A STUDY OF LANDSLIDES
BETWEEN
PIPALKOTI – BADRINATH
AND
JOSHIMATH – BHAPKUND
DISTRICT CHAMOLI, UTTAR PRADESH

DISSERTATION
IN PART FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF

M.Sc. Tech. DEGREE IN APPLIED GEOLOGY

SUBMITTED BY
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CERTIFICATE

Certified that the dissertation entitled "A Study of Landslides Between Pipalkoti – Badrinath and Joshimath – Bhapkund, District Chamoli, Uttar Pradesh" being submitted by Shri BRIJ KUMAR SINGH in partial fulfillment for the award of Degree of M.Sc. Tech. Applied Geology of the 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 Deploma.

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

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The writer thanks all his teachers and friends for their advices and suggestions throughout the work.

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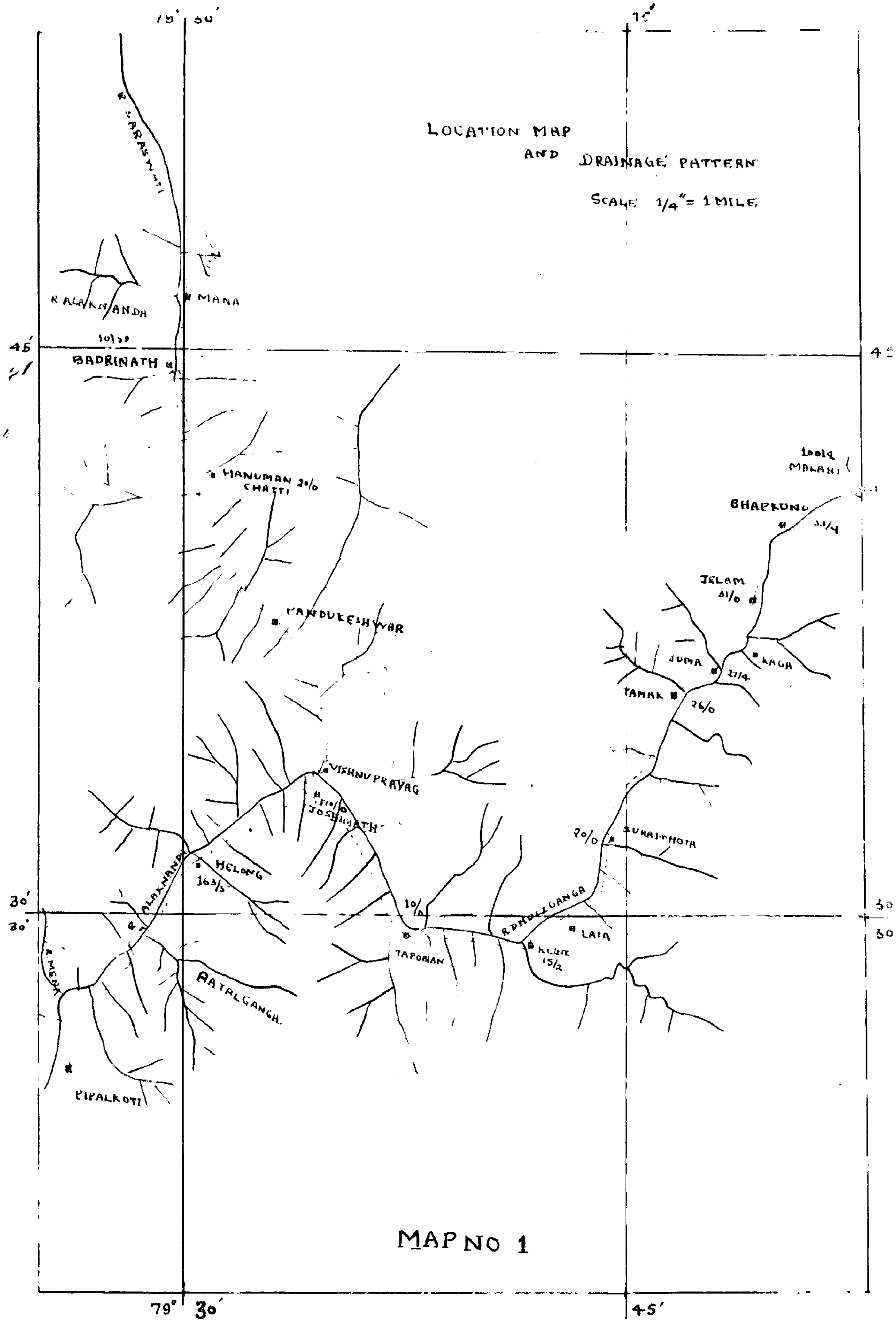
CHAPTER 1


LOCATION MAP
AND DRAINAGE PATTERN
SCALE 1/4" = 1 MILE
79° 30'
45'
30'
R SARASWATI
R ALAKNANDA
MANA
BADRINATH
HANUMAN CHATTI
PANDUKESHWAR
VISHNUPRAYAG
JOSHIMATH
HELONG
ALAKNANDA
PATALGANGA
TAPOBAN
R DHULIGANGA
LATA
SURAITHOTA
TAMAK
JUMA
LAGA
JELAM
BHAPKUND
MALARI
PIPALKOTI

MAP NO 1

CHAPTER 1

INTRODUCTION

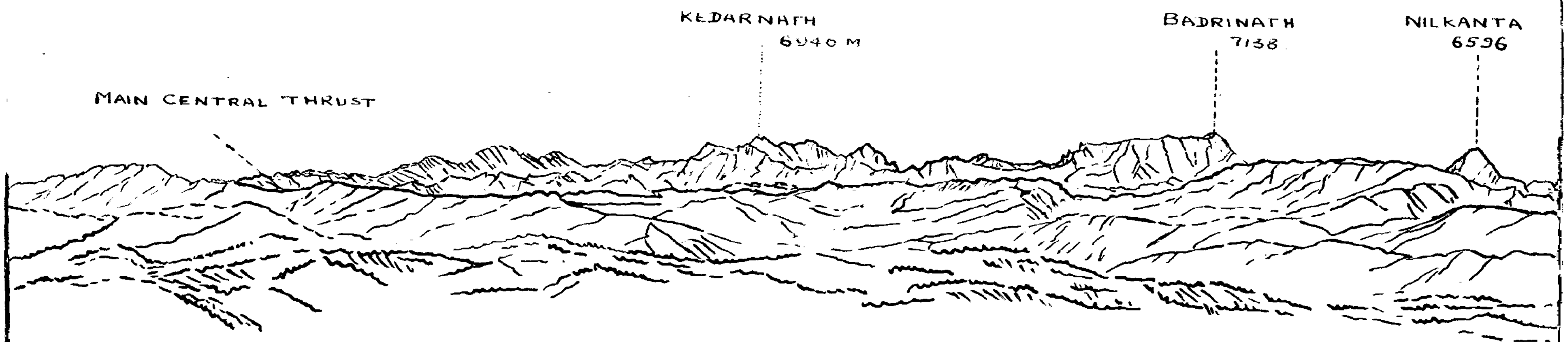
Location – The area is situated between latitude 79° 30' and 79° 55' and between longitude 30° 25' and 30° 40' and lies in survey of India Quarter inch ToposSheet No. 53 N, Half inch Topo Sheet No. 53 N/SE and 1:50,000 scale Topo Sheet No. 53 N/6 53 N/10 and 53 N/14.

The area is approchable by a motarable road from Rishikesh, the nearest Railway terminus of the Northern Railway. By private bus it takes nearly ten hours to reach Pipalkoti from Rishikesh. The private buses are available upto Joshimath. Between Joshimath and Badrinath U.P.Roadways buses are available. Between Joshimath and Malari no bus service operates and road is still in the stage of construction.

The villages are siutated far from each other and on high slopes and the only way to go is by foot. The river is crossed by hanging bridges and at places the bridges are constructed of ropes.

Scope of work

The precent work was carried out with a view to study the landslide phenomena which is very common along the roads in this part of the Himalya. The relation between landslides and the geology of the region has been studied in greater detail to help in solving the problem of remedial measures which could be profitably taken up. The idea of the writer



PANORAMA OF EASTERN KUMAON HIMALAYAS

CLEAR DIVISON BETWEEN CENTRAL HIMALAYAS & LOWER HIMALAYAS

THURST PLANE CLEARLY MARKS CHANGE OF TOPOGRAPHY.

"AFTER GANSEER"

FIGURE NO. 1.1

was also to study and find any alternations to the present road alignments and if any alternation exists, what problems would arise in the new alignment. To get an answer to all such problems it was thought proper to start with geological mapping. But at places the exposures are covered with thick cover of slided material and no study was possible of the original out crops and at such places the type of such material has been shown in the map. Since a very old map on 1/6" scale was available, it was enlarged to 1" = 1 mile. To form the base map three Topo Sheets No. 53 N/6 N/10 N 1/14 were, however, made available to the writer by the Border Road authorities on 1:50,000 scale and these were utilised to correct the above enlargements to 1:50,000 scale. The area where land slides are more frequent were studied in large scale maps at times as large as 1" = 50 feet.

The present area lies in middle Himalayan zone according to Wadia and West (1964) and in Central Himalayas according to Heim and Gansser (1939). Following Gansser(1964) the present area lies partly in the Middle Himalayas and partly in the Central Himalayas.

Pipalkoti the starting point of the present studies lies in the Middle Himalaya. There is a clear demarcation between the middle Himalayas and the Central Himalayas. The sketch drawn by Gansser(1964) clearly shows the demarkation line as shown in Fig. No. 1.1

The important localities in this region are given with their height and distance from Hardwar in the table No. 1.1.

TABLE No. 1.1

PLACE	Latitude	Longitude	Height in feet	Distance mile/ furlong.
				from Hardwar
Pipalkoti	79°25' 51"	30°26' 13"	4600'	163/o
Belakuchi	79°27' 34"	30°28' 24"	4675'	163/4
Helong	79°30' 30"	30°33' 16"	4900	163/5
Joshimath	79°34' 0"	30°32" 10"	6167	170/2
				from Joshimath
Tapoban	79°37' 30"	30°29' 16"	6167	10/o
Renivillage.	79°42' 0"	30°29' 3"	6029	15/2
Suraithota	79°44' 41"	30°31' 50"	7128'	20/o
Tamak	79°47' 3"	30°36' 43"	7060	26/o
Juma	79°49' 12"	30°36' 19"	8210	27/4
Jelam	79°49' 41"	30°39' 24"	8004	31/o
Bhapkund	79°50' 43"	30°40' 13"	8906	33/4
Malari	79°53' 37"	30°41' 8"	10,014	37/o
Pandukeshwar.	79°33" 2'	30°38" 0	6350'	13/o
Hanumanchatti	79°31" 0'	30°41" 58'	8300	20/o
Badrinath	79°29" 39'	30°44" 45'	10,150	27/o
Mana	79°30'	30° 1' 22	10,161	29/o

The first snow peak is observed from Pipalkoti and the first hundred mile journey from Hardwar is covered in a low lying dissected topography, but as the road reaches Chamoli high mountain greets the visitor.

Vegetation — The vegetation is controlled by height, climate and lithology. The mountains of height less than 10,000 or sometime upto 11,000 feet are covered with thick forests and they provide good timber wealth to the country. But above 11,000 feet very few trees are seen and between 11,000 feet and 13,000 feet grass lands knows as Bugyal are present which are on gentle slope and slopes covered with glacial outwash.

Thus from the point of view of vegetation this area may be divided into two broad-groups.

I. Zone of tropical climate below 10,000 feet

II. Higher zone above 10,000 feet to 13,000 feet

The snow line in western Himalyas is above 13,000 feet but in certain areas it descend to a height of 12,000 feet.

Climate — Independently of the enormous variety of topography the vast altitude differences of the mountain alone is sufficient to cause very great modification of climate. Onbehalf of the total mass of atmosphore and three fourth of the water suspended in the form of vapour lie below the average altitude of the Himaloyas and of the residue one half of the air and virtually almost all the vapour comes within the

RAINFALL - The rainfall in this region is chiefly related to Monsoon. The monsoon starts with the advent of July and continue through out the month of August and september. During this period the rainfall is continuous for days together and this is the time of frequent landslips.

The october and November are the best season of field work in the Middle Himalyas but May and June are good for the field work above 10,000 feet. The snowfall starts from the middle November in the central Himalaya and snowfall even takes place in the month of July in higher regions. The month of January, February and December are very cold. The winds are strong and general direction is from E to W or from SE to NE.NW.

PREVIOUS WORK : Although no detailed mapping of the area under investigation has been carried out on a scale more than quarter inch to a mile, yet excellent reports of the geological traverses undertaken by Auden(1935) and Heim and Gansser(1939) are available.

Auden took traverses in (1935) between Ranikhet-Badrinath and beyond. According to him the limestones and quartzites occuring between Pipalkoti and Helang may be correlated with Deoban limestone of Chakrata and Jaunsar series of Simla respectively. The quartzites, gneisses, schists and "granulites" occurring between Joshimath and Badrinath are termed by him as bedded paragneisses and have been correlated with Jutogh. A.Heim and A.Gansser took traverses upto Badrinath and between Joshimath and Lata in this influence of the highest peaks.

The mean winter temperature at 7000 feet is 47° F and summer mean temperature is about 65° F but in the valleys the temperatures are as high as 90° F to 100° F during May and June.

At 9000 feet the mean temperatures of the coldest month is 39° F. At 12,000 feet the temperature remains above freezing point from the end of May to middle of October but at 15,000 feet and above the temperature is always below the freezing point. The snow in the form of glacier is seen upto 9000 feet in central Himalayas. Glaciers are seen in the valley of Alaknanda after Badang chatti on both sides. Below 8000 feet snow fall is rare except at few places otherwise rain is the main form of precipitation.

Above 10,000 feet rains are usually in the form of drizzle whereas above 12,000 feet the snowfall takes place. The general relation of temperature to altitude as determined by various observers, in the Himalayan region is as follows:

1. The decrease of temperature with altitude is more rapid in summer.
2. The temperature changes with elevation. The northern slopes have higher temperature in comparison to southern slopes. The valleys are generally East-West and sometime NE-SW and thus the sun rays penetrate deep in to the valleys.

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a. massive crystalline limestone
b. about 500 meters of Chamoli quartzite
c. about 150 meters of massive coarse marble (crystal incertain places upto 5 cm. recalling Ramri).
d. quartzite and sericite schist of the Daling type at the mouth of urgam valley:
e. mica schist interbedded with quartzite
f. biotite gneiss with fluidal internal folding of the Darjeeling type:

Heim and Gansser(op. cit) regard their "main central thrust" between (c) and (d) or (d) and (e): They regard the limestones to belong to the Tejam limestone equivalent to Jaunsar series.

The rock between the thurst plane at Helong and Badrinath have been divided by Heim and Gansser as follows:

I 7.3 km. mica schist and gneisses
II 0.4 km. quartzite (Granulities)
III about 4 km. of injected paraschists characterised by Lime silicate layer:

They have described these rocks as "central cystalline series".

Ravi Prakash and Prem Swarup (1960) have recently given following tectonic sequence between Joshimath and Bolakuchi a part of the present area investigated.

Table No. 1.2

Age	Rock Formation	Locality
Algonkian	Gneisses and schist with coarse crystalline marble occuring in lenses and bands	Joshimath and Baragaon
Precambrian	Quartzite	Jharkula and Paini
	Grey limestone	Baragaon and Dhak village.
	Garnetiferous schist calc silicate rock with crystalline grey limestone	
	Biotite schist with basic intrusive and thin quartz vein	Nalong
——X——X——X——X——X——		Thrust
Tal ?	Thin calc zone consisting of grey limestone, dolomite	Langsi and North
	massive quartzite with basic schist	
Krol ?	Slates, massive limestone dolomite, soapstone	Patalganga and Bolakuchi

CHAPTER 2

CHAPTER 2

GEOMORPHOLOGY OF AREA

The geomorphology of the area gives clear proof of the powerful river erosion on one hand and the action of ice and glaciers on the other. The deep gorge near Pipalkoti, the acute V-shaped valleys of R.Alaknanda and R.Dhauli and the presence of numerous moraines and river terraces have faithfully preserved the geological actions of various agencies in the past and those which are continuous upto the present times. The surface features carved out in this fashion have been further modified by the avalanche, and landslides of various dimensions. Large, high and elongated mountain ranges and ridges, cut deep by the river valleys are broadly the main features of the region.

The major orientation of the ranges are SE-NW, which is the general trend of the Himalayas. The joints are the most important structural controls. The entire area is geomorphologically in young stage and the erosion is comparatively rapid. The slopes are steep and unstable except in regions which have suffered extensive slides in the geologically recent past. With the result that such slopes have attained maturity and stability. However due to the road building activities, this stability has been disturbed at several places.

The drainage of the area is dendritic but beyond

Joshimath the drainage pattern becomes rectangular as seen in the drainage map No.1. The main rivers of the area are R.Alaknanda, R.Dhauli Ganga and R.Rishi Ganga.

River Alaknanda orginates from Bhagat Kharak glacier and Satopanth glacier and it forms longitudinal valley before it meets R.Saraswati near Mana. River Saraswati has its origin near Mana Pass about 30 miles north of Badrinath.

River Dhauli Ganga which meets R. Alaknanda at Vishnuprayag, rises in the Zanskar ranges near Nitipass and receives numerous streams draining the northern and western slope of Nanda Devi. It is an anticedent river and has cut deep gorges. The presence of pot holes and river gravels at about 800' to 1000 feet from the present river level confirm the idea. The photograph No. 4 plate II and photograph No. 14, 15 plate 8 and photograph No. 9 plate 9 shows the river gravel deposits.

River Rishi Ganga originates from Nanda Devi glacier and according to Heim and Gansser (1936) carries half the water as carried by River Dhauli Ganga. This joins River Dhauli Ganga at Reni village near 14/o mile on the Joshimath Malari Road.

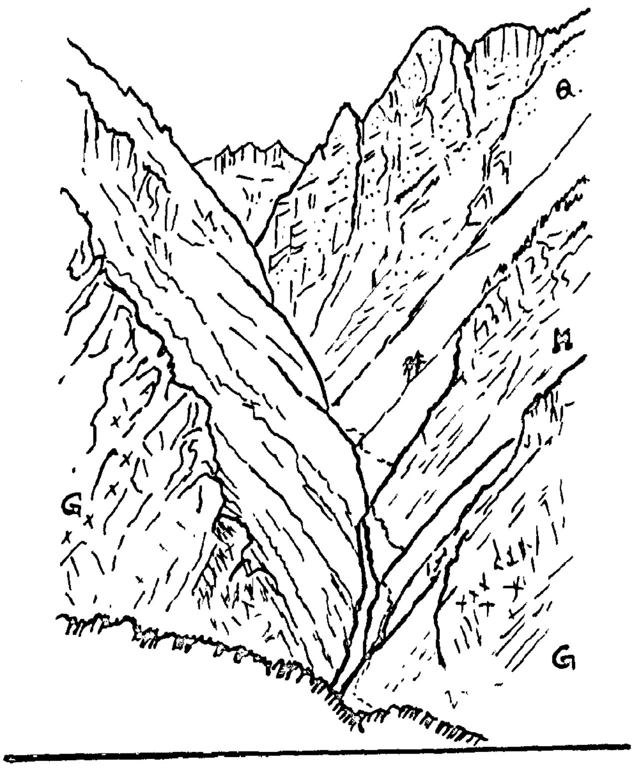
River Alaknanda - This river has cut an imposing gorge near Pipalkoti into the limestone(Photograph 2 No. Plate 1.) Both sides of the river show typical convex shape steepening downward. River terraces have been formed by the river and the photograph No. 2 plate 1 shows river terraces near Pipalkoti. Further north, R.Alaknanda is joined by several small rivers like R.Mana, and R.Patalganga which have steep gradient and great erosive power. R.Patalganga has cut an epigenetic gorge about 2 miles north of Belakuchi due to prehistoric landslide in limestone region which had blocked the river sometimes in the past, (photograph No. 20 plate 12).

Below Joshimath the river Alaknanda forms a longitudinal valley. The rightside of the valley is steep made up of joint planes whereas the left side is formed of slided mass (photograph No.26,25 plate 15) .

Here it seems that the old mountain slide of Joshimath forced the river to the right side thus giving rise to a rend steep slope to the right wall of the valley.

Beyond Joshimath, R.Alaknanda is seen to flow in a transverse valley. The shape of the valley is V shaped and the slopes of the two sides are convex. This is evident from the fig. No. 21 . The two sides of the valley, therefore just abutt against each other. Upto Pandukeshwar the river flows in a comparatively narrow valley with steep gradients. The valley widens, however, near Pandukeshwar where several small mountain slides have come down from both sides of the valley.

The river flows in a transverse valley upto Hanumanchatti in a direction N 30° W roughly but at Hanumanchatti suddenly changes its direction to E-W for a distance of 2 furlong and then again resumes its earlier direction. This may well



THE GORGE OF THE ALAKNANDA R.

ABOVE VISHNUPRAYAG VIEW TOWARDS N.

M = GARNET MICA SCHIST

Q = QUARTZITES

G = GNEISSES

FIG. No 2.1

be due to the following of the weaker joint plane, or some other structural weakness.

Between Radang chatti and Bamni village about 2 km south of Badrinath, the river gradient has become very steep, but near Badrinath the river valley has become sufficiently wide and gradient is also comparatively gentle.

According to Heim and Gansser (1939) the R.Alaknada from Badrinath 3080 meter at the bridge to Mana 3170 meter i.e. 3.5 km. in a straight line has only a gradient 5.5% whereas below the dam of Bamni it is about 18% on an average over a length of 3 km.

From Radang chatti further northwards there are several small glaciers (frozen river) seen on the righthand side of R.Alaknanda, Photograph No.39 Plate 24 shows a glacier just about 1 furlong south of Bamni. They form talus cones at the place where they meet with the river. On the left handside i.e. on the road side R.Kanchan ganga is present in the form of a glacier. Gradient of these glaciers is very steep.

Further northwards of the place where R.Alaknanda meets the R.Saraswati i.e. near the village of Mana, the R.Saraswati has got a steep gradient and a natural bridge is formed due to big boulders.

These boulders came down from the left side of the valley due to avalanche in the past and blocked the river. Moving parallel to R.Saraswati, crossing the high ridge formed of huge boulders, the presence of a wide valley and the signs of lake deposits confirm the idea of river damming during the past.

The wide valley of Badrinath which is in the form of bowl needs a explanation. According to Bose(1968) this is a gigantic old amphitheater where old glacier met in the past. This valley is formed due to blocking of river in geological recent past and lake deposit mixed with moraines are seen. Peat has been found below the ground. On the left handside of the wide valley fan shape deposits are seen which are morains left due to the recession of glacier.

<u>River Dhauli Ganga</u> — R.Dhauli Ganga which meets R.Alaknanda at Vishnuprayag has formed deep valley and first making a transverse section and then cutting a logitudinal section down to its confluence with the R.Alaknanda. They meet at obtuse angle.

The River Dhauli Ganga in its north western course has been forced to the right, so that the right side of the valley is formed of steep walls. This forcing of the river to the right can be explained due to the general dip of the gneisses and schists towards NE and due to slipping of the left valley sides on the micaceous bedding plams.

River Dhauli ganga has cut epigenetic gorges at several places, the first epigenetic gorge as seen moving along the road is at Tapoban (Photograph No. 33 Plate 20) Here according to Heim and Gansser (1939) moraine deposits are seen below the slide material but writer could not find the morain deposits. A characteristic landform marked B in the photograph No. 33 Plate 20 is present just after Tapoban and this is a flat topped hill made up of glacial moraine deposit. The rocks of this region show in situ alteration (Fig. No. 3.5) This might have been the remonent of an old slideed mass which blocked the path of river and the flat surface may have been formed due to the overflow of water. The photograph No. 33 plate 20 shows this flat topped hill, the river is narrow at this place but widens after this block. This place can be taken as the last point upto which glaciers were active in recent geological past. All along the road upto the village Reni 14/o mile the river valley is moderately wide.

Near the village of Reni, boulders and gravels are seen and they indicate the old river level (photograph No.4 plate II. From this the idea can be derived about the cutting power of the river. The river Dhauli Ganga suddenly widens after milestone 17/o near the village of Lata. This wedening of valley which extends to 2 km towards Suraithota may well be explained by the blocking of river due to mountain slide. River terrace deposits and as well as gravel deposits are seen.

Fluvio-glacial deposits are seen all along the road between milestone 26/o to 27/7. Near the village of Tamak, glacier striation were seen in a boulder. Very good river sand deposits are present near Tamak. The current bedding is seen in these river deposits and photograph No. 16 plate 9 shows well graded bedding.

Beautiful varve clay deposits are seen along the road about a mile from village Juma and here the river suddenly changes its course direction at right angle for one furlong and again assumes its original direction. This may well be explained due to the moraines which were left due to receding glacier and this in turn caused, the blocking of the river. Photograph No. 16 Plate 9 shows river deposits near 28/1 milestone.

As seen from the village of Juma, the Kagchills shows ices on dip slopes. This clearly indicate that the northern slopes have luxurient vegetation and they are also ice covered. The southern steeper slopes do not have much of vegetation photograph No. 3 plate II .

The valley of R. Dhauli ganga widens after the village of Juma and about 3 miles from this place near 23/0 mile or Mark's view, river has cut again an epigenetic gorge and the evidences of the formation of lake are still present, as the material has not yet been complotly eroded. On the left side of the valley river gravels are seen standing vertically. The left hand side of the valley is quite steep whereas right hand valley wall is gentle. According to villagers about 25 years back a huge mountain slide took place and material came from a tributor of R. Dhauli Ganga, flowing in East-West direction and meeting R. Dhauli ganga near Mark's view. From the villagers description it was inferred that it was probably due to some avalanche.

The river valley again narrows down further northwards. At Bhapkund river flows in a valley extremely narrow due to the large boulders brought as avalanche debris. Consequently the velocity of the river has suddenly increased.

The river gravels as seen at different places particularly along the Dhauli Ganga contains boulders of granite, limestone which has altered to ferrogeneous material. This indicate the distance of transportation of these boulders from a far place.

Thus it can be concluded that the river has kept pace with the upheaval of Himalayas and have cut deep gores.

The other important geomorphological feature in this area are the hanging valleys. U shaped hanging valleys are well seen near Tamak, between Pipalkoti and Belakuchi. Glaciated valleys shows features such as truncated spurs in the form of tremendus cliff, which appear for-midable where the river has cut deep and this is well seen between Lambagar and Badrinath along R.Alaknanda.

The water falls are located where ancient tributary glaciers have joined the main glacier, the typical hanging valleys. Thus water falls have been observed near the vill-age of Torosi along Alaknanda. The Vasudhara fall on the R.Alaknanda near Mana is formed due to the hanging valley. The U shape of the above valley is very clear from a far distance.

Near snow line hanging glacier are common. They gener-ate avalanches among the valley above the snow line. The glaciers seen from Badrinath are good example of hanging glaciers they rest on the spurs of the rocks.

The upper portion of the glaciated valleys are choked by glacial moraine. Ground moraine fillup the bottom of great U shaped valleys and the present R.Alaknanda and R.Dhauli Ganga has cut deep gorges through them.

As seen near Bhapkund the valley is U shaped and old morain deposits are standing vertically on the left side of the valley about at a height 2000 feet from the present river level.

CHAPTER 3

CHAPTER 3

Geology and Structure of Area

The lithologic units occurring in the area can be convintently be divided in two main groups-

I. The older Metamorphic series- It comprises the meta-psammites represented by quartzites, quartz gneisses and biotite schists and the metapelites represented by augen gneiss, chlorite schist and biotite schist and comparatively smaller calcareous units. This series is essentially the same which was called by Heim and Gansser(1939) as "Central crystalline series" equivalent to Jutogh series.

II. The Pipal Koti Series- It comprises the quartzites, dolomitic limestones, and slates. These rocks are less metamorphosed in comparison to the rocks of the "Older Metamorphic Series". These rocks have been considered as equivalent to Tejam limestone series by Heim and Gansser (1939) and corresponds to Jaunsar Series. Ravi Prakash and Prem Swarup (1960), however, consider the equivalent to Krol and Tal series.

The older Metamorphic Series has been thrusted over the Pipalkoti Series near Helong according to Heim and Gansser (1939). However, the thrust plane is not very clear near Helong. On the basis of the presence of augen gneisses near

Helong and again at Gulabkoti about one and half mile from Helong towards Belakuchi, it has been concluded that at least there are two movements at this place. These two together have been referred to as Gulabkoti Helong thrust zone.

The rocks of both series have been traversed by basic sills which are now represented by the Amphibotites. A tectonic succession of the area between Pipalkoti and Dhapkund out lining only the major lithological units has been given in Table 3.1.

TABLE 3.1

Designation	Rock type	Age
Intrusives	Amphibotite sills Aplite Dyke	
Older Metamorphic Series	Quartz micagneiss with Kyanite developed along joint plane and foliation plane.	
	Felspathic quartzite with bands of garnetiferous quartzite.	Jutogh ? Precambrian.
	Quartzmica gneiss with marble lense Bio	
	Biotite schist	
	Biotite quartz gneiss	
	Augen gneiss	
	Biotite schist with chlorite schist	
	Augen gneiss	

____ x ______ x ______ x ______ Fault.

	Biotite schist with chlorite schist	
	Sericite quartzite with thin bands of pink marble	
	augen gneiss	
	___ X ______ X ______ X ______ X ______	FAULT
Pipalkoti Series	White to greenish quartzite with bands of marble	
	Dolomitic limestone	Jaunsar ?
	Slate	

I Pipalkoti Series:- The rocks in an around Pipalkoti are white to grey dolomites, interbedded with slates and marble. This succession of rocks are present upto a distance of 7 miles from Pipalkoti towards north and is followed by quartzite for a further distance of about half a mile.

All these rocks have been traversed by quartz veins along the foliation or bedding plane or across them. Some quartz veins shows minute folding along with the rocks whereas certain late quartz veins do not show any folding. These quartz veins are of two different ages.

<u>Dolomitic limestone, Slates and Marble</u> - These rocks are folded into ~~a~~ plunging anticlines and synclines, more or less in the form of anticlinorium. The structural map on a Scale 1:50,000 of area between Pipalkoti and Helong shows the folding. Fig.no. 3.1

The dolomitic limestone very in colour from grey to in the dolomitic limestone between the milestone 153/6 and 154/4 on Pipalkoti Joshimath road. Disseminated grains of pyrite are visible in nearly all the rocks of this series. The development of pockets of talc has been marked along the bedding planes of the dolomitic limestone near Belakuchi. The slate shows well developed slatey cleavage and can be split into fine laminae. The rock shows minor folds and kinks all along the road between Pipalkoti and Belakuchi (158/4). The bedding plane and slatey cleavage is parallel to each other thus S_1 is parallel to S_2

Quartzite - The quartzites are massive white and green coloured, the colouration is due to presence of sericite and chlorite along the bedding planes. The first exposure of the quartzite is met with near 161/6 milestone on the Belakuchi helong road. These are highly jointed and fractured and some joints show polished surface. Near 162/6 milestone the quartzite are found to contain small blades of bluish Kyanite. The quartzites are also folded but due to their competent nature, the folding is not so marked as in the slates and limestone. The well jointed characters of the rocks indicate the structural deformation suffered by these rocks. The presence of numerous joints and fractures, the occurrence of kyanite are indications of the extreme stress to which these rocks have been subjected to.

