# CHAPTER III

# GEOLOGICAL SETTING

## GENERAL

The study area, comprising a part of the unfossiliferous Lesser Himalaya, has been variously described by the previous workers (Table III.1). Inspite of a good deal of work carried out in this section of Nepal Himalaya by almost all the previous workers, the geology of this section has remained quite controversial mainly regarding its tectonics and stratigraphy.

The detailed mapping done by this author in collaboration with B.N. Upreti, in this crucial part of the Kali Gandaki Valley, has revealed a very interesting structural and

Table III.1 : Table showing the proposed tectonic and lithostratigraphic names by different workers to the study area.

| Name of the workers: | Hagen (1969) | Bordet et al. (1964) | Nadgir & Nanda (1966) | Fuchs (1967) | Talalov (1972) | Ohta & Akiba (1973) | Sharma (1973) | Remy (1975) |
|---|---|---|---|---|---|---|---|---|
| Name of the unit and formation | Nawakot nappes; Nawakot nappe No. 3 | "Series of Kuncha" | 'Supari-tar series' | 'Chail Nappe, 'Chail series' | 'Okhar-bot & Tara suite' | 'Midland Meta-sediment group' | 'Mahabharat limestone group' | 'Nepalese series' |

geomorphic history. Structurally, the study area has been found to comprise two tectonic units, separated by a prominent thrust running WNW-ESE across the south-western corner of the area along the village of Phalebas. This dislocation (referred to as Phalebas Thrust) dips moderately due NE and separates the more metamorphosed unit of the north from the incipiently metamorphosed unit of the south. Major portion of the study area lies within the Northern Unit. A high angled reverse fault cutting the Northern Unit at Kusma extends almost parallel to the Phalebas Thrust. On account of this fault (referred to as Kusma Reverse Fault), the rocks to its north have been pushed up.

The geological map of the area prepared by the two workers (Fig. III.1) clearly brings out the structural pattern exhibited by the rocks. A look at the foliation trends of the study area (Fig. III.2) reveals large N-S running antiform and synform, which has been folded subsequently by the WNW-ESE to E-W folds. The various structural features have been found to be related to four distinct folding episodes.

The present author has mainly restricted his studies to the Northern Unit, which consists of low grade metamorphic rocks mainly represented by slates, sandstones, phyllites, and quartzites. The major groups show variation within themselves, giving rise to a number of lithological types recognisable in the field. The lenses of basic volcanics add to the variety. The intermixing of the coarse and fine components in all proportions has very often produced an imperceptible gradation from the most micaceous to the most quartzose type. Inspite of this transition, several fairly distinct rock types have been recognised. Apart from the variation due to the original nature of sediments, the varying effects of metamorphism and deformation have also influenced the rocks producing distinct varieties. The various rock types show difference in colour, grain size, mineral content and structural features.

Taking into consideration the rocks of the Southern Unit as well, the author has arrived at the following succession of the rocks which from south to north:

| | | |
|---|---|---|
| Kusma Unit (Northern Unit) | Balewa Formation | Quartzose phyllites, gritty quartzose phyllites, micaceous quartzites |
| | Kusma Quartzites | White to light brown coloured quartzites with lensoid intercalations of spilites |

------ Kusma Reverse Fault -----------

| | | |
|---|---|---|
| Kusma Unit (Northern Unit) | Balewa Formation | Quartzose phyllites, gritty quartzose phyllites, micaceous quartzites |
| | Kusma Quartzites | White to light brown coloured quartzites with lensoid intercalations of spilites |
| Phalebas Thrust | | |
| Sirkang Unit (Southern Unit) | Sumsa Formation | Purple, green and grey slates, slaty phyllites with thin layers of dolomites and sandstones (graywacke) |
| | Phoksing Dolomites | Bluish grey to dark grey stromatolitic dolomites with minor intercalations of carbonaceous slates and intraclastic dolomites |
| | Bihadi Slates | Carbonaceous slates and shales with occasional layers of sandstones and dolomites |

The author has given local names to the different rock groups to avoid further confusion that has been prevailing on account of the variety of names suggested by previous workers. Obviously, the above nomenclature adopted for the different rock groups does not imply any regional significance, and this has been done for the convenience of description only. The thicknesses to the different rock groups have not been assigned because of the problem presented by the repetition of the strata due to intensive foldings.

The main aim of this chapter is to describe at length the different lithology and their distribution in the area. The geological map (Fig. III.3) prepared by the author shows the distribution of different lithological types. Brief reference to microscopic characters have been made at places only to facilitate the description.

## MAIN LITHOLOGICAL TYPES

The rocks of the study area comprises the following main lithological types:

1. Slates (purple, grey, and green coloured)
2. Slaty phyllites
3. Grey and green phyllites
4. Quartzose phyllites
5. Gritty quartzose phyllites
6. Gritty conglomerates
7. Micaceous quartzites
8. Massive quartzites
9. Impure feldspathic sandstones (graywacke)

10. Massive to foliated diabasic and basaltic spilites
11. Altered tuffs
12. Crystalline limestones
13. Dolomites
14. Quartz veins

Slates (purple, grey and green coloured)

These rocks are grey to ash grey in colour, occasionally the colour changes to greyish green or purple. At places, the rock shows a colour banding - dark grey to ash grey, and in such cases, the cleavage-bedding relationship can be easily observed. Broken surfaces of some of the slaty rocks show a subconchoidal fracture. The purple slates are invariably calcareous, and also display sedimentary features like sun-cracks. Thin section study of the slaty rocks has revealed their silty, argillaceous and calcareous nature.

Slaty phyllites

These rocks are grey to greenish in colour and very much similar to slates, but due to the development of abundant white mica films on the cleavage planes, they show a shining lustre. Occasionally, like the slates, they display colour bandings. At places they are very dark in colour and carbonaceous. These rocks are quite intensely folded at mesoscopic and microscopic scales; as a result, they exhibit conspicuous mullions, rods and puckers (Plate No. III.1). Megascopically chlorite and white micas can be recognised. On weathering the colour changes to brownish due to iron leaching.

Grey and green phyllites

These rocks form a distinctly recognisable lithological group. Fresh samples are grey to green, on weathering the colour changes to cherry brown. They are finegrained shining rocks, with a distinct development of sericite and chlorite along the foliation surfaces. The other constituent recognised megascopically is the finegrained quartz that forms the layers. Occasionally these rocks are spotted. The microscopic study has revealed that the spotting is due to the weathered stray grains of tourmaline, magnetite and iron oxides. At places, the pyrite cubes are seen developed abundantly. With a better development of mica and increased fissility, sometimes they look more like chlorite schists.

