the papaeozoic and later times. The oldest rocks of the area the biotite-metapsammites, are however, very different from the others, because of their higher degree of metamorphism.

The petrography of the rocks occurring in the area will be described in this chapter on the basis of the strat-igraphic units, rather than on the basis of rock types. This has been done in order to have a clarity of presentation.

1. GRANITISED-BIOTITE METAPSAMMITES

The rocks are comprised mainly of thickly bedded biotite quartzite and bands of quartz biotite schist of varying thickness. These are granitised and traversed by pegmatite veins and dykes. Granitisation is more pronounced near the upper contact with Martoli formations.

Biotite metapsammite

Megascopic characters - These are light coloured medium to coarse grained rocks with biotite flakes showing parallel arrangement. When the amount of biotite increases the schistosity becomes conspicuous. Quite frequently the closely spaced biotite rich bands give it a gneissic character. At places especially near. Nitti gorge and Bhapkund there are some light coloured thin quartzofelspathic bands in biotite schist which give it a streaky character. White and fibrous kyanite has developed along the planes of shearing in the rock.

Microscopic characters -- In thin sections the rock is medium to coarse grained. Grain boundaries are subhedral to anhedral and quartz grains show some preferred elongation. The rock shows granoblastic texture with varying degree of schistosity due to parallel arrangement of biotite flakes.

Biotite metapsammites consist mainly of quartz felspars biotite and small amounts of garnet kyanites muscovite and chlorite. Quartz occurs in slightly elongated and anhedral grains with slight to strong undulose extinction.

The felspars are comprised mostly of plagioclase and little of orthoclase. Plagioclase grains also subhedral to anhedral polysynthetically twinned. On the basis of the extinction angle with albite twinned lamellae, the maximum anorthite content has been found to be An 9. Orthoclase is present in anhedral grains and shows simple twinning.

Biotite occurs in dark brown flakes and shows strong pleochroism from light brown to dark brown. The leaching of biotite is quite frequent with the result that some times nearly half of the lamellae is brown and the rest is colourless. Biotite is at times altered to chlorite on the margins.

The biotite content shows progressive increase with corresponding decrease of felspars and quartz as the rock acquires more schistose character. Kyanite, in addition to the megascopically prominent form (Microphoto. No. 13) is also present in the biotite schist section (Thin section No. 4/274, microphoto. No. 14) as fine acicular aggregate with preferred orientation parallel to schistosity. In most of the cases the extinction is parallel but some needles show extinctions upto 30°. Chlorite and muscovite are present in discontinuous mass some times merging with the biotite grain boundaries.

In one thin section (No. 4/277) calcite was noticed along with biotite,chlorite,muscovite and plagioclase.

Tourmaline, apatite and zircon are occasionally present.

Granitised portions of metapsammites

The texture of the rocks is porphyroblastic. The porphyroblast of albite and tourmaline are embedded in an almostgranoblastic groundmass (Microphotograph No. 15) The various minerals which are recognised in the thin slide are albite, quartz, perthite, tourmaline, muscovite, biotite, chlorite, seracite, apatite, rutile and magnetite. Albite is the most conspicuous mineral in the slide. It occurs in subhedral to anhedral grains. It shows an alteration to sericite. The myrmekitic intergrowth between quartz and biotite albite is also seen, although this is not common.

Quartz occurs in two generations. The quartz of the first generation occurs as small grains with sutured margins, and often occurs as inclusions in albite, muscovite or tourmaline. The quartz of the second generation occurs as irregul intergrowth filling the intragranular spaces (Microphoto. No. 15).

Perthite - The perthitic intergrowths between orthoclase and albite are seen in several grains. The perthites occur in anhedral grains and are seen altering to Kaolinite.

Tourmaline - Tourmaline occurs as large crystals having inclusions of quartz and kaolinised orthoclase. The pleochroism is from neutral pale brown to greyish blue. At times several detatched tourmaline grains have crystallized separately, but these grains have optical continuity. It seems that tourmalinisation has followed the formation of albite and the alteration of felspars.

Muscovite, biotite, chlorite, sericite are the minerals which occur in small amounts and are largly of secondary origin. Apatite and rutile are accessory minerals. Some highly folded bands with opaque mineral are present which are probably the original bedding planes with iron oxide. The complex folding of such bands reflects the intense deformation which the rocks have undergone. At places sericity is also present along these bands.

Pegmatitic veins and dykes

Numerous dykes and veins of granitic and pegmatitic material with muscovite and tourmaline traverse the biotite metapsammites in all directions. At places the pegmatite dyke is of 3 - 4 metre in width.

The quartz is snow white in colour. The felspars are perthitic whose plagioclase component is albitic in composition. The plagioclase is forming microscopic irregular and branching veins within the orthoclase. Tourmaline is dark in colour and the long column or crystals of it are oriented in all directions. It some times has traces of chalcopyrite.

Muscovite is colourless to milky in colour and quite frequently has hexagonal outline.

At the contact with country rock (metapsammites) garnet has also developed which has inclusion of quartz.

Beryl could be found present in association with quartz,felspar and garnet in pegmatitic vein in a rolled metapsammite boulder at Bamkosa. In it the beryl though less abundant but is present in well shaped hexagonal columner crystals.

2. MARTOLI SERIES

The rocks comprising this series are black and green arenaceous phyllitic slates with argillaceous quartzite bands.

Green Arenaceous phyllitic slates

Its main constituents are fine grained chlorite sericite and muscovite with quartz grains embedded in it. The chlorite sericite and especially the comparatively larger muscovite flakes show a preferred orientation but without distinct rock cleavage. The quartz grains are irregular in outline and some show strong undulose extinction. Pyrite porphyroblasts are also present.(Microphoto No. 16)Limonitic staining is present preferably along the weak planes. Rutile is present as heavy mineral.

Black phyllitic slates

The rocks are black slates tending towards phyllite. The slaty cleavage is well developed and microwarping and fracturing has taken place due to tectonic disturbances (Microphoto. No 17).

The rock is comprised of quartz grains embedded muscovite show preferred orientation. There is seen the microscopic compositional banding with some bands more rich is quartz than other. The limonitic staining is generally more in more sandy bands.

3. GARBYANG SERIES

The rocks belonging to this series are comprised of purple, and green Ralam conglomerate quartzites, brown weathering dolomites, arenaceous limestone and subordinate phyllitic bands.

Ralam Conglomerate

The boulders are large rounded and embedded in the sand size recrystallised matrix. The boulders are of white, greyish and micaceous quartzites which are very hard and do not show any noticeable elongation.

The white quartzite boulder is very fine grained, x with brownish yellow spots and has small cavities. The thin sections (No. 4/252), under the microscope show fine grained granoblastic texture. It consists mainly quartz. The quartz grains are subhedral and equigranular. Some spots of browish yellow jasper are also seen. Only a few small muscovite flakes are present. This composition and texture can throw light on its source.

The micaceous quartzite boulder (Thin section No. 4/252A) consists of anhedral quartz grains embedded in fine grained. Matrix consisting of chlorite, sericite and small muscovite flakes. Tourmaline is present probably as detrial heavy mineral. On the basis of the similarly in the composition and texture with the Martoli quartzites, it may be inferred, of course, not with certainty, that these micaceous quartzite boulders were derived from the Martolis.

Brown spotted quartzite

These are purple and green quartzites with brown limonitic spots. The original colour seems to be greenish changing to purpăo due to purple coloured iron oxide (hematite) leaching over it.

Under the microscope the anhedral quartz grains are present with argillaceous matrix. Chlorite and sericite form the matrix and often they occur as clots. Chlorite changing biotite is also exhibited in some grains in which central part is greenish with brownish zone on the out side. Muscovite is present as laths and is quite distinct from the matrix. A few grains of plagioclase, identified by the lamellar twinning, are also present.

The pyrite is present in perfect bubic and pyritohedral crystals, partly altered to limonite. In some of the cases, the crystal outlines are well preserved and the limonite occurs as pseudomorphs.