Structure- The dip of the rocks belonging to Pipalkoti series varies from Pipalkoti to Langsi bridge due to folding. The dip of the rocks at Pipalkoti is 30° due N 30° E which gradually changes towards Helong to 35° - 0° due N 15° E. The rocks shows a series of minor folds and the strike direction changing between S 60° E – N 60° W to S 50° W – N 50° W between S 60° E – N 60° W to E – W and then S 50° W – N 50° W and finally the strike again becomes normal i.e. S 60° E – N60°W. The dip of amount varies between 0° to as high as 70° which is due to intense folding suffered by these in competent rocks. These direction denote the minor folds developed due to major anticline.

The plunge of the fold varies from 41° due N 55° E to 25° due NE and at some places the plunge is 0° and strike is S 45° E – N 45° W. At such places where fold have become nearly horizontal good caves have been developed as seen in photograph No. 5 plate III.

The photograph No. 6 plate III shows the folding in grey slaty limestone near at 155/4 milestone. The folding has affected the joints thereby indicating that joints are earlier than the folding.

The major joints are as follows:-

1. 56° to 80° due S 40° W
2. Vertical joint strike S 60° E – N 60° W
3. 85° due E
4. 62° due N 15° W
5. Vertical strike N 10° E – S 10° W
6. 69° due N 25° E
7. 58° due S 20° W

The joint 58° due S 20° W surface has been polished. The spacing of joints is about 6 to 25 cm but in slates spacings are close. As a result the slates have been highly fractured and shattered.

The rocks are faulted near 162/7 milestone between Belakuchi and Helong. The rocks at this place are dolomitic limestone, augen gneiss and quartzites. The dip of fault plane varies from 56° due N 10° E to vertical to 6?° due N 20° E. These readings are taken along the road where the fault is exposed due to fresh cuttings. The gaunge is present and this fault marks the end of augen gneisses towards Pipalkoti from this point. The fault is a reverse fault or rather, a high angle thrust.

II <u>Older Metamorphic Series</u> — This series has been called "Central crystalline series" by Heim and Gansser(1939). It has been considered the oldest series of Himalayas and according to Gansser(1964) and Auden(1936) is equivalent to Jutogh series.

The Older Metamorphic Series has been thrusted over the Pipalkoti series. The rock units belonging to this series can be grouped broadly as follows.

TABLE 3.2

Meta-pelites

(1) Augen gneisses

(2) Chlorite schist and Biotite schist
with thin bands of marble

Meta-psammites

(3) quartz mica gneiss
with at places rich Garnetiferous zones.

(4) felspathic quartzite

It must be hastened to add that these units cannot be interbedded with each other. However, certain generalisation can be made.

Between Gulabkoti and Vishnuprayag on Pipalkoti-Badrinath road and between Joshimath and Reni on the Joshimath Bhapkund section, the rocks are mostly meta-pelites i.e. augen gneisses, chlorite schist and biotite schist, although subordinate bands of quartzites, quartzgneisses and marbles also occur. Beyond Reni on one side and Vishnuprayag on the other, the rocks are mostly meta-psammites, although here too the subordinate bands of biotite schist and occasional thin bands of augen gneisses are present. Chlorite schist are absent beyond Tapoban, although bands of augen gneisses persist upto Lata. Augen gneisses are, however, not met beyond Lata, although, biotite schists bands continue to occur even upto Bhapkund.

These rocks have been correlated with the Darjeeling gneisses by Heim and Gansser(1939). According to Pasco(1950) they represent the root of Garhwal nappe.

These rocks are simple dipping beds without any major discernable structural deformation for a distance of nearly 30 mile upto Bhapkund. The dip varies from 30° to 60° due N 15° E to NE. This uniformity of dips has prompted earlier workers to call these as "monotonous".

(1) <u>Augen gneisses</u>: The augen gneisses are met near Gulabkoti and then again at Helong. They again reappear at Jharkula chatti and continue in and around Joshimath. Augen gneisses also occur near Reni (14/4) in a zone of about two furlong. These augen gneisses are the strike continuation of Joshimath augen gneisses.

The rocks shows good augens of felspar and are light coloured. The biotite flakes have arranged themselves in bands thus giving rise to colour bands. These rocks are coarse grained.

The quartz veins show ptygmatic folding and Fig. No. 33 shows the ptygmatic folding of quartz vein. The biotite flakes have bent around the quartz lenses. The veins of quartz are along the foliation plane. The rocks are folded and plunge is 26° due N. Tourmaline crystals have developed around the margins of quartz lenses. The dip varies between 40° to 35° due N 40° E to NE. The rocks are highly jointed. Lenses of quartz are common in these rocks and photograph No. 11 plate 6 shows a lense near milestone 16/1.

The augen gneiss particularly those between Tapoban and Lata are very characteristic in showing yellowish and brownish encrustation probably, due to leaching of some sulphide minerals.

(2) <u>Biotite schist and chlorite schist</u> – The rocks between Helong and Gulabkoti, between Baragaon and Tapoban, and those between Paini and Shelong are chlorite schist and biotite schist. They occur as intercalated bands and are of variable thickness. The rocks in between Baragaon and Tapoban are quartz muscovite hematite schist. The hematite grains have arranged themselves in a linear pattern and have given rise to lineation. These rocks are green to dark coloured and dip of foliation varies between 40° to 35° due N 60° E to NE.

These rocks are folded to large extent into minor folds. The plunge varies between 40° due N to N 10° E. The rocks are faulted near Tapoban and the hot spring of Tapoban may be related to this fault.

Quartz veins have intruded along the foliation planes and they are showing pinching and swelling structure. The quartz veins at Tapoban carry small plates of Wolframite and a detailed study of this area is warranted for the further information about minearlisation.

(3) Quartzmica gneisses with garnetiferous rich zones- The rocks between 13/o and 14/o milestone on Tapoban-Reni section and between Suraithota and Juma are garnetiferous biotite schist and quartzite bands are inter bedded. The dip is 30° due N 36° E. Garnets have been arranged in a linear pattern giving a lineation, the direction of lineation is N 30° E. The bands of quartzites are as thin as 4 cm. to 6 cm. The garnet stand prominantly and can be recognised with nacked eye. The schist and gneisses are intercalated and at places, yellow encrustation and sulphur smell is present, which may be due to the presence of some sulphide minearls. Quartz lenses are common and biotite schist have bent around it. Fig. No. 3.2 shows the quartz lense and also the pinching and swelling of quartz vein.

(4) Felspathic quartzite - The rocks are light coloured and shows a little gneissosity which is due to the muscovite flakes. The general texture in handspecimen can be said to be of granoblastic type.

Some bands contain garnet giving it a distinct appearance. The garnets are arranged at places in a linear pattern but otherwise they are randomly distributed. These rocks are highly jointed and the bands of biotites schist are intercalated with quartzites and are folded into minor folds. In these quartzites, quartz lenses are present and development of tourmaline is seen at the contact of quartz lenses. It appears, that these quartz lenses were probably intruded as veins together tourmaline and were later subjected to movements and caughtup as lenses.

The quartz gneisses, quartzites and schists continuou to show similar occurrence upto Bhapkund. The dip of foliation varies from 30° to 60° due NE to S 70° E. Minor foldings and minor faults with throws as small as 3 cm are common.

Near Bhapkund the development of fibrous kyanite has been noted along the joint planes in biotite schist and quartz gneisses. These have probably developed due to shearing forces.

STRUCTURES

The rocks are simple dipping but due to the minor folding the dip changes from 30° to 45° due N 15° E to NE to N 70° E. Also at places dip becomes 60° due S 70° E. The plunge direction varies from 26° due S 80° W to 36° due N 80° E to 75° due N 20° W. The rocks have been faulted but the faults are of minor nature.

The fault which is seen near Tapoban is named as Tapoban Fault. The dip of fault is 35° due N 20° E and strike is S 80° E - N 80° W. The throw is small and the chlorite schist are disturbed due to faulting. The drag effect is clearly seen and indicate that the fault is of reverse type.

Another fault is seen near twenty one and half mile on Joshimath-Malari Road, the dip of the fault plane is 40° due N 10° E and rocks affected are quartzite and quartz mica gneiss. The throw is only 3 cm.

The rocks are highly jointed and major joints are as follows:-

(1) Vertical joint strike N 20° E - S 20° W
(2) 85° due N 60° E
(3) Vertical joint strike N 75° W - S 75° E
(4) 67° due N 75° W
(5) 65° due S 20° E
(6) 80° due S 40 W
(7) 79° due W

The joints are closely spaced but the spacing varies and and places intense fracturing and shattering is seen in gneisses and quartzite at 18/o milestone. This may well be indication of secondary thrust movements. The presence of amphibolite sills also point towards such a possibility. These joints are the main cause of rock fall because they give rise to blocks as seen in Fig. No.3.4.

III INTRUSIVES

(1) Amphibolite sills- The rocks of both the series have been intruded by basic sills and the thickness of sills varies between 20 feet to 5 feet. They are coarse grained to fine grained and are greenish in colour. The general texture in hand specimen is granoblastic but due to arrangement of hornblende crystals into linear arrangement, a

schistose texture is seen under microscope. They have caught pieces of gneisses in between them. At one place near 13/6 milestone on Joshimath-Malari Road, the amphibolite at the contact have developed Diopside. Probably at this place the basic sill has intruded along the marble band intercalated with quartz mica gneiss. At this place the amphibolite has been bifurcated and the portion between the two amphibolite bands show a concentration of Clinozoisite, which is another evidence in support of above statement.

CONTACT BETWEEN OLDER METAMORPHIC SERIES AND PIPALKOTI SERIES

The area between Helong and Gulabkoti (162/7Mile) has been considered by the author as a thrust zone. Earlier workers like Auden(1935) and Heim and Gansser(1939) have considered and indicated that the thrust passes through Helong and is well seen at the mouth of Urgam valley. The present writer could not see any clear thrust plane in this area. Gansser (1964) pp.104 has also reported that "In the R.Alaknanda valley, the thrust is less clearly defined, since underlying metamorphic rocks resulting from an upward increase of metamorphism in the quartzite section of Tejam belt are not unlike the over thrust masses and the latter are complicated by some secondary imbrications".

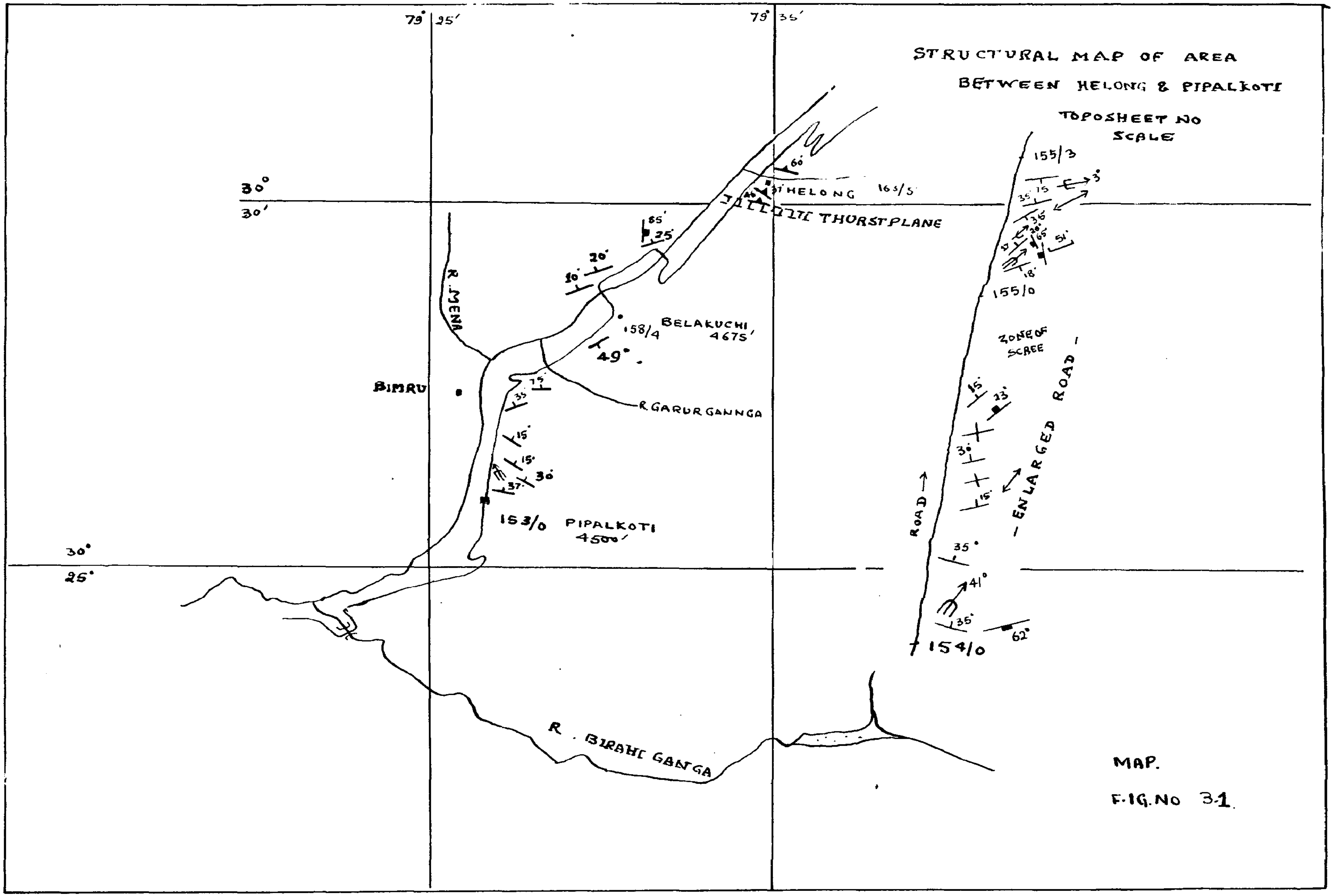
During these investigations, it was found that although a clear thrust plane is not seen at Helong, but the amphibolites present here show cataclastic texture(Slide No. 4/49) indicating thereby some dynamic metamorphism or movement. The micro photograph No. 45 plate 27 shows the broken hornblende crystals. However, the rocks on both sides of the amphibolite are similar i.e. augen gneisses, chlorite schist and biotite schist. If we regard amphibotites to indicate the thrust plane as Gansser (1964 p. 104) have done, two exactly similar rock types occurring together will have to be grouped in two different series. If, one agrees with the statement of Gansser stated above that the rocks of Pipalkoti series have been metamorphosed here to such a degree as the Older Metamorphic series, the field evidences do not support such views. For example quartzites and dolomitic limestone and slate of Pipalkoti series do not show any resemblance to those of the Older Metamorphic Series.

A fault was noted by the writer near Gulabkoti. It is a major fault separating chlorite schist, augen gneiss and marble with the quartzites and dolomites of the Pipalkoti series. The quartzites at this place are highly jointed, the joint planes are very weak and small scale movements are noted in them. It is thought that these structural deformations are probably sympethitic to the thrust movements and that the fault at Gulabkoti is probably a thrust. The dip of the Gulabkoti thrust plane varies from 60° to 56° due north 10° east.

Thus, on one hand, there are indirect evidences of a thrust near Helong, supported by the view of Heim and Gansser (1939) and Auden (1935) and direct evidences of movement at Gulabkoti. The rocks between Helong and Gulabkoti resemble very much with those of the Older Metamorphic Series, than with the rocks of the Pipalkoti series. This leads to the idea that possibly these are two thrusts between Helong and

Gulabkoti. The problem has been much aggrevated by the paucity of exposures between these two places as the area is covered by slided debris. It is quite likely that between these two thrusts, there may be one or two more thrust and the thrusting might have taken place along several parallel planes. However, the writer will not like to persue the problem with the limited data at his disposal.

The idea of the two thrust planes is however, not completely new. Heim and Gansser (1939) have shown two thrust planes to exist the gneisses at the Kauri Pass Section, which is very similar to the present area. A geological section of the Kauri Pass area and that of the present area has been given in Fig. Nos. 3·6, 3·7 and these sections show the resemblance.


STRUCTURAL MAP OF AREA
BETWEEN HELONG & PIPALKOTI
TOPOSHEET NO
SCALE
79° 25'
79° 35'
30° 30'
30° 25'
HELONG
THORSTPLANE
155/3
155/0
ZONE OF SCREE
ENLARGED ROAD
ROAD
154/0
BELAKUCHI 4675'
158/4
R. MENA
BIMRU
R. GARUR GANNGA
153/0
PIPALKOTI 4500'
R. BIRAHI GANGA

MAP.
FIG. NO 3.1

QUARTZ VEIN SHOWING
PTYGMATIC FOLDING
IN QUARTZ MICA GNEISS
AT 19/4 MILE
THICKNESS OF QUARTZ VEIN 1" to 2"

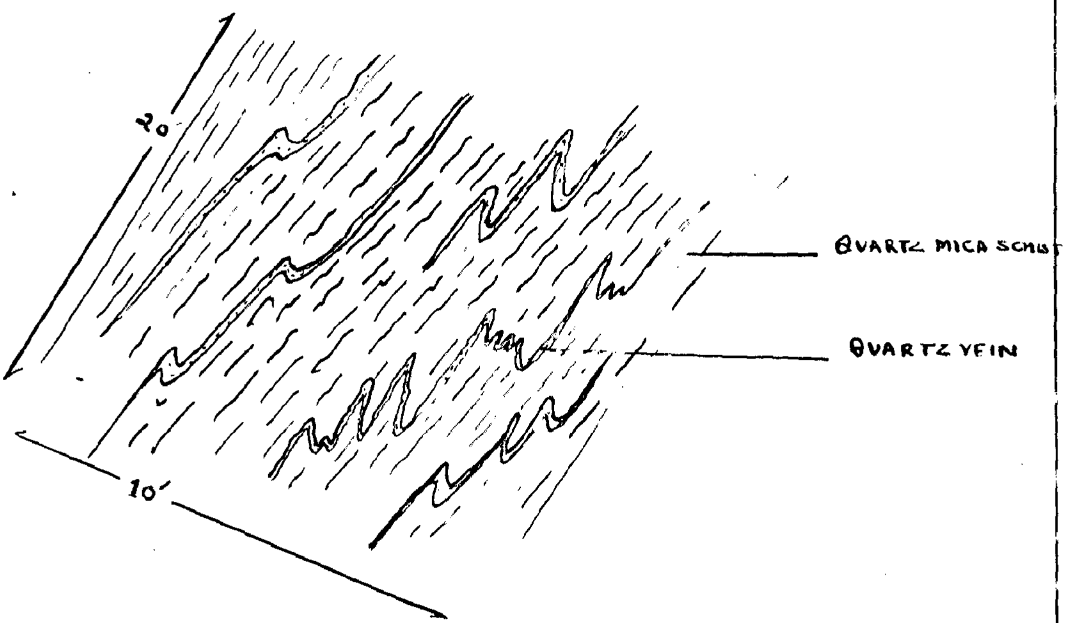


FIG. No 3·2 PINCHING AND SWELLING STRUCTURE
IN QUARTZ MICA GNEISS AND SCHIST
AT THE MARGIN OF QUARTZ, TOURMALINE AND GARNET ARE DEVELOPED
AT MILE 13/0
ON JOSHIMATH
MALARI ROAD

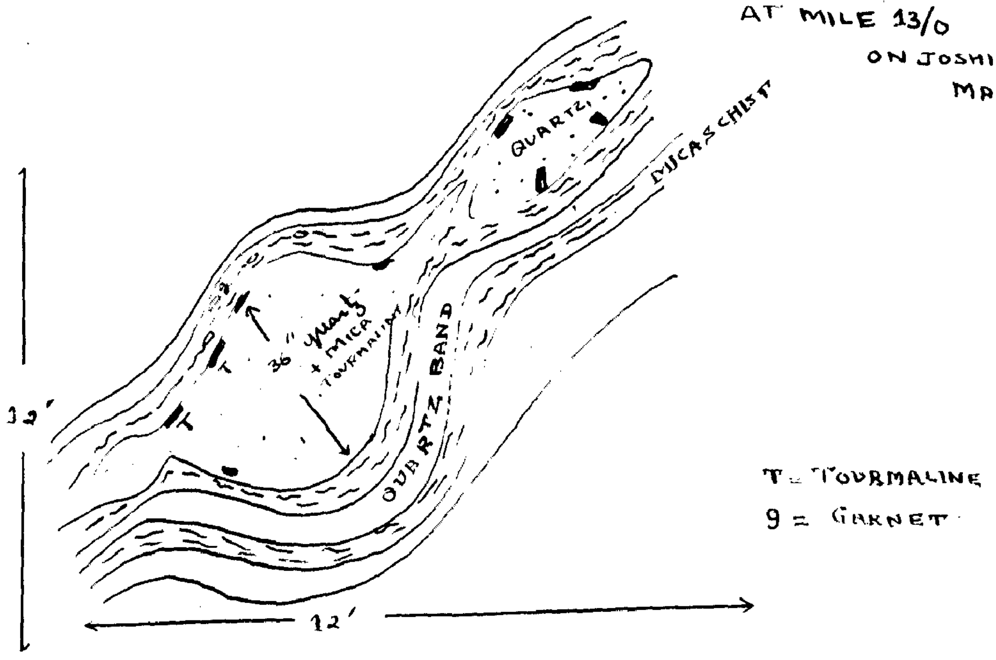


FIG No 3.4 QUARTZITE BLOCK SHOWING JOINTS PATTERN NEAR 10/6½ M.

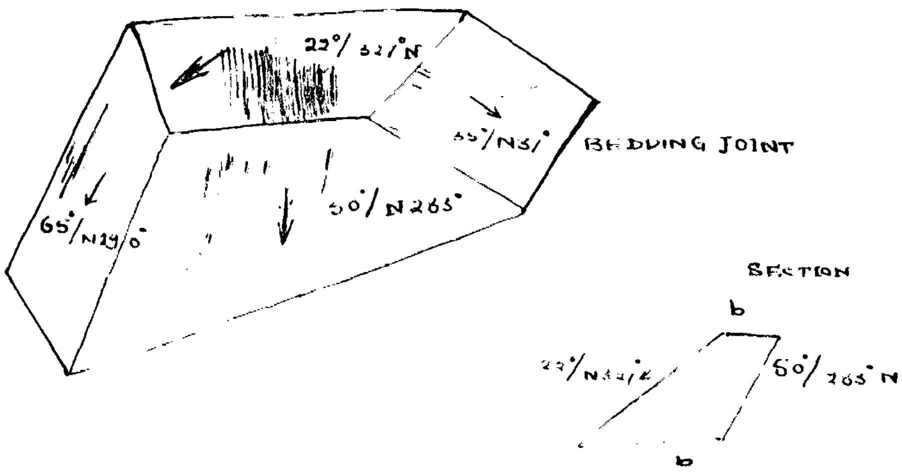
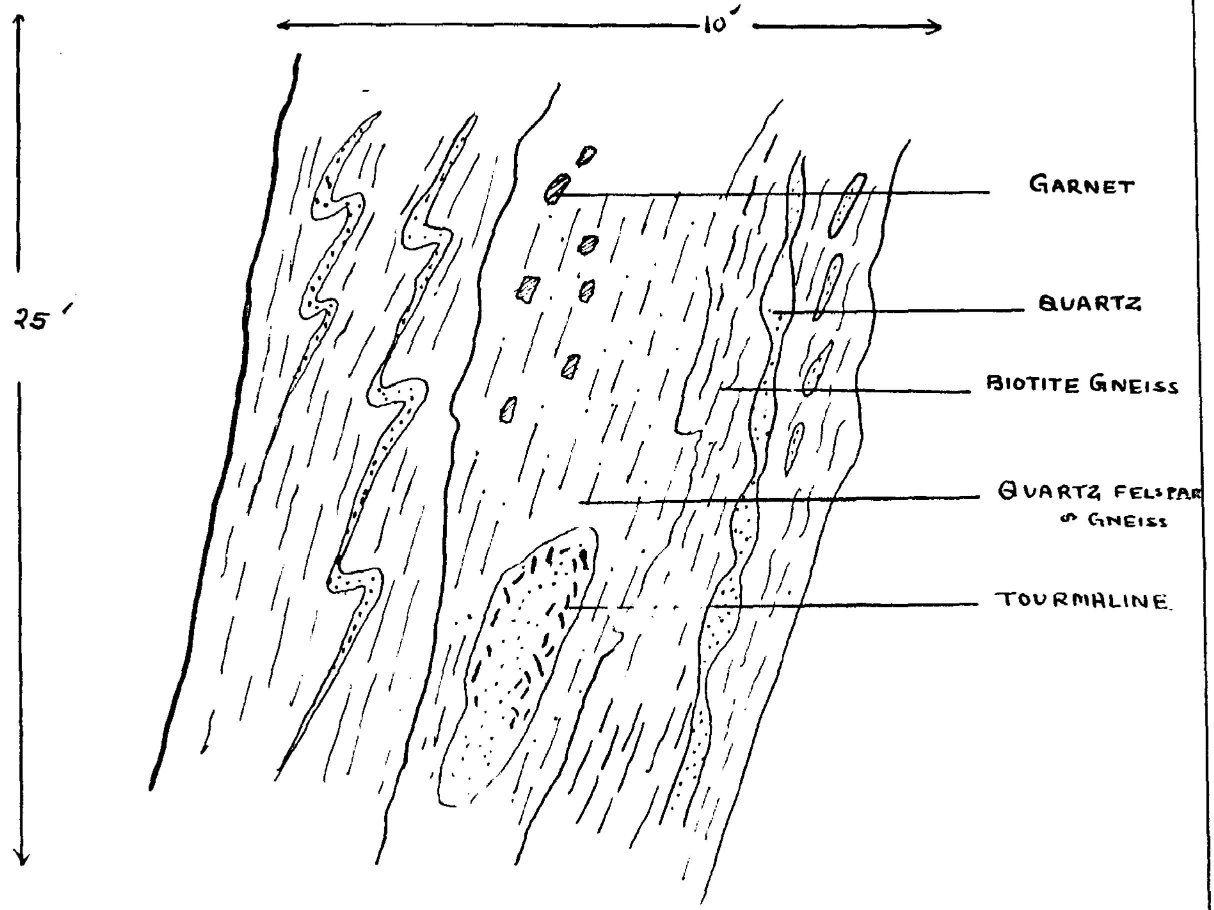


FIG No 3.5 INSITU ALTERATION OF CHLORITE SCHIST IN BOULDER CLAY · ACTION OF G W NEAR 11/2 MILE

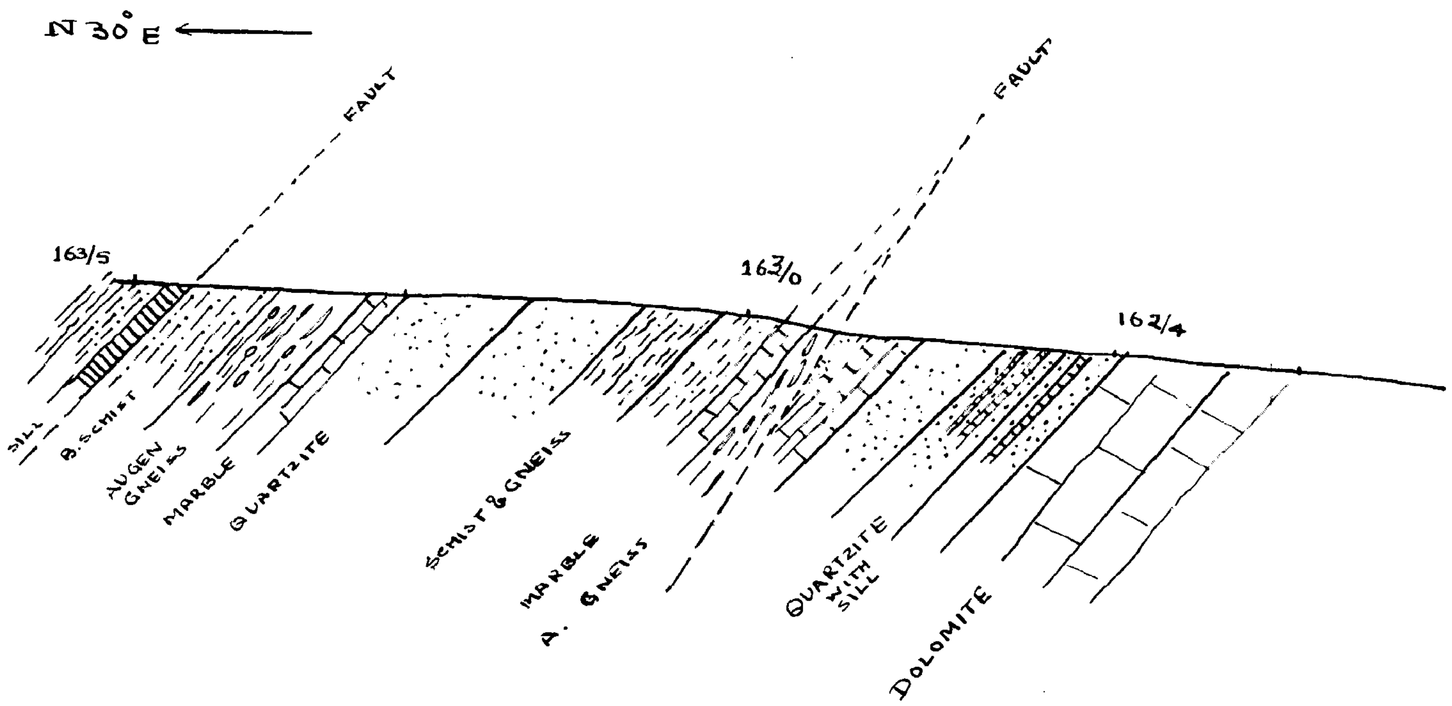


QUARTZ VEIN SHOWING PINCH & SWELL

STRUCTURE IN GNEISS

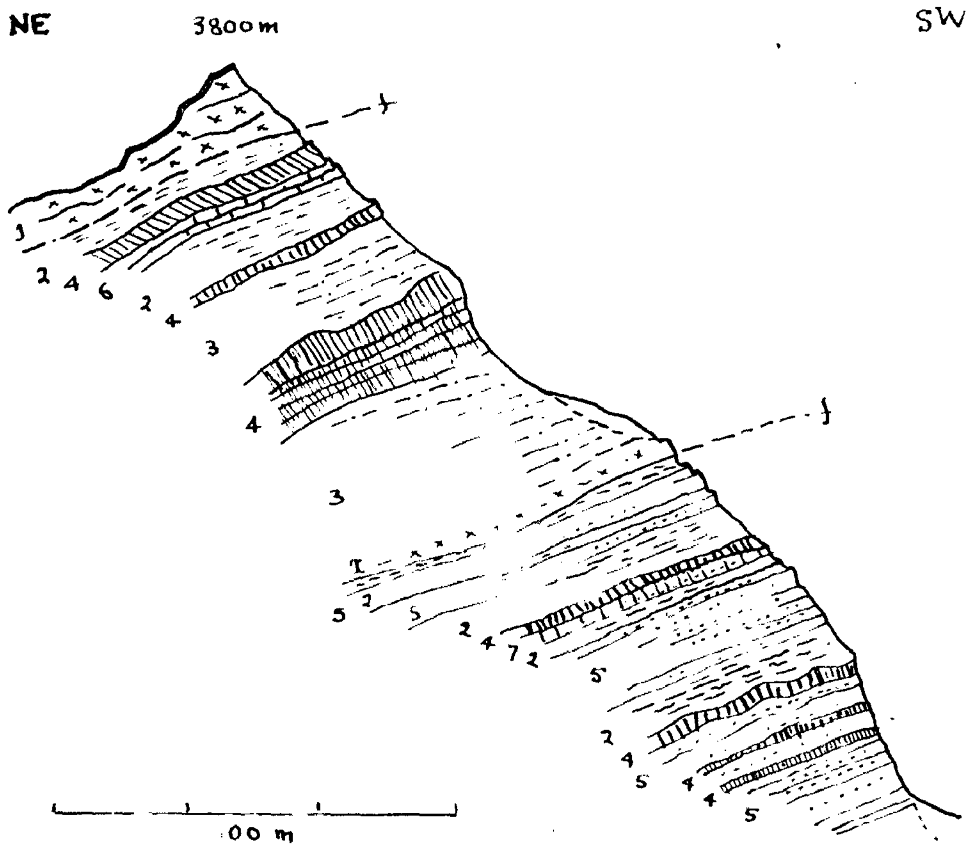
AT 13/2 MILE NEAR SONE BRIDGE

FIGURE NO 3.6



A SECTION ALONG ROAD BETWEEN HELONG AND 163/4 MILE STONE.