Quartzose phyllites

Quartzose phyllites form one of the most important rock type of the study area. They are fine to medium

Plate No. III.1

Mullion structures in slates (Loc. Silme, north of Sumsa) grained, greyish coloured rocks, on weathering they show a greyish brown colour. They are massive and thickly bedded with well defined foliation. Quartz, sericite, chlorite and muscovite are distinctly recognisable megascopically. Sericite and chlorite films give the shining lustre. Occasionally big flakes of muscovite are seen developed along the foliation. The quartz grains are of variable sizes - varying from fine to medium, shapes being elongated, rounded or ovoidal. With the decrease of quartz content and increase of mica minerals, the rocks grade into grey phyllites, but with the increase of quartz and corresponding decrease of mica, they grade into gritty quartzose phyllites. The unusual dark spotting in these rocks is due to the weathered grains of tourmaline and other iron minerals, which deceptively resembles the weathered garnets.

<u>Gritty quartzose phyllites</u>

These rocks are similar to quartzose phyllites, but differing in respect of the size and shape of the quartz grains. Like the quartzose phyllites, they are greyish coloured, thickly bedded rocks with well defined foliation. They are medium to coarsegrained, quartz grains being angular to somewhat elongated. Megascopically, chlorite, sericite, muscovite and the quartz are easily recognisable. The grains of tourmaline and magnetite are always present in subordinate proportions.

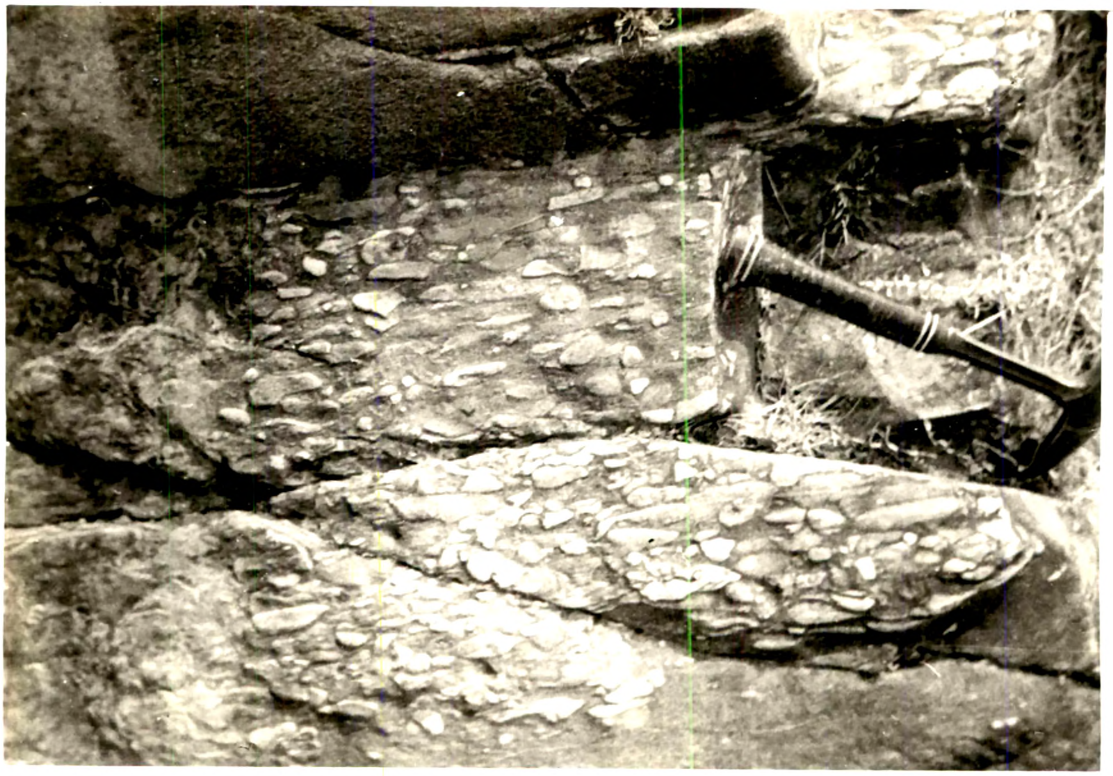
## Conglomerates

Occasionally in the gritty quartzose phyllites, thin layers of conglomeratic horizons are encountered, which consists of sub-rounded to sub-angular elongated and stretched pebbles of quartzites embedded in a matrix of gritty quartzose phyllites (Plate No.III.2). The thickness of these layers vary from a few cm to as much as a metre. The pebbles of these greyish coloured conglomeratic rocks are stretched along the dip direction of the rocks, having given rise to a distinct lineation due to their elongation. The quartz pebbles vary in size from above 1 cm to 5 cm in length.

## Micaceous quartzites

These form a variety of quartzites, which contain more micaceous minerals and are transitional rocks. These rocks show weak but distinct foliation. With the increase of mica minerals, they grade into quartzose phyllites. They are fine to mediumgrained and are comparatively brittle and

Plate No. III.2



Conglomerates (Loc. Lamai Khola)

hard. Tourmaline and feldspar grains form the other accessory minerals. They are white in colour, when weathered they disintegrate into white powdery mass.

Massive quartzites

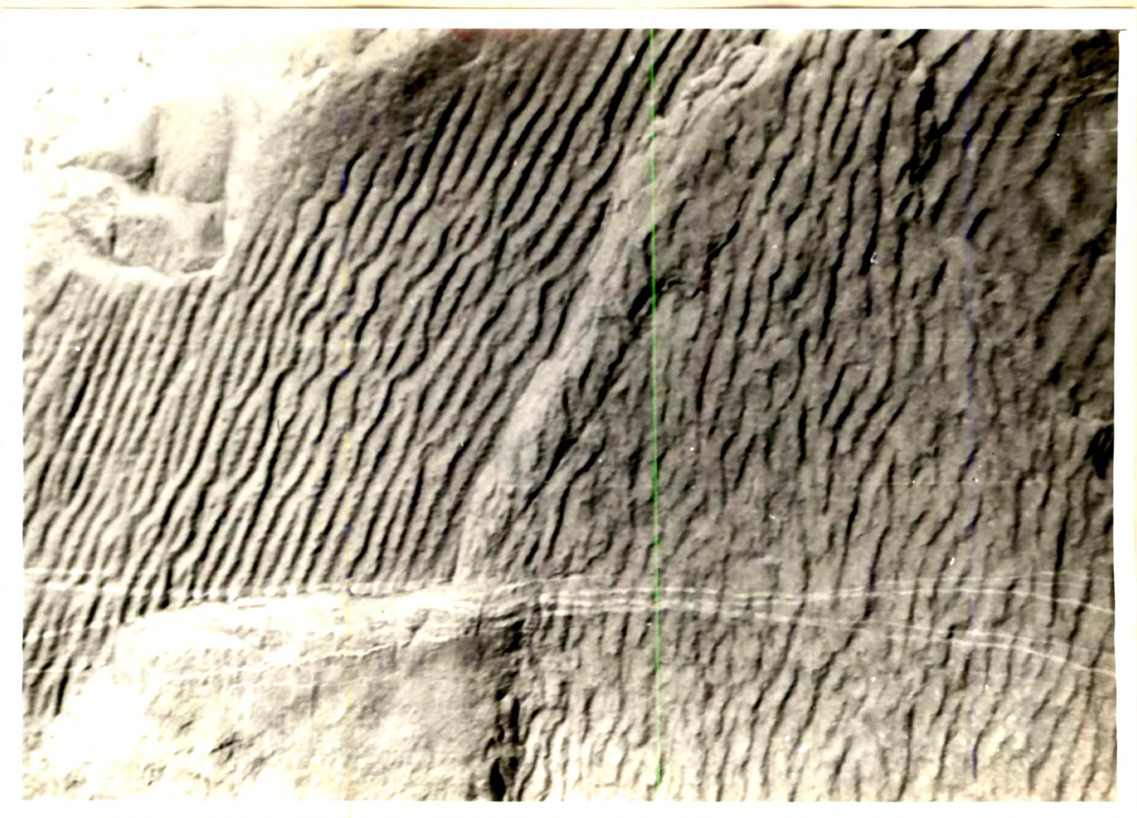
Forming a conspicuously recognisable variety of quartzites, these rocks are similar to micaceous quartzites, but differ in their very low mica content and thickly bedded nature. Sedimentary features like ripple marks and cross-beddings are very common (Plate No. III.3 & 4). Occasional colour banding helps in identifying the bedding planes in the varieties not showing sedimentary features, They are fine to medium grained, white rocks. Apart from quartz, tourmaline is the other recognisable mineral which occurs as stray grains.