Tourmaline, kyanite and rutile are the important accessory minerals and appear to be original detrital grains

Brown weathering dolomite

It consists of thickly bedded dolomite band with thin greenish white phyllitic bands. It shows brown weathering on the surface but inner unweathered portion is bluish buff coloured.

It consists of well crystallised carbonate grains, coarse grained with subhedral boundaries. The texture of the rock is granoblastic. Only a few carbonate grans show calcite type twinning. A few quartz grains are also present here and there and their boundary showing replacement texture with carbonate material.

Limonitic staining and patches are the cause of brown weathering colouration. Some grains are showing more limonitic alteration in the around the grain boundaries. These may be rich in siderite content which may be the main reason of extensive brown weathering.

Greenish white phyllite

These show slaty to phyllitic cleavage and fine lamination parallel to the bedding. These laminations are reflection of the microscopic banding of chlorite rich and muscovite rich compositional banding. An interesting structure is seen in the thin section (No. 4/220) of the phyllite bands. In which the lamination is cut across by a straight edged quartz rich chlorite sericite veins (Microphoto. No. 18). The anhedral quartz grains are embedded in the chlorite sericite matrix. The width of the veins is fairly uniform and appear to be filling in the fractures or joint planes. These are reflected on the surface by minor ridges. Since these phyllites are with in thick dolomite bands the presente of quartz chlorite sericite filling is difficult to explain but probably it is penecomtemporeneous phenomena.

Fossiliferous Arenaceous Limestone

These are overlying the brown buff dolomites and are fossiliferous ~~but~~ the fossils are so obliterated that they can not be indentified.

It consists mainly of carbonate calcite, quartz and little of argillaceous material. The carbonate matter consists of calcite which is mainly cryptocrystalline but some times recrystallised, coarse grains are also present. The fossil sections are of pure coarse calcite. The quartz grains are with crenulated margins showing replacement texture with the calcitic matrix.

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4. SHIALA SERIES

The limestones of this series are constituted of cryptocrystalline calcite embedding varying amount of quartz grains and elongated chlorite sericite patches. The quartz grains are with cranulated margins and show replacement texture with the calcitic matrix. Fossil sections are made up of pure coarse grained calcite.

Some limestone thin sections show microscopic compositional banding whereby in some bands quartz appears in significant amount. This banding is not sharp in vertical direction but is gradational.

The lower horizon (thin section No. 4/207) some elliptical to circular sections of purer calcite are present with diffused outer boundaries. The absence of concentric circles in them does not permit them to be identified as oolites. These may however be the section of some limestone pellets or remains probably the crinoidal spines.

5. SOMNA SERIES

The various limestone and shale bands are having distinct colours but in some the colour distinction is not very sharp. The petrography of main type of limestone and shales in general have been described here.

Grey limestone

The greyish limestone (4/193) and contains quartz grains embedded in cryptocrystalline carbonate matrix. A little argillaceous material that is chlorite and micas is also present. It shows microscopic compositional banding with some bands richer in quartz and argillaceous matter.

Whitish limestone

The whitish limestone exposed just near the confluence is more arenaceous and calcitic matrix is comparatively coarser. This also show microscoping compositional banding and also monograin thick quartz bands in which grains are coarser and margins well fitted with adjacent grains. Some chlorite and micas are invariably present.

Fossiloferous Noduler limestone

It is grey to dark grey in colour and fossiliferous thin banding of light and dark colour and fossil rich material is present.

The colour banding is the reflection of compositional variation. Some are relatively richer in quartz and are lighter. Quartz grains are embedded in calcareous material which is the main constituent and is cryptocrystalline. The fossil sections are of pure, well crystallised calcite.

It also shows small circulat to elliptical sections of pure calcite, (Microphoto 19,20). In some there is a nucleus of quartz grain may be the sections of limestone pellets. But in others it is not present and some sections are definitely of fossil remains which may probably be the sections of the spines of crinoids in different orientations.

Same shaly laminae and patches are also present consisting of chlorite sericite and muscovite. Iron oxide staining is also present at places.

Shales

Shales are of various colours and contain fine grained chlorite sericite little calcareous and arenaceous grains embedded in the matrix of chlorite sericite.

6. MUTH SERIES

Red Quartzite -

Quartz grains are subangular to angular, medium in size and embedded in the matrix of cryptocrystalline calcite with a few muscovite flakes. Among the heavy mineral rutile is present. Iron oxide staining is quite common.

White Quartzite -

This consists of mainly of quartz. Quartz grains are subrounded to rounded and show slight undulose extinction.

Some grains are highly fractured and crushed. The inter granular material is also recrystallised. Some cryptocrystalline grains are also present which were probably cherty in the beginning.

Rutile is a distinct heavy mineral present with angular grains. The patches of iron oxide staining are quite rare.

7. BLACK SHALES AND LIMESTONES

Microscopically the shaly bands show argillaceous ground mass embedding the grains of quartz and rods, flake and rounded grains of calcite. These calcite rods and grains are parallel to the chlorite-muscovite lamination of ground mass. The quartz grains are rounded to subrounded and few in number. It also shows microscopic cross fractures more prominent in one direction (Microphoto. No. 21). These shales seems to have been derived from carbonaceous sandy marl. The shaly limestone bands have more cryptocrystalline calcareous material with little chlorite and micas.

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CHAPTER V

GEOLOGICAL ASPECTS OF THE CONSTRUCTION AND STABILITY OF THE ROAD IN THE AREA.

Road construction is one of the most difficult engineering problem in the area like this. The difficult terrain, deep valleys with steep slopes glaciers and structurally deformed rocks in the area are the reason for this. The loose glacial deposits and scree material which has to be crossed at various places are the most unstable zones for road stability. The loose scree and glacial deposits which have attained temporary stability under present natural conditions become unstable when disturbed. That is when cut-through, then constantly slide down during rains and snowfalls. Retaining and breast walls have their limitations to serve their purpose. Neither the drainage can be provided nor other method of stabilisation adopted within economical limits. The highly jointed rocks with steep joint planes does not allow the over-hangs so the whole overlying mass slides down during or just after rock cutting. Rock cutting and blasting on vertical cliffs adds to the hazards which the brave men working their has to face.

A brief account of the various geological features which have great bearing on alignment and construction has been dealt with here as met with along the Bhapkund Malari Sumna traverse. One point which is very important is that at most of the places there is no other alternative alignment possible for the reasons of topography and accessibility. So the usual alignment has to be followed what-so-ever the geological features may be. The solution, therefore, lies in finding the means and techniques to overcome these difficulties rather than changing the alignment. The problem of road building material is not acute but metalling matter will be not available so easily at many places especially in crushed schistose limestone and shale zones. However, road metalling material, if needed, will not be very difficult to get. Metalling may not be useful in this region of snow and frosting.

The biotite quartzite and biotite schist rocks just below Bhapkund are forming steep slope, partly covered by huge rock boulders and scree. At Bhapkund the road passes through glacial and avalanche debris before crossing the river through a bridge. The right abutment of the bridge is also over such material. Then the road has two hair-pin bends upto Bamkosa. The whole slope is covered with loose soily scree material. The loose material keeps on sliding during the rains & snowfall.

The road climbs the slope upto Bamkosa shop through three legs with two hairpin bends. The hair-pin bends necessiate more cutting and high retaining walls thus aggrevating the problem. Near and ahead of Bamkosa shop the slope is gentle but then again road passes. Through granitised metapsammites with bands of biotite schists. The hill slope becomes steeper and finally enters the most difficult rocky section for 1 km, nearly 3 km. short of Malari.