FIG. NO. 3·6



THE INCREASE IN METAMORPHISM TOWARDS "MAIN CENTRAL THRUST" IN THE SECTION NEAR KAURI PASS "HEIM & GAN (19

1.	Granite gneiss	5	quartzite
2	Mica schist	6	Marble
3	Garnet schist	7	Sandy limestone
4	Amphibolites	f	Main and secondary thru

FIG. NO. 3.7

CHAPTER 4

CHAPTER 4

PETROGRAPHY

The geology of the area has been described in Chapter 3. The petrography of the various rock types occurring in the area will be dealt within these pages. The rock types occurring in the area may be summarised as follows:-

I. Pipalkoti Series -

1. Dolomitic limestone
2. Quartzite
3. Slate
4. Chlorite schist

II. Older Metamorphic Series -

1. Schists
   (a) quartz muscovite chlorite schist
   (b) garnetiferous quartz mica schist
2. Gneisses
   (a) Augen gneiss
   (b) Quartz albite mica gneiss
   (c) Garnetiferous quartz biotite gneiss
   (d) Garnetiferous biotite clinozoisite gneiss
3. Quartzites
   (a) Felspathic quartzite
   (b) Garnetiferous felspathic quartzite
4. Marbles
   (a) Biotite marble
   (b) Diopside marble

III. Metabasics -

(a) Chlorite amphibolite

(b) Chlorite epidote amphibolite

(c) amphibolite showing cataclastic texture

(d) Garnetiferous albite epidote amphibolite

(e) Garnetiferous andesine epidote amphibolite

IV. Acidic dykes -

(a) Aplite

I. Pipalkoti Series -

(1) Dolomitic limestone - They are dark grey to light grey in hand specimen. They show banded nature and are well crystalline. They do not readily react with Hcl, thereby indicating that they are dolomitic limestone.

Under microscope the rock is inequigranular and fine grained. The dolomite grains are occurring as subhedral grains. The grains have irregular denticulate margins and have formed interlocking sutured aggregate. Bands of fine grain and corase grain minerals are present and they have given rise to banded structure. The texture may be termed as granoblastic.

Following minerals are present: -

Dolomite :- It occurs as subhedral grains. It is colourless and show lamellar twinning in crossnicols. It is present in abundance.

Calcite :- It is occurring as anhedral grains and relief is lower than dolomite.

Quartz :- Occurring as anhedral grains and it is present in a minor amount.

Flakes of Muscovite and small qubic crystals of Pyrite are other minerals present in this rock.

(2) Quartzite - The rock shows granoblastic texture. But fine needles of muscovite have arranged themselves in a preferential direction, giving rise to a linear arrangement.

Following minerals are present:-

Quartz:- It occurs as anhedral grains and boundaries are well sutured against each other. The grains show undulose extinction. About 95% constituents of the rock are quartz.

Biotite:- It occurs as fine needles which have arranged themselves in a linear arragement. It is present in a minor amount.

Kyanite:- It occurs as prismatic to tabular crystals. One set of cleavage is well developed. Mostly it shows parallel extinction but in some of the grains the angle is 30°.

(3) Slate - The texture of the rock is granoblastic but due to the arrangement of chlorite flakes and also due to the parallel orientation of biotite and sericite the rock has developed foliation. Slaty cleavage is developed.

Following minerals have been identified under the microscope:-

Quartz :- It occurs as anhedral grains. This is widely distributed through out the rock. A few quartz grains are arranged in layers. These represent the original siliceous layers.

Calcite:- It occurs as subhedral to anhedral grains thereby indicating recrystallisation. Lameller twinning is seen.

Minute flakes of Sericite and Chlorite are also present and they are usually arranged in bands. Incipient crystallisation of biotite is also discernible in the thin section. Small cubic crystals of pyrite are present in significant amount.

The rock seems to have been derived due to metamorphism of argillaceous sediments which were containing calcareous material.

(4) Chlorite Schist - It shows schistose texture. Chlorite flakes have arranged themselves in a linear pattern giving rise to schistosity. Chlorite flakes have bent around the quartz felspar grains.

The following minerals are present:-

Chlorite:- It is pleochroic from greenish to colourless. It shows parallel extinction.

Quartz:- It occurs as anhedral grains, arranged in between the flakes of chlorite.

Sphene:- Occurs as needles and crystals arranged in clots and also showing preferential parallism.

A few grains of felspar are also visible, but their exact identification could not be made.

II. Older Metamorphic Series -

1. Schists

(a) quartz muscovite chlorite schists-

The rock shows schistose texture which is imparted to the rock due to the linear arrangement of micaceous minerals.

Following minerals are present:

<u>Quartz</u>:- It occurs as subhedral to anhedral grains. The boundaries are well marked and certain quartz grains shows sutured boundaries. Wavy extinction is characteristic.

<u>Chlorite</u>:- It shows green colour under polarised light. The pleochroism is weak. It occurs as radiating fibrous mass. The interference colours are extremely low order grey. In many flakes anomalous blue colour was seen.

<u>Biotite</u>:- It shows pleochroism from light brown to dark brown. It occurs as flakes.

<u>Sphene</u>:- It is present in large quantity. It occurs as needles and as clusters.

<u>Muscovite</u>, <u>apatite</u> and <u>felspars</u> occur in minor amount.

(b) Garnetiferous quartzmica schist :-

The rock is fine grained and dark coloured. Schistose texture is seen in hand specimen.

Texture - The grains are subhedral to anhedral. The garnet occurs as rounded grains and biotite flakes have arranged in a linear pattern. Due to the partial arrangement of biotite flakes, schistosity is developed giving rise to schistose texture.

Following minerals are present:

Plagioclase - Occurs as small grains, subhedral in shape and shows albite twinning and carls bed twinning. Extinction angle as determined in Albite twin plane varies between 22° to 20°, giving rise to a composition of Albite becase R.I. < C.B.

Garnet - It occurs as rounded to subhedral grains. They show sieve structure and are isotropic. The boundaries are well marked and biotite flakes occur around the garnet grains. It occurs as porphyro-blasts and it contain inclusions of quartz and biotite.

Biotite - It occurs as flakes and shows pleochroism from dark brown to light greenish. Its extinction varies between 0° to 3°. The flakes have generally surrounded the garnet and clinozoisite.

Quartz - It occurs as anhedral grains and few grains are present.

Orthoclase - Few grains are present, but they are altered to sericite.

Clinozoisite - It occurs as subhedral grains. It is colourless and non-pleochroic in the ordinary light. It has got one set of cleavage. Its relief is high and refractive index is greater than canada balsam. The interference colours 1st order. Anomalous blue colour is very common.

2. Gneisses -

(a) Augen gneiss - The rock shows gneissose texture and the flakes of mica and grains of quartz and felspar are arranged in a linear fashion and porphyroblasts of felspars are developed giving rise to augen structure. The flakes of biotite have been bent round the augens and they at places criss cross each other.

The following minerals are present:-

Felspar:- It occurs as purphyroblasts. Sericitisation has taken place and the appearance is cloudy. R.I. < C.B. Lamellar twinning is not present. On the basis of these characters the felspar is identified as orthoclase.

Plagioclase:- It shows albite twinning and extinction angle is 17°. R.I. < C.B. and hence the minerals is albite. It is altering to sericite.

Quartz:- It generally shows sutured boundaries. It is anhedral in shape but at places well developed subhedral grains are seen.

Biotite:- Occurs as flakes and have bent around the augens of felspar. Pleochroic from light brown to dark brown and shows parallel extinction.

Garnet:- It occurs as rounded grains and show sieve structure At places it is surrounded by mica flakes.

Flakes of muscovite, needles of sphene and grains of apatite and magnetite are other minerals present in this rock.

(b) Quartz albite mica gneiss :- The rock contains xenoblastic grains of quartz. The grains of quartz are sutured. The plagioclase and felspar also occur as subhedral grains. It has developed gneissose texture. The biotite flakes occurs arranged in a preferred orientation.

Quartz :- quartz is abundant in the rock and occurs as anhedral grains. It has sutured boundaries.

Plagioclase :- It is albite as determined on albite twin plane, extinction angle is 18° to 21°.R.I. < C.B.

Orthoclase :- It is altering to a large extent to sericite. It occurs as subhedral grains.

Muscovite, biotite, sphene, apatite, sericite and ironores(magnetite) are the other minerals occuring in minor amounts.

(c) Garnetiferous quartz biotite gneiss :-

The rock is fine grained and grains are subhedral to anhedral. The lepidoblastic biotite and muscovite has arranged themselves in a parallel fashion. The alternate granoblastic quartz and felspar and lepidoblastic biotite have given rise to gneissose texture.

Following minerals are invariably present :-

Quartz:- It occurs as anhedral to subhedral grains. It has recrystallised to a large extent and boundaries are well defined. It contain inclusions of biotite and sphene.

Plagioclase:- Occurs as subhedral grains. It shows albite twinning and extinction on albite twin plane is 12°. R.I. < C.B. The mineral is albite. It is present in a large quantity.

Orthoclase:- Alteration has given it a cloudy appearance. It has got low refractive index. It contains inclusion of quartz and muscovite.

Muscovite:- It occurs as laths and flakes. It has bent around the garnet grains.

Garnet:- It occurs as rounded grains. It shows sieve structure and mica flakes have bent around it. It contains inclusion of quartz and sphene.

Apatite:- It occurs as six sided colourless basal section. Also rectangular sections are present.

Biotite, sphene and magnetite occur in minor amount.

(d) Garnetiferous biotite clinozoisite gneiss - The rock occurs in between two amphibolite bands near 13/6 milestone on Joshimath Malari Road. Slide No. 4/80

The rock shows gneissose structure, the gneissosity being displayed by biotite and prismatic, lenticular grains of clinozoisite. Following minerals were identified in the slide.

Plagioclase:- Occurs in subhedral grains showing albite law and combined albite-pericline and albite -carlsbad twinning. The refractive index is higher and the extinction angle is 22°. The specie comes out to be andesine.

Biotite:- Occurs in laths or basal plates and often its margin with the garnet is not sharp. The biotite do not show exact preferred orientation, but on large scale they depict the gneissosity.

Garnet:- Rounded to sub-rounded grains of garnet with occasional euhedral margins. Frequently occur in the slide. The garnet usually contain inclusions of biotite and quartz. The biotite is also present around the margins, although the bending of laths is not marked.

Clinozoisite:- Laths and lenticular grains of clinozoisite, slightly pinkish in colour and showing anomalous lemon-yellow or upto first order yellow colours are very common. This is usually associated with biotite although the association is not universal.

The quartz minerals present in the slide are anhedral grains.

3. Quartzites

(a) Felspathic Quartzite – The rock contain about 90% quartz and quartz grains occurs as xenoblastic but few flakes of mica occurs in the inter spaces. The texture is granoblastic.

Quartz:- The quarz grains are small and they have well defined boundaries. It shows normal extinction.

Plagioclase:- It shows albite twinning and extinction angle is 21°. R.I. < C.B. Hence it is albite.

The other minerals present are flakes of muscovite, grains of apatite and needles of sphene.

(b) Garnetiferous quartzite – In field it occurs as bands in quartz mica gneiss.

It shows granoblastic texture and following minerals are present:

Quartz:- It shows corroded margins and it consitutes about 75% of the rock.

Garnet:- It has got corrugated margins and the garnet is broken into calcite and chlorite and at places a rim of chlorite is present around the garnet. It includes grains of quartz and sphene.

Biotite:- Biotite occurs around garnet and at places has bent around the garnet it occurs as poikiloblastic laths.

Chlorite:- It is due to the alteration of garnet i.e. due to the breaking of garnets.

The other minerals present are sphene, apatite and calcite. The calcite occurs either at the border or in the cracks of garnet.

4. Marbles

(a) Biotite marble – (Slide No. 4/62)

Locality – 12/6 milestone on Joshimath Malari Road

The marble lense occurs in between the biotite schist. The clcite crystals have recrystallised and boundaries are well marked. They show granoblastic texture but the biotite flakes have arranged them-selves in a linear arrangement. There are bands of coarse and fine grained calcite and a schistocity is developed due to the biotite flakes.

Following minerals are present:

Calcite:- Occurs in well crystallised grains and lamellar twinning is common. They occur as subhedral to euhedral grains.

Biotite:- The flakes of biotite have arranged themselves in a linear direction and thus schistosity is developed.

Clinozoisite:- Subhedral crystals of the minerals are developed in cracks and fractures and they occur in between the calcite grain.

The chlorite and quartz are present in minor amount, and chlorite is developed along the fractures.

(b) Diopside marble - (Slide No. 4/88)

The rock occurs along the margins of amphibolite at 13/6 milestone. The rock shows the development of large crystals of diopside, together with calcite.

Diopside:- Diopside occurs as large crystals with subhedral to anhedral margins. It shows alteration to hornblende along the margins and in the cracks. Inclusions of calcite grains are seen particularly towards the margins. It has been identified due to its neutral colour, relief, two sets of cleavages at 86° and 94°, extinction angle of 41° and maximum interference colour of second order yellow.

Calcite:- Occurs in well crystallised grains with typical lamellar twinning. It occurs as individual subhedral crystals or as anhedral grains included in diopside.

Hornblende:- It occurs as an alteration product of diopside along the margins, cleavage plane and fractures.

III. Metabasics-

The amphibolite sills occur all along from Pipalkoti to Bhapkund. They are coarse grained to medium grained in handspecimen and shows at places calcite pockets with pyrite. The contact with the country rock is sharp. But at places along the contact a zone rich in garnet has developed.

(a) Chlorite amphibolite - Under microscope it shows well developed schistose texture which is due to the linear arrangement of hornblende and chlorite crystals. Lepidoblastic grains of chlorite have bent around the grains of plagioclase.

Following minerals are present in Slide No. 4/20.

Hornblende:- The colour is light green and it shows pleochroism from light green to dark green. Crystals are arranged in a linear pattern giving rise to schistosity Hornblende altered to chlorite and only few unaltered hornblende grains are present. Generally the core is of hornblende and margins are of chlorite. The maximum extinction angle is 20°.

Plagioclase:- It is albite and the extinction on the albite tw plane is 20°. R.I. < C.B. Few grains of plagioclase show heavy alteration.

Quartz :- It occurs as anhedral grains. The quartz is associated with felspar in the common ground mass of the rock. It does not show undulose extinction. Boundaries are clearly marked. It often contain inclusions of hornblende and felspar.
Chlorite :- It generally occurs as alteration product of hornblende. It is greenish in colour and shows first order yellow polarisation colours. The extinction angle is 0° to 6°.
Muscovite and Biotite :- They occurs as flakes and they are arranged in linear pattern.
Sphene :- Occurs as needles. They have high refractive index and relief.

(b) Chlorite epidote amphibolite - It shows schistose texture. Lepidoblastic grains of chlorite have bent around the grains of plagioclase and quartz.
Chlorite :- It is present in large proportion and almost all hornblende has changed to chlorite except at few places where hornblende occurs as core of the grain. Some of the chlorite grains show anomalous interference colours.
Plagioclase :- It is of albite composition and extinction angle is about 18° on albite twin plane. Refractive index is lower than canada balsam. It occurs in large quantity.
Hornblende :- Occurs only as core in some chlorite grains.
Epidote :- It is colourless to yellowish green, shows some pleochroism. It has cleavage in one direction. Relief is high and refractive index is greater than canada balsam. The polarisation colours are of third order.

Grains of quartz and calcite are other minerals of the rock.

(c) Amphibolite near Nalong 163/5 milestone -slide No. 4/45. The texture is cataclastic and hornblende grains are broken in a preferred direction. The parallel arrangement of hornblende prism have given rise to schistosity. At places the quartz grains are completely surrounded by hornblende grains. At places a little rotation of quartz grains are seen and due to this the hornblende grains are also rotated. Following minerals are present :

Hornblende :- The hornblende grains are fractured along a certain direction and otherwise they are showing complete margins. Microphotograph No.   shows the effect of fracture.

Quartz :- They occur as anhedral grains and show effect of rotation.

Plagioclase :- The subhedral grains are common and albite twinning is seen. Extinction angle on albite twin plane is 17°. Refractive index is less than canada balsam. It is albite.

Grains of apatite and needles of sphene are common in this rock.

(d) Garnetiferous albite epidote amphibolite - The rock is medium grained. The amphiboles are forming slender prism and laths. They have arranged themselves in a linear fashion but often they criss-cross each other. Biotite flakes also show marked parallelism but at places these flakes cut each other. Garnet is occurring as idioblastic grains and is also arranged in a band and it occurs as phorphyroblasts. Quartz and felspars are anhedral in aggregate and occurs interstitial grains.

Hornblende :- It is pleochroic from dark green to light green and extinction angle is 16°. Cleavage is well developed and often basal sections are present. Inclusions of quartz grains are common.

Garnet :- Its boundaries are sharp but at places garnet has given rise to biotite. It occurs as porphyroblasts.

Biotite :- It occurs as flakes around garnet.

Quartz :- It is present in sufficient quantity and occurs as anhedral grains.

Plagioclase :- The plagioclase is albite showing an extinction angle of 130° on albite twin plane.

Epidote :- It occurs as slender prismatic grains. It has got high relief and refractive index is greater than canada balsam. It shows parallel extinction. It may be due to sassuritization of plagioclase.

Clinozoisite :- It is colourless in ordinary light. Cleavage is perfect in one direction. It shows first order middle interference colours but they are anomalous. In most sections the extinction is parallel.

Needles of sphene and grains of magnetite are other minerals present in this rock.

(e) Garnetiferous andesine epidote amphibolite - The general texture is granoblastic but at places a little schistosity is developed. Hornblende occurs as lepidoblastic grains. Following minerals are present :

Hornblende :- It shows pleochroism from light green to bluish green. Two sets of cleavage at an angle 124° is seen in basal section. Extinction angle is 18° and symmetrical extinction is seen in basal sections. More than 60 % of the rock is made up of hornblende.

Plagioclase :- It is andesine and extinction angle is 18° on the albite twin plane but refractive index is greater than canada balsam.

Garnet :- It occurs as disseminated grains and shows sieve structure. It is fractured and bounderies are irregular.

The grains of quartz, needles of sphene, flakes of chlorite and euhedral grains of apatite are other minerals of the rock.

IV. Acidic Dykes

(a) Aplite :- (Slide No.4/118)

The aplite dyke has cut across the foliation plane of mica-schist near 20/7 milestone on Joshimath - Malari Road.

The texture is medium graded, allotriomorphic. The minerals present are as follows :

Quartz :- It occurs as anhedral grains. Some quartz grains are clear whereas others have needles of tourmaline which have forms circular rings.

Orthoclase :- It occurs as subhedral to anhedral grains. It is altered kaoline and hence the appearance is cloudy. It also contains needles of tourmaline and these needles are restricted only to some part of the rock.

Tourmaline :- It occurs as needles which are accicular nature. It is pleochroic from neutral to slate blue. It shows parallel extinction. Relief is high and this variety of tourmaline is schorlite.

Crystals of pyrite and limonitic material is present in this rock.

CHAPTER 5

CHAPTER 5

LANDSLIDES : A review of the causes and Pre-historic slides.

In a country where mountainous regions are vast, rainfall intensity and concentration are high, seismological disturbances are frequent, the geological structure is young and unstable, the problem of landslides are very complex. They require through investigation and a correct analysis of the slide is necessary to decide upon the preventive and corrective measure.

In the words of Terzaghi (1960) the term landslides refers to a rapid displacement of a mass of rock, residual soil or sediments, adjoining a slope in which the centre of gravity of the moving mass advances in a downward or outward direction.

The author has studied some landslide zones between Pipalkoti and Badrinath and that of between Joshimath and Bhopkund. The rocks as earlier stated are dolomitic limestone, slates and quartzite between Pipalkoti and Helang. These are thrusted upon by older metamorphic series including augen gneisses, quartzites and biotite schists. The rocks are often overlain by unconsolidated masses of pre-historic slides, glacier moraine, fluvio-glacial deposits and river terraces. The lithology, structure and insitu alteration are the factors causing the land slides in the consolidated material and disturbances of natural angle of repose, atmospheric agencies like rain, wind, avalanche and the action of surface and subsurface water are the chief causes of land slides in the unconsolidated material.

CAUSES AND CLASSIFICATION OF LANDSLIDES -

The moving mass or material may proceed down-ward by any one of the three principle types of movements namely.

I. Fall

II. Slide

III. Flow

I. Fall- The moving mass may be rock or soil and it falls due to action of gravity. The rock is loos-ened by different agencies and in the end this loose rock falls. The Fig. No. 5·1 shows falls due to action of different agencies.

II. Slide- In ~~true~~ slide the movement results from shear failure along one or several surfaces which are either visible or may be reasonably inferred. There are two sub groups based on the quality of material.

(a) Slump

(b) Block slide.

(a) Slump- In the case of slump the moving material is not deformed and the slide is of rotational shear type. In this case the dimension of unit is great than the displacement. Movement is controlled by surfaces of weakness such as faults, joints, folia-tion plane. The movement in slump takes place along internal slip surface. The surface of rupture is a concave upward curve surface and it is seldom a circular arc of uniform curvature. The shape of the curve is greatly influenced by faults, joints and other preexisting discontinuties in the material for example the lithological changes, the Fig. No.5.2 shows diagram of the slump along lithological boundary.

The scarp at the head of slump may be almost vertical when the mass moves considerably downward, the steep scarp is left unsupported and minor slides takes place in due course of time. Any water that finds its way into the head of slump may be pounded by the back-ward tilt of the unit block or by other irregularities in the topography and due to this water the surface is kept wet constantly and this results in more slumps and continue till the slope has attained stability. Slump generally takes place in unconsolidated strata.

(b) Block slide - Block slides are those slides which take place along the planar surfaces particularly along the bedding plane and rotary movement is lacking. The block slide takes place depending upon the angle of dip and presence of intercalated slip surfaces. Some time after slide huge blocks of rock remain in the same structural position and dip remains the same with the result that it becomes difficult to decipher whether a particular block is insitu or is a slided mass.

This type of slides are common in the present area. The landslide near 9/3 miles on Joshimath-Badrinath road can be grouped as block slide. Here the rocks are quartz gneisses, and slip takes place along the dip slopes.

III Flow- When the material is unconsolidated and is made up of plastic clay, then due to action of water the clay starts flowing. This type of flows are not seen in this area.

The land slides may be classified depending upon the three factors namely-

I. Type of material- which may be soil, rock formation boulder, river gravels.

II. Type of movement- whether the movement is due to fall, slide or flow.

III. Cause of movement- The causes may be ice, wind, river, glacier, and groundwater.

These three factors taken into consideration gives classification of landslides. Terzaghi(1950) has correctly stated "A phenomenon involving such a multitude of combination between material and disturbing agents opens unlimited vistas for the classification enthusiast. The result of classification depends quite obviously on the classifiers opinion regarding the relative importance of the many different aspects of the classified phenomenon".

According to George, E. Ladd(1935) there are four main types of slides-

I. Mud flows.

II. slope readjustment

III. under mining of strata

IV. structural slide.

These above types are dependent upon the type of material involved. Thus local lithology of the site of slide plays an important role in the causes of landslides.

The second classification which is adopted by David J. Varnes in Eckel (1958) pp.21 takes into consideration two main variables:-

a. Type of material

b. Type of movement

The classification proposed by him is given in table No. 6.1.

TABLE 6.1

Classification of land slides after varnes

Type of movement		Type of material			
		Bed rock		Soil	
Falls.		Rock falls		Soil falls	
Slide		Rotational slump	Planar	Planar	Rotational.
	Few unit	slump	Block slide	Block slide	Block slump
	Many unit.		Rock-slide	Debris slide	failure by lateral spreading
		All consolidated			
		Rock fragments	sand	silt	mixed
flow	Dry	rock fragment flow	sand flow	loess flow	
	wet		sand/silt flow		Debris flow
Complex		Combination of material or type of movements.			

Description of landslides - It has been noted by the writer that all important cities of Garhwal Himalayas and Central Himalayas are situated on the old landslide or on river terraces in the river valleys. The river erosion is one of the main cause of land slides in the present area. The road to Badrinath and Malari from Joshimath passes at places through old landslide zones or through glacial morain material, which when disturbed i.e. the angle of repose is disturbed, becomes new zones of landslides.

From the point of study the landslides of this area have been divided into two groups based on whether the slided mass has attained stability or not. These two groups are :-

I. Prehistoric slides - All old major landslides which have taken place in the geological past are included in this group. The slope of the slided masses have attained stability.

II. Recent slide zones- The slide zones has not yet attained stability and the movements are still taking place from time to time. These will be dealt in the chapter. 6 .. and they are of current significance.

The prehistoric landslides include the following prehistoric major landslide zones of the area and will be dealt in the following order:

1. R. Patal ganga landslide zone - Between Dalakuchi and Helong near Langsi village.

2. Joshimath landslide zone.

3. Pandukeshwar landslide zone.

4. Tapoban landslide zone, on Joshimath Malari road.

5. Jolam landslide zone.

1. Patal ganga landslide zone:- This landslide had taken place in the dolomitic limestone of the Pipalkoti series. The course of river Patalganga has been changed due to this landslide. The photograph No. 20 Plate 12 shows the present positions of R. Alaknanda and R. Patal ganga. A geological plan Fig. 5.4 shows the present valley of the rivers and the relation of the slided mass with the rock formation of the area. The possible cause seems to be the action of ground water through the limestone. The slip has probably taken place along the bedding plane of Dolomite limestone and the under cutting by the R. Patal ganga must have further helped in causing the slip.

2. Joshimath landslide zone - The township of Joshimath is situated on a old landslide. The rock types involved are augen gneisses, biotite schist. The old landslide zone extends for a distance of about 4 mile from west to east along the road as seen with map No. 6.4 . The area have attained the angle of repose and general slope is 28° to 30°. The photograph No. 26 plate 15 shows the stable slope of this area.

Some problems have arisen in this area due to the construction of new road. These will be described at on at an appropriate place.

3. Pandukeshwar landslide zone - Pandukeshwar is a small town situated 13 miles from Joshimath towards Badrinath. The rocks are quartzite with inter-calated layers of schist. The valley becomes wide at this place which can be explained easily on the basis of old mountain slide. As studied the slides seems to be controlled by the dip plane and huge blocks of quartzite must have slided along the foliation plane as the dip of the rock is high (46° due N 80° E to NE) resulting in the damming of river. The drainage is faulty and it is along the dip slopes. The area has attained stability.

4. Tapoban landslide zone - The main villages situated on this landslide are Tapoban, Baragaon and Dhak. The road Joshimath-Malari passes through the slided material between 8/0 mile to Tapoban 10/0 milestone.

This slide has been named as Kauri landslide by Heim and Gansser(1939) due to the fact that the slide has its origin east of the Kauri pass at 4000 meters.

The Dhauli ganga has been forced to right side of the valley near Tapoban, which is evident from the steep walls at right side of the valley. The forcing of the river towards right is not caused only due to the general slipping of the left side of the valley along the mica-ceous foliation plane.

This slide extends from village of Baragaon to Tapoban (a distance of two mile). This slide can be classified as structural slide as well as block slide and some vertical scarps are seen in the south eastern part of the slide. A section has been drawn a cross the valley near 10/6 mile-stone – Fig. No. 5.5 and 5.6.

The slope is 25° to 30° at present and which is stable slope. Big boulders of gneisses and quartz-ite are embedded in fine matrix of clay and crushed material.

In the photograph No. 32 plate 20 a triangular sloping plane which is marked (A) is seen. This probably was forming the frontal part of this Tapoban landslide. Due to this slide the river valley was filled thus causing a damming of river. The river did not flow through its original path but had cut an epigenetic gorge in the mica schist and quarzite marked (B) in the photograph No.33 plate 20.

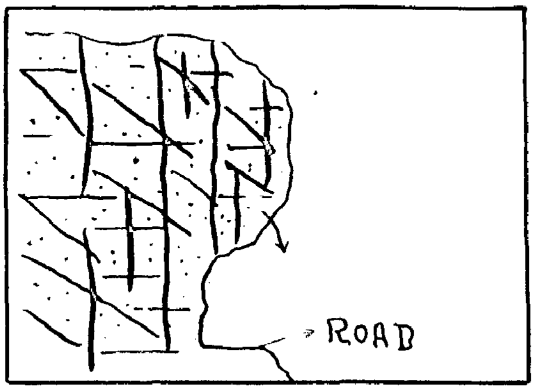
Avery interesting feature to be noted in the photo-graph No.33 plate 20 is the flat topped land mass which must have been formed due to overflow of water in olden times. This slided material is partly boulder clay deposited due to glacier and partly rock boulders which show heavy insitu alteration. Fig. No.3.5 shows insitu alter-ation at 11-2 milestone.

6. Jelam landslide zone – The next prehistoric landslide zone includes Jelam (30/6 mile) and Jelam itselfs situated on the slided mass.

The right handside of R.Dhauliganga valley is made insitu weathering of rocks. Here the prehistoric slide seems to be from the right hand side. The rocks are quartz mica gneisses dipping at 70° due E.

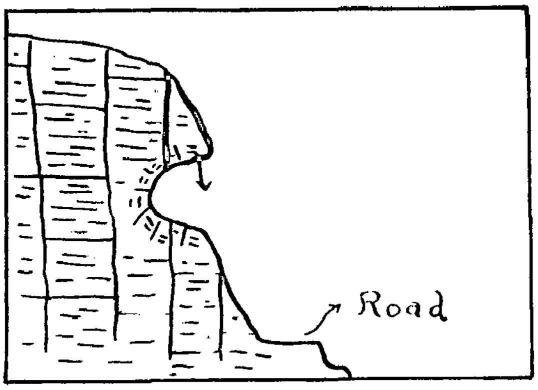
The evidences of landslide are found in this area covered, are bending of R.Dhauliganga at right angle twice within a short distance and river being forced toward left. River gravel deposits and pot holes are observed along the road which are atleast 1000 feet above the present river level. This proves how old the pre-historic slide is in this place.

DIFFERENT TYPE OF ROCK FALL



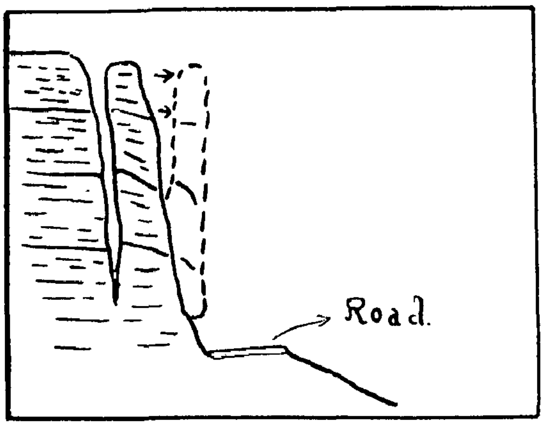
A

vertical joints –
Homogeneous – non homogeneous
Jointed Rock – overhang



B.

Overbreakage and
blast fracturing.



C

Frost wedging in jointed
homogeneous Rock.

Fig – 5.1

SLOPE FAILURE IN NON HOMOGENEOUS MATERIAL. SURFACE RUPTURE FOLLOWS DIPPING WEAK BED.

A.