These quartzites at or near the vicinity of the basic volcanics are greenish in colour. The microscopic study has revealed that the colouration of the quartzites is due to the presence of chlorite.

Impure feldspathic sandstones (graywacke)

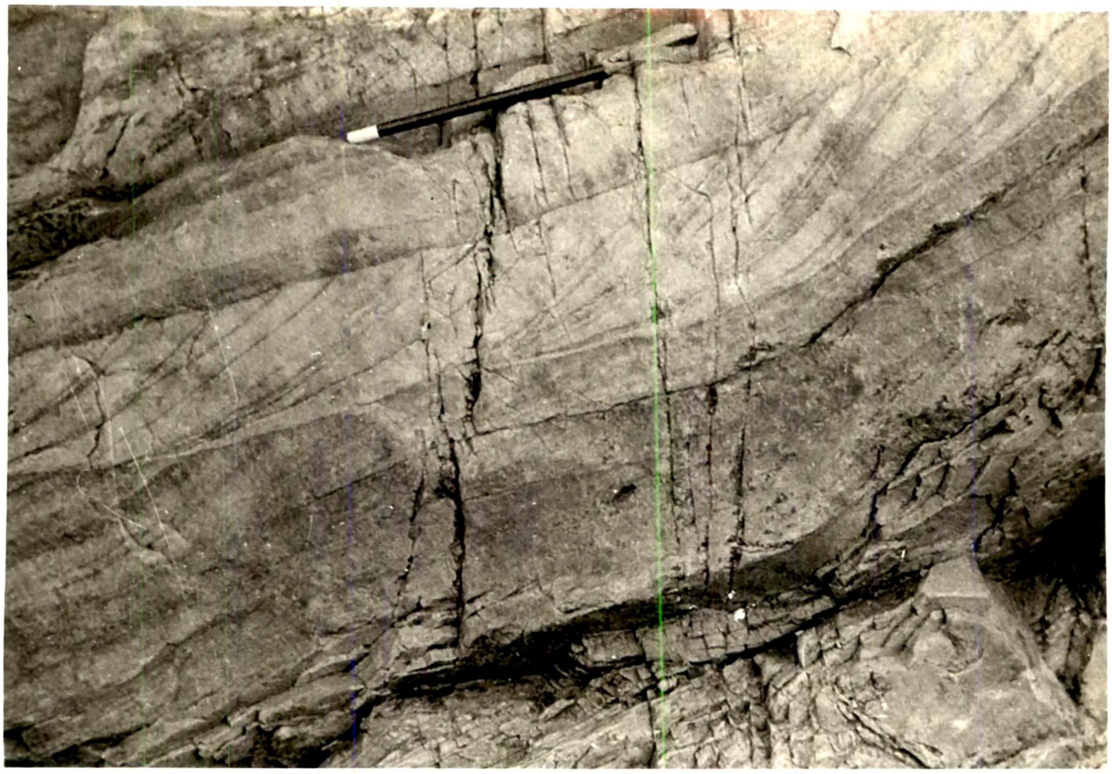
These rocks are found only in the area to the south of the Phalebas Thrust. They are dirty greenish to grey coloured rocks and comprise detrital quartz grains,

Plate No. III.3



Ripple marks in quartzites (Loc. Khahare Khola - Chuwa)

Plate No. III.4



Cross bedding in quartzites (Loc. Lamai Khola) feldspar and micaceous minerals in a dark green matrix of unknown composition. Sedimentary features like current bedding and ripple marks are very common.

Spilitic diabase and basalts

The lenses of spilitic diabase and basalts are confined to the quartzites. They are fine to coarsegrained greenish coloured rocks. Megascopically, chlorite, feldspars, epidote and radiating fibres of amphiboles are the visible minerals. Along the rock fractures and in the main rock mass calcite is usually present. The veins of epidote are seen cutting the main rock mass. Sporadic cubes of pyrite and grains of other iron oxides are recognised megascopically.

Altered tuffs

Lenses of tuffs are seen occasionally in the quartzites and gritty quartzose phyllites. They are dark greenish in colour. Exposed and weathered surfaces show reddish brown colour. They are finegrained rocks. The chlorite is the only visible mineral in this rock. The cubes of pyrite and grains of magnetite and ilmenite are invariably present. The sheared variety resembles chlorite schist.

Crystalline limestones

Thin intercalations of crystalline limestones are occasionally encountered in quartzites. Buff to white in colour, these rocks have been found to contain calcite and dolomite with scattered grains of pyrite and chalcopyrite.

Dolomites

Thin intercalations of purple coloured dolomites are seen in the similar coloured slates. These rocks are very finegrained. Under the microscope, they are found to comprise of fine dolomitic aggregates with frequent oolitic structure.

Quartz veins

Quartz veins are common in all rock types, and occur as ptygmatic veins showing a diversity of sizes and extensions. They quite often show intricate flow folding of disharmonic type. Mostly they follow the foliation but their growth along joint planes are not uncommon.

DISTRIBUTION AND FIELD CHARACTERS

Sumsa Formation

Sumsa Formation comprises the rock groups outcropping south of the Phalebas Thrust, occupy the south-western corner of the study area (Fig. III.3). The name Sumsa Formation have been applied to these rocks because of their good development around the village of Sumsa. It comprises slates (purple, grey and green coloured) and slaty phyllites with thin intercalations of impure feldspathic sandstones (graywacke) and dolomite.