The rocks in this zone are forming a near vertical cliff. Many closely spaced sets of joint planes are developed in them. Some of them are very prominent and nearly vertical parallel to the surface. The joint planes are gaping and showing minor displacement. Some shear zones are also present. All these factor had posed a great difficulty in construction. The difficulty was to cut the rock by blasting thereby under-cutting the support of overlying rock mass which then slides down making the work unsafe. This mass which comes down with great momentum washes down the road also. Blasting also disturbs the rock masses on the face which are just in resting position and creates problem. Therefore, at such places controlled and very careful blasting and excavation has to be done which is governed by the intelligence and efficiency of the men engaged in the work in various capacities. The hasty or faulty supervision may zeopardize the life of many human beings. Here the intution as to what is about to happen coupled with intelligent planning is a most effective tool in the hand of the engineer over there.

At Bhujgarh 1 km short of Malari the boulder clay deposit is present. The clay is white and slightly compacted. Towards Malari side the rock is showing insitu alteration upto considerable depth. From there to Malari Dak-Bungalow there is gentle stable soily ground occupied by cultivated fields.

The Malari nallah is a occupied by glacier in which the glacier persists even upto July. The ~~xxx~~ feeding area above though not large is very steep so the glacier must be having tremendous force in its peak times. This has very great bearing on the site and design of the bridge to be constructed across it. The nallah is very wide and filled with glacier morainal material. Thus the foundation and abutments has also to be made quite strong so as be capable of standing and holding the super structure against the force of glacier and avalanches.

Beyond Malari upto 1.5 km. there is comparatively less steeper partially cemented scree slope. After this there are loose rock boulders, gravel deposit and slided earth material for about 1 km. This land slide zone just above the confluence of Dhauli and Girthi Rivers is quite large (please refer Chapter II 'Geomorphology' Page 9). The perfect steeply dipping joints coupled with under cutting by river down below has provided the favourable condition for the land slide. This zone will continue to pose severe problems even after completion of the road.

After 3 km. from Malari upto 6 km there are gentle scree zone and shale, conglomerate and quartzite horizons through which road passes. The average dip of the shale is 38° /N39°W are jointed and at places show crushing. The conglomerate and quartzite have average dip of 38° / N45°E. The joints and dip problem is not very acute at one place only where there is dip slope at 6.4 km from Malari some difficulty of overlying mass arised. The whole section is relatively easy to deal with. But 6 km to 7.9 km there are several steeply sloping scree zones. The continuous pour of boulders from above even by wind is a constant hazard. The scree cones are of considerable dimension, one of them is comprised of brown weathering dolomitic matrix and boulders. Making road through these will create great problem of both the retaining and breast walls. Moreover, the top part will drop over the road section huge debris continuously. At 8 km the quartzites on the left side of river Girthi, are highly jointed and disturbed. The joints are gaping and rock is in very critical state. It is for this reason that road has to be taken across through a bridge. On the other side however, after a short distance the glacier deposit and glacial stream is to be crossed. The glacier again poses the same problems as at Malari even more severe than it. Other alternative is to make bridge still upto stream where again though are glacial stream has to be crossed but is of smaller size and can be eliminated by under cutting the rocks to an extent that glacier falls off the outer edge of the road. There are then good bridge sites 2-3 kms on upstream side comparatively narrow and having hard rocks on both the sides. By changing the site to such distance will eliminate one more glacial deposit at 10 kms. when the track starts climbing towards Baramatia. This will probably have one more advantage that being in narrow valley location and targetting from the air will be more difficult as compared to first site.

There after 10 kms the road enteres a zone which will pose still difficult problems. This zone is the very deep gorge (please refer Chapter II ,Page 10) and extends for about 4 miles. The rocks encountered upto the confluence of River Girthi and Kaiogad are quartzite and dolomites. These are highly jointed but dipping in favourable direction that is gently inward. The weathered and jointed dolomite, however, and vertical wall will make the work harger. Thereafter the shales and limestones of Shiala and Somna series extending upto Somna are also steeply dipping highly jointed and crossed nearly at right angle to strike by Kaiogad through a gorge (Photo. No. 1). The dip joint and other major joints dipping vertically have made large blocks which when disturbed will be liable to fall and cause extensive damage. The shales and shaly limestone horizons are highly splintery which are very difficult to blast and excavate. Just 2 - 3 km short of Somna again we have loose glacial material zone.

The difficult land slides and scree zones between Malari and Girthi dobla can be avoided by taking a another alternative alignment. That is climbing the Malari hill nearly along the trach to Topidhunga and then descending gradually over the northern slope to cross the River Girthi before it confluence with River Kaiogad. But this will be passing over the dip slopes on the northern slopes of Malari hill. This slope is very unstable especially when cut made through it. It will, in addition to this difficulty, have to clime and envolve longer route at the higher altitude. It will have more problems of snow and will also expose the road to aerial detection as compared to the roads in lower levels along the river. Though the permile cost of construction and maintenance of road will be higher in the lower level but the overall cost of the longer route through that type of slopes will be considerably more. Therefore, this alternative can safely be dropped in comparison to the first described.

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CHAPTER VI

DISCUSSION

DISCUSSION

With only the geological traverses being taken along valleys in an area of such complexities, it will be not proper to discuss the geological history of the area. However, an attempt is being made to review some of the salient features in the light of the present and previous works.

Stratigraphic Correlation

The geology of the area has been described in chapter 3. The geological setting and the discussion regarding the stratigraphic correlation with the known Indian equivalents has mostly been done there, nomenclature adopted for most of the rock series has been taken from the equivalent in Kumaon area to simplify the problem. The only exceptions being in case of the Somna series, a name given to the silurian formations of this region. This has been done purposefully as much confusion exists in the case of silurian in this area.

Another departure from the existing terminology has been in the case of meta-psammites, earlier grouped as central crystalline series by Heim and Gansser (1939). These are supposed to form the core of the Central Himalayan axis and equivalent to the Jutogh series of Simla. Krishnan (1956) regards Jutoghs as Archaeans equivalents of extra-Peninsular India.

Arenaceous phyllites and quartzites of Martoli Series overlying the meta-psammites have been taken as belonging to

Algonkian in age following Heim & Gansser (1939) and Krishnan (1956, p.99) and hence equivalent to Cuddapah and Delhi system of peninsular India. Martoli formations are overlain by a succession of rocks ranging from Cambrian to Triassic with a great break between Devonian to Upper Triassic (Muschelkalk) reflected by the black shales directly overlying the Muth quartzites.

Granitization

The general characters and mineral constituent of the metapsammites have been dealt in chapter 3 and 4 (pages 14, 15 and 33 to 38). The mineral assemblage quartz-biotite-albite shows that these have undergone regional metamorphism of Albite-epidote amphibolite facies. This must have taken place during the sinking of these rocks to greater depths with deposition of the overlying rocks in the Tethys geosyncline. The maximum depth to which these were burried was estimated by Heim and Gansser (1939, p.225) as 30 Km but still remaining higher than the Sialic layer over them. The great pressure and temperature during this phase caused the metamorphism and was supposed to have caused granitisation in these rocks. The granitisation continued probably during most of the movements at the depth granite proper could be found, and the granitization is also not complete in any part of the area. The effect of granitization is mostly confined to the large scale albitisation. This was followed by tourmalinisation. Although a few small pegmatite dykes occur in the area, the signs of any granite "magma" are not directly visible. Almost complete preservation of stratification also rule out any possibility of a large scale mobilisation. The presence of streaky gneisses resembling with migmatites at Niti gorge may be indicative of a slighty higher stage of granitization.

Nothing can be said, however, about the exact mechanism and process through which the granitisation has taken place. Was it a case of diffusion or permeation is also difficult to speak of at the present moment. The probabilities are, however, more in favour of adiffusion to have taken place. Also because of inadequate means. The age of granitisation can not be acertained..