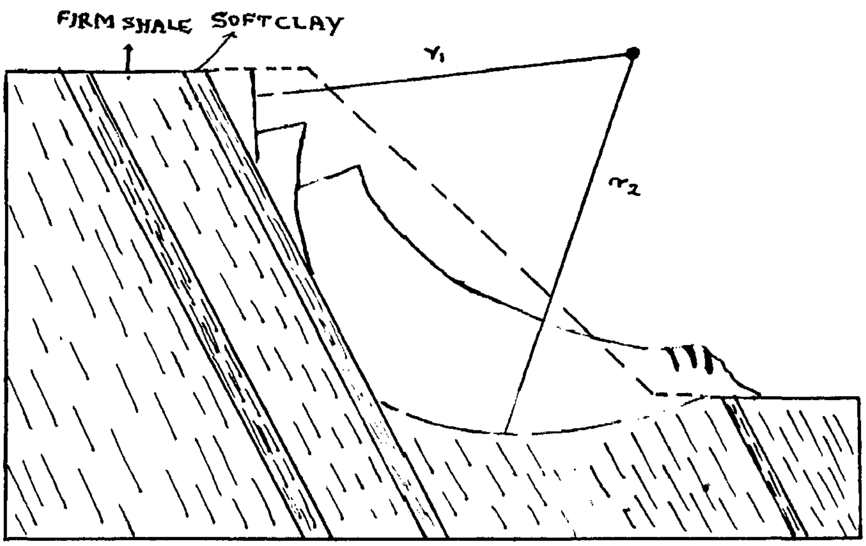
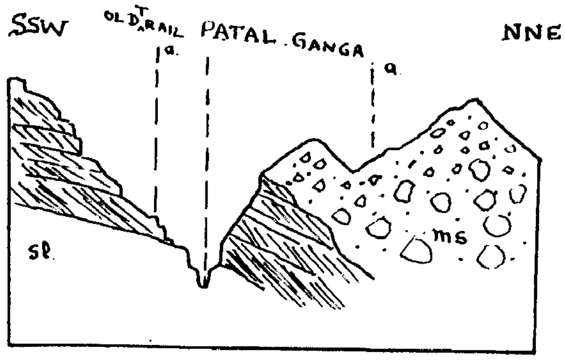


FIGURE NO 5·2

B. THE EPIGENETIC GORGE OF PATALGANGA BELOW OLD BRIDGE



Sl = Dark slate
ms = OLD MOUNTAIN SLIDE

FIGURE NO - 5·3

GEOLOGICAL PLAN OF AREA AROUND R. PATALGANGA

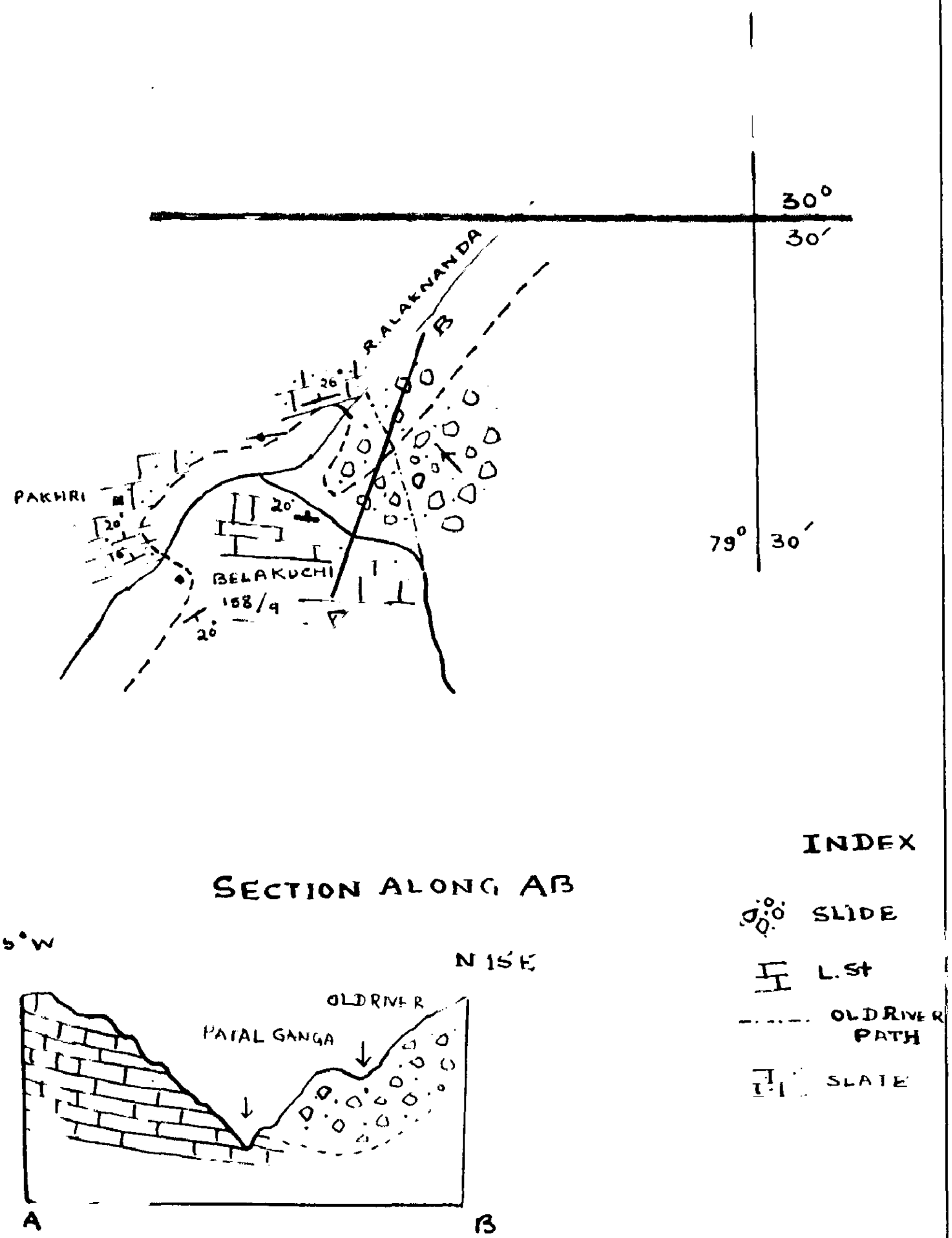


FIG No. 5.4

THE KUARI MOUNTAIN SLIDE

AFTER A. HEIM.

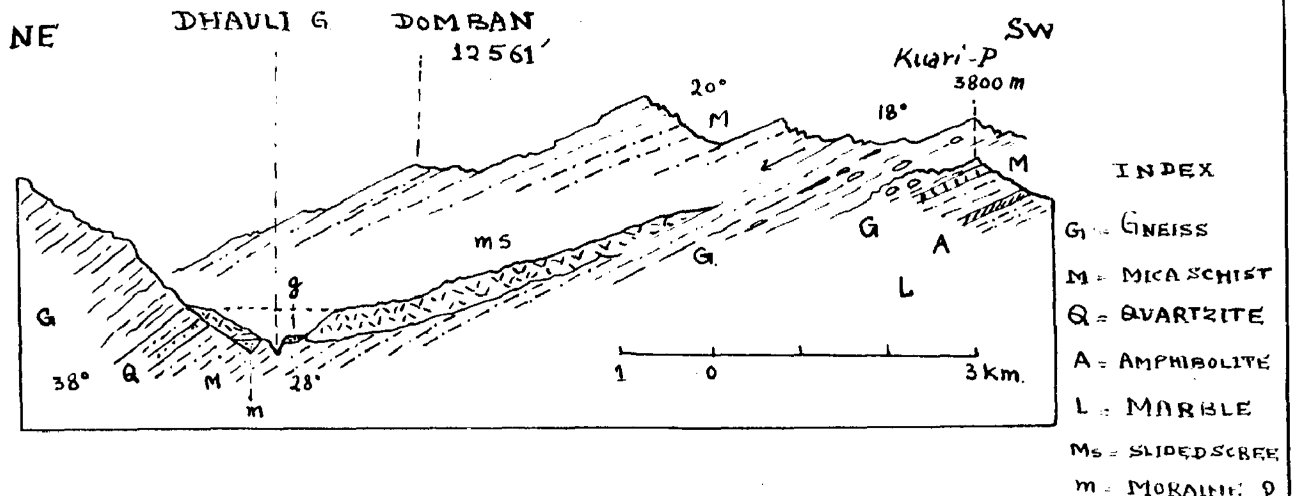


FIGURE NO 5.5

THE EPIGENETIC GORGE OF THE DHAULI GANGA

AS SEEN FROM THE EAST

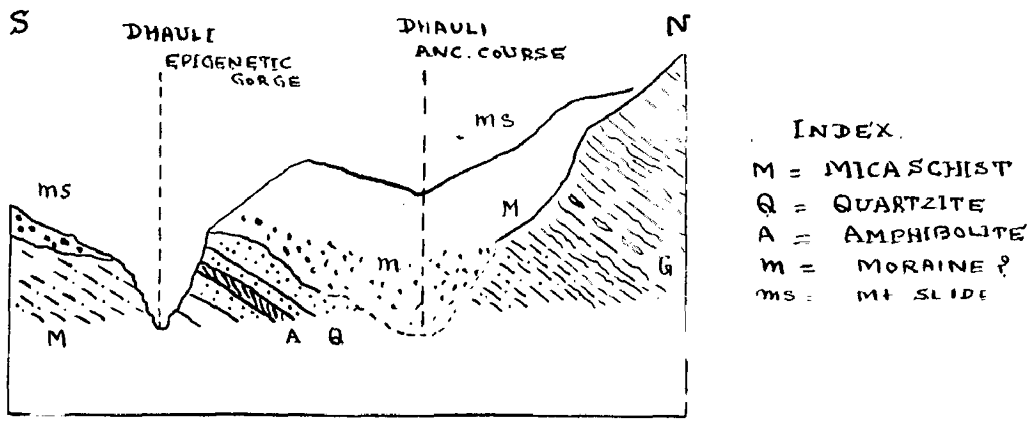


FIGURE NO 5.6

CHAPTER 6

CHAPTER 6

Recent landslide zone of the area

The recent landslide zones of the area will be described in this Chapter. For the sake of clarity individual zone will be described separately without any biased grouping as to their cause or material.

The whole area has been divided into zones as

I. Land slide zones between Pipalkoti - Helong.

II. Land slide zones between Helong - Badrinath.

III. Land slide zones between Joshimath - Bhapkund.

I. Land slide zones between Pipalkoti and Helong.

The rock types in this area are dolomitic limestone, slates quartzite with intercalated chlorite schist and amphibolite sill.

(1) Land slide zone near 156/7 milestone between Pipalkoti and Bolchuchi. The rocks are limestone and they are dipping at an angle 30° to 35° due S 60° E. The direction of river Alaknanda is roughly N 65° E - S 65° W.

This zone lies between two tributaries of R. Alaknanda namely R. Garur Ganga and R. Pani Gad. These two tributaries are flowing roughly parallel to each other. Seepage of water is seen through the joints in the limestone. The slip usually takes place along the joint plane, which dip ~~16~~

40° due S 40 E, due to the action of water. The slope of valley side is about 48° and is it-self in unstable condition. A section across the river Fig. No.61 shows the geological and structural condition of the area.

The main causes of land slides are presence of following major joints-

(i) 62°/ N 15 W

(ii) 70°/ N 62°E

(iii) 40°/ S 40°E

The seepage of water through the joints is very heavy and much damage is done due to the caving along the joint planes. The individual blocks are thus made loose and due to the high angle slope the blocks slide down. The undercutting by the R.Alaknanda is yet another factor affecting the stability of the area, by removing the support at the base, making the upper blocks unsupported from below or by causing the flow of debris on the slope of the valley side.

The landslide can be controlled by providing proper drainage facilities to check the seepage of water on the upper reaches and putting blocks of concrete on the bank of the river upto the flood level of the river to check the under cutting.

(2) Landslide zone between 157/6 to 158/0 milestone This is an active slide zone. The rocks are limestone and calcareous slate and these are highly jointed and joints are closely spaced thus the rocks give an

appearance of highly crushed material. Dip of the limestone is 45° due S 40° E and joints are

I 62° due N 16° W

II 65° due N 60° E

III 45° due S 40 E

The road direction at this place is N 80° E – S 80° W. Thus the dip is away from the road but the joint 62° due N 16° W is main cause of slip along this plane. The photograph No. 17 Plate No. 10 and a section (Fig. No. 62) drawn across the river Alaknanda will show the true nature of the slip zone.

The presence of joint plane and seepage of water and high slope are the main causes of this landslide. Due to the solution channels being made in the limestone and high angle joint slopes being present, the rockmasses are overlain by earlier slided debris. These loose debris continue to fall with slightest disturbance, say to the strong winds. The problem of water seepage is, however, not so important in this locality as the high angle of slope.

The remedial measures which can be taken are as follows–

(i) Benches can be made on the upper slope. This will be a good and effective method of control of slide.

(ii) A cheaper way of solving the problem is the construction of small breast walls at different heights so as to prevent the falling of material. This will, of course, be not as

(iii) The slope angle to be reduced to 30° from 60°. This will imply huge expenditure but the slip will be permanently stopped.

(3) The land slide zone near 153/1 milestone-

This zone extends for about 2 furlong. The rocks are dolomitic lime stone dipping at an angle 46° due N 15°E and they are highly jointed. The major joint direction are -

(1) 83° due S 50 W

(2) 62° due N 15° W

(3) 65° due N 70° E

The road direction is approximately N 25 E - S 25° W. The slope is made up of loose weathered soil and crushed material. The photo No. 10 Plate 11 shows the steep upper slope and fresh slip surfaces. The rocks are folded and crushed due to closely spaced joints. The slope above the road is more than 45° but below the road it becomes gentler nearly 30°. During the rainy season the water seeps into the loose soil and along the joints dissolving the carbonates and creating gaps in the joints and along these joints huge blocks fall. This slides is a combination of structural slide and rock fall. The slope is gentler upwards, but becomes steeper downward towards the road. The result is that as the road fall continue the higher and gentler portion loose their support and begin to fall down. A section across the landslide zone (Fig. No. 6·3) and a photograph No. 10 Plate 11 depict the various features.

The remedial measures as can be suggested for this zone are as follows.

1. Since the fragments continue to fall on the road, a wire mesh can be used to cover the entire fall zone so as to prevent the blocks of limestone coming directly over the road.
2. The slope should be cut at an angle less than 30°.

II. Land slide zones between Helong and Badrinath-

The rock types between Helong and Badrinath are augen gneiss belonging to older Metamorphic series. These rocks are hard and compact but their highly jointed nature and intercalation of biotite schist- layers provide planes of easy movement of huge blocks of rocks.

(1) Jharbula rock fallzone - This major rock fall zone is near 163/6 milestone and extends for a distance of one furlong. This rock fall zone is apart or sub unit of major prehistoric landslide of Joshimath and this probably marks the western boundary of the Joshimath slidezone. The rocks of the zone are quartzite and they are highly jointed. The huge blocks of quartzite are resting on a slope which varies from 65° to 80° above the road. Below the road the slope is varying from 30° to 60° at different places. Along with the quartzite, which are insitu, huge blocks of gneisses are also embedded in a matrix of clay and rock fragments. These rocks boulders when disturbed

roll down on the road. The disturbance may be due to earth tremor or the rain may wash fine material thereby reducing the shearing force between the boulder and the matrix. These boulders behave like unexpected guest. Due to earth tremors on 27th June 1967, which were felt in most of the Himalya and northern India, the equilibrium was disturbed. There was considerable rock fall activity in this zone. A huge boulder came down suddenly overturning a road roller working on the road. Two persons were killed due to this episode. The photograph No. 56 Plate 14 shows the road roller at the place and the boulders resting on slope. This problem can be tackled by blasting these big boulders into smaller ones and putting timber spikes on the slope, so as to check the movement of these boulders. A cover of the logs can also be provided to the road. The Fig. No. 6.4 and Fig. 6.5 show plan and section across the road respectively, showing the general features of the zone.

2. Joshimath landslide Zone : Joshimath is situated on a hugh prehistoric landslide(Chapter 5, pp65) which had attained stable slop. However, the construction of the new roads in this part have created certain frequent landslip zones due to the disturbance of natural angle of repose and the seepage of water through new cuttings. The problem of landslide in this zone is, however not very acute and can be tackled by providing suitable benches and effective drainage. Proper channelisation of water at various levels will check

many slips.

The water coming from the upper part of the slide zone can be collected into a big reservoir and then it can be used for producing electricity. Because from reservoir it can be taken to the lower level by pipes and turbines can be driven with this force of water.

The Photograph No.26 Plate 15 shows the slope of Joshimath and also the road is seen.

(3) Landslide zone near 9/2 milestone from Joshimath.

The road has been constructed in a direction across the strike of the formation, except a very small portion where it is parallel to the strike. The rock in the region are quartz gneisses with intercalations of Biotite schist dipping at an angle 45° due N 10° W. The slope towards the road is a dip slope. The rocks are well jointed and the bedding joints are specially well developed.

The blocks of quartzite and gneisses slip along the foliation plane because of the removal of lateral support during the road cutting. The slope become stable when the unsupported slab come down. The photograph No. 27 and 28 Plate 16 shows the foliation plane which is devoid of any material due to fresh slide. This type of slide may be called structural slide. A plan of the area and a section is given in Fig. No. 6.6.

The best way is to plan the road alignment in such a way so that the road does not run parallel to the strike of the formations, but are at an angle to the strike or runs across the strike. Even now the problem created can be solved by rock bolting or by removal of all unsupported blocks.

(4) Govind Ghat land slip zone — A fresh slip in which about 60 feet portion of road was completly washed away took place near Govind Ghat at 11/o milestone. The slip occurred in 29th June 1967 at 11 A.M. due to heavy rains in the area. About 100 feet west of the slip there is a nallah and a cause way has been provided. But due to heavy rains the water started flowing on the road. Seepage of water took place from the road side and through a seepage made on the road near the place of slipping. The water reduced the cohesive strength of the material and thus a 60 feet long strech of road was washed down. This caused a traffic dislocation for three days.

The plan of the area is shown in Fig. No. 67 and from the plan the action of water becomes more clear.

This type of slips are unusual and occurs exceptionally. The only remedy for such slips lies in the proper design of the causeway. The causeway should be so as to permit the maximum water flow at one time. For this it is necessary to have a proper survey and estimate of the catchment area of the nallah and rain fall frequency should be predetermined.

(5) Hanuman Chatti landslide zone — Hanuman Chatti is situated at 20/o milestone from Joshimath on Badrinath route. This area presents a constant slip problem and in the begining almost with the first advent of rain the rocks

were made unserviceable and at place even the whole stretch had slipped.

The road passes through a glacial deposit for a distance of 1 1/2 mile. The material is hetrogeneous consisting of big boulders of granite, quartzite and gneisses along with small pebbles and fine clay. The origin of this material is due to glacier and also due to old land slides.

Present road has three legs all in this material and a rise of 201 feet. has been attained by providing three bends and then the road has been cut in rock formations which are dipping at an angle 45° due N 40° E. Two photographs No. 20 plate 17 and photograph No. 29 plate 20 clearly shows the position of three legs, and the horizontal distance between three legs. The photograph No. 20 plate 17 shows a composite picture of the whole area. In this the road in rock formation is also shown. The river course is shown in plan Fig. No. 6.8 . The left hand side of the valley is almost vertical. The angle of repose which was attained by old glacier moraine deposit has been disturbed and slope varies from place to place but general slope can be taken as 40° to 55°. But at places even 60° slope is present. A section along the line marked A.B. is shown in Fig. 6.9, on a scale 1" = 50 feet.

There are two main causes of landslide in this area.

1. River erosion — Since the river is taking a turn and is cutting at its outer margin, thus removing

lateral support from the toe of the slide.

2. Rain water seeps into the loose material and reduces the shearing strength and also increase the pure water pressure. Due to the flow of water gullies are formed. These gullies are well seen in photograph No. 30 plate 18. The horizontal distance between the two legs is very small at places nearly 60 feet thus if one of the leg slips the other leg is also disturbed.

Preventive measures — At present the preventive measures taken are construction of retaining walls and breast walls as seen in photograph No. 29 plate 18. But since the foundation of these retaining walls and breast walls are also on this material and when the surface of rupture is deep, the whole mass slips to-gether with the retaining walls.

Different ways and means may be suggested for the stability of this important road, link between Badrinath and Joshimath.

There are two main question arises:-

(1) Whether the present road should be maintained and some measures of its stability should be used.

(2) Whether the present alignment of road should be discarded and a new road at different alignment should be constructed.

For the present alignment to be made stable the following preventive measure can be suggested :-

(i) Proper drainage should be provided for the rain water. This can be done by making master channels and several secondary channels to allow all the surface water to run through these and also by putting horizontal perforated pipes through this material.

(ii) Slope should be made gentler and benches should be constructed i.e. retaining walls and breasts walls should be constructed in step wise fashions.

(iii) River erosion should be controlled by putting concrete blocks on the left hand side of the valley.

(iv) By spreading asphalt over the slip surfaces so as the seepage of water is stopped. This will will be one of the useful method in this area.

A collective use of all these method will definitely be able to stop the landslips. The alternative alignments are not found suitable due to constructional difficulties and their heavy cost.

III. Landslides between Joshimath and Bhopkund -

Between Joshimath and Bhapkund the first landslide zone is met at 10/2 milestone.

(1) Landslip zone near 10/2 milestone:-

The rocks are boulder clay consisting of crushed quartzite, angular grains of gneisses and quartzite. Due to intense activity of groundwater the rocks have been weathered to a large extent resulting to fine grained sandy soil. This sand is being quarried for the use in road construction. The angle of slope is about 40° to 45° which is quite unstable slope. Slumps take place due to loose character of sand and lubrication of internal slip surfaces during rains.

(2) Landslip zone near 11/2 milestone:- The material is loose soil which is made up of angular fragments of quartzite, and gneisses. The slope is 40° at the upper side of the road and more than 45° below the road level.

Near a dry nallah marked (A) in the plan of this area Fig. No.6 two persons died due to slide of the material. They were buried alive, the cause of slide was removal of lateral support.

Near 11/2 milestone the trees on the lower side of road are bending and the Photo No. 24 plate No. XI clearly shows the tree bends. These trees indicate that the movement has slowly taken place in the recent past and might be taken place even during the present time.

The remedial measures which can be adopted in both the above slipzones may include:-

a. Construction of benches and bunds, both towards the retaining slopes as well as breast slopes.

b. Slope should be made gentler.

c. Deforestation should be checked because the roots of trees are one of the good agents of binding and they also stop the removal of soil. Due to Deforestation infilteration of water is more thus causing a increase in pore water pressure.

In the same area a few hundred yards away from this place, formation of soil cone along the road due to wind is seen. The finer material falls due to wind and form a cone photograph No. 38 plate 21. This actually proves the unconsolidated nature of the soil with a poor cohesion.

The above slide may be called slump and the surface of movement will be a curve surface controlled by the bed rock.

(3) Landslide zone at 14/8 mile near Rani village - The rocks are gneisses and biotite schist with amphibolite sill and dip is 40° due NE. The slabs of the gneisses are about 10 cm. thick and bedding joints are well developed. The road is running in a direction approximately parallel to the strike i.e. south east - north west

and thus the road cutting has left a free face to the slope. The lateral supports is removed due to road cutting thus causing the blocks to slide on the road. This slide can be termed as structural slide and takes place along the foliation plane. Photograph No. 36 Plate No. 22 and a section Fig. No. 6.12 shows the main geological features affecting the slide.

(4) Landslide zone at 15/7 milestone :- At 15/7 milestone before village of Lata the road is cut into rock formations. The rocks are biotite quartz gneisses and quartzite dipping at angle 35° due N 60° E. They are highly jointed and measured joints are:

(i) 55° due S 60° W

(ii) 63° due W

(iii) Vertical joint strike E-W.

The direction of road is E-W.

Thus the vertical joint is having its strike parallel to the road. These are gaping joints and a huge block is almost seperated from the main mass of rock. The rock fall takes place along these vertical joint. These section across the river Fig. No. 6.13 and photograph No. 37 plate 22 clearly shows the geological conditions. The photograph also shows the gap of the joint.

The only remedy at this place is the mild blasting of this huge block so that the other portions are not shattered by the blasting.

At 14/4 milestone the vertical joint striking N 20° E - S 20° W is very prominent. The road direction is exactly parallel to the strike of the joint i.e. the conditions are similar to those as described above. Hence similar remedial measures may be adopted.

(6) Landslide zone at 18/6 milestone :- The rocks are quartz micagneiss with intercalated bands of biotite schist. The rocks are highly jointed and sheared. The dip of foliation plane is 20° due N 30° E. Major joints are:-

i. 74° due S 55° E

ii. Vertical joint strike E-W

iii. 50° due S 65° W

iv. 60° due N 5 E

v. 40° due N 40° E

The joints have given rise to blocks and these blocks fall from the rock formations on the road.

Due to blasting these joints become gaping and blocks of rock are loosened thereby they fall due to slight tremors, even due to the movement of heavy vehicles. When huge blocks of rocks fall down, the road cannot bear the impact and a portion of the road falls down together with the fallen blocks.

The preventive measures which can be suggested are :-

1. The blasting charge used should be of moderate strength so that the joints are not widened.

2. Overhanging ledges should be removed.

3. The slope below the road should be made gentler, or benches and bunds be constructed. This will support the road atleast during minor rock falls.

SECTION ACROSS R. ALAKNANDA
AT 156/7 MILE STONE BETWEEN
R. GARUR GANGA AND R PANIGAD.

ROCKS LIME STONE

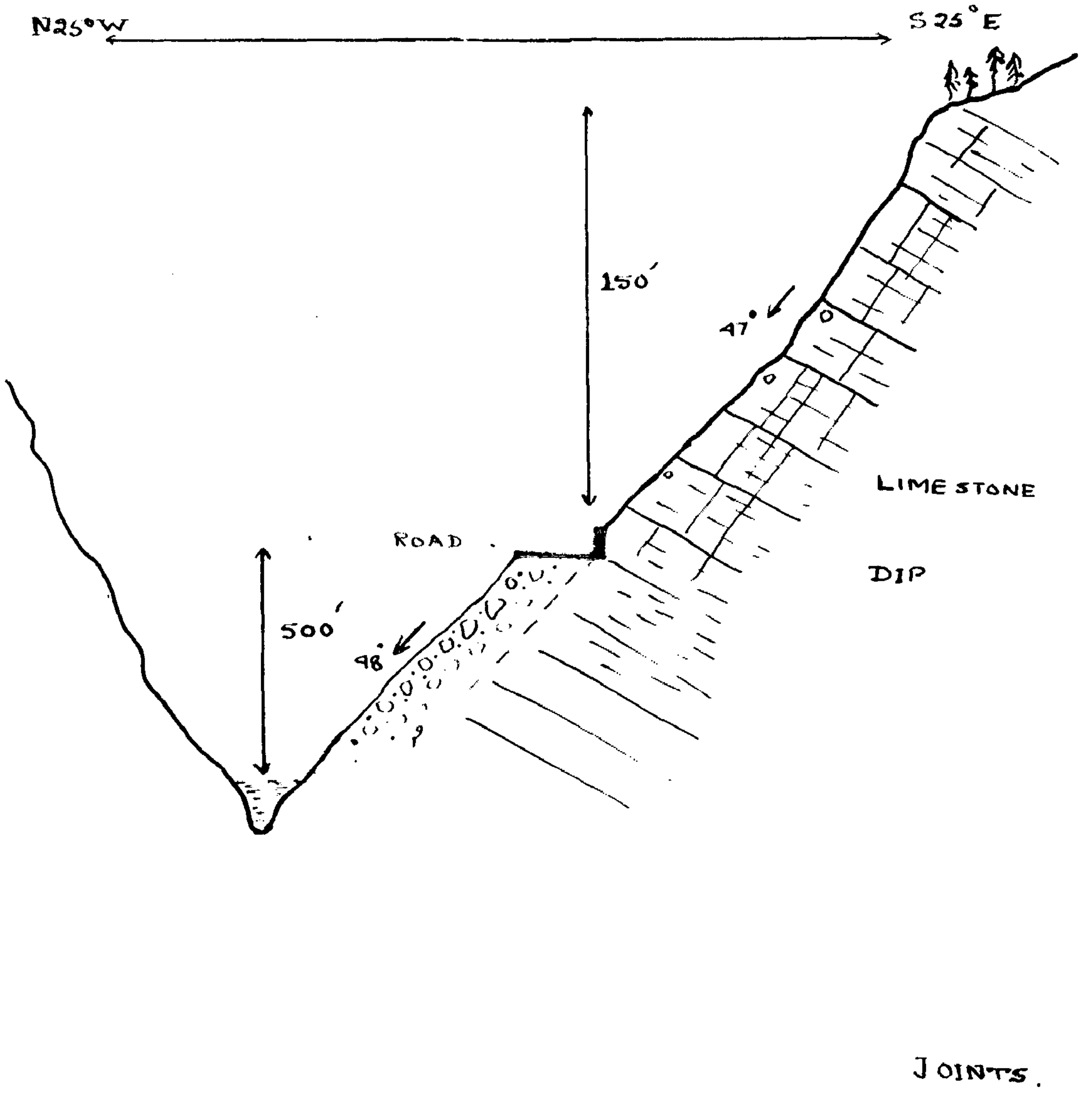
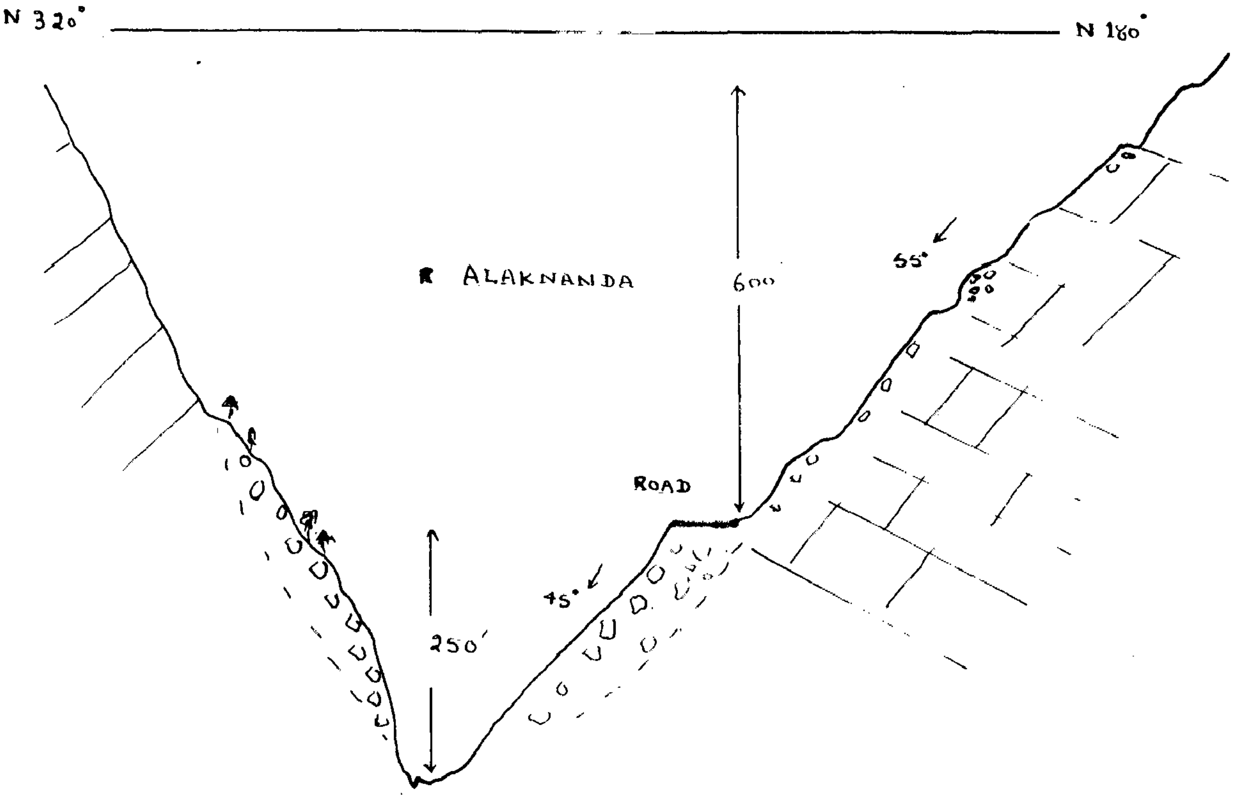