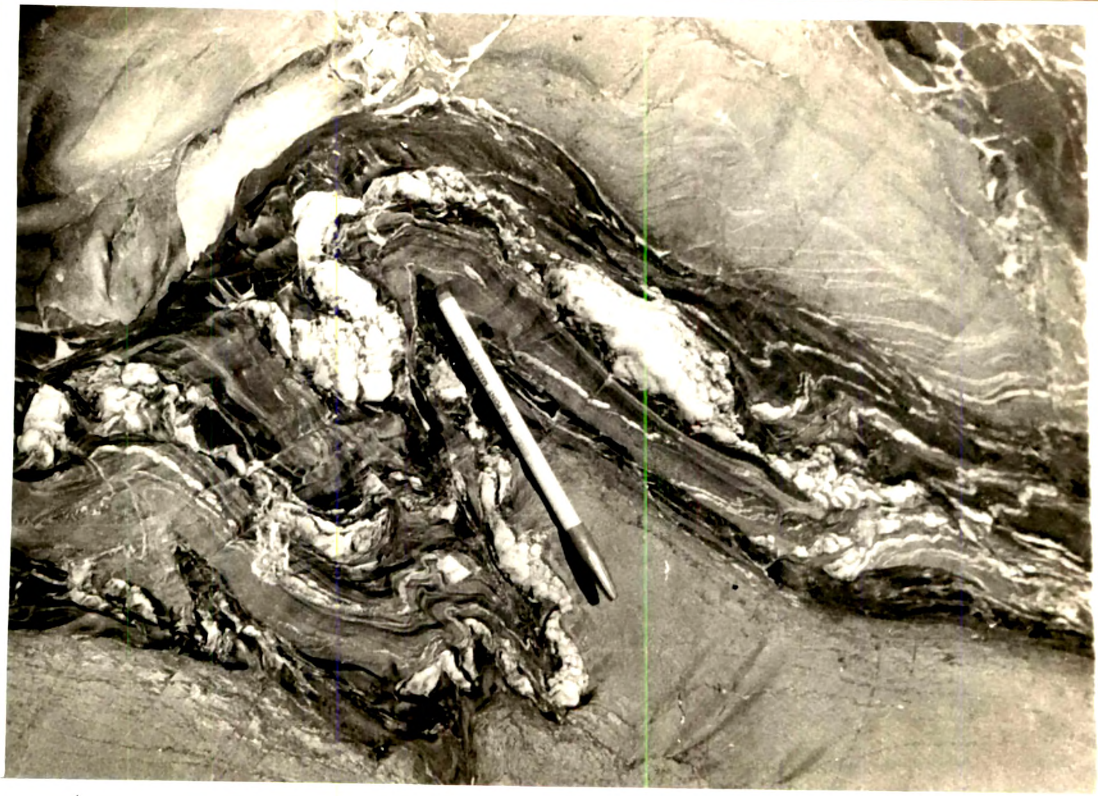
Sumsa Formation, though covers a small portion of the area studied has been found to extend southward and form extensive exposures to the south as well as to the SE and NW of the Sumsa Village.

In the vicinity of the Phalebas Thrust, the dominantly slaty rocks of Sumsa Formation are comparatively more metamorphosed and could better be considered as slaty phyllites. Good exposures of slaty phyllites are seen at Silme, Lamai Khola, Theule Khola and Chirdi Khola sections. Due to the high degree of folding, the strike of these rocks varies considerably, fluctuating between E-W to NW-SE. However the general trend is roughly NW-SE, and dips invariably due N or NE. The dip angles also vary considerably, from moderate to high (35° to 50°) near Silme and Theule Khola section to almost horizontal near Lamai Khola-Kali Gandaki confluence. Associated intimately with the slaty phyllites are the impure feldspathic sandstones, which occur as thin intercalations. Thin layers of limestones are also occasionally noted. The slaty phyllites in the Lamai Khola and Theule Khola sections are occasionally carbonaceous in nature.

These slaty phyllites reveal very well evidences of more than one folding. Extensive occurrence of mesoscopic tight folds point to an early isoclinal folding, such that the cleavage and beddings are parallel at most places, except at the hinge of the folds. The cleavage, obviously shows axial plane relationship. These tight folds show normal to reclined attitudes. Superimposed over them are the evidences of (i) open E-W to WNW-ESE and (2) NNE-SSW to NNW-SSE flexures. These later folds have affected the rocks on all scales and have developed very conspicuous mullions, flow folds (Plate No. III.5) and puckers. Interference between the two later flexures have quite often given rise to mesoscopic domes and basins on the cleavages.

Southward, these slaty phyllites become almost slates. Their typical exposures can be seen at the village of Sumsa and in the Chirdi Khola. These slates are invariably intercalated with the dirty green impure feldspathic sandstones, which near Sumsa ferry, show a prominent development; the sandstone layers measuring upto 15 to 20 m in thickness.

Plate No. III.5



Flow fold in slates (Loc.Silme, north of Sumsa)

Very often these sandstones show sedimentary features like ripple marks and cross-beddings. In the region to the south of the Sumsa village, slates of Sumsa Formation become purple in colour, which further south forms a dominant rock group. With the change of colour from grey to purple, both slates and sandstone become more calcareous. These slates are also found intercalated with thin purple dolomitic layers. These purple coloured slates exhibit the sedimentary features like sun-cracks.

The grey coloured slates of the village of Sumsa and Chirdi Khola are extensively used for roofing purposes, and at number of places these rocks have been exploited by the local people.

The quartz veins cutting across and parallel to the slate rocks, north of Sumsa, are observed to contain copper minerals like chalcopyrite, chalcocite and azurite. This mineralized zone is about 10 to 20 metre in thickness and extends almost WNW-ESE across the localities of Chirdi Khola, Bajakhet and Chokya Khola. This zone is conspicuous and easily recognised even from a distance due to the greenish blue staining on the exposed surfaces. Old workings of the copper ore are recorded at a number of places, where the tunnels and holes have been dug following the ore rich quartz veins. The old workings of copper ores have been also reported from the adjacent areas on this belt outside the study area. The copper ores in the mineralized quartz veins occur in the form of thin layers and pockets disseminated in the strike direction of the rocks. The surface indications do not suggest any economic value.