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SUMMARY

The geological traverses were undertaken in Bhapkund-Malari-Somna and Malari-Niti sections of District Chamoli, U.P. The aim of this was to study geology, stratigraphy and structure of the area. The geologic factors affecting the road construction and stability were also studied. The area lies partly in main axial Himalayan belt and partly in Tethys Himalaya with alpine type of climate. Therefore, lofty snow bound peaks with deep valleys are common geomorphic features. The main river draining the area are River Dhauli, a tributory to River Alaknanda and its tributory River Girthi. These are joined by many other smaller rivers and streams in their entire run. The course of the main rivers mainly run almost parallel to the strike of the formations. But at places these cut across, governed by major joints and result into a deep gorge. Glacial and gravel deposits are present at many places in the valleys.

On the basis of field studies following succession was established and was later correlated with the known Indian equivalents. A short resume' of the succession is presented in the following table :

Succession

series	lithology	age
	Glacial and river gravel deposits.	Pleistocene to recent.
	— unconformity —	
Black Shales	Black shales and limestone inter-banded, fossiliferous.	Triassic (Muschelkalk)
	— unconformity —	
Muth Series	Red and white quartzite	Devonian
	— unconformity —	
Somna Series	Variegated shales and limestones fossiliferous.	Silurian
	unconformity	
Shiala series -	Shales and limestones.	Ordovician
	[illegible]	
Garbyand Series	Limestone, dolomites, quartzite with basal Ralam conglomerates	Cambrian
Martoli Series	Arenaceous phyllites and quartzites.	Pre-Cambrian (Algonkian)
	— unconformity —	
Meta-psammites	Biotite quartzite with quartz-biotite schist bands; granitised and traversed by pegmatite veins & dykes.	Archean

Almost all the limestones are fossiliferous but fossils are mostly difficult to identify. The black shales are by far the most rich in fossils in which full and fragmentary ammonites are predominantly large in number. Some of the fossils collected from the black shales were identified as - Meekoceras affine, Ptychites c.f. rugifer, Ptychites sumitra and Orthoceras c.f. campanile which form the Himalayan Muschelkalk faunal assemblage.

The black shales were also examined for microfossils but except for some siliceous sponge spicules no foraminifera and ostracoda were found.

The rocks in the area are of sedimentary origin metamorphosed to varying grades and fall in a zone of strong compressional stresses. The structures of the area are, therefore, reflection of all these factors. The contacts between the formation of different series are unconformable except for that between the Garbyang and overlying Shiala series which appears to be conformable. Reverse movement of probably considerable magnitude have taken place along these contact planes. Girthi monocline is a major fold in the area which has its steep northern limb with its axis plunging with low angle due N35°W. The rocks, especially the dolomites, show intense minor folding, all asymmetrical. A series of parallel step like normal faults with variable throw are present in the area. One of larger throw is met at 8 kms. from Malari towards Somna side. Sedimentary primary structures, the current bedding and oscillatory ripple marks are also present in the quartzites and shally limestones.

The mineralisation of chalcopyrite and pyrite in sparsely disseminated form, especially in conglomerates and dolomites has been noted at various places. Magnesite and barytes boulders are also found in some places.

On the basis of microscopic examination of the rocks in thin sections (chapter - 4), certain points were noted. The metapsammites have conspecous arenaceous affinity followed by the arenaceous phyllites and quartzites of Martoli series. The lower part of the Garbyang series is arenaceous while the rest of the formations except Muth quartzites are calcareous and argillaceous. Rocks belonging to almost all the series have some certain heavy minerals, for example, Martoli quartzites have tourmaline and rutile, in Garbyang series, the quartzites have tourmaline, rutile, kyanite and apatite. Rutile is consistent right upto the Muth quartzites. All the limestones are arenaceous to varying amounts. The dolomites show only a few quartz grains.

On the basis of lithology and structure, the geological facters which have important bearing on the construction and stability of roads, have been discussed in chapter V. It was found that the road construction in the area, is one of the most difficult engineering task. The difficult terrain, deep valleys with steep slopes, glaciers and structurally deformed rocks, are the reasons for this difficulty. Stability of the roads is also a serious problem. The loose glacial and scree deposits are the most unstable zones when cut through.

The complete appreciation of the various geological factors and anticipation of the possible difficulties can be of great help in efficient and economical road construction programme.

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CONCLUSION

The geological traverses undertaken in the area have given a general geological picture of this hither-to unmapped patch in the Geological map of India. The geology of the Himalaya, espécially needs very extensive and intensive traverses along all the accessible courses to give the complete regional picture. This work as already admitted is not final but still it is hoped that it will prove to be a milestone in the detailed geological investigations in the future. The problem of engineering constructions, especially the roads in this difficult terrain can also be assisted to great extent by the proper understanding of the Geological factors envolved. The problem has assumed an immense dimension of great urgency for the reasons of national security.

SELECTED BIBLIOGRAPHY

1. Auden, J.B. (1935), "Traverses in the Himalayas" Rec. G.S.I. Vol. LXIX.

2. Auden, J.B. (1937), "The Structure of the Himalayas in Garhwal" Rec. G.S.I.Vol.71.

3. Billings, M.P.(1954), "Structural Geology" Charles Tuttle Company, Tokyo.

4. Carozzi, A.V. "Microsopic Sedimentary Petrography" John Wiley Inc. New York.

5. Diener, Carl "The Fauna of Himalaya", Muschel-Kalk", Paleontologia Indica Series XV Vol. V, Mem.3.

6. Dave, V.K.S. and Rawat, B.S. (1966), "A Priliminary account of geological traverses in Bhapkund - Malari-Somna -Niti areas of Chamoli District, U.P. Ist Seminar on Himalayan Geology, Punjab University, Chandigarh.

7. Eckel, E.B.(Editor) 1958, "Landslide and Engineering Practice", Highway Research Board Special Report No.29, Washington D.C., N.A.S., N.R.C. Pub.544.

8. Engeln, O.D.Von(1960), "Geomorphology" Mac Millan Company, New York.

9. Gansser, A. (1964), "Geology of the Himalaya" Inter Science Publishers, London.

10. Griesbach, C.L.(1891) "Geology of the Central Himalayas" Mem.G.S.I. Vol.XXIII.

11. Heim, A., and Gansser, A. (1939) "Central Himalaya Geological Observations of the Swiss Expedition 1936" Mec. Soc. Helvetigue des science Natun Zurich Vol. 73, Mem 1.

12. Heinrich, E.W.M.(1956) "Microscopic Petrology" McGraw Hills Company Inc., New York.

13. Holmes, A. (1965) "Principles of Physical Geology" Thomas Nelsons(Privates)Ltd.

14. Jones, Daniel, J. (1956), "Introduction to Microfossils", Hawper and Brothers Publishers, New York.

15. Kerr, Paul F. (1959), "Optical Mineralogy", Kogakusha Company, Tokyo.

16. Krishnan, M.S. (1956), "Geology of India and Burma" Higgin Bothams (Pvt.) Ltd. Madras.

17. Krishnan, M.S. (1956), "Structures and Tectonic History of India" Mem. G.S.I. Vol.81

18. Krynine, D.P. and Judd, W.R. (1957), "Principle of Engineering Geology and Geotectonics" McGraw Hills Book Company, Inc. New York.

19. Legget, R.F. (1939), "Geology and Engineering" McGraw Hills Book Company, Inc. New York.

20. Lobeck, A.K. (1939), "Geomorphology" McGraw Hills Book Company, Inc. New York.

21. Pasco, E.H. (1939), "Manual of Geology of India and Burma" Vol.II, Govt. of India, Pub. Div., New Delhi.

22. Pandey, I.C. and Verma P.K. (1966), "The Mignatites of Wajula area in district Almora", U.P., Ist Seminar on Himalayan Geology, Abstract No.30, Punjab University, Chandigarh.

23. Pettijohan "Sedimentary Rocks" Oxford Book and Stationery Co., Calcutta.

24. Prakash, R. and Swarup, P. (1960), "Progress Report on Some Geological Investigations in Garhwal", Directorate of Geology and Mining, Uttar Pradesh.

