CHAPTER III

GEOLOGICAL SETTING

Geologically the Ranikhet-Pilkholi area constitutes an important region of the Kumaon Himalaya. Its rocks - a group of crystalline metamorphics, are supposed to form an overthrust sheet below which lie younger stratigraphical units showing lesser metamorphism. The two tectonic units have been correlated as Chandpurs and Nagthat - Deobans respectively by Auden(1937).

Succession:

Author's investigations have led him to establish the following succession of the various rock groups encountered in the area:

Chaubatia schists (300 to 400 meters)	}	Pilkholi Series
Jhuladevi gneiss (20 to 200 meters)	}	Crystalline rocks of Ranikhet-Almora Nappe of Heim & Gansser (1939) & Garhwal Nappe of Auden (1937)
Paniali schistose group (300 to 400 meters)	}	
---------- Upradi Thrust ----S. Almora Thrust (Heim & Gansser 1939)		
Upradi-Bajina interbedded quartzites and phyllites (700 to 750 meters)	}	Bajina Series
Bamsyum limestone (5 to 10 meters)	}	Krol Nappe of Auden(1937)

The names given to the various rock groups are based on the localities where the exposures are typically seen. The above nomenclature, however, is only for the convenience of description and does not have any regional significance. Considering the fact that the succession is only a structural

one and not stratigraphical, the nomenclature has also enabled the author to deliberately avoid the use of the words 'upper' and 'lower' schists in Pilkholi series. The figures given for the thickness of various rock groups are only approximate and not original, as considerable thickness of the strata could be on account of repetition due to folding. The various metamorphic types are seen in the field to form recognisable groups that can be traced for considerable distance along the strike. Their distribution is shown in the accompanying geological map (Fig. 1).

The lithological types encountered in the area include mostly pelites, semi-pelites and psammites with some limestone. The above mentioned groups show variations within themselves also, ultimately giving rise to a number of lithological varieties. The semi-pelites at many places show gradational relation with pelites and psammites. The variation in rock types has been found to be both due to original nature of sediments, and also

due to the varying effects of metamorphism and deformation. Migmatisation of the pelites has given rise to a group of felspar-rich gneisses. The different rock types vary in colours, grainsize, structure and in mineral composition, and are easily recognisable in the field.

The author has, in this chapter, given the megascopic characters and areal distribution of various rock types. Brief references to microscopic characters have been made at places to facilitate the description. Detailed petrography is discussed in the next chapter.

(A) MAIN LITHOLOGICAL TYPES:

I. Pelites and allied rocks:

(1) Schists:

(a) Quartz-biotite-muscovite-garnet schists.

(b) Graphite schists.

(c) Quartz-biotite-muscovite-chlorite-garnet schists.

(d) Quartz-chlorite-muscovite-garnet schists.

(e) Quartz-muscovite-sericite schists.

(2) Gneisses:

(a) Porphyroblastic gneiss.

(b) Augen gneiss.

(c) Permeation gneiss.

(d) Felspathic schists.

(3) Phyllonites:

(a) Chlorite phyllonites.

(b) Sericite phyllonites.

(4) Phyllites:

(a) Green chloritic phyllites.

(b) Sericitic phyllites.

(c) Dark siliceous phyllites.

II. Semi-pelites:

(1) Siliceous schists.

III. Psammites:

(1) Quartzites:

(a) Flaggy quartzites.

(b) Garnetiferous quartzites.

(c) Massive quartzites.

IV. Crystalline dolomitic limestone.

V. Quartz veins.

(B) MEGASCOPIC CHARACTERS:

I. Pelites and allied rocks:

(1) Schists:

(a) Quartz-biotite-muscovite-garnet schists:

Fairly coarse-grained and well foliated, these are highly micaceous rocks with varying garnet content. The minerals visible in handspecimen are quartz, biotite, muscovite and pink garnet. At places weathering has imparted a characteristic bronze colour to these rocks. These schists show typical schistose structure marked by a parallel orientation of the tufts of mica. The garnet occurs as unaltered well formed porphyroblasts.