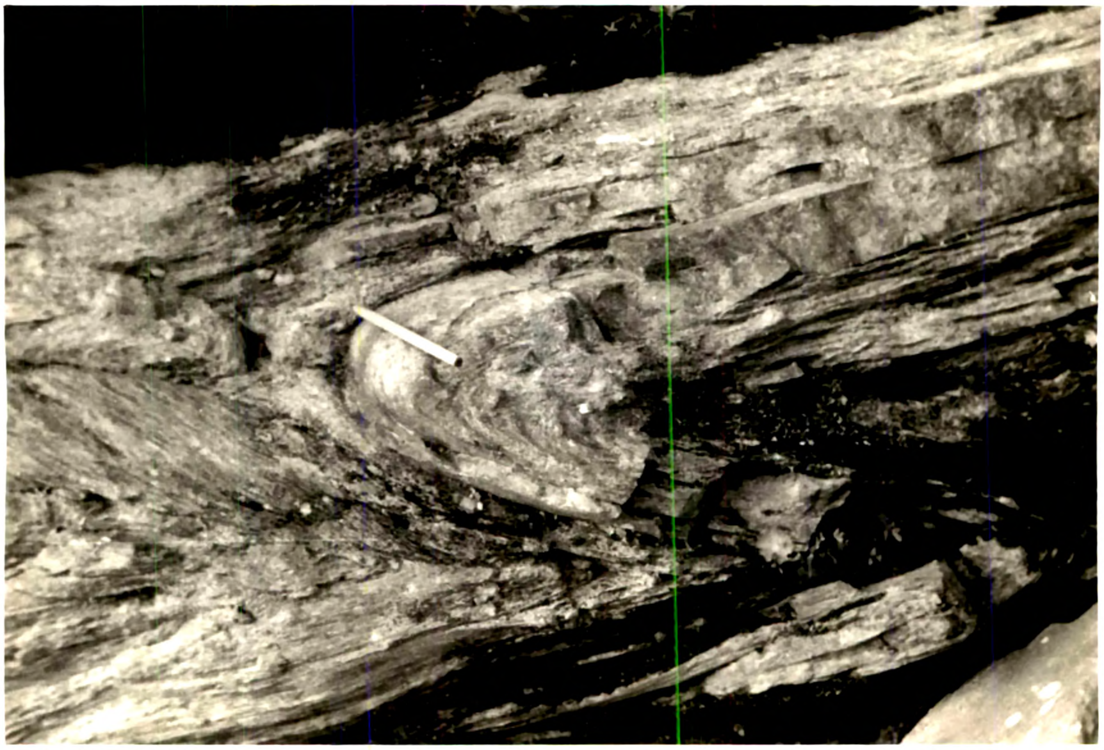
Like the slaty phyllites, the slates in the south also have preserved the effects of the different fold episodes. Due to the effect of various deformations, the strike of these rocks shows much fluctuation in the range of 20 to 30 degrees around NW-SE and dipping moderately due NE. In the areas, south of the village of Sumsa the attitude of the rocks suddenly change to N-S and with dips due E. This change is due to the effect of a regional tight reclined to isoclinal folding and a subsequent N-S fold.

## Phalebas Thrust Zone

The Phalebas Thrust Zone, which separates the northern comparatively more metamorphosed formations (Kusma Unit) from the southern unmetamorphosed or incipiently metamorphosed rocks of Sumsa Formation (Sirkang Unit), runs almost WNW-ESE along the village of Phalebas in the south-western corner of the study area. For the major part of the study area, the Phalebas Thrust Zone lies underneath the thick Kali Gandaki terraced conglomerates. The nature of the Phalebas Thrust Zone has been studied on the southern slope of Thana hill, along Lamai Khola and along Theule Khola sections. However, in these sections also, the Phalebas Thrust Zone is concealed beneath the cultivated fields with occasional exposures here and there. At such places, where the exposures are encountered, it forms a linear zone of 15 to 20 metre thick characterised by highly sheared and distorted rocks involving the rocks lying on either side of the zone. As such, the thrust zone is not well defined and it is rather difficult to pin point it precisely in the field. Its existence is based on indirect evidences of metamorphic and structural diversities of the rocks on two sides. If the rocks on either side of the Phalebas Thrust Zone are studied carefully, the apparent metamorphic reversal can be very well visualised.

Structurally, the rocks lying above and below the thrust zone show very tight E-W to NW-SE drag folds (Plate No.III.6). Such folds are nowhere noted in the study area, otherwise folds related to this episode throughout the

Plate No. III.6



Mesoscopic $F_3$ tight fold in the spilitic tuffs and basalts at the vicinity of Phalebas Thrust (Loc. Jyamir Ghat).

region are very open. Obviously, these tight east-west folds near the thrust are related to the movements along this zone, and the tightening of the folds indicates their proximity to the thrust zone.

Considering the dips of the rocks of the thrust zone and the rocks lying above and below the zone, it has been postulated that the Phalebas Thrust is moderately dipping (35° to 40°) due NE.

Kusma Quartzites

This formation is named after the village of Kusma in the northern part of the study area, where typical sections of quartzites are exposed. The constituent rocks dominantly comprise massive quartzites and micaceous quartzites with thin intercalations of gritty quartzose phyllites and lenses of spilites and altered tuffs. The Kusma Quartzites are found exposed in three linear belts. One in the south, directly above the Phalebas Thrust extending across the villages of Armana, Sirbari, Mudikuwa and Jyamir Ghat. The second belt runs roughly north-south along the villages of Karkinetta, Limihatiya, Bumi and Gyandikot in the eastern part of the area. In fact, this belt is the folded extension of the former. The third belt extends east-west in the line of Pang, Kusma and Jare Khola in the northern part of the area, across the Kusma Reverse Fault.

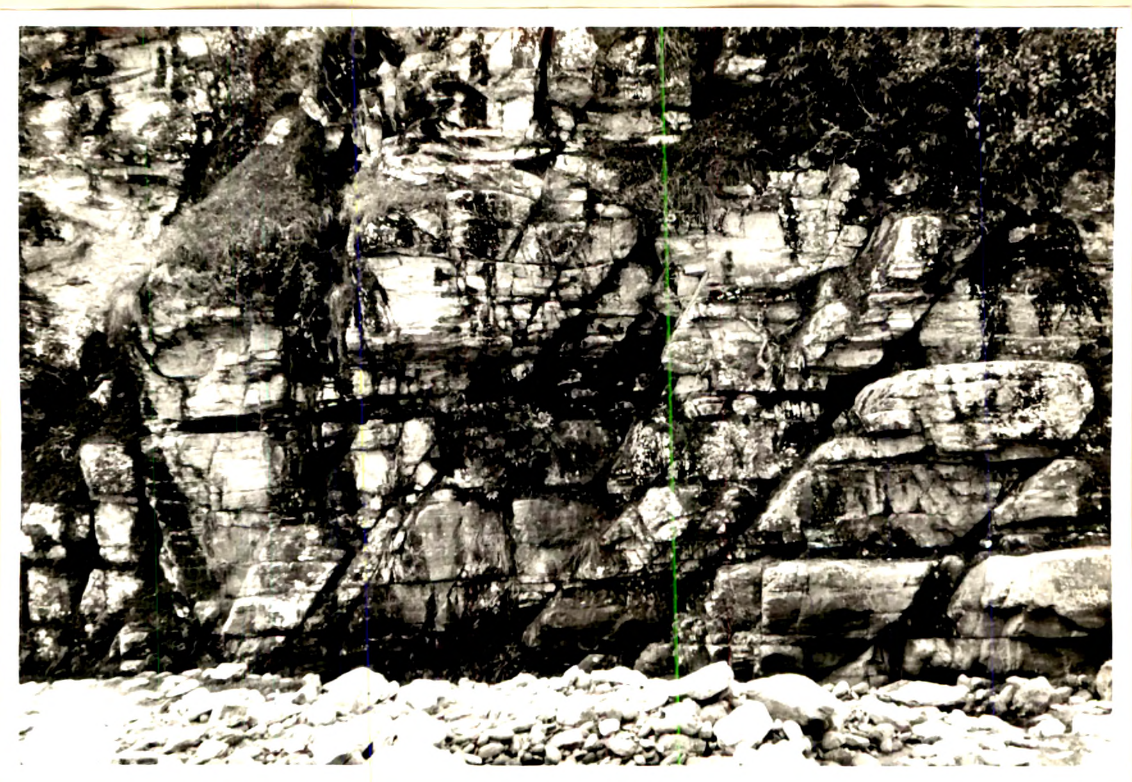
The southern belt of Kusma Quartzites, extends as a linear belt parallel to Phalebas Thrust in the NW-SE direction. Due to a regional antiformal structure, this band takes a northerly trend in the SE, and appears again in the area as the N-S belt, which in turn abuts against the Kusma Reverse Fault. The southernmost belt of these quartzites, as also the N-S belt, is considerably affected by more than one set of folds, and as such show a great variation in the actual thickness and aerial extension.