25. Read, H.H. (1956), "The Granit Introversy" Thomas Manlay Company, London.

26. Sastri, M.V.A. (1960), "Some Triassic Fossils from Eastern Byans, Central Himalayas" Rec.G.S.I., Vol.89, Pt.II.

27. Shrock, Robert, R. (1953) "Principles of Invertegrate Paleontology" McGraw Hills Book Co..

28. Terzaghi,K. (1950),"Machavies of Landslides in Application of Geology in Engineering Practice" Burkey Volume.

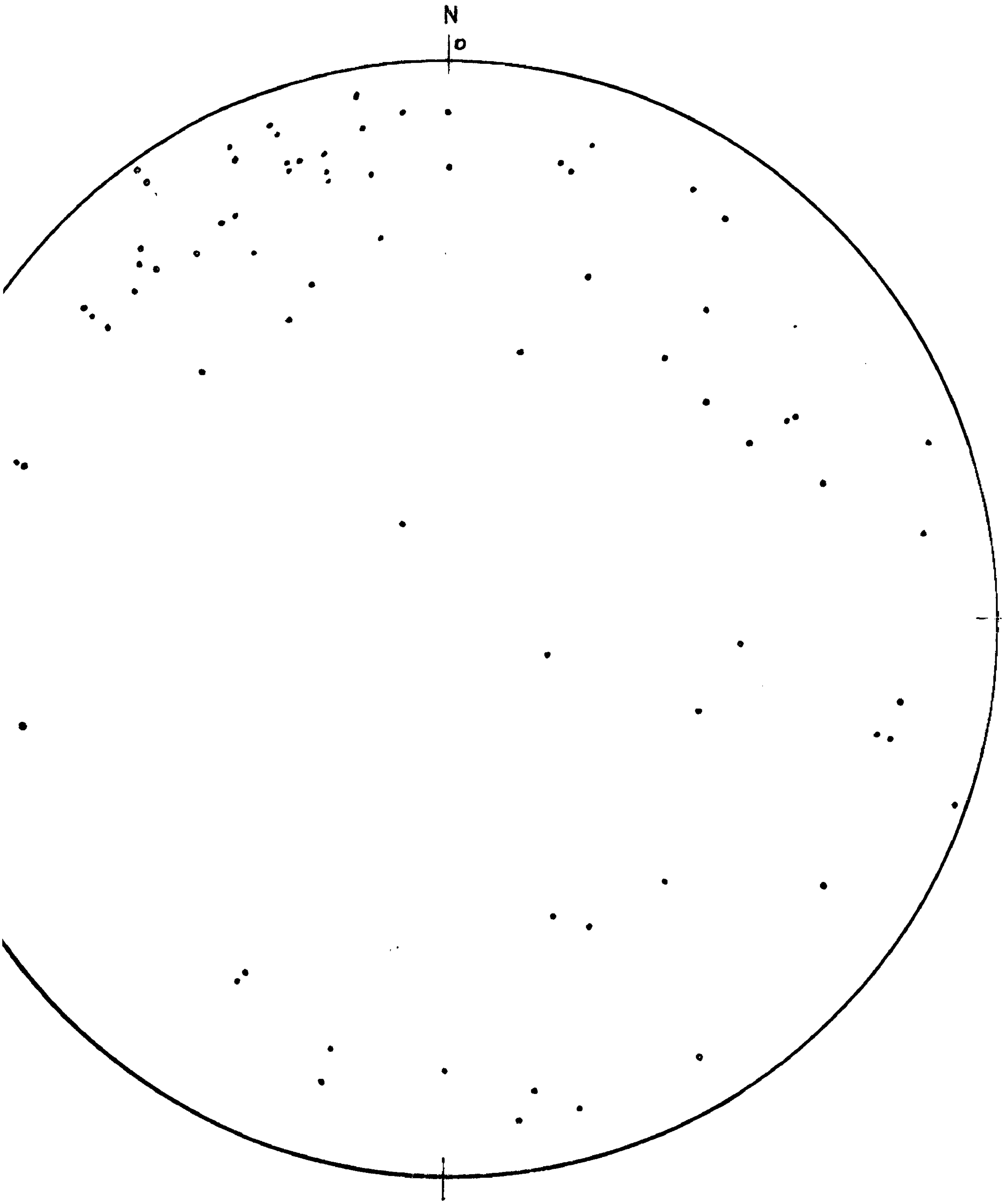
29. Wadia,D.N. (1961),"Geology of India" Mac Millan and Company Ltd., London.

APPENDIX

Reading of the Plunges of "b" Lineation

Sl.No.	Amount of plunge	Direction	Remarks
1	2	3	4
1	12°	N	in Biotite-meta-psammites
2	20	N 15°E	
3	19	N 14 E	
4	40	N 40 E	
5	15	N 15 E	
6	40	N 80 E	
7	40	N 50 E	
8	30	N 70 E	
9	30	N 60 E	
10	30	N 60 E	
11	14	N 17 E	
12	14	N 30 E	
13	20	S 80 E	
14	30	N 40 E	in Martoli Series
15	21	N 10 W	
16	40	S 25 E	
17	20	S 5 W	
18	21	S 15 W	
19	12	S 15 E	
20	20	N	
21	22	S 76 W	
22	40	N 5 W	
23	50	N 80 E	
24	40	S 45 E	
25	20	S 75 E	in Garbyang Seri and overlying formations upto black shales
26	22	S 78 E	
27	10	S 35 W	
28	40	S 45 E	
29	20	N 15 W	
30	20	N 15 W	
31	15	N 40 W	
32	10	N 70 W	
33	10	N 40 W	
34	15	S 15 W	
35	10	S 55 E	
36	15	N 44 W	
37	20	N 40 W	
38	15	N 60 W	
39	15	N 15 W	
40	15	N 50 W	

1	2	3	4
41	8°	N 25° W	
42	10	N 70 E	
43	3	S 17 E	
44	18	N 70 W	
45	35	N 22 E	
46	9	N 20 W	
47	10	S 30 E	
48	16	N 20 W	
49	30	N 75 E	
50	10	S 30 W	
51	15	N 18 W	
52	2	N 30 W	
53	5	N 10 W	
54	75	N 25 W	
55	36	S 59 W	
56	50	S 20 E	
57	16	N 35 E	
58	10	N 6 W	
59	12	N 10 W	
60	24	S 30 W	
61	12	S 3 E	
62	17	S 10 E	
63	6	N 61 E	
64	20	N 30 W	
65	10	N 25 W	
66	32	N 10 W	
67	5	N 35 W	
68	20	N 28 W	
69	40	N 28 W	
70	21	N 50 W	
71	38	N 60 E	
72	22	S 35 W	
73	27	N 20 W	
74	38	N 45 W	
75	5	S 40 E	
76	15	N 25 W	



POINT DIAGRAM OF 76 PLUNGES OF 'b' LINEATION
IN NITI-MALARI-SOMNA
AREA

FIG. 6

PHOTOGRAPHS

PHOTO 2 - Girthi Monocline - view on the left side of River Kaiogad, steeply dipping limestones and shales (Shiala series), monoclinally folded at the top. (4 km from Girthi-dobla