FIG. No. 6.1

SECTION ACROSS R ALAKNANDA

AT 157/7 MILESTONE

ROCK - LIME STONE DIP 45°/N 140°



JOINTS
62°/ N345°
65°/ N 60°
DIP 45°/ N140°

Fig. No 6.2

SECTION AT 158/1 MILESTONE

ROCK - LIME STONE DIP 45°/ N150°

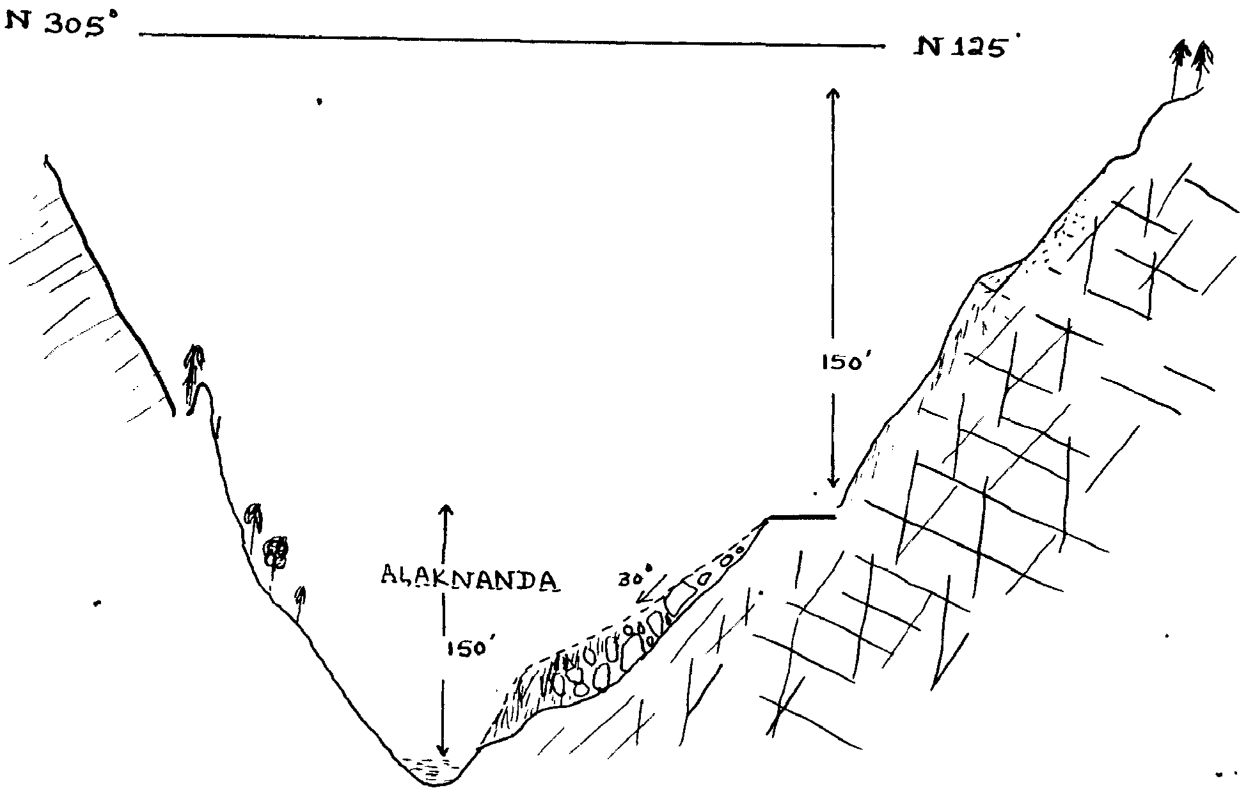
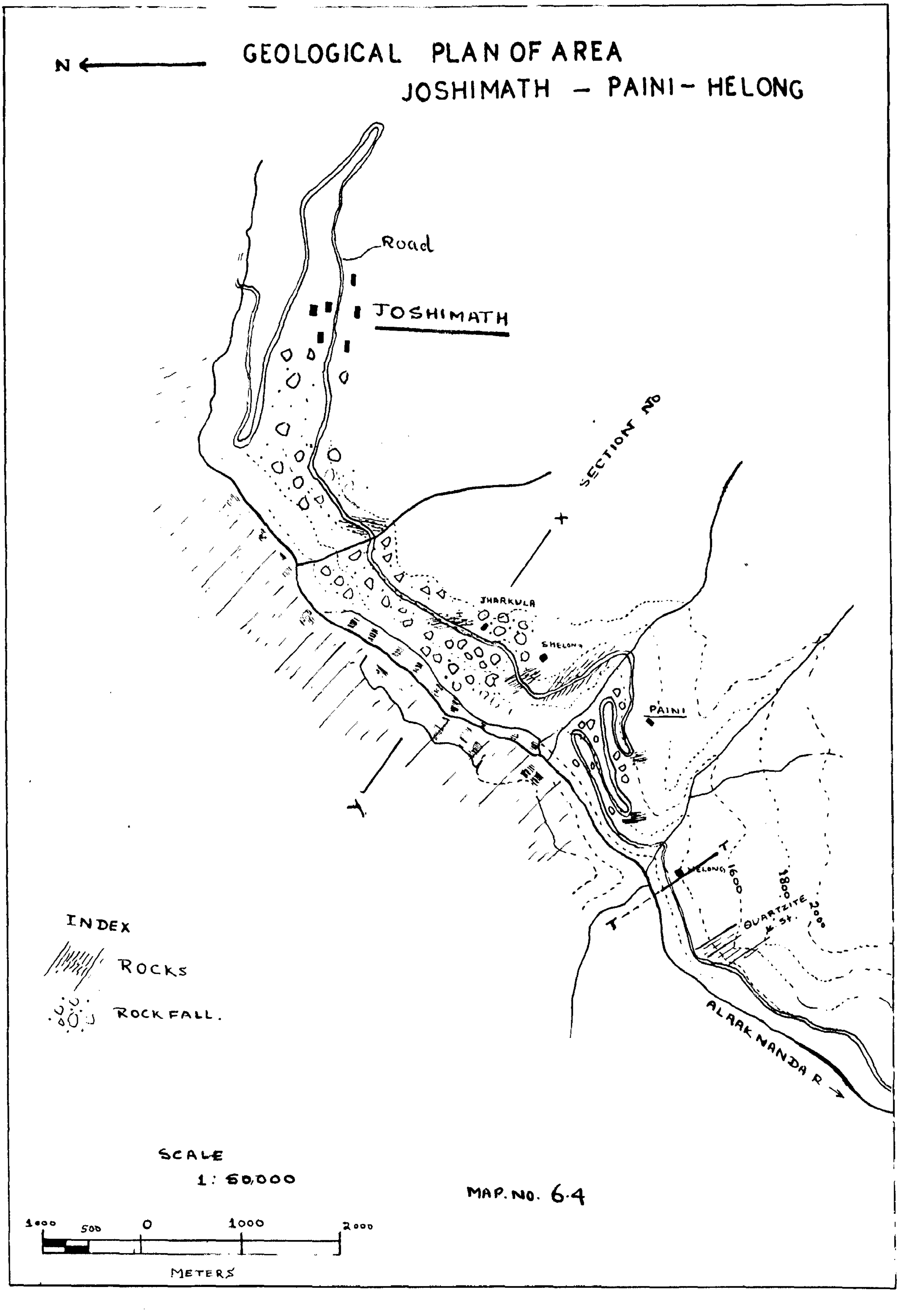


FIGURE NO 6.3

JOINTS

1. 62° DUE 345°
2. 45° DUE 150°
3. 80°/ N65°


N
GEOLOGICAL PLAN OF AREA
JOSHIMATH – PAINI– HELONG
Road
JOSHIMATH
SECTION NO
JHARKULA
PAINI
1600
1800
2000
QUARTZITE
ALAAKNANDA R
INDEX
ROCKS
ROCK FALL.
SCALE
1: 50,000
MAP. NO. 6·4
1000 500 0 1000 2000
METERS

SECTION ALONG LINE XY NEAR JHARKULA CHATTI
AS SHONN IN PLAN

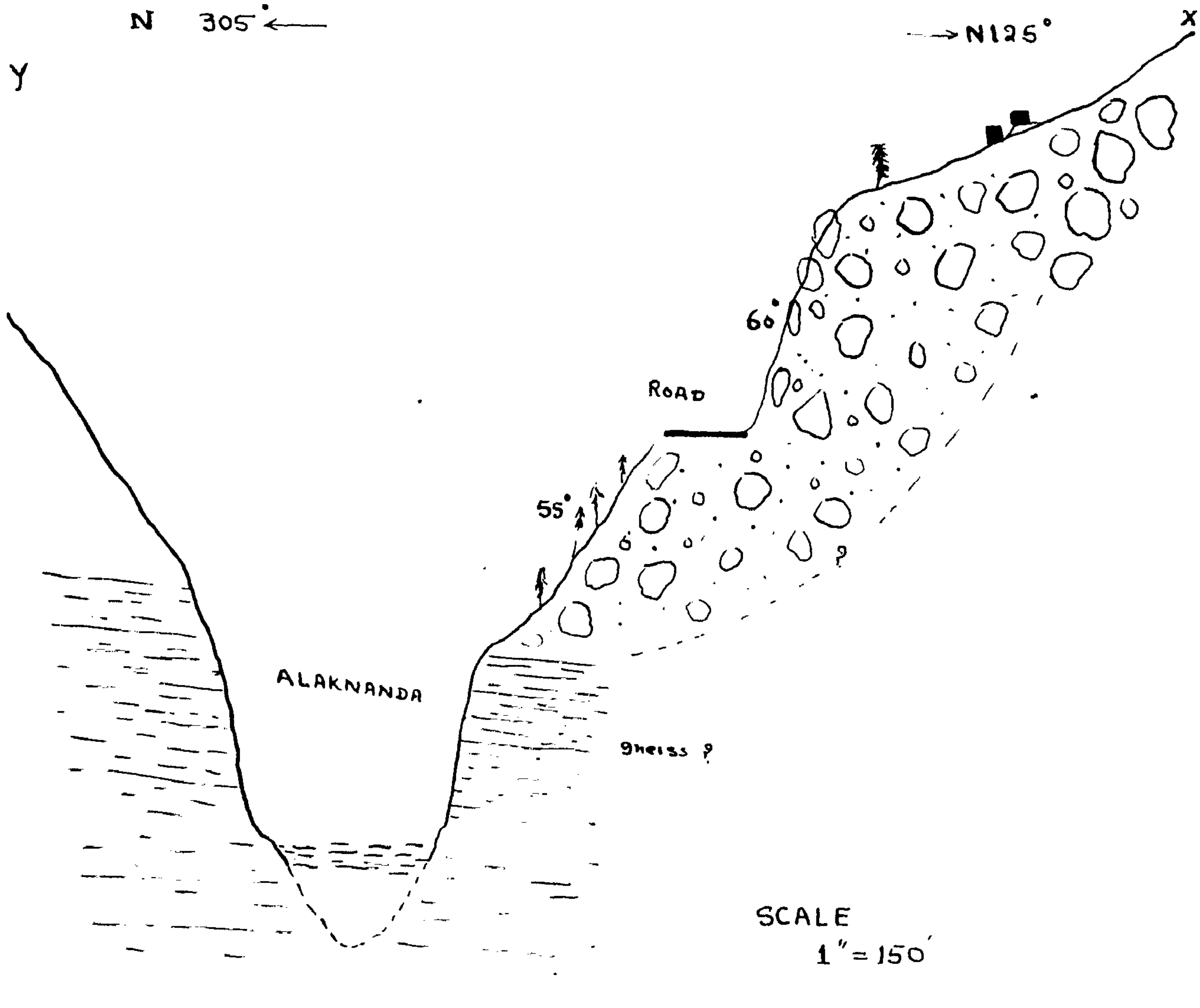
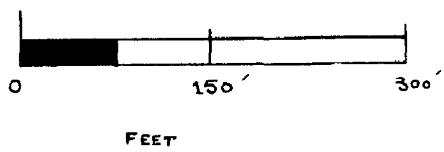


FIG.NO 6.5



PLAN OF AREA NEAR 9/3 - 9/2 MILE STONE
TOWARDS PANDUKESHWAR FROM JOSHIMATH

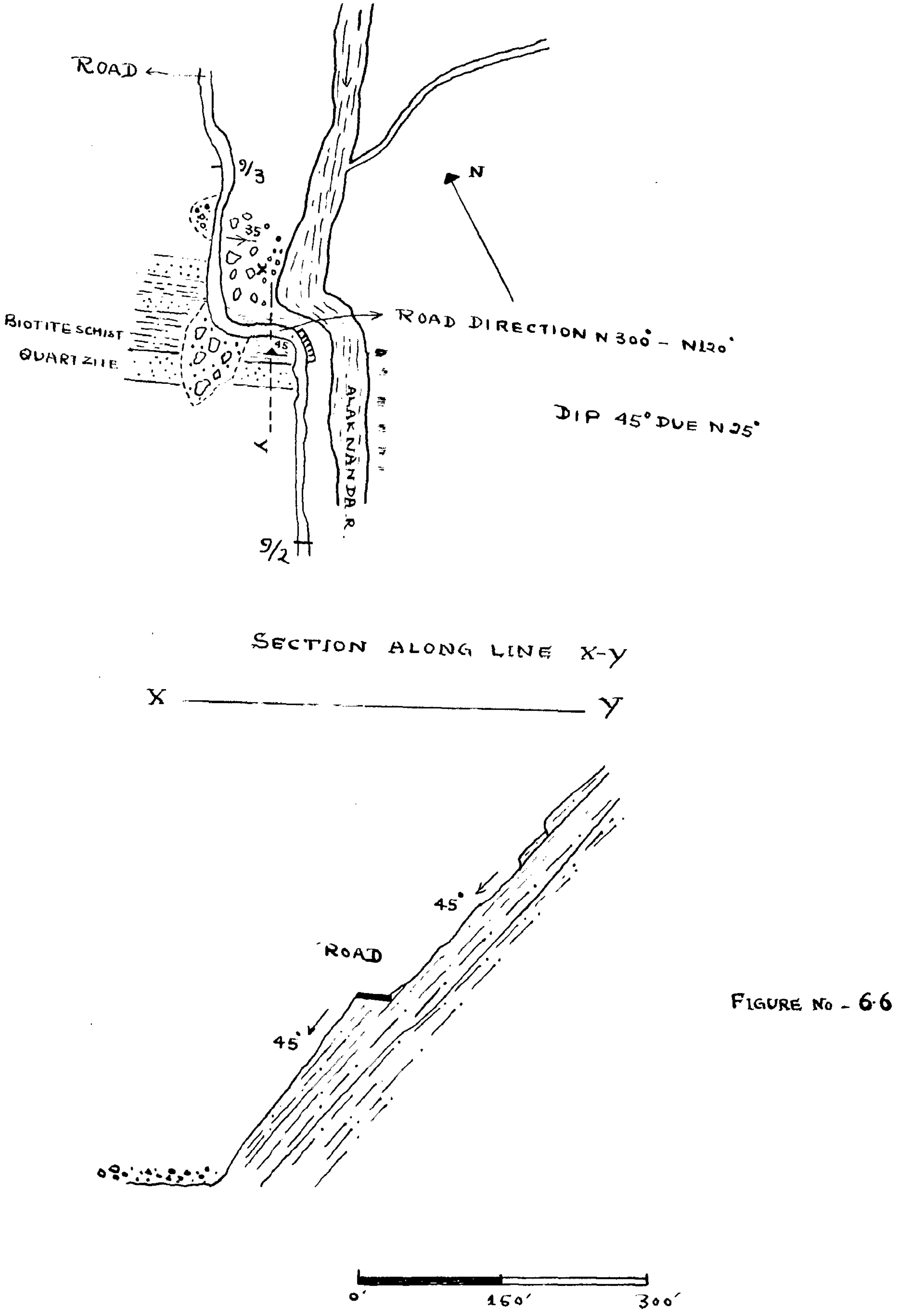


FIGURE No - 6.6

PLAN OF LAND SLIP
NEAR
PANDUKESHWAR

DATE 29-6-66

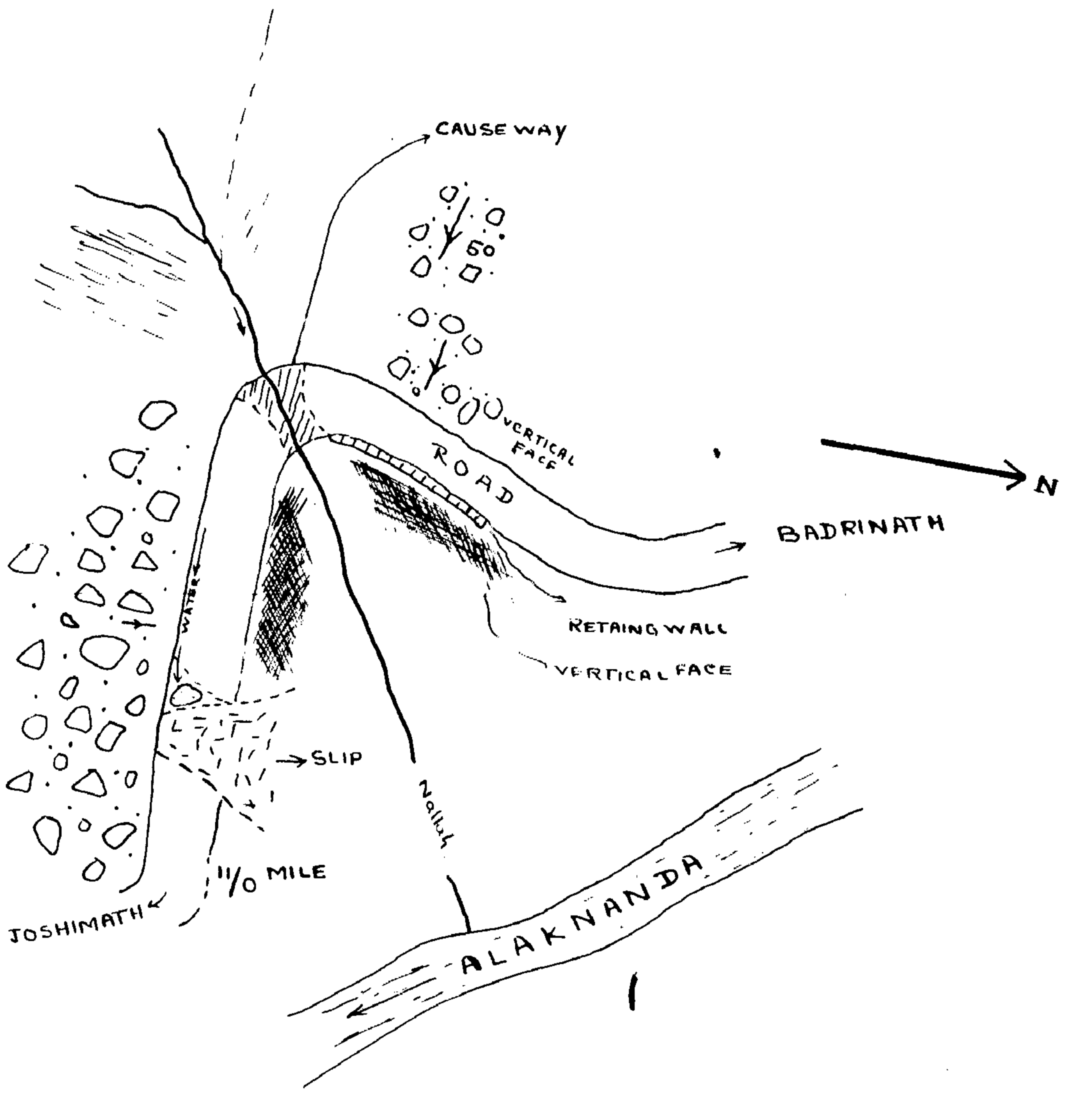


FIG. No 6·7

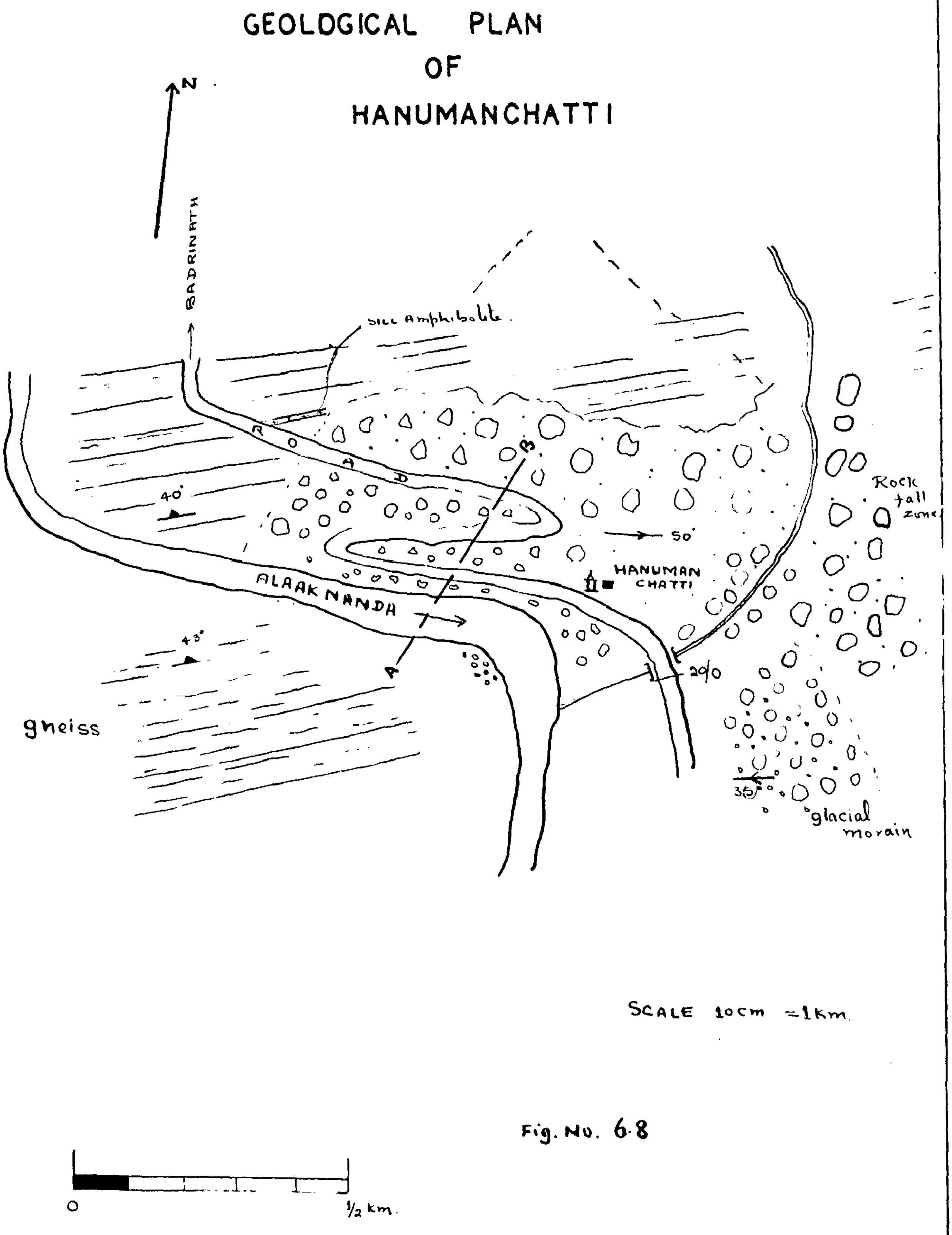

GEOLOGICAL PLAN
OF
HANUMANCHATTI
N
BADRINATH
SILL Amphibolite
ROAD
B
A
40°
43°
50°
ALAAK NANDA
HANUMAN CHATTI
Rock fall zone
20/0
35
glacial morain
gneiss
SCALE 10cm =1km
0
½ km