(b) Graphite schists:

This variety is easily recognised by its black colour and soapy touch. It soils

the finger and easily marks a paper. In handspecimen, it is a dark grey fine grained foliated and friable rock. It shows a fine schistosity defined by parallel arrangement of mica and graphite. The essential minerals that constitute the rock are quartz, graphite, muscovite and sericite.

(c) Quartz-biotite-muscovite-chlorite-garnet schists:

This variety is of brownish colour with a greenish tinge. The green colour is due to the presence of chlorite in it. The other recognisable minerals are biotite-muscovite-quartz and garnet. Quite often schistosity exhibits a fine puckerings. Under microscope these are seen to consist of quartz, biotite, muscovite, chlorite, garnet and some plagioclase. The garnet porphyroblasts are seen altered to chlorite. Schistosity is marked by long flakes of mica occuring generally in tufts. The intervening space is filled with quartz granules.

(d) Quartz-chlorite-muscovite-garnet Schists:

This variety shows a bottle green colour and has a fairly strong and fine schistosity. The rock is seen to contain chlorite, fine muscovite and tiny altered garnets. The other visible minerals are quartz and magnetite. In thin sections they are seen to consist of strongly foliated fine grained aggregate of muscovite (sericite), chlorite and quartz. Garnets are seen highly altered.

(e) Quartz-muscovite-sericite schists:

This variety is silky white in colour and with perfect schistosity, marked by a parallel arrangement of muscovite and sericite. Other recognisable minerals are quartz and magnetite.

(2) Gneisses:

These are coarse to medium grained light coloured rocks and show considerable textural and mineralogical variation. Based on the field study alone, the gneissic group can be classified into four types:

(a) Porphyroblastic gneiss:

Coarsely foliated greyish rock with abundant porphyroblasts of felspars; the ground mass consisting of felspar, quartz and micas - both biotite and muscovite.

(b) Augen gneiss:

Less felspathic than the former, lacking in porphyroblasts; instead the felspars occur as augens which are uniformly scattered and are invariably wrapped round by the selveges of biotite. These augens appear to have grown as eye shaped grains by pushing apart micaceous folia. Foliation is due to parallel orientation of mica flakes.

(c) Permeation gneiss:

It contains felspars as small elongate grains (never exceeding few mm. in length) which are seen wrapped round by mica flakes.

(d) Felspathic schists:

More or less schistose, highly micaceous and containing small felspar grains. As compared to schists this contains more felspars but while compared to above mentioned varieties of gneiss, the felspar content is less.

(3) Phyllonites:

Phyllonites are phyllite looking rocks of light green colour and silky lustre. These occur right in the vicinity of the thrust, and are the product of dislocation metamorphism. They are seen to consist of fine grained aggregates of sericite, chlorite and fine granules of quartz. A very characteristic feature of these crushed rocks is the abundance of tiny grains of magnetite.

(4) Phyllites:

These are light green (chloritic) and dark (feruginous), fine grained and foliated

rocks. In handspecimens only chlorite and very fine granules of quartz can be recognised. Under microscope they show fine foliation characterised by parallel arrangement of sericite and chlorite. Thin lenticular aggregates of quartz granules are seen alternating with micaceous patches. The dark variety is more siliceous.

II. Semi-pelites:

(1) Siliceous schists:

These are rather transitional rocks between pelites at one end and the psammites at the other. The semi-pelitic schists are hard and compact rocks, and are seen to consist mainly of quartz and mica with some garnets.

III. Psammites:

These are highly siliceous quartzitic rocks and consist of mostly quartz and a small amount of felspar and mica. In the field three varieties viz., (a) Flaggy quartzites

(b) Garnetiferous quartzites and (c) Massive quartzites are recorded:

(a) Flaggy quartzites:

The flaggy quartzites are rather micaceous and can be easily split along parting planes. They are seen under microscope to consist of an aggregate of interlocking grains of quartz with occurrence of potash felspar grains in the interstitial spaces. Small parallel flakes of micas are seen throughout the