PLATE 2

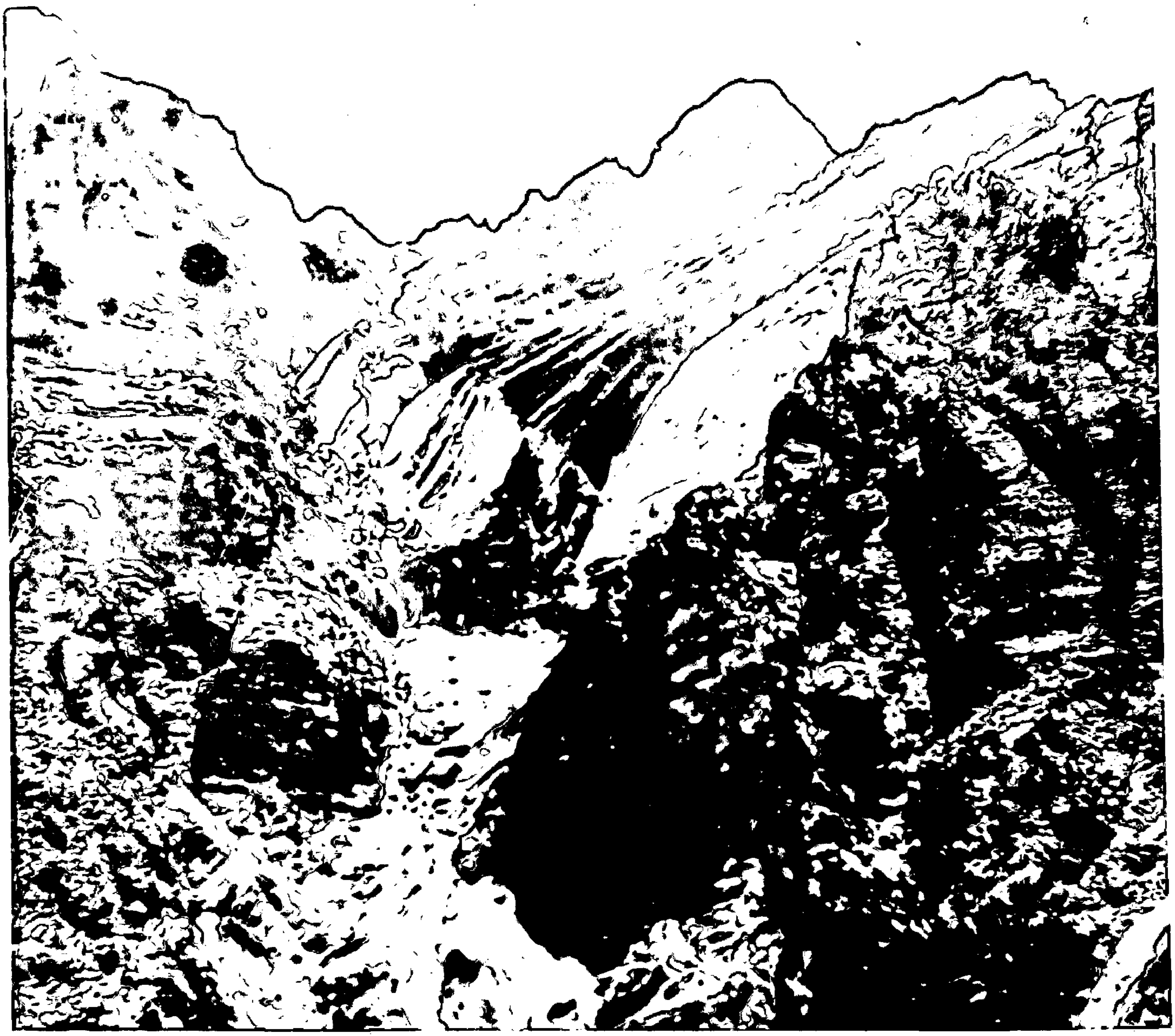
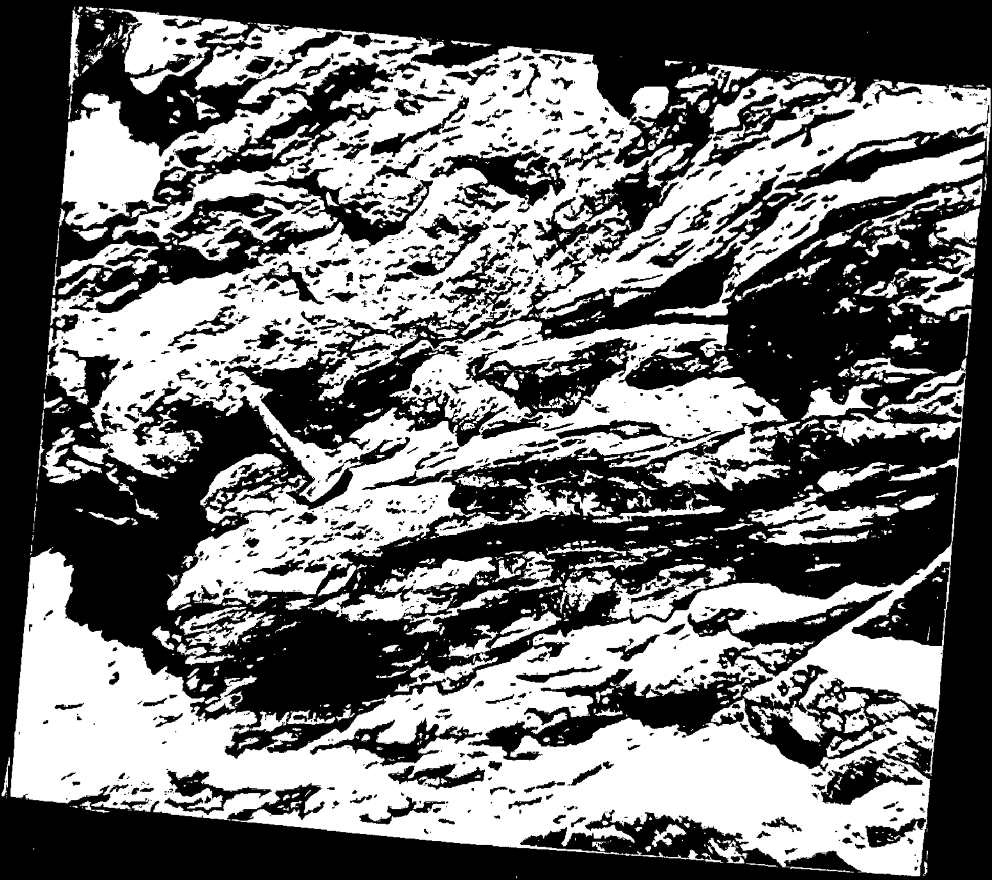


PHOTO 3 - The contact between Ralam conglomerate and underlying Martoli phyllites and quartzites, hammer lying across the contact plane; at 1.5 km. from Malari on Somna track.

PHOTO 4 - Plunging asymmetrical anticlinal fold in the thickly bedded dolomites, in Girthi area; at 0.5 km from Girthi dobla.