West of Kali Gandaki river, the southern belt shows good exposures of the quartzites along the southern slope of Githe hill, Jyamir Ghat and Sarangdi. Here, the strike of the quartzites is almost E-W near the Phalebas Thrust and this changes to almost N-S in more northerly portion. The dips are always moderate due N or W. The structure is obviously the western limb of a regional anticline. Near Jyamir Ghat and Theule Khola, the quartzites contain thin intercalations of grey and buff coloured crystalline limestone and phyllites. These limestones are pyritiferous and also contain traces of chalcopyrite. It is in this section, that the lenses of spilitic volcanics are observed at Jyamir Ghat. These volcanics form 20 to 30 m thick bands, that extend for about a km or two and then pinch out. The spilites are of dark green colour, show a finer grain near the contact with the country rocks, but towards the core they tend to be coarser so as to be called as ~~the~~ diabase or coarser basalt. The finegrained variety shows abundant cubes of pyrites. The coarser core portion is traversed by pistachio green veins of epidote, and white quartz. The chloritic quartz veins are seen in the country rocks near the vicinity of the spilitic lenses.

East of Kali Gandaki river, good exposures of Kusma Quartzites are seen at Mudkuwa, Armana and in Lamai Khola sections. In this region, the quartzitic rocks strike dominantly due NW-SE and dip due NE. Variation in the strike and dip are due to the fold effects. They are highly jointed (Plate No. III.7) and fractured. Spilitic lenses are noted in Armana and Lamai Khola sections.

The contact between Kusma Quartzites and overlying Balewa Formation is gradational, the upper horizons of the former increasingly show intercalations of gritty quartzose phyllites, ultimately grading into the dominantly phyllitic sequence of Balewa Formation.

Plate No. III.7



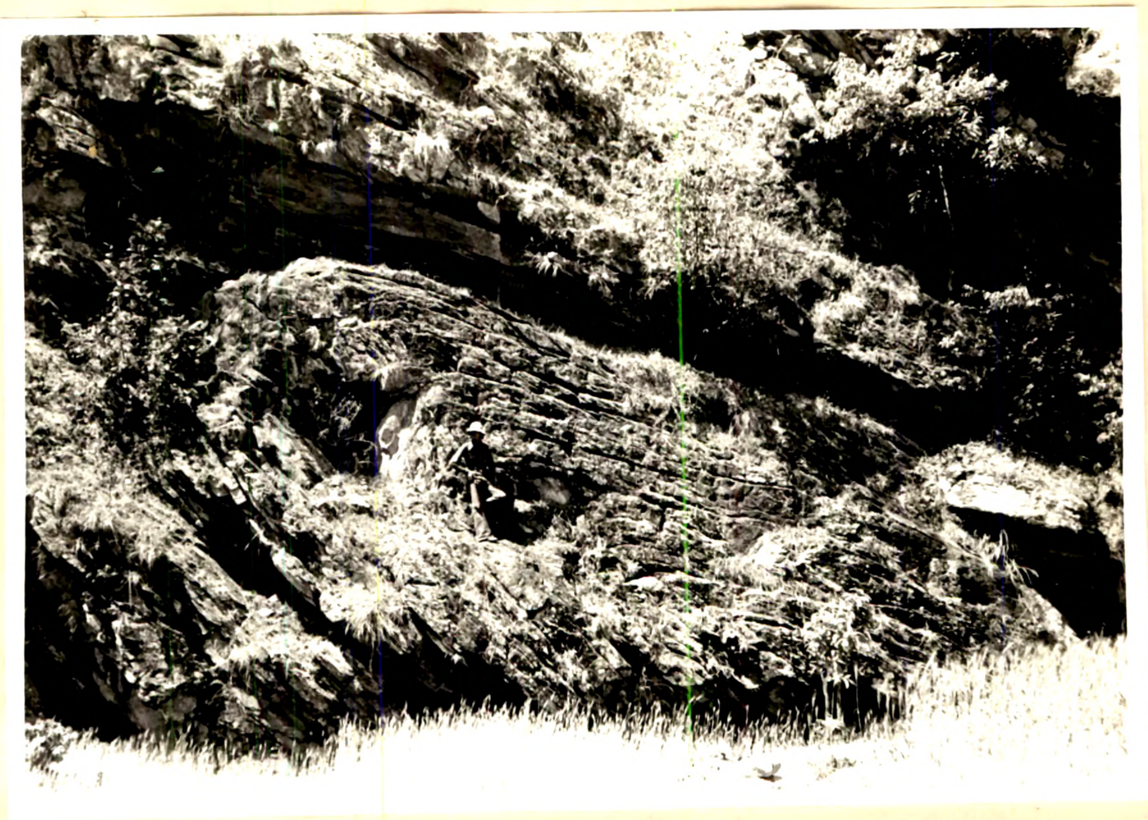
Jointing in quartzites (Loc. Lamai Khola)

The rocks of this belt show the effect of various folding events. Superimposed upon the earliest isoclinal folds, are N-S antiformal and synformal structures. Besides this, minor folds of mesoscopic and microscopic scales and lineations related to the later E-W to NW-SE folds and NNE-SSW to NNW-SSE folds are abundant. In the quartzites of Lamai Khola, tight isoclinal folds are ideally recorded (Plate No. III.8). Related to this early folding is the prominent quartz-stripe or rodding lineation, which is very common in this belt.