Fig. No. 6.8

GEOLOGICAL SECTION SHOWING THREE ROAD LEGS AT HANUMAN CHATTY

DIP OF ROCK 45°/350°

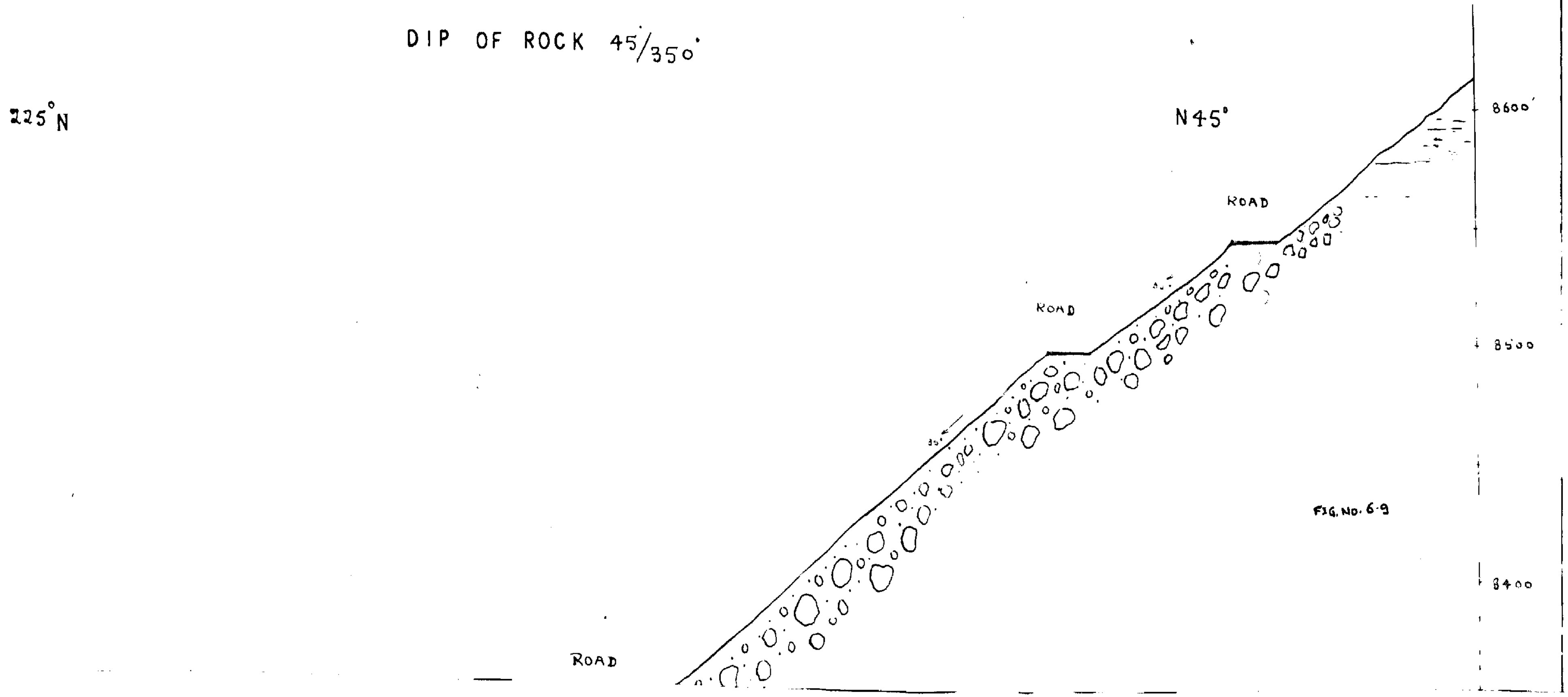


FIG. NO. 6·9

PLAN OF AREA

TAPOBAN AND RINGI VILLAGE 11/4 mile.
(10/0)
NOT TO SCALE

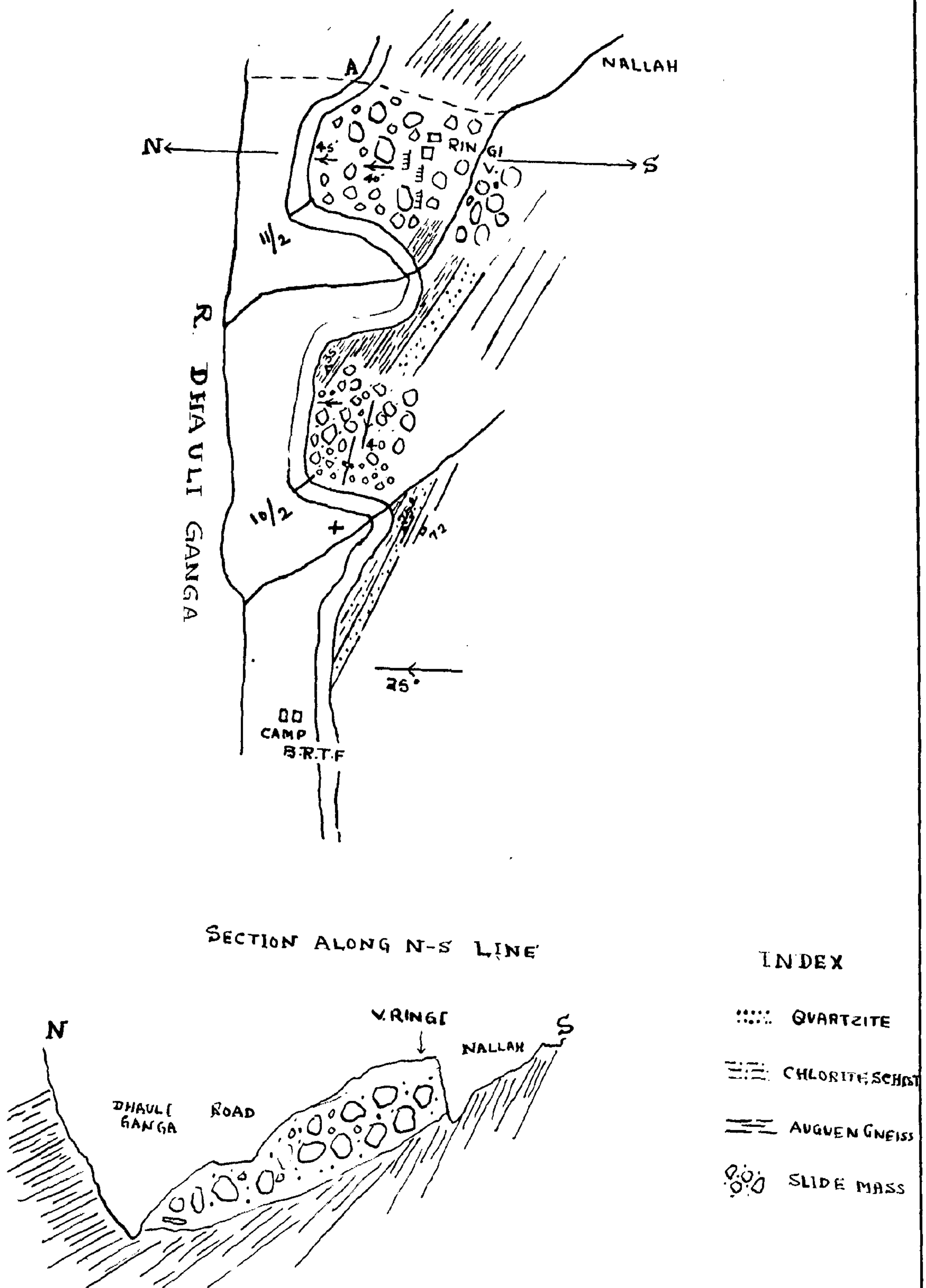


FIGURE No 6.10

SECTION ALONG XY LINE NEAR REINI VILLAGE.
MILE 13/7 FROM JOSHIMATH

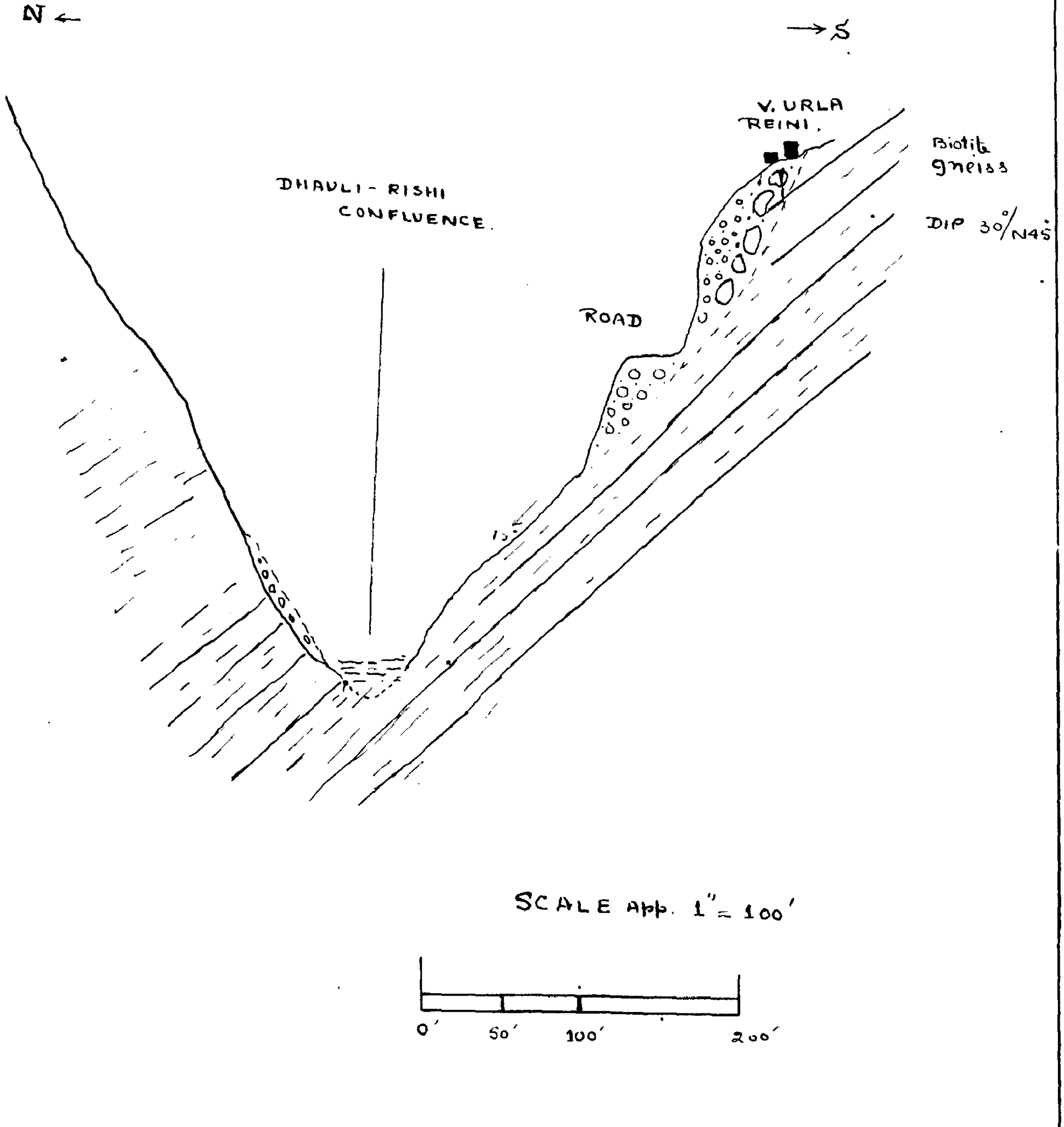


FIG. No. 6.11

SECTION ALONG XY NEAR 14/2½ M. Stone FROM JOSHIMATH

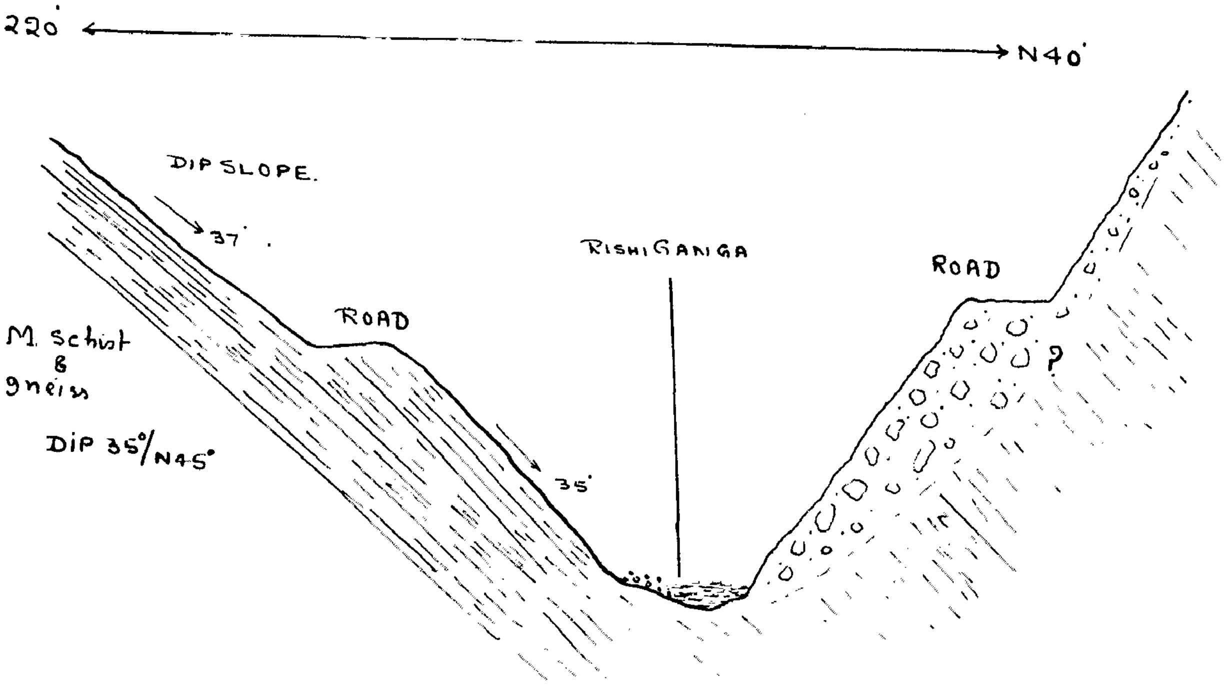
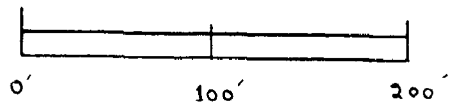


FIG. No. 6.12

SCALE app. 1" = 100'



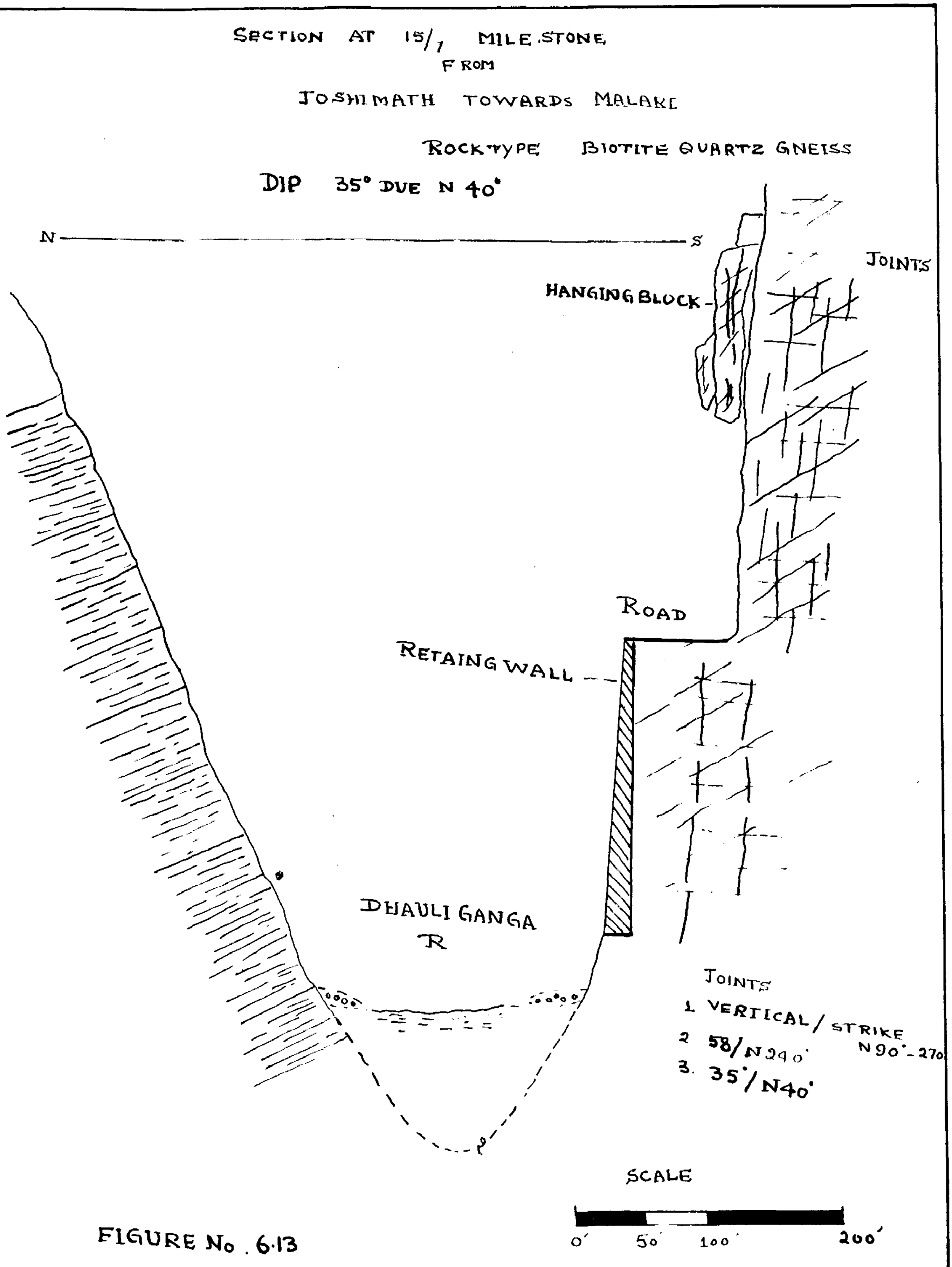


FIGURE No. 6.13

CHAPTER 7

CHAPTER 7

D I S C U S S I O N

The several landslide zones occurring in the area have already been described in the previous two chapters. On close examination, it will be revealed that the landslides can convinlently be grouped into to main categories. In the first category, those landslides can be taken which occur in the consolidated rocks and in the second category those which occur in the unconsolidated and loose rocks.

I. Land slides of the consolidated rocks :

The land slides which take place in the consoliated rocks are controlled mainly by the structural features and to a small extent by the lithology of the rocks. The effect of structures, particularly the joints dipping towards the road at high angles (more than 45°), can be seen throughout the area. The important localities are the Belakuchi land slides (Miles 157/1 to 160/4) and Lata landslides (Mile 18/o). St some places steeply dipping strata, are also forming landslide zones, particularly where the dip slopes face towards the road, the roads are parallel to strike and the dips are high. A very good example of such landslides are seen near Mile 9/2 between Joshimath and Badrinath.

Where as, such structural slides are common in the consolidated rocks on one hand, landslides due to block slide and rock falls are also quite common on the other. The rock falls usually take place at localities, where three or more than three sets of joints are present in the rocks dividing the rocks into small blocks. More close the spacing is between the joints, greater are the chances of rock falls. At such places great damage is done due to the higher charge of blasting being employed, with the result that the residual stresses in the rocks accumulate. As a result the blocks of rocks fall continually on the road even after several days have lapsed after the blasting. The vibrations even due to moderately strong winds cause such blocks to fall down. An important sign to ensure such a land slide zone is the unusual widening of gaps between the joints, during blasting. Land slides due to rock falls are also structurally controlled.

Lithology plays a significant role in the land slide phenomena, although in itself the lithology is not decisive control. All other things being equal, it was found that the angle of repose in schists, slates, limestones and quartzites are gradually higher. Thus lower angles of dip of foliation, bedding or joints can cause landslides in slates, schists and lime stones, particularly during the rainy season, when the bedding planes are soaked with water reducing the shearing resistance to considerable amounts. The formation of solution cavities and channels in limestone creates enumerable problems of land slide as can be seen in this area between Pipalkoti and Helong.

II. Land slides in the unconsolidated rocks:

There are several places in the area, where the exposures of consolidated rocks are not available. These are usually buried under a cover of unconsolidated rocks, due to the large land slides, glacial deposits avalanche debris, river gravels, residual soil covers or talus and scree deposits. Field identification of the material often brings out the idea regarding the origin, depth and the type of movement which is likely to take place in such deposits. The flow is, however, the most important type of movement in such places, particularly when the finer particles are more abundant. The rock is more or less confined to such regions, where the removal of the lateral or basal support is an important cause of the land slide. The unconsolidated materials can be identified in the field on the basis of following characters associated with each of them:-

(a) Pre-historic landslides - Pre-historic land slides can be identified by the large surface area covered by loose materials, angular to subangular rock boulders associated with fine soil and thick vegetation. The evidences of pre-historic damming of rivers as seen in sudden widening of the river and river terraces before such materials, the presence of epigenetic gorge and stable slopes are other indications which might be associated with pre-historic land slides. The rock types necessarily belong to the same area, although these are no more in situ.

(b) Glacial moraines - Glacial moraines can be identified by the presence of unassorted, sub angular to sub-rounded rock fragments, mostly foreign to the area mixed up with sandy and gritty soil. These are usually present at the mouths of the tributary valleys (terminal moraine) or in between the confluences (medial moraines). The identification of the lateral moraines is, however, a bit difficult. The presence of striations is not necessary, although they are conclusive proofs of the glacial origin. The slopes may or may not have attained stability and vegetation is usually scarce. The evidences of river damming might be present in this case too.

(c) Boulder-Clay deposits - These are also associated with the glaciers. In this case, however, the finer materials are much more prominent than in the glacial moraines. The boulder clays are usually white , granular, with very little plasticity and large amount of sand. The main constituents of sand are coarse grained, sub-angular to sub-rounded quartz grains.

(d) Fluvio-glacial deposits - These deposits can be identified partly by the presence of the characters of moraines (lateral moraines, particularly) and partly by that of the rounded, river gravels and sand. It is common to find the deposits due to river and glaciers showing clear demarcations, The boulders also show a tendency to develop graded beddings, although the heterogeneous character predominates.

(e) <u>River gravels and terraces</u> — These show well rounded pebbles and boulders deposited over the rock formations. The graded bedding are well developed and sometimes the current beddings are also seen in sand and gravels. At times more than one set of these deposits may be seen at different levels showing the river terraces, in a step like fashion. The activity of the rivers can also be seen in the presence of pot. holes, polished surfaces and proofs of whirling action of river water at height of more than 600 feet above the present water level. The river gravels are distinctly brought from large distances and they are usually quartzites, limestones, slates and even fossiliferous limestone of unmistakable Tethys Himalayan affinities.

(f) <u>Avalance Debris</u> — Avalanche debris can be identified by the presence of huge boulders, many of them several feet in length and breadth, occurring without any arrangement whatsoever, and resting one over other in just-a-position. The result is that if one boulder is disturbed many of them became unstable. There are wide gaps of all shapes between the boulders. Usually the avalanche debris are seen in narrow valleys with snow laden peaks above. The mountain face stands prominently as vertical scarps, with nearly polished surface having vertical groves on it. It is, however, not necessary to have the peaks with perennial snow. These localities from where the snow line has receded, such occurrence of debris denote the pre-historic avalanche activities in the area.

(g) Talus and Scree deposits - These deposits do not need any comment, as these are readily identified in the field.

Causes of Land slides

Gravity is the most fundamental cause of the land slides However, gravity does not become operative unless, the cohesive forces in the rocks, internal friction or shearing resistance are overcome. Water is an important agent which reduces the cohesion or the shearing resistance and that is why landslides become road hazards during the rainy seasons. Water may be soaked through the pore spaces, joints, fractures and bedding planes in the rocks and cause the damage. Removal of lateral supports by side cutting or the under cutting by the geological agents like rivers and wind, are also the important causes. Internal forces like the earthquake, avalance, sudden melting of glaciers causing a gushing flow of water and frost-wedging are the factors which are by no means smaller causes and do extensive damage. The groundwater is also one of the important agent to cause landslides by way of making solution cavities and channels in chemically susceptible rocks and thus removing the supports. Capillary action, the loss of cohesion and the lubrication of plane surfaces are universal activities of the groundwater, particularly in the permeable and well bedded or well jointed formations.

The Natural Angle of Repose -

Landslides, slips or flows are natural geological phenomena and they continue to take place till acquire the natural angle of repose, when the gravitational forces are balanced by the shear resistance. If a dry, clean sand or gravel is poured carefully and without impact on the earth surface, it will form a pile. The slope the pile makes with the horizontal ground surface "natural slope" is called angle of repose. In unconsolidated rocks this is acquired by the continuation of slumps and flow. The slump takes place in step and they form little terraces giving rise to the desired angle of repose. The angle of repose of noncohesive soils, varies according to the shapes and grading of the constituents and the density of packing. The greater the density of packing greater will be the angle of repose. The height of the slope also plays an role but is of minor significance.

In consolidated rock formation, the angle of repose is either the dip of the formation when the dip is less than 45° otherwise the scree and overlying rock fragments continue to collect at the base of the slope and slowly acquire angle of repose. The angle of repose is of greater importance in the case of unconsolidated formation than that in the consolidated rocks. Because as earlier discussed the consolidated rock formations slide due to structural weaknesses and unconsolidated ones due to the angle of repose and loose nature of material.

One of the main cause of land slide in the rocks which have attained stability is the man. The natural angle of repose is disturbed by cutting road thereby removing lateral support. The construction activities in the unconsolidated regions is one of the main cause of landslides. The construction of dams and reservoir in hills also leads to slide in the adjacent areas as the water seeps in the adjacent strata thereby causing a reduction in friction between the particles.

Remedial Measures

Several remedial and precautionary measures have been suggested in Chapter 6 in connections with the slides described therein. A discussion on these measures may be profitable at this place.

1. The construction of the benches and bunn helps in two ways.
   a. The material falling from the slope is stopped at bench and it does not block the traffic movement on the road.
   b. In due course the angle of repose will be attained due to accumulation of material on benches.

2. Retaining walls and breast walls are constructed on the valley side and formation side respectively. The breast wall and retaining wall provide the support to the toe of the slide. But the walls should be of moderate height and generally

speaking should not be more than 4 feet above ground. They should be placed where ever possible on the firm rock but if the depth of slided material is great, the walls can be constructed in steps or supported by piles.

(3) River training is carried out to check the cutting action of river. The river cutting action is maximum at the outer side where the river takes a turn as in the case of Hanuman chatti. At such localities concrete blocks should be placed upto the flood level supported by piles, bolts or on rock foundations. These concrete blocks will check the bank erosion and thus, the water cutting by river will be controlled.

(4) A proper arrangement of drainage is important for the control sub-surface water as well as for the surface water. Channels can be provided for the rain water and these channels should be maid up of cement and asphalt coating should be provided for the prevention of seepage. For the control of sub-surface water perforated pipes horizontal or inclined towards the slope may be put in the unconsolidated material. These will check the rise of pore water pressure.

(5) The surface of the unconsolidated material may be sprinkled with asphalt which will ultimately reduce the percolation of rain water into the surface. This can be successfully used in the

In the case of unsorted material where big and small boulders occur together the cement grouting might be found successful as this will provide the binding material between the fragments.

(6) Timber spikes may well be placed on the slopes which will check the movement of the boulders.

(7) The blasting of the boulders in zones of rock fall will help in checking the movement of the boulders and will also help in making the slope angle equal to angle of repose. But a precaution which should be taken into consideration is the use of blasting charge. Heavy charges should not be used.

(8) In places where the small boulders and fragments fall due to the action of wind and earth tremors, the wire mesh of proper size can be placed. This will save the road from damage and road will be made safe from the point of view of traffic. At places wooden logs can also be provided to give a cover to the road, so as to check the fall of rock fragments on the road.

(9) In the case of dip slopes where huge slabs slip along the foliation plane, rock bolting can be done. But it is costly method and its application requires a specialised technical knowledge. Therefore this method has not been

suggested as a normal course of remedial measures. However, this may prove to be extremely effective.

It must be pointed out here, that all the methods suggested above are of general nature. What should be the exact specifications of various measures or what measures should actually be adopted depends upon the actual conditions at the site and económics of the remedial measures. In many cases, the posting of a rescue and cleaning squad may prove to be more economical in the long run, where as in some others a realignment of the road may be profitable.

CHAPTER 8

CHAPTER 8

S U M M A R Y

The area between Pipalkoti- Badrinath and Joshimath - Bhapkund has been studied along the road. The work was carried out with a view to study the landslide zones in this area. The action of different geological agencies causing the landslides has also been studied. The climatic variations, rain intensity and their effect on the slides were noted.

The rocks of the present area belong to two different series namely the Older Metamorphic Series and Pipalkoti Series. The rocks of Older Metamorphic Series have been thrusted over the rocks of Pipalkoti Series. The rocks of the Older Metamorphic Series comprise of the augen gneisses, quartz mica gneiss, chlorite schist and biotite schist with thin bands of marble. The rocks of the Pipalkoti Series include dolomitic limestone, quartzite, slate and few bands of chlorite schist. Since the rock types of the two series are vastly different, they have given rise to different factors causing landslides. The thrust separating the two series has been taken as a thrust zone existing between Helong and Gulabkoti.

The rocks of Pipalkoti series have been folded into minor synclines and anticlines and they are part

of a major anticlinorium. They have been jointed and fractured to a greater extend and these joints to large extent have been found responsible for the slides. The rocks of older metamorphic series are simple dipping beds. They have been affected by small scale folding and faulting. They are also highly jointed and especially the vertical joints have been found responsible for the cause of rock fall in different areas. These joints are closely spaced and have given rise to blocks which fall on the road due to blasting and earthquake tremors.

For studying the landslides and for obtaining a better idea about the type of landslide a brief description of the typical landslide zones of the area has been given in the Chapter 5 and 6. On the basis of stability of the slopes, the landslide zones have been grouped in two:-

1. Prehistoric landslide
2. Recent slide zones

The prehistoric landslides have been studied in Chapter 5 to give a better picture for the understanding of the causes of present day slides.

In the Chapter 6 the recent landslide zones have been dealt under three heads.

1. Landslide zone between Pipalkoti and Helang
2. Landslide zone between Helang and Badrinath
3. Landslide zone between Joshimath and Dhapkund

These groups have been made for discussing the landslide zones without any consideration of the causes and type of material.

The causes of landslides and type of material involved have been studied individually in each case. The remedial measures which might be of some help in preventing the landslides have also been considered along with. The different landslides have been assigned to different groups depending upon the cause and type of movement.

In the end a discussion has been made with a view to systematically generalise the classification, causes and remedial measures of landslides occuring in this area. It has been find that lithology and structure have played an important role in causing the landslide.

In Appendix I a brief remark has been made regarding the proposed alignment of road from Mana to further north ward. A new alignment has been proposed and due consideration are given to the geological conditions prevalent in this area.

It should be emphasized, at the end that for the study of a particular landslide, a very detailed geological and structural mapping is essential, confined to that very locality. Similarly, the knowledge of the velocity of river, porosity and permeability of the formations, particularly of the unconsolidated ones and the historical background of the each landslide same may prove to be of immense help in choosing proper precautionary and remedial measures. For want of the data of the above nature, the present work could not be shaped into a exhaustive document. There is no doubt, however, that these studies will mark an humble approach towards solving the landslide problems being faced by the highway engineers in Himalayan terrains and that it will be taken as small contribution towards the science of engineering geology.

Appendix I

A Note on the Road alignment near Mana

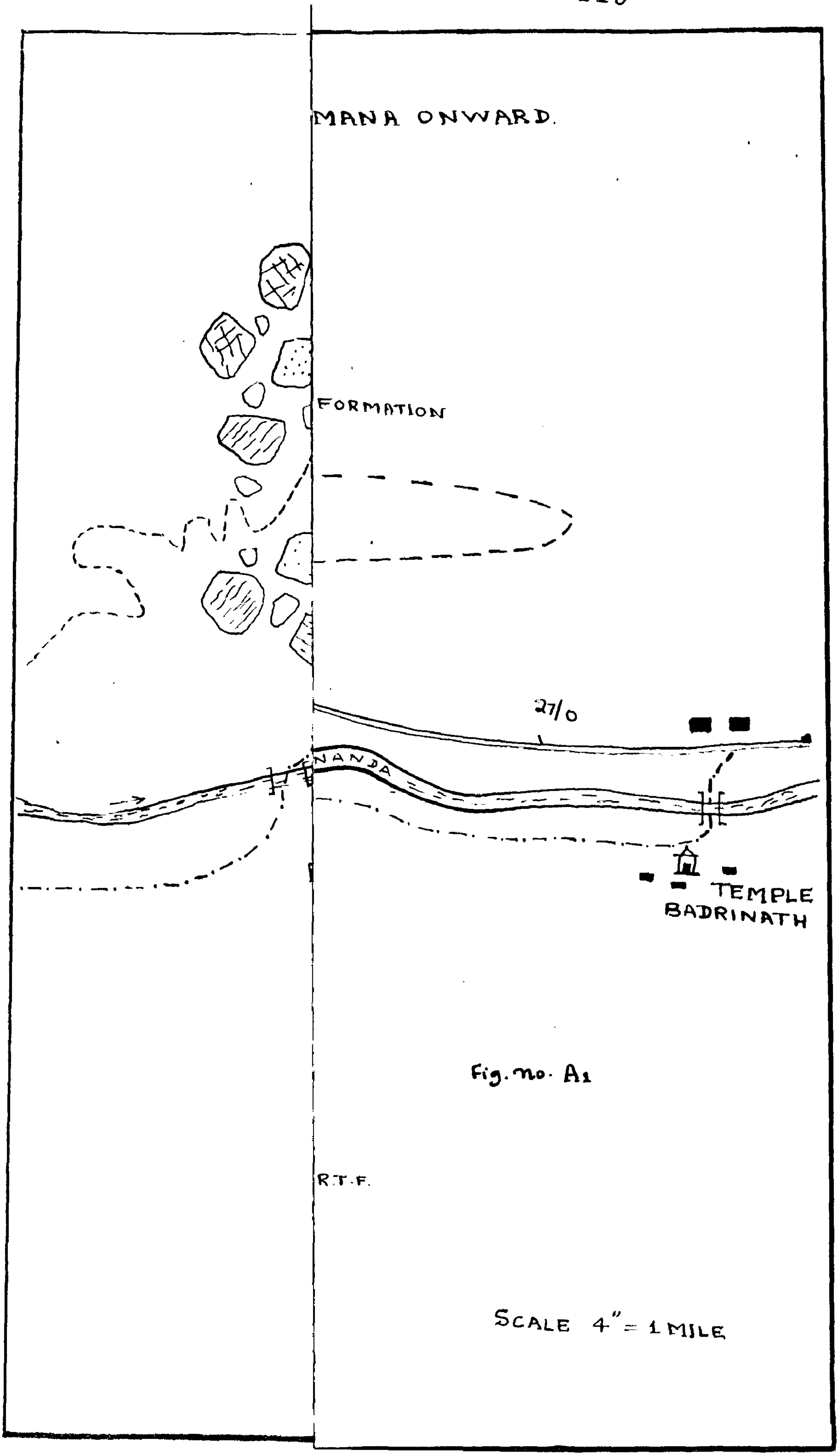
There is a proposal to construct a road between Mana and further north. The proposed road has to cross the ridge north of Mana. This ridge is made up of huge Avalanche debris consisting of boulders of calcsilicate, gneisses and quartzite. For crossing this ridge it is essential to obtain a rise of 1200 feet. A proposal, for obtaining this height by constructing the road with the help of thirteen loops in a narrow area of about one mile width, was put forward.

A geological traverse was taken in this area to study the conditions affecting the stability of the road. The rocks through which 8 loops have been proposed are glacial boulder clay the material is hetrogeneous and the slope is 45° at present, and has, yet to attain angle of repose. However due to the growth of vegetation it seems to be stable.

But when the road construction will begin several problems will creep in, firstly, the horizontal distance between the loops being very small, the slopes between the rocks will be very high, particularly in the first three logs, where the roads will be virtually are above the other. The loose boulder-clay is not likely to withstand normal vibrations too. The remaining fine loops pass through the avalanche debris, and will not cause much trouble, once the road is constructed.

A plan of the area, showing the position of the thirteen loops is provided in Fig.A_1 The new alignment suggested by the author is also shown therein by dotted lines. The alignment being suggested here has following merits and demerits. According to this proposal the 1st leg is taken back upto 27 milestone giving it maximum possible gradient (1 in 20) and then from 27th milestone giving a bend and take the 2nd leg to the point shown in the plan and join it to the third loops of the original proposal. Thus nearly a rise of 600 feet is attained and this avoids the lower three loops of the original proposal. The rest of the loops then can be safely made in the boulder clay. Here it is also proposed to lengthen each loop further towards the north, so that the horizontal spacing between them is increased. This suggestion will enforce the construction of two bridges at point d and c and also a third bridge may have to be provided at point (b) if the nallah is great depth otherwise cause way at a and (b) will solve the problem.

For a better picture and correct alignment, detailed mapping on the map 8" = 1 mile is essential.