PLATE 3



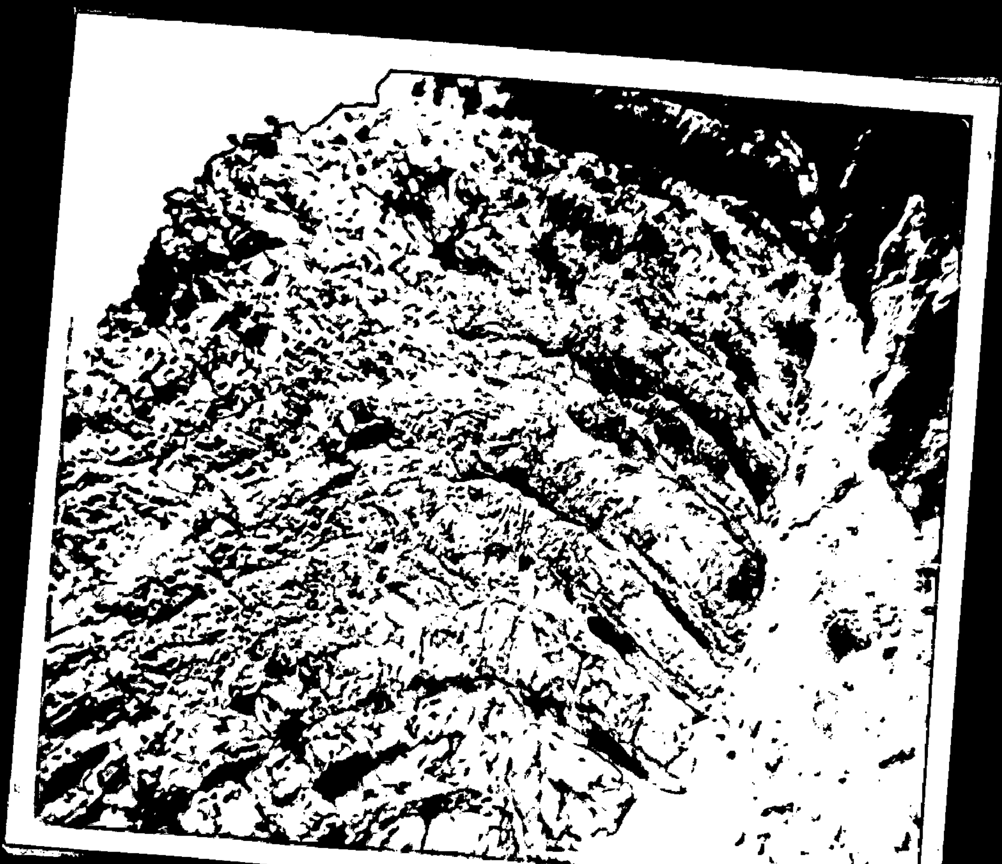


PHOTO 5 - Plunging asymmetrical anticline in thickly bedded dolomites, at Girthi dobla stream.

PHOTO 6 - Flexures & gentle folding in dolomites, near Girthi dobla.

PLATE 4

PHOTO 7 - Butte like feature between River Kaiogad and River Girthi near their confluence as seen from 11 km. from Malari on Somna track.

PHOTO 8 - Slicken side with transverse puckering in the limestone forming the limb of Girthi Monocline at 1.5 km. from Girthi dobla.

PLATE 5

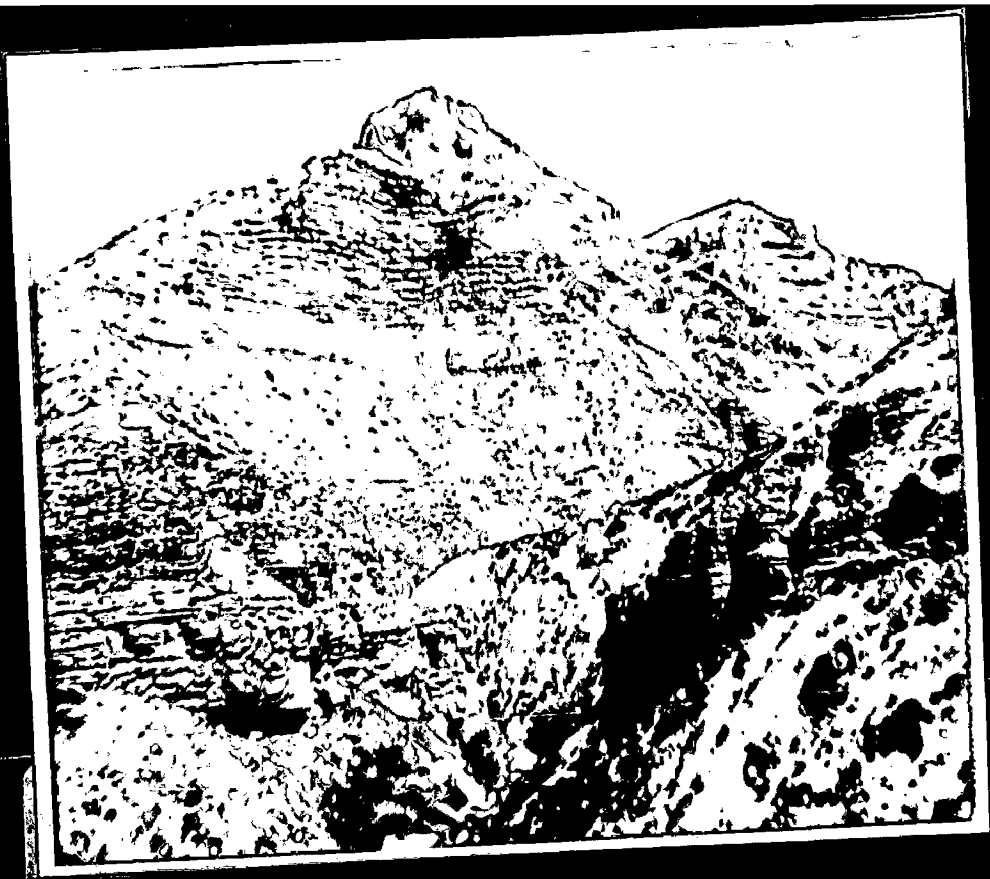
PHOTO 9 - Waterfall in the Muth quartzites at 2.5 km. from Somna on Leptal side; the upper thickly bedded well jointed white quartzite and fairly bedded and jointed red quartzites in the lower left.

PHOTO 10 - The contact between the red quartzite of Muth series and underlying nodular limestones and shales of Somna series. The quartzites are fairly bedded. The nodular limestones and shales showing drag folding.

PLATE 6

PHOTO 11 - The black shales (grey) and limestone (white) bands forming the top of the hills. The limestone bands, the white due to the whitist encrustation over their surface, 6 kms. from Somna on Rimkhim side facing NE.

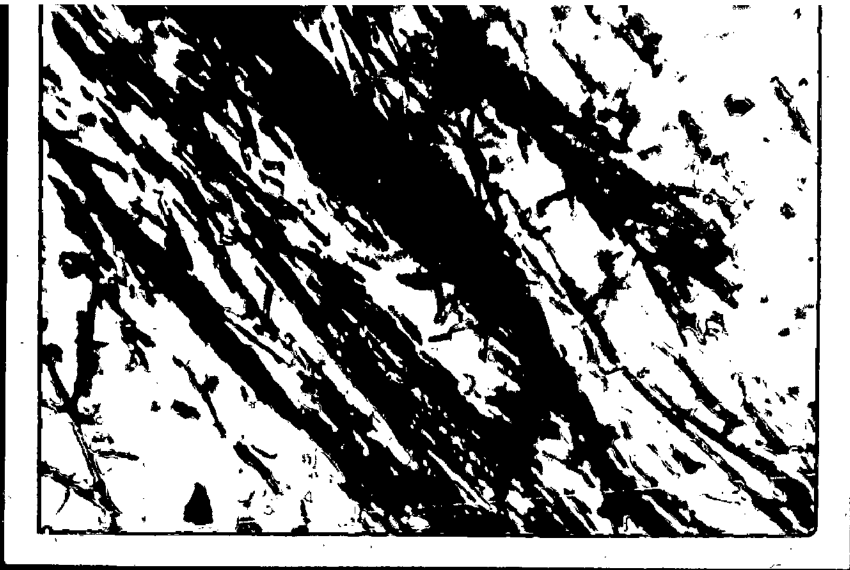
PHOTO 12 - Dip slope in highly jointed shaly lime-stone of Shiala series nearly 4 kms. from Girthi towards Somna.



MICRO- PHOTO 13 - Kyanite in quartz biotite schist developed along shear planes. Dark colour due to very high relief. Nicols uncrosse Enlargement 48 times.

MICRO- PHOTO 14 - Fine acicular kyanite parallel to the schistosity in quartz biotite schist ban of metapsammites. Nicols crossed enlarge 48 times.