The second belt of Kusma Quartzites in the eastern part of the study area is rather narrow. Good exposures of these quartzites are seen south of Karkinetta, Bumi and in the Gyandikot villages. The quartzites in this belt are very often associated with the gritty quartzose phyllites and the lenses of volcanics. The lenses of altered tuffs and spilites are noted near Karkinetta, Bumi and in the southern slope of Gyandikot hill, and these are highly sheared and look like green chloritic schists.

The strike in this belt change considerably on account of E-W folding. Overall dips are moderate due NW, W, and SW. In this belt, mesoscopic E-W to WNW-ESE folds are quite

Plate No. III.8



Mesoscopic $F_1$ isoclinal fold in quartzites
(Loc. Lamai Khola)

common. The later NNW-SSE to NNE-SSW fold episode is recognised by the micro-puckers and gentle undulations on the foliation. Though isoclinal folds are not encountered the related quartz stripe lineation is prominently developed.

The third belt of Kusma Quartzites in the north, running along the villages of Pang, Kusma, Dobilla and in Jare Khola is flanked to the south by Kusma Reverse Fault, but northward, the quartzites grade upwards into the rock sequence of Balewa Formation. This repetition of the Kusma Quartzites to the north is due to the vertical movement along the Kusma Reverse Fault. This belt runs almost WNW-ESE. Along the trend of Modi Khola, a NNE-SSW strike slip fault has affected these quartzites, along which considerable shifting has taken place; the western block has shifted southward relatively to the eastern block. The quartzites of this belt comprise mainly massive quartzites and micaceous quartzites with minor intercalations of gritty quartzose phyllites in the upper horizon. The lenses of altered tuffs and spilitic rocks are encountered in these quartzites in the regions of Chhamerke, Chuwa, Sallyan, Dobilla, Rati Khola and Jare Khola. In this belt, the rocks show a general strike of WNW-ESE dipping due N or S, obviously the dip direction reflecting the regional E-W folding. Besides, they also show the minor folds and lineations related to the later fold events (E-W and NNE-SSW to SSE-NNW folds).

The rocks of the Kusma Quartzites in all the regions, show sedimentary features like ripple marks and cross-beddings, and the attitude of these structures clearly indicates that these quartzites are in their normal position, and that there has been no regional overturning of the strata.

Balewa Formation

Gritty quartzose phyllites, quartzose phyllites and phyllites of this formation comprise dominant rocks of the study area. The rocks of Balewa Formation are very well developed in the central part of the area in the sections of Balewa and Gyandi.

To the west of Kali Gandaki, in the regions of Balewa and Amalachaur, the rocks of this formation dominantly strike N-S and dip moderately to gently due W, forming the western limb of a regional N-S antiform, and overlie the Kusma Quartzites occurring in the south. The local variation of the strike within the range of 15 to 20 degree is due to the very open westerly plunging E-W folds. In this region, Balewa Formation extends right from the vicinity of Phalebas Thrust to the Kusma Reverse Fault on the north.

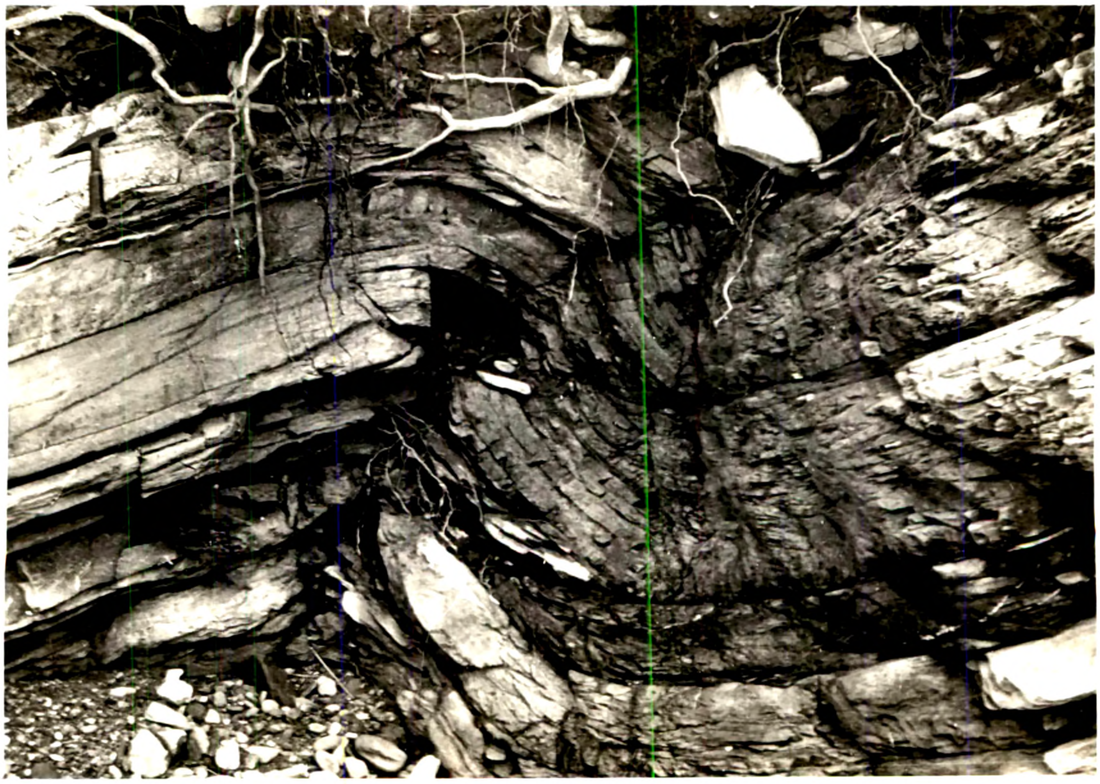
East of Kali Gandaki, the Balewa Formation makes a big NW-SE trending synform that extends right upto the south-eastern boundary of the study area. In the south, the rocks of the former overlie the Kusma Quartzites, the boundary between the two being very gradational, it is at times very hard to delineate their exact limit.

To the north, this formation is again in contact with the Kusma Quartzites along the line of Kusma Reverse Fault, and hence is sharply marked. In the region of Rugdi, Gyandi, and Malyangdi Khola, these rocks form a bowl like basin structure due to the superimposition of a late E-W to WNW-ESE fold over a N-S fold. It is due to this, that the strikes and dips of these rocks show considerable variation in this area.

The minor structures in Balewa Formation related to various fold episodes, comprise small folds (Plate No. III.9 & 10) and various lineations (Plate No.11 & 12) related to them.