MANA ONWARD.
FORMATION
27/0
NANDA
TEMPLE
BADRINATH
Fig. no. A1
R.T.F.
SCALE 4" = 1 MILE

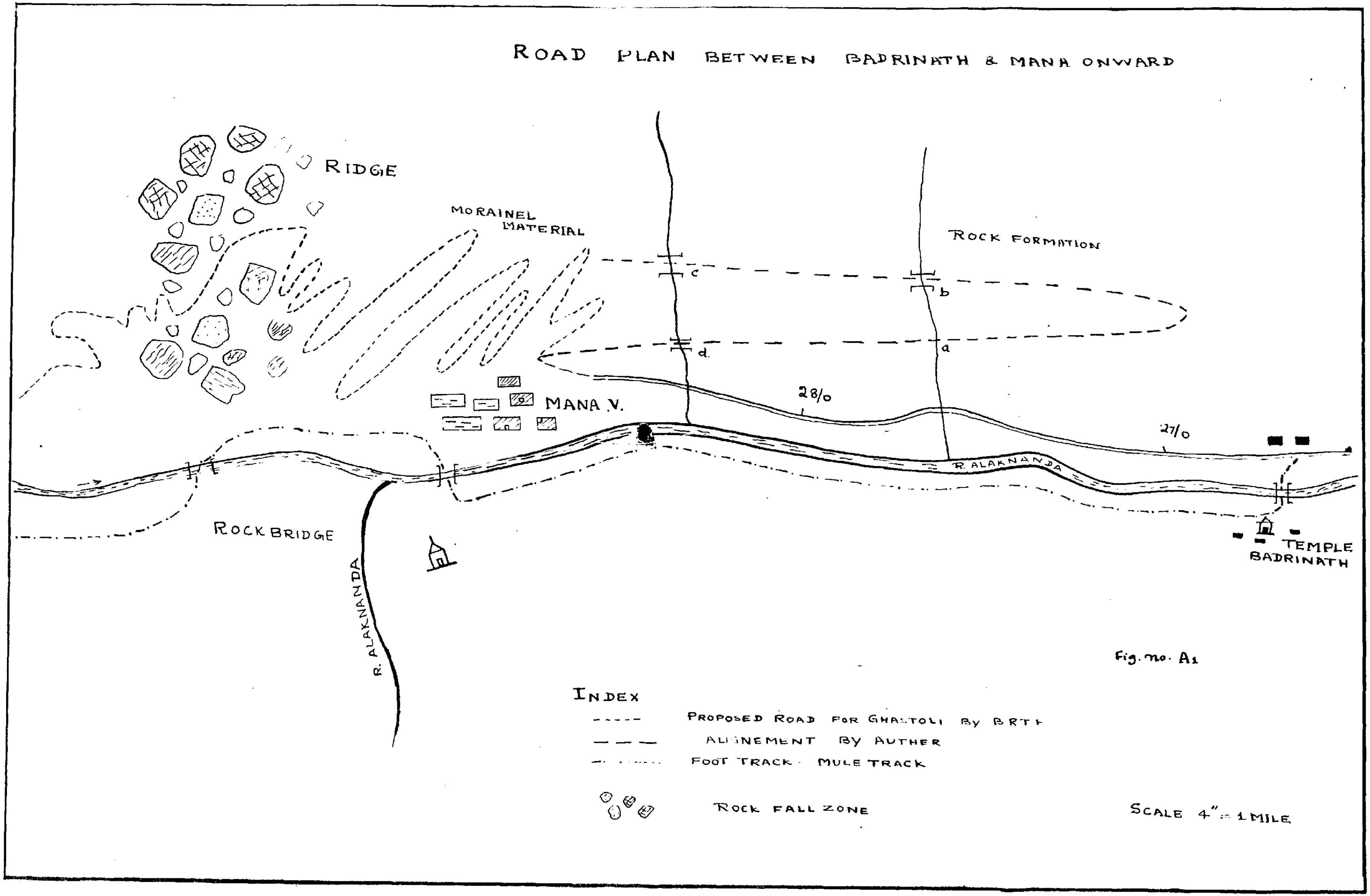

ROAD PLAN BETWEEN BADRINATH & MANA ONWARD
RIDGE
MORAINEL MATERIAL
ROCK FORMATION
c
b
d.
a
28/0
27/0
MANA V.
R. ALAKNANDA
ROCKBRIDGE
R. ALAKNANDA
TEMPLE
BADRINATH
INDEX
PROPOSED ROAD FOR GHASTOLI BY BRTF
ALIGNEMENT BY AUTHER
FOOT TRACK · MULE TRACK
ROCK FALL ZONE
SCALE 4" = 1 MILE

Fig. no. A1

Appendix II

Hot springs in this area

1. Badrinath hot spring— The temperature of the water is 55° C to 60° C. The total quantity of water coming out from the ground is four littler per second. The water contain traces of H_2S and quite good amount of lime which is evident from the lime deposits seen at the bank of river Alaknanda where the water of hot spring falls.

   A second but smaller spring comes out to the surface about 100 meter further south. It may be a off shoot. The quantity is 8 litter per minute and the temperature is 37° C.

2. Tapoban hot spring — The temperature of the water in the tank is 40° to 45° C but at the main outlet the temperature is 55° C. Water is slightly radioactive and pH value is 7.0. The rate of discharge is approximately 22 litters per second. Thus the rate of Tapoban hot spring is greater than that of Badrinath.

   These hot springs can be developed for the medicinal purposes but a detailed study is warranted for the exact constituents of the water.

R_E_F_E_R_E_N_C_E_S_

1. Auden, J.B. (1935) ..."Traverse in the Himalayas" Rec. Geol. Survey of India, 69(2)

2. Bose, S.C. (1965) ..."Legacy of ancient glaciers in the High Himalayas", in seminar on the Himalayas, Indian School of International Stud Delhi school of economics.

3. De Sitter, L.U. (1959)... "Structural Geology" McGraw Hill Book Company.

4. Eckel, E.B. (Ed) (1958)... "Landslides and Engineering Practices" Highway Research Board, special Report - 29, Washington, D.C.

5. Gansser, A. (1964)... "Geology of the Himalayas" Interscience Publications Jhon Willey & Sons Ltd., London

6. Heim, A. and A. Gansser (1939) ... "Central Himalayas" Geological Observation of the Swiss expedition 1936, Swiss publication.

7. Krishnan, M.S. (1953)... "The Structure and Tectonic History of India" G.S.I. Mem. Vol. 81.

8. Krishnan, M.S. (1960)... "Geology of India and Burma" Higginbothams (Private) Ltd., Mount Road, Madras.

9. Krynin, D.P. & W.R. Judd (1957)... "Principles of Engineering Geology to Geotechnics" McGraw Hill Book Company, New York.

10. Kerr, P.F. (1959)... "Optical Mineralogy" McGraw Hill Book Company, Inc., New York.

11. Ladd, G.E. (1935)... "Landslides, subsidence & Rock fall" American Railway Engineering Association Proceeding Vol. 36.

12. Mithal, R.S., V.K.S.Dave and B.K. Singh (1966)... "A Study of some Landslides on Pipalkoti-Badrinath and Joshimath-Bhapkund Roads" - Abstract. Publication of the Centre of Advanced Study in Geology No. 1 Punjab University, Chandigarh.

13. Pascoe, E., (1959)... "Manual of Geology of India and Burma", Publications Division Govt.of India.

14. Ravi Prakash & Prem Swarup (1960)... "Progress Report on Some Geological Investigation in Garhwal" Directorate of Geology and Mining, U.P.,India.

15. Terzaghi, K. (1960)... "Mechanics of Landslide" in "Application of Geology to Engineering Practise", "Berkey Volume", Published by Geol.Soc. of America.

16. Turner, F.J. and J. Varhoogen (1962)... "Igneous and Metamorphic Petrology" McGraw Hill Book Company, Inc. New York.

17. Wadia, D.N. (1957)... "Geology of India" Mcmillan and Company, New York.

18. Wadia, D.N. and W.D. West (1967)... "Structure of Himalayas" XXII International Geological Congress.

PHOTOGRAPHS

PLATE 1

Photograph No.1 : A medial moraine at Hanuman Chatti. Photo taken from valley in the east.

Photograph No.2 : River terraces of Alaknanda near Pipalkoti. The terraces are clearly seen and R.Alaknanda is flowing deep in the gorge. Photo taken from Pipal koti towards down stream direction.

PLATE - 1

PHOTO NO 1

PHOTO NO 2

PLATE II

Photograph No. 3 : Kaga hills as seen from Juma 27/4 mile stone. Dip slopes are covered with snow.

Photograph No.4 : River gravels on the road side at Reni village 14/o mile stone on Joshimath - Malari Road.

PLATE II

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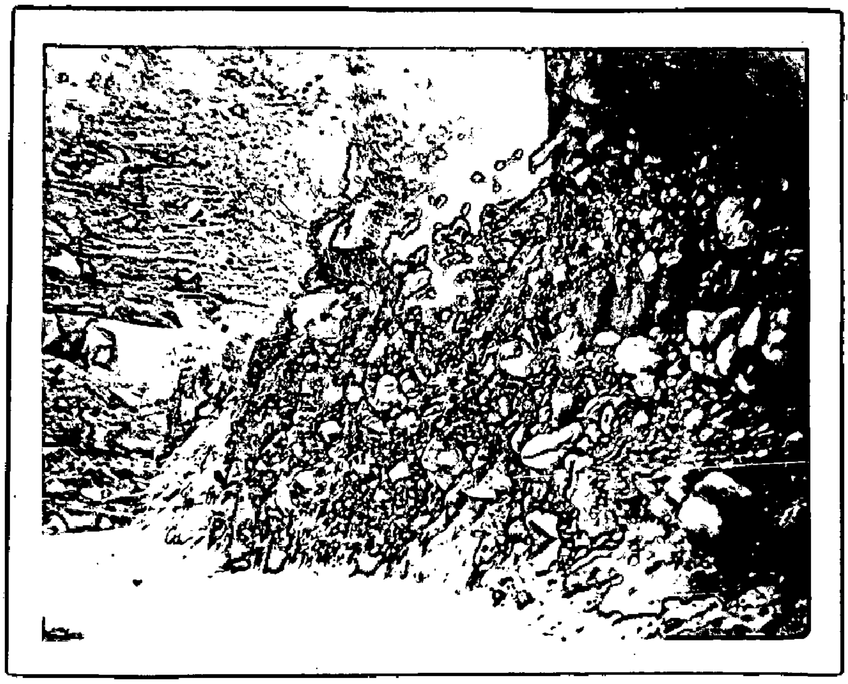

PLATE III

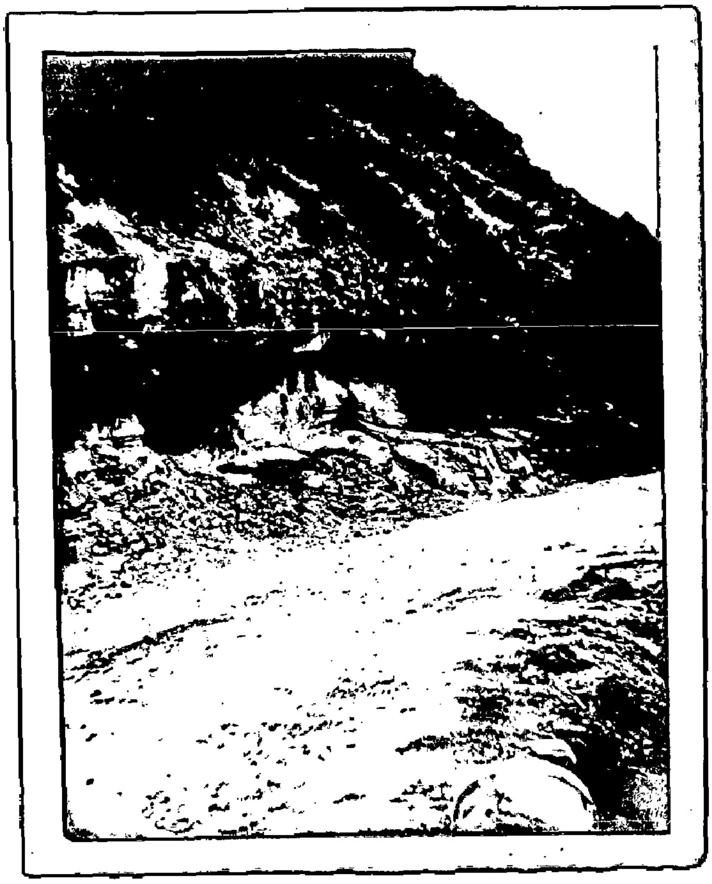

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PLATE IV

Photograph No. 7 : The formation of stalagmites and stalactites in limestone, between Garur ganga to Pani Gad. 156/6 -1/2, on Pipalkoti - Belakuchi road.

Location - 156/6 - 1/2 mile stone on Pipalkoti - Belakuchi road.

PLATE IV

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PLATE V

Photograph No. 8 : Quartz mica gneiss dipping away from the road. Hanging ledges are present.
Location - near the bridge of Helong.

Photograph No. 9 : Joints in quartzite underlying garnetiferous schist.
Location - near Tapoban 10/1 mile.

PLATE V

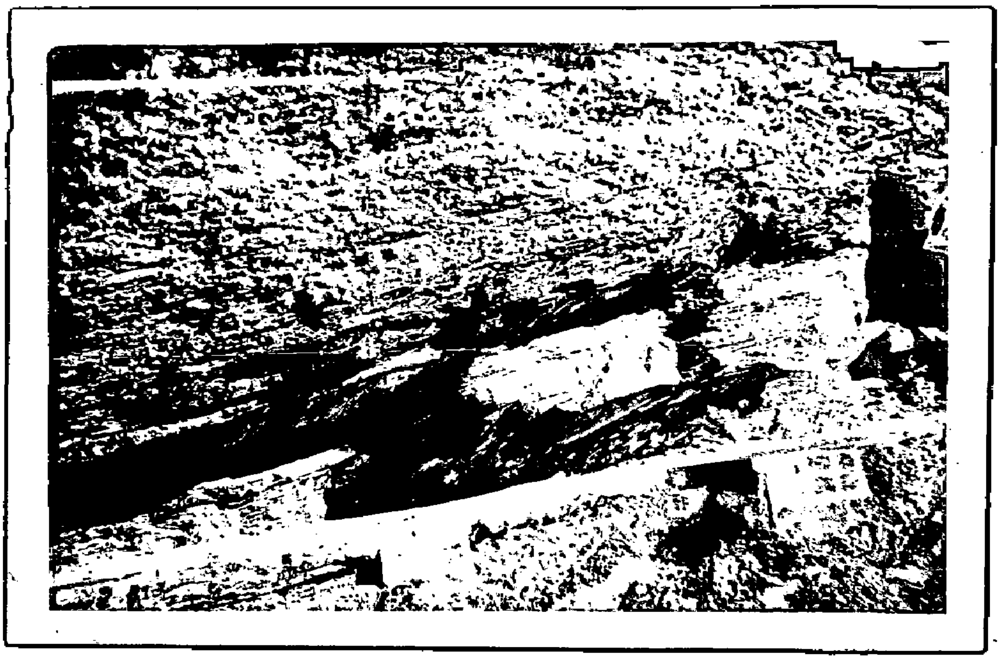

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PLATE 6

Photograph No. 10 : Fault in quartz mica gneiss near Reni village 15/3 mile stone on Joshimath Malari Road, showing the drag folds due to faulting.

Photograph No. 11 : Quartz lense in Augen gneisses, 1 mile north of Reni village.

PLATE 6

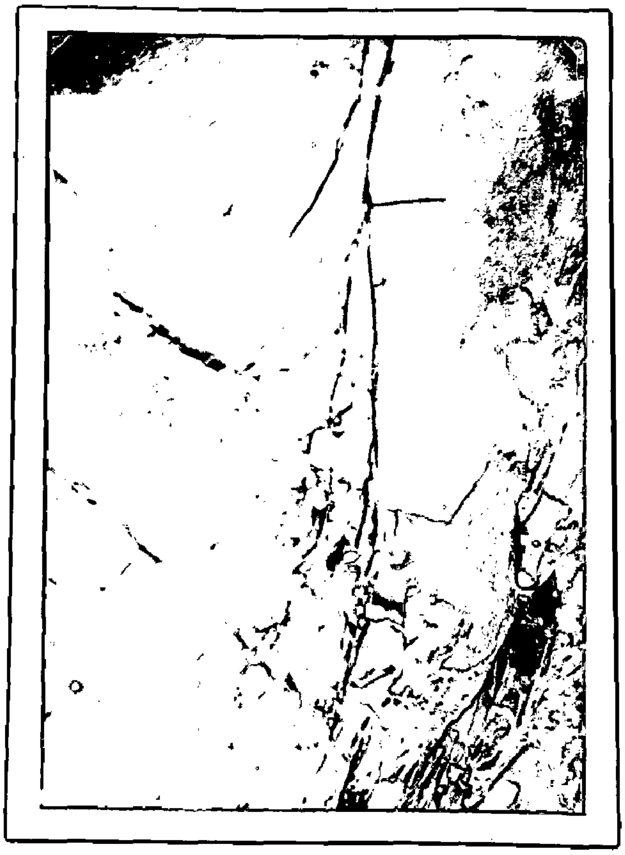

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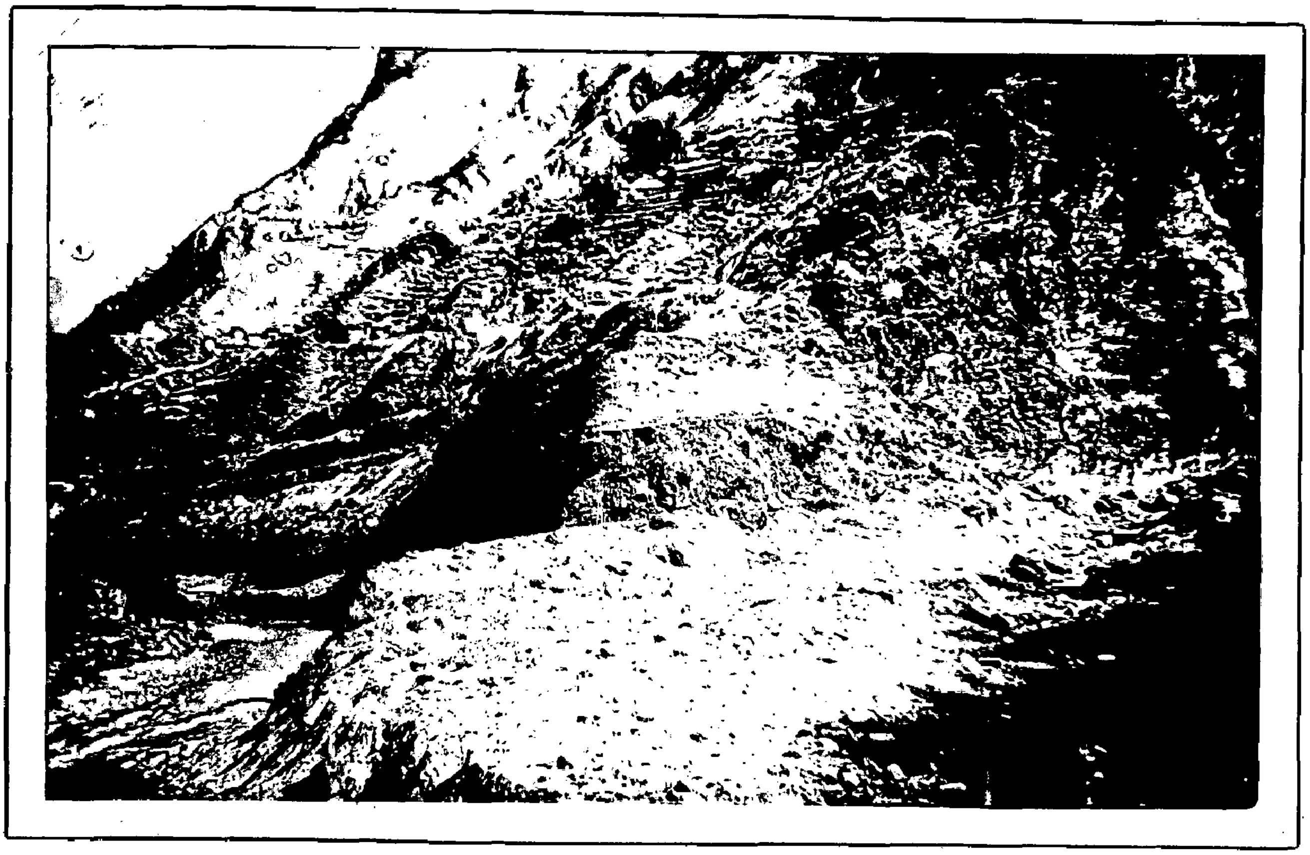
PLATE 13

Photograph No.22 : Photo show 5 legs of the road near the village Paini, photo taken from upperleg towards N 250° the slope is stable.

PLATE 12



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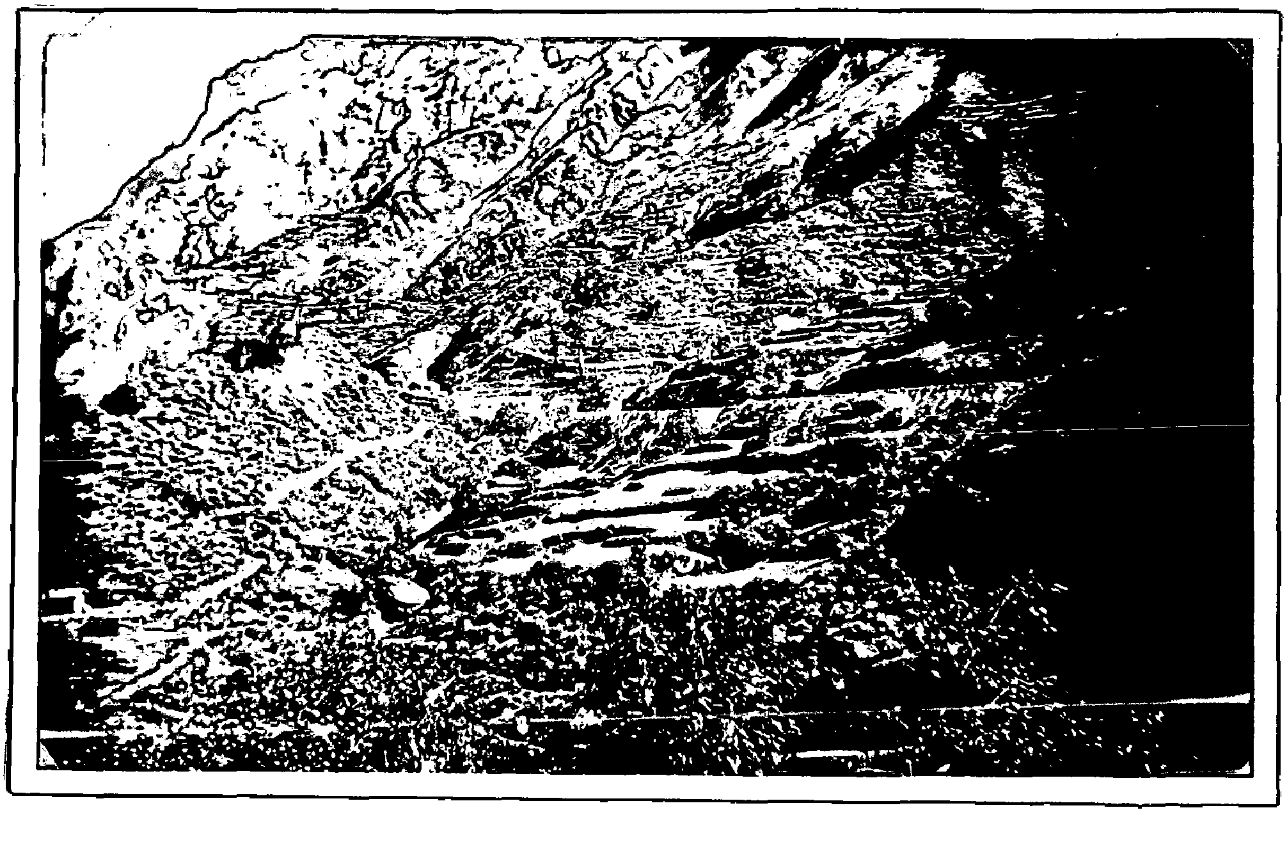


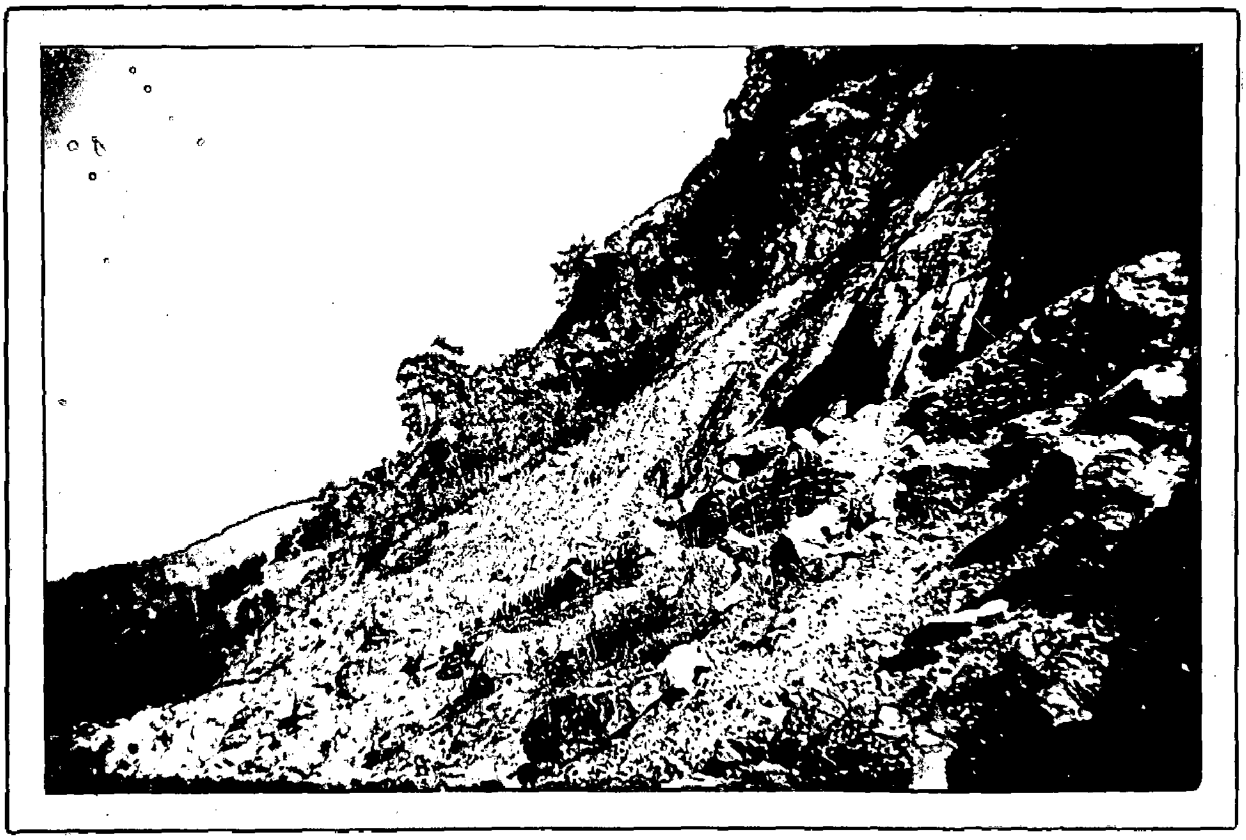
PLATE 12

Photograph No. 20 : showing the old landslide material at about 1 mile from Belakuchi towards Joshimath. R Patal ganga flows towards right and R. Alaknanda towards the left in the photograph.

Two stages of R.Patalganga are clearly visible.

Photograph No. 21 : Road in loose weathered soil and this whole area is due to old landslide which has attained stable slope. Photo taken from Gangsi school in the direction N 65,

PLATE 11



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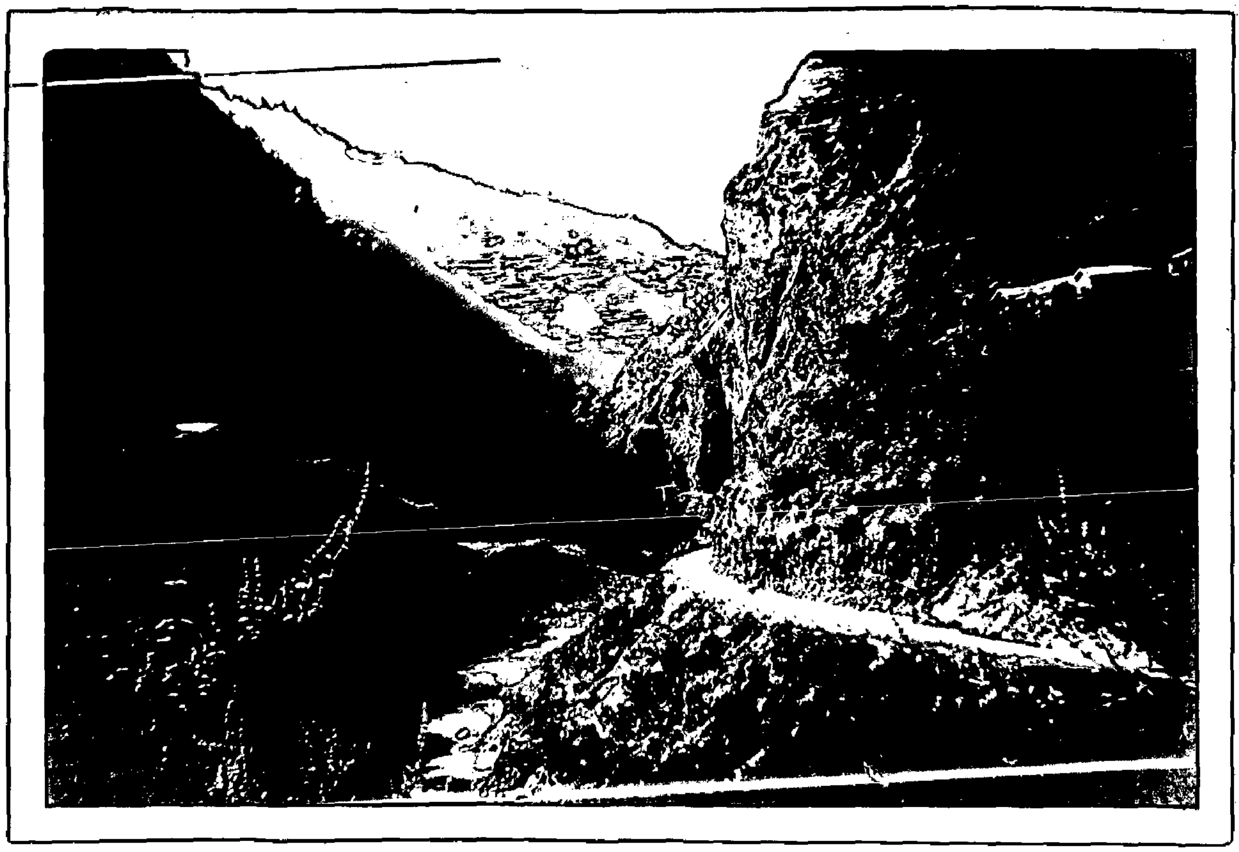

PLATE 11

Photograph No. 18 : Slide zone at 158/1 milestone
The upper slope is steep and
fresh cuts are visible which
are devoid of vegetation.
Photo taken from valley towards
N 180°.

Photograph No. 19 : Shows road in slates. The
vertical cuts have been made
for construction of road.
Photo taken in the direction
S 40° W from Langsi bridge.
Location - One and half mile from
Belakuchi towards Joshimath.