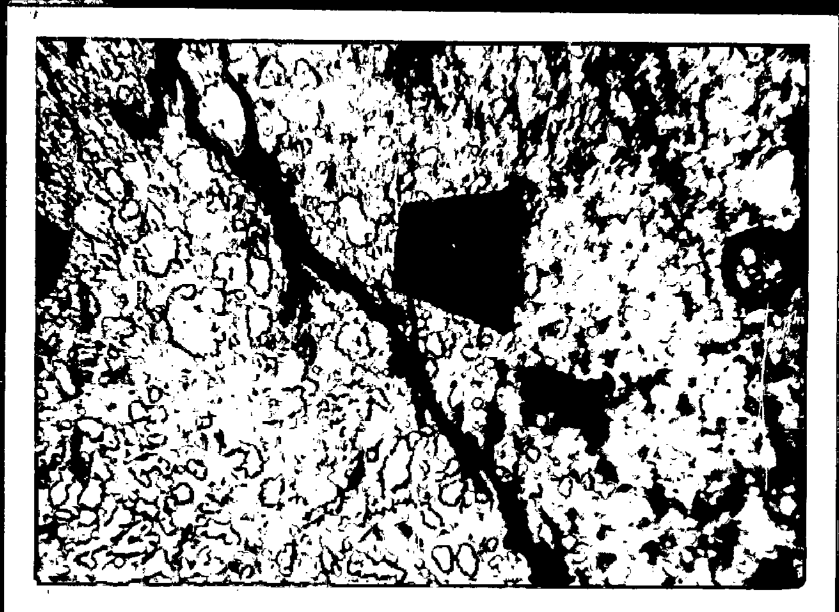
PLATE 8



CRO-PHOTO 15 - Granitised metapsammites, felspars and the original quartz grains with anhedral margins, secondary quartz in irregular intergrowth in inter granular spaces. Nicols crossed, enlargement 50 times.

ICRO-PHOTO 16 - Pyrite porphyroblast in phyllitic quartzites of Martoli series. Quartz grains showing granulated margins embedded in chlorite mica matrix. Nocols uncrossed, enlargement 48 times.

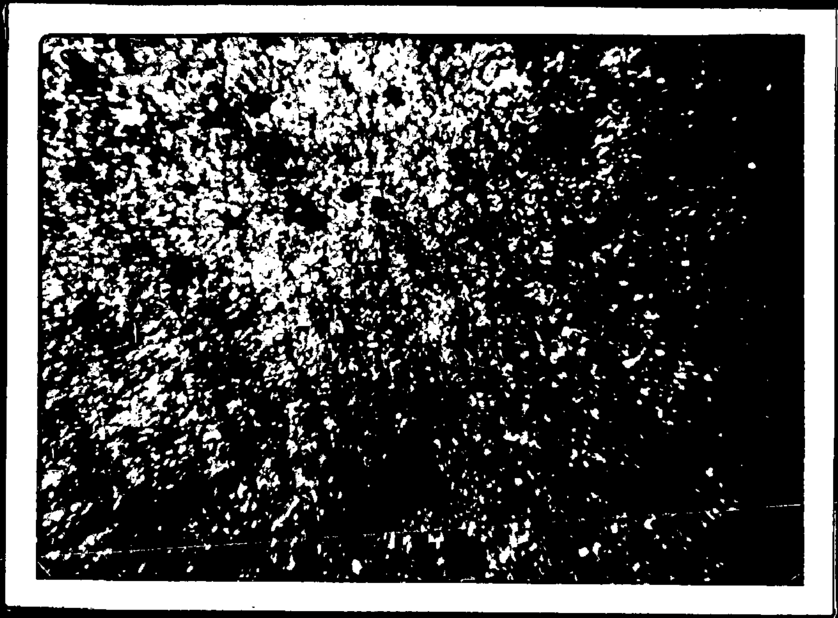
PLATE 9



)- PHOTO 17 - Microscoping warping in black arenaceous phyllites of Martoli series. Nicols uncrossed, enlargement 48 times.

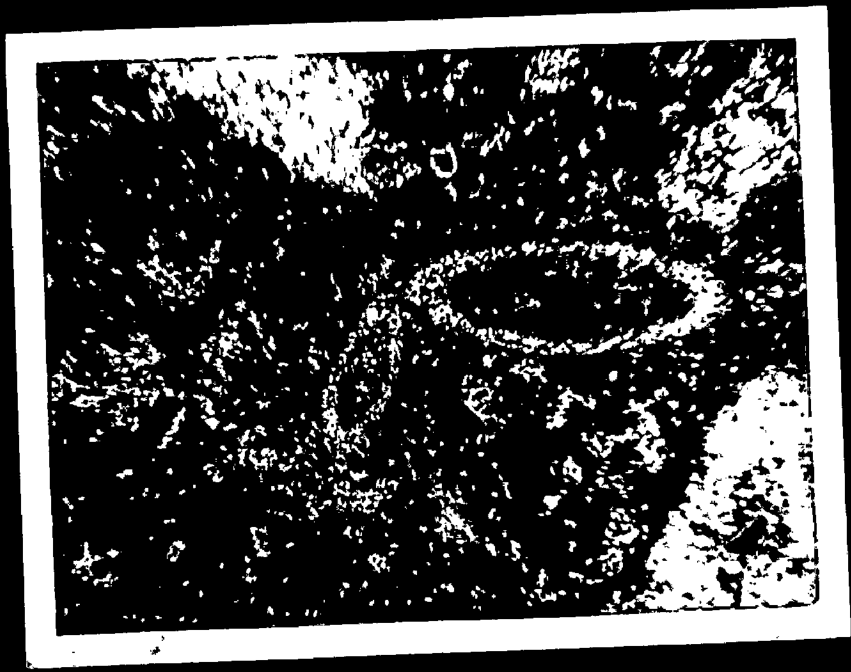
[illegible]ROPHOTO 18 - Quartz,chlorite-sericite vein (left) cutting across the lamination of greenish white phyllite bands (right) in dolomites and limestones of Garbyang series. Contact is seen which quite sharp and straight, probably contemporaneous fractine filling Nicols uncrossed, enlargement 48 times.

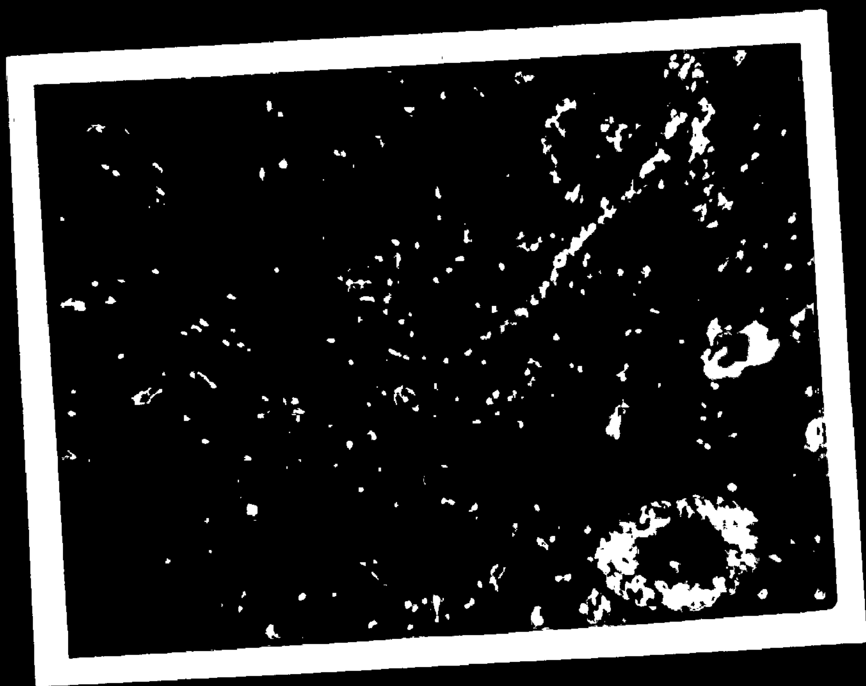
PLATE 20



MICROPHOTO 19 & 20 - Fossiliferous nodular limestone of Somna Series, fossil sections of purer well crystallised calci of different shapes. The section in Photo - 19, lower right corne with a quarts grain in the centr is probably of limestone pallet. Nicols uncrossed, enlargement 48 times.

PLATE 11





MICROPHOTO 21 - Calcite rods and laminae in black shales with cross fractures filled with calcite. Nicols uncrossed, enlargement 48 times.

PLATE 17