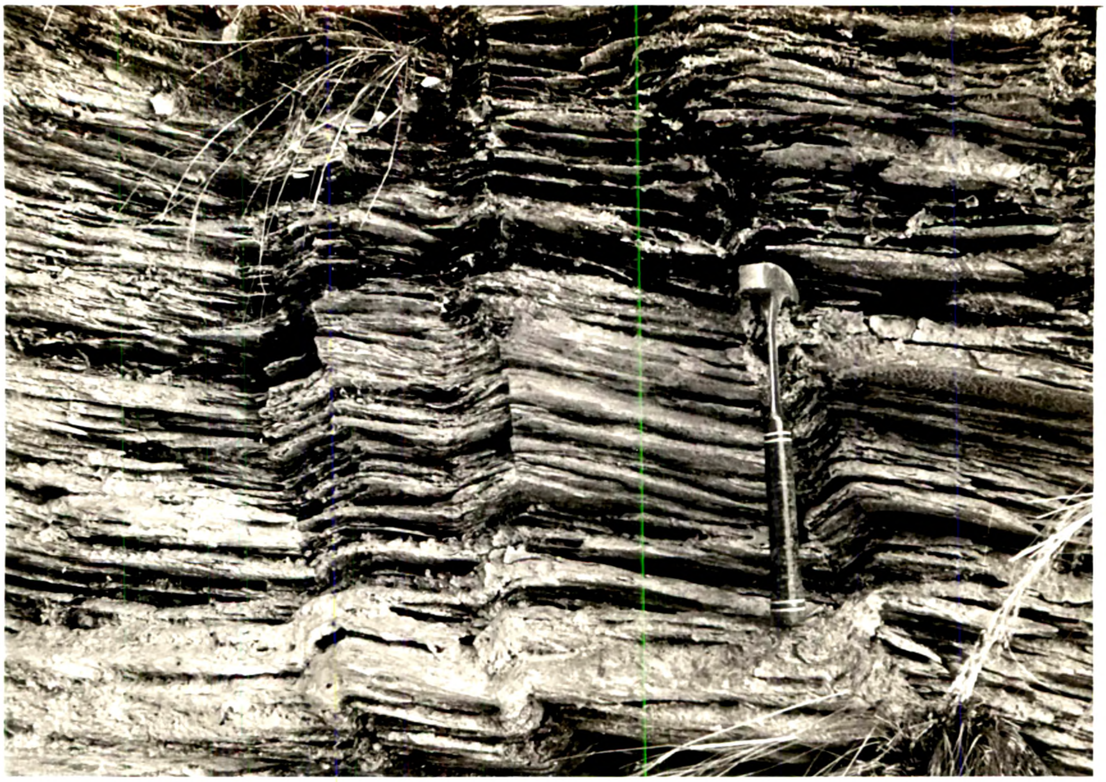
The Lower part of the Balewa Formation comprises gritty quartzose phyllite and quartzose phyllite with

Plate No. III.9



Mesoscopic $F_3$ open fold in gritty quartzose phyllites (Loc. Khaldanda).

Plate No. III.10

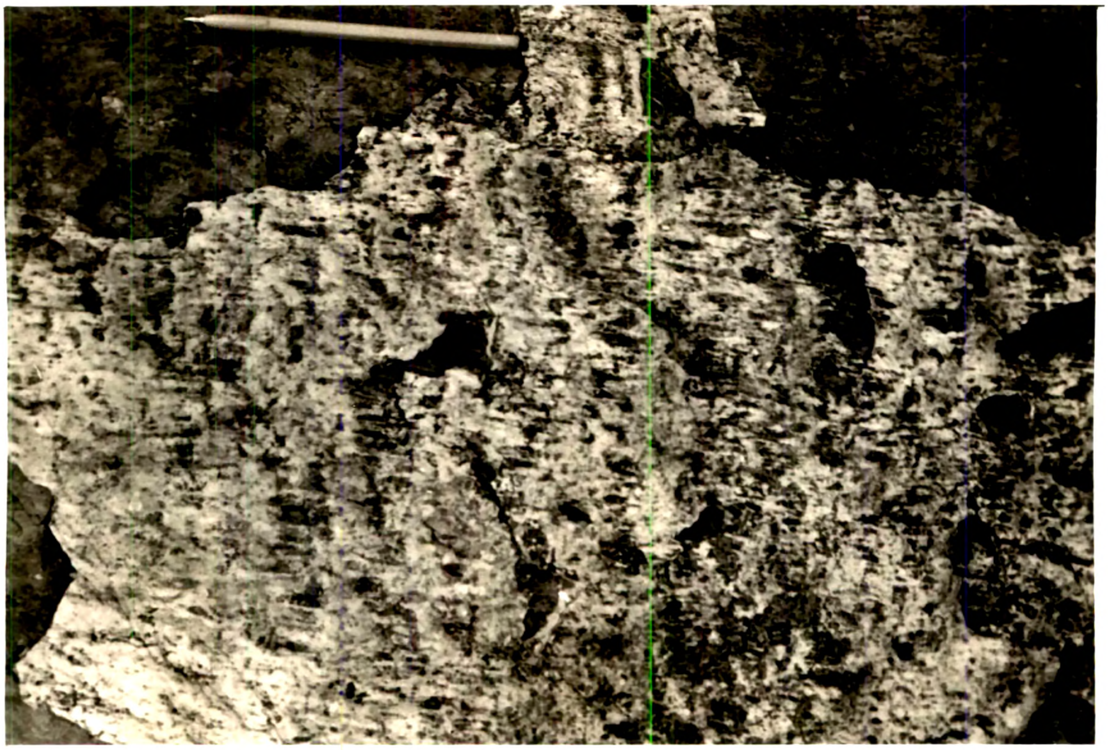


Mesoscopic $L_3$ kinks in phyllites (Loc. Malyangdi Khola).

Plate No. III.11

Mesoscopic $F_4$ very open fold in gritty quartzose phyllites (Loc. Malyangdi Khola).

Plate No. III.12



$L_1$ quartz ribbon lineation in gritty quartzose phyllites (Loc. Balewa).

thin intercalations of quartzites and tuff lenses. In this lower sequence, a sort of graded bedding has also been observed. In the sections at Lamai Khola, Malyangdi Khola and Balewa, the author has noted the gritty quartzose phyllites to grade upwards into quartzose phyllites and downwards into thin conglomeratic horizons (30 to 60 cm thick). Such grading is found to be repetitive in most of the sections. The coarser conglomerate consists of quartz pebbles ranging in size from three centimeter to six centimeters, which are compacted in the matrix of gritty quartzose phyllite. The quartz pebbles are usually elongated parallel to the direction of dip.

The upper part of the Balewa Formation is made up of mainly quartzose phyllites and phyllites. Graded bedding is occasionally observed, gritty quartzose phyllites grading into quartzose phyllites and phyllites. The conglomeratic layers are scarce.

The rocks of Balewa Formation are also observed at two localities in the extreme north beyond the Kusma Reverse Fault. One forms the hill top of Sallyan north of Kusma, where the rocks of Balewa Formation are found overlying the Kusma Quartzites. The other exposure is seen east of Modi Khola around the villages of Ramja and Ramjakot. Here also, they overlie the Kusma Quartzites. In both the cases, its boundary with the Kusma Quartzites is gradational. The rocks in these localities are seen striking almost E-W to WNW-ESE and dip moderately to gently due N. The dominant rocks are gritty quartzose phyllites and quartzose phyllites.