PLATE 10

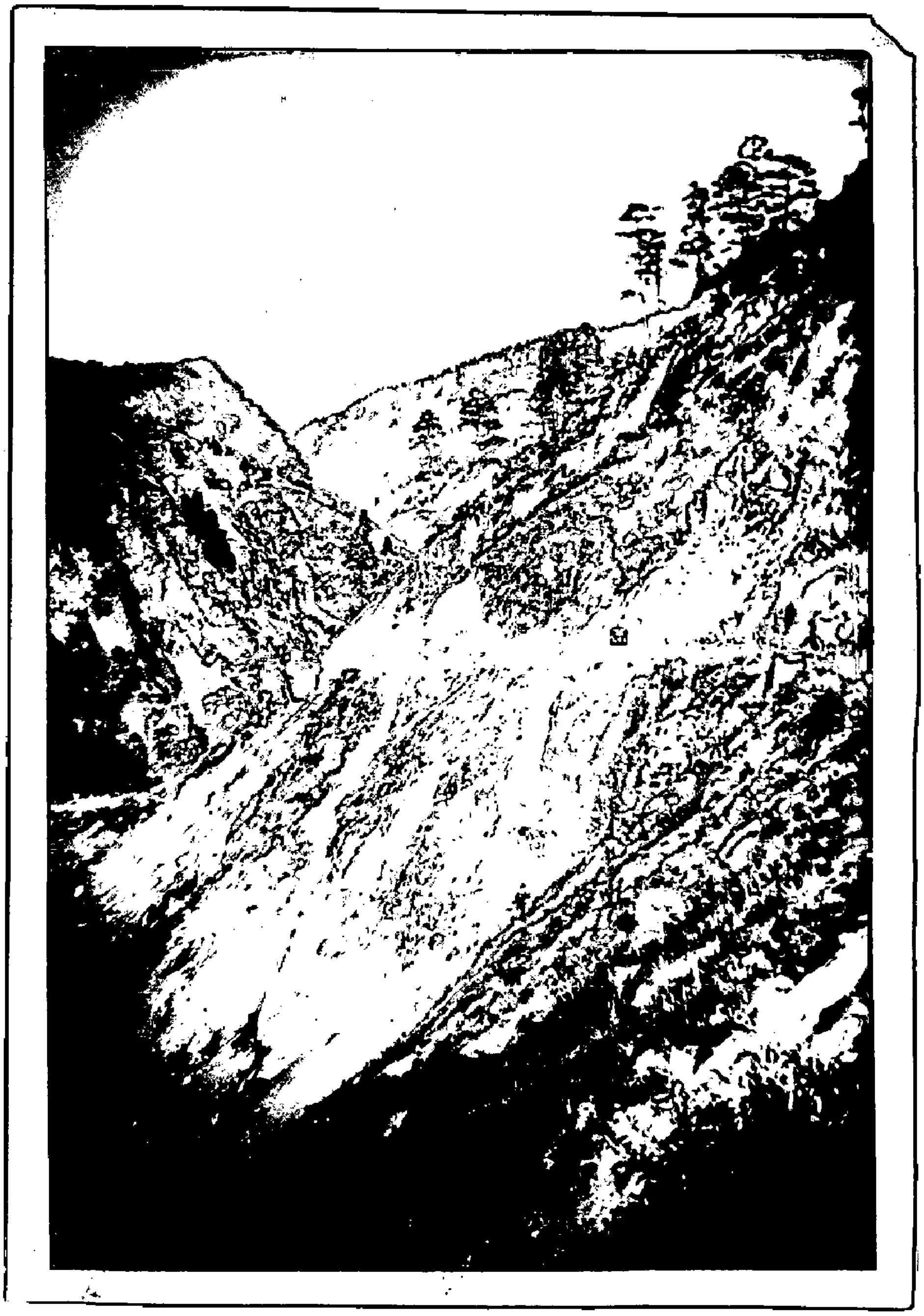

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PLATE 10

Photograph No. 17 : Shows land slide zone in limestone the slope is 55° and more, above the road and 60° below the road. Formation of gullies are seen, Slided material covers original rocks.

Location - at 167/7 milestone Pipalkoti-Joshimath road.

PLATE 9

PLATE 9

Photograph No. 16 : Graded river deposit near 28/1 mile stone near Juma on Joshimath Malari Road.

<u>From top to bottom.</u>

River gravel.

Fine black grit - shows current bedding

Black sand.

Alternating bands of clay and black sand.

PLATE 8

14

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PLATE 8

Photograph No. 14 : Graded bedding on the road side, near 26/3 mile, on Joshimath Malari Road.

Photograph No.15 : Fluvio-glacial deposits near 26/5-1/2 mile on Joshimath Malari Road. Bottom layer is sand followed by river gravels. The top portion is a glacial tillite.

PLATE 7

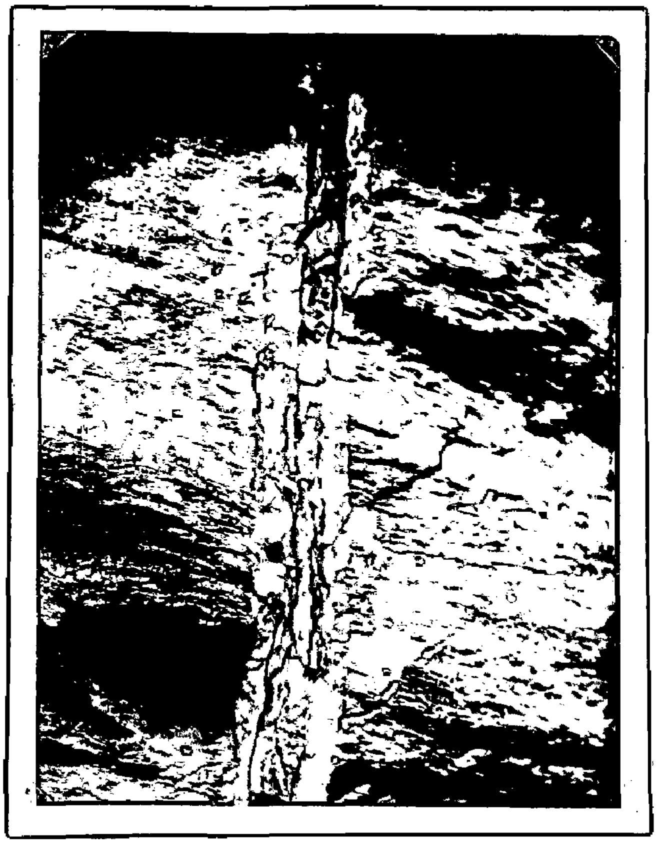

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PLATE 7

Photograph No. 12 : Aplite dyke cutting across the foliation of mica schist near 23/7 mile stone on Joshimath Malari Road.

Photograph No. 13 : River gravel on the opposite bank of river, the top portion shows the rock formations. Formation of cones due to the sliding of river gravel. Location - 23/7 mile stone on Joshimath Malari Road.

PLATE 13

PLATE 13 A

Photograph No. 23 : Photograph showing the 1st and 2nd leg of road near Painia In the back ground norther dipslopes are seen covered with vegetation where as the steaper southern slopes are devoid of any vegetation.

PLATE 13 A

PLATE 14

Photograph No. 24 : Rock fall zone of Jharkula, the lanslides are very frequent here due to the sliding of well jointed quartzites. The slip takes place along the joint planes. A road roller damaged due to a slide can be seen. The slope below the road is also steep.

PLATE 14

PLATE 16

Photograph No. 25 : Joint slope of Hathi Pahar North of Joshimath. On the right side of R.Alaknanda the road passes through augen gneisses.

Photograph No. 26 : Stable slope of Joshimath two legs of road on the left side of R.Alaknanda are visible. In the background the road on the right side of R.Alaknanda is visible.

PLATE 15

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↑ 25

PLATE 16

Photograph No. 27 : Photograph showing the landslide zone near 9/2 milestone on Joshimath-Badrinath road. The slide takes place due to block jointing in quartz-gneisses and sliding along the foliation planes.

Photograph No. 27 A : A close up of the above spot. Hanging blocks of rocks are clearly visible. The road is parallel to the strike of the formation.

PLATE 16

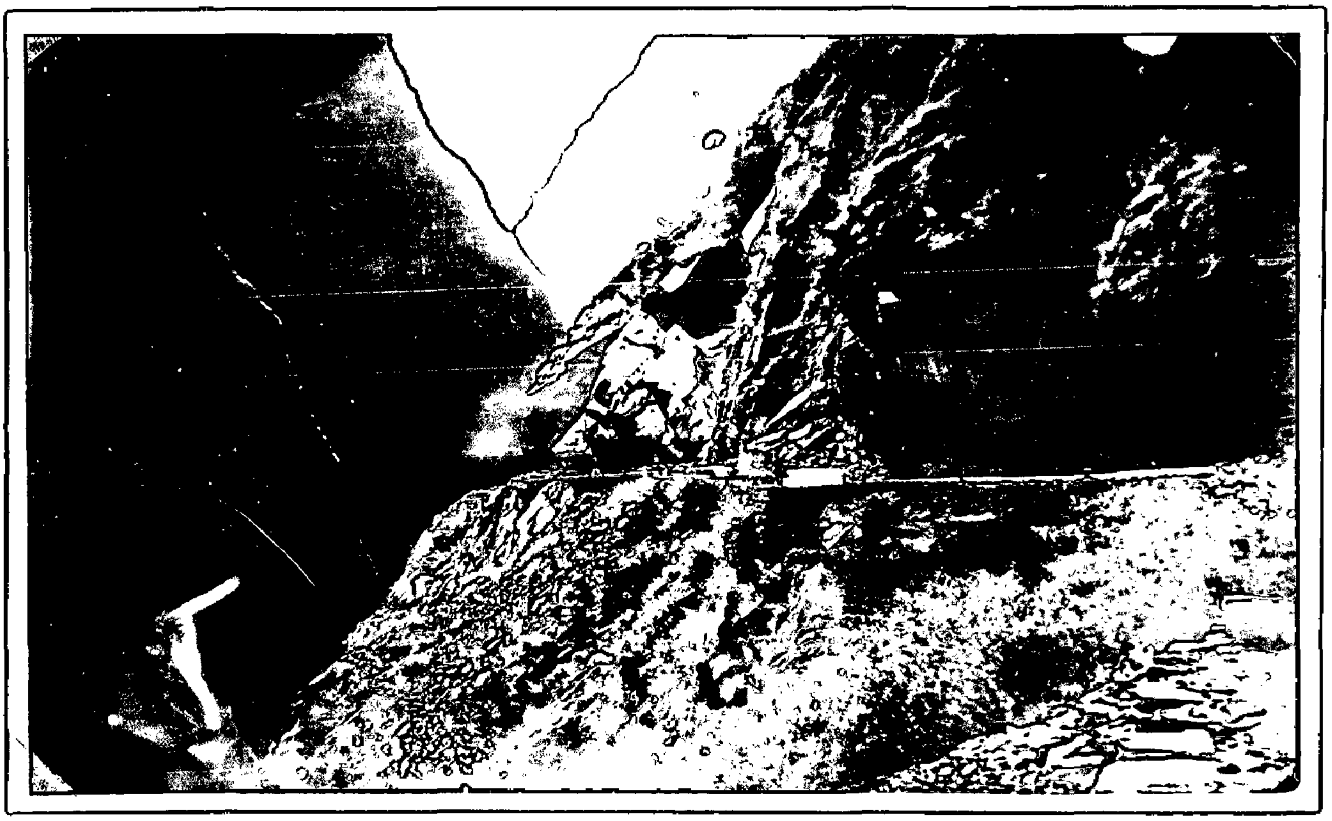

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PLATE 17

Photograph No. 28 : A general view of the Hanuman chotti landslide zone: showing all the three legs and extent of slide zone, River bend can be noticed.

PLATE 17

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PLATE 18

Photograph No. 29 : Another photo of Hanuman chatti. Photo shows three legs and the village Hanuman chatti. Development of gullies are seen in all the slopes and steep nature of slope is also clearly seen.

PLATE 18

PLATE 19

Phtograph No. 30 : A close up view of the road following the river bend. Development of gullies can be seen.

Photograph No. 31 : Note the well jointed quartzite and quartz mica gneisses dipping into the hill. Verticale joints dipping at 45° which are strike joints cause slipping. The locality is adjacent to the Hanuman chatti landslide zone. The upper leg of the road passes through these rock (top right)

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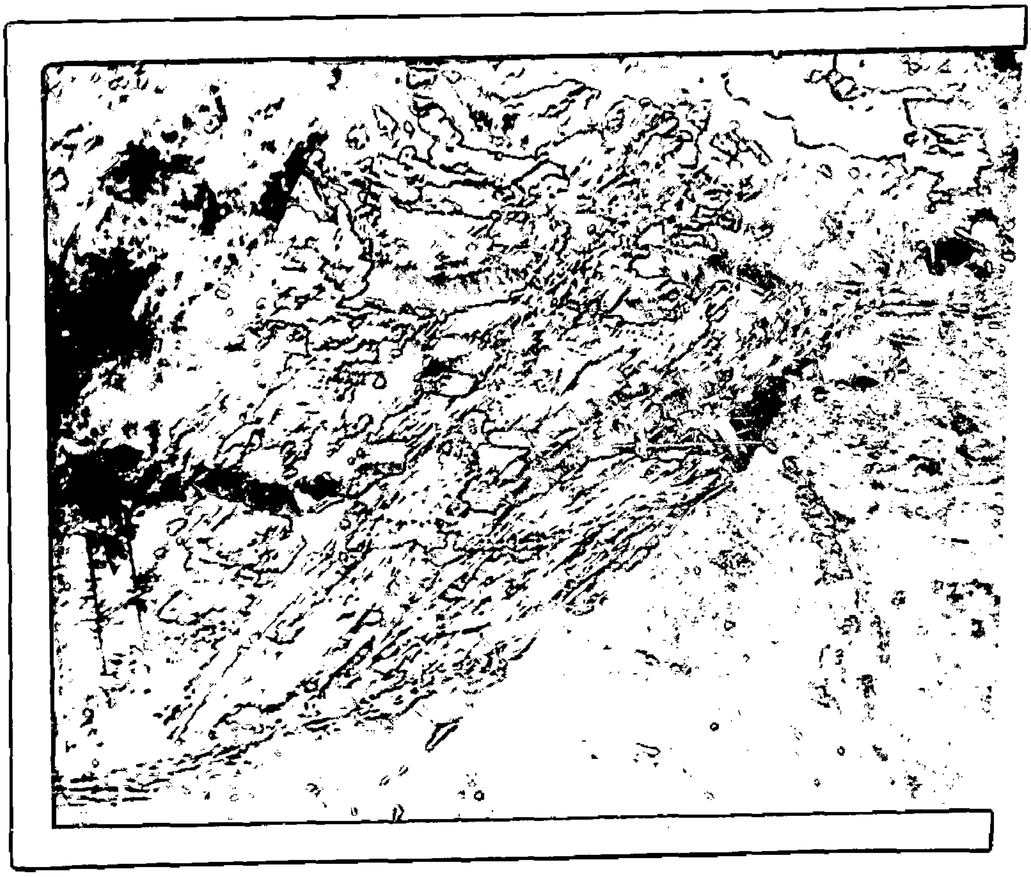
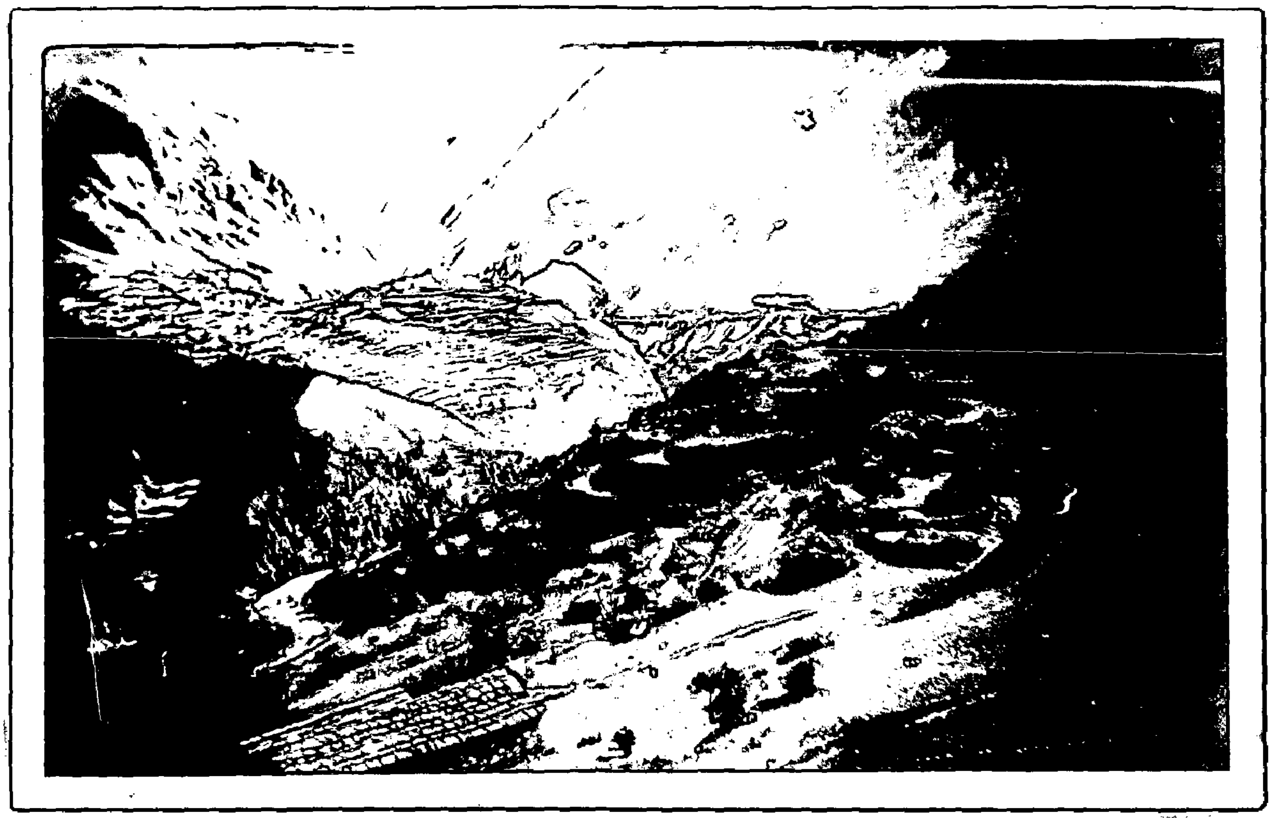


PLATE 20

Photograph No. 32 : Shows the frontal part of Tapoban land slide and which caused the damming of river Dhauli Ganga.

Photograph No. 33 : The glacial moraine deposits which block the R.Dhauli Ganga. The flat top are remanent of old natural dam as seen in the back ground. R.Dhauli Ganga has cut an epigenetic gorge(not visible in photograph).

PLATE 20



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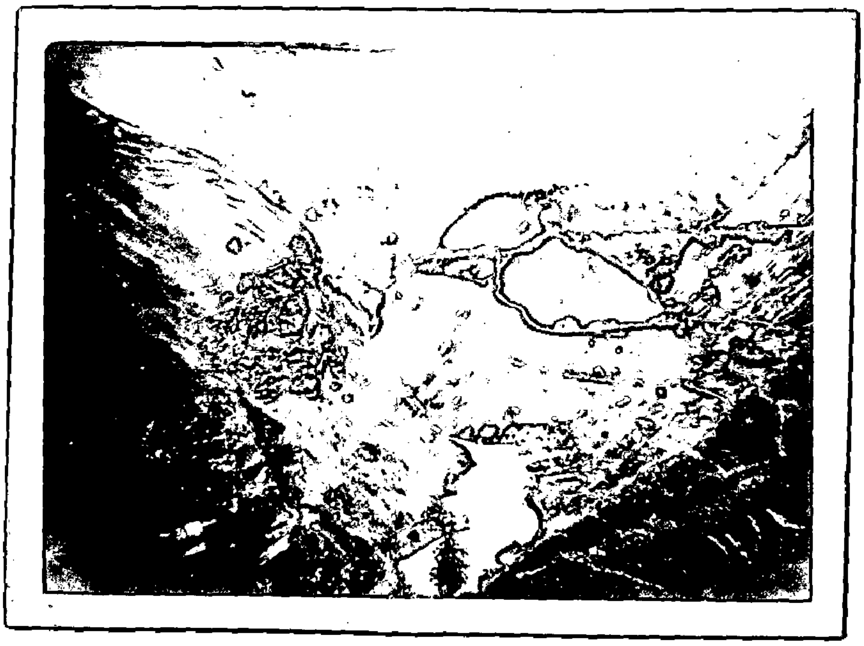

PLATE 21

Photograph No. 34	:	Three trunks are bent indicating mass movement along the steep slopes. location between 10/6 and 10/7 on Joshimath-Malari Road.
Photograph No. 35	:	Formation of cone due to wind. The loose weathered soil fall due to wind, near 11/5 milestone on Joshimath Malari Road.

PLATE 21

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PLATE 22

Photograph No. 36 : Dib slope in augen gneiss at 14/2 milestone near Reni. The sliding takes place along the foliation plane.

Photograph No. 37 : Photograph showing the vertical joint. wide gaps have developed due to blasting. This is the zone of frequent landslide and rock falls. Location - 16/7 milestone on Joshimath Malari Road.

PLATE 22

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PLATE 23

Photograph No. 38 : showing road in slided material, photograph taken from 28/7 towards East: natural angle of repose can be seen in the portion through which the road does not pass. The effect of disturbing this angle for road construction can be visualised.

PLATE 23

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PLATE 24

Photograph No. 39 : Frozen river or glaciar about I furlong from Bamni village, on the right side of the valley of river Alaknanda.

Photograph No. 40 : Showing remanants of old blocking of the river near Jelam, the gradient of the river is very gentle in this part. In the right bottom side partly eroded glacial moraine is visible.

PLATE 24

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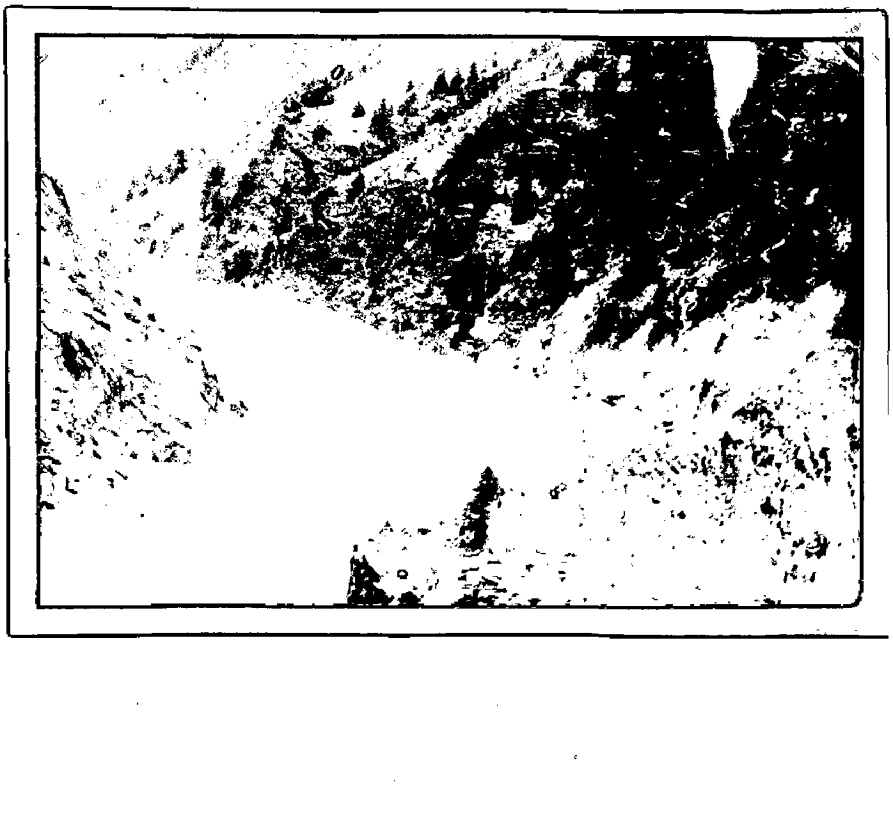
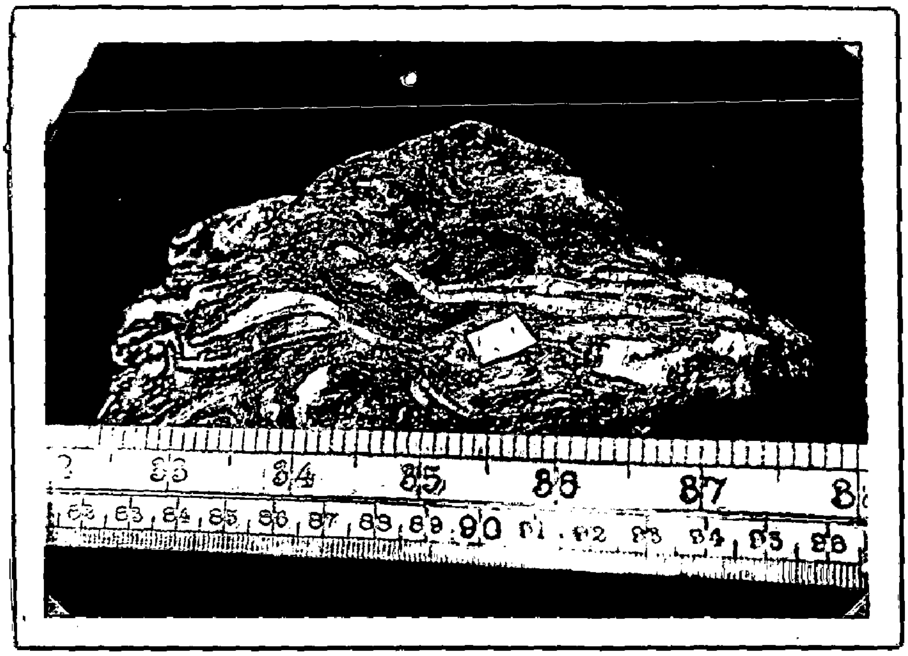


PLATE 25

Photograph No. 41 : The specimen of chlorite schist showing quartz veins. The quartz veins show pinching and swelling texture.

Photograph No. 42 : The Augen gneiss showing augens of quartz and felspar of variable width.

PLATE 25



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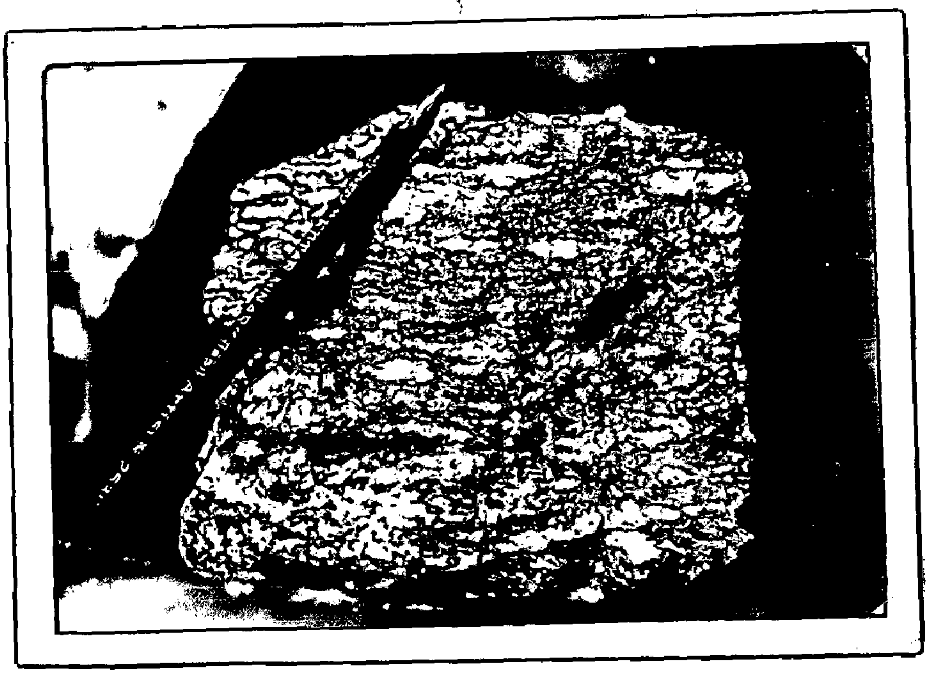
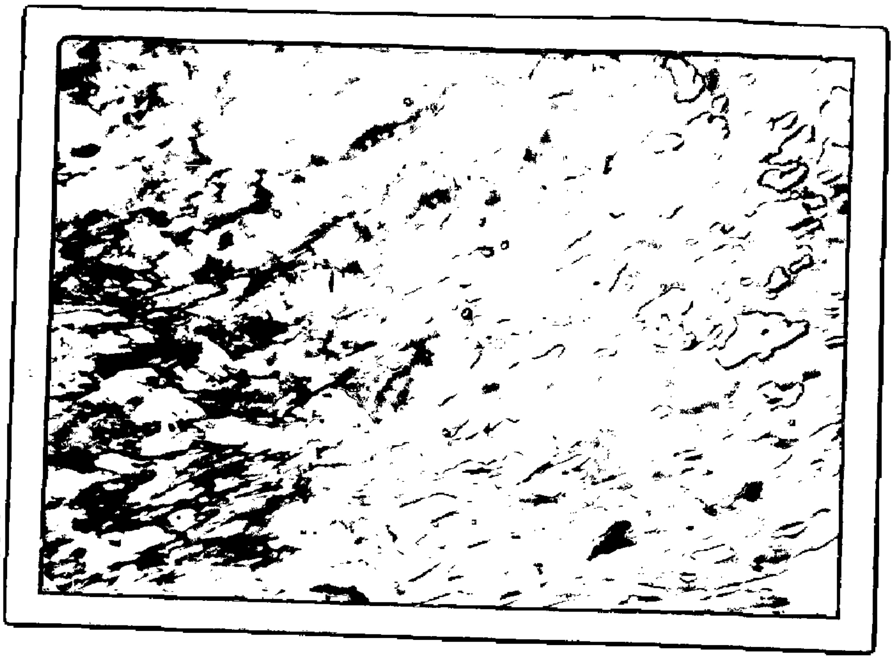


PLATE 26

Microphotograph No. 41 : Chlorite schist showing schistose texture. The chlorite flakes have arranged themselves in a linear pattern (ordinary light).

Microphotograph No. 42 : Augen gneiss showing a big augen of felspar under xnicol.

PLATE 26



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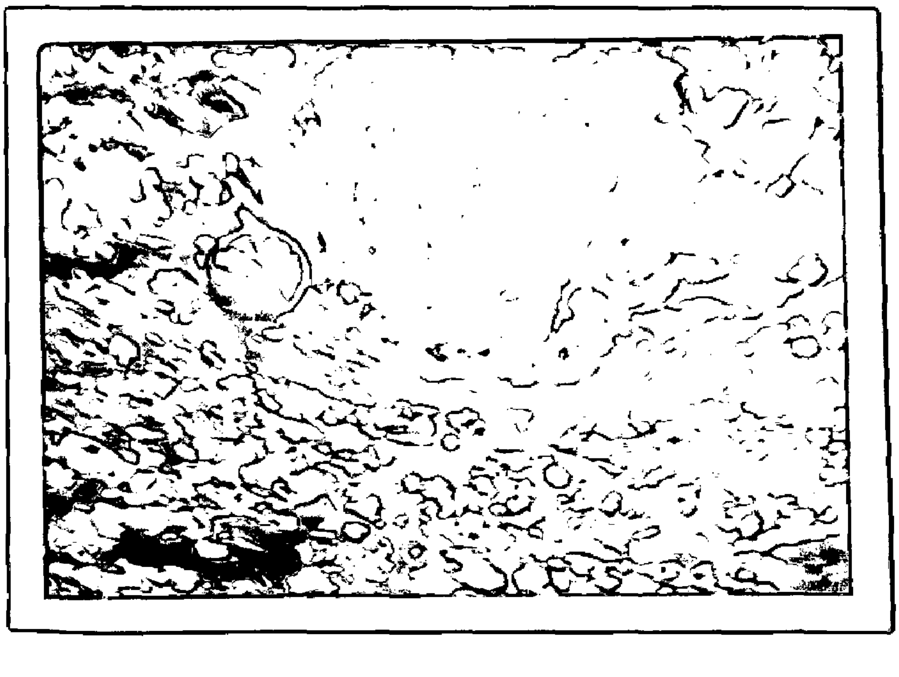

PLATE 27

Microphotograph No. 45 : Slide No. 4/45. The horn blende grains are broken along certain direction and the rock shows cataclastic texture under ordinary light.

PLATE 27

45

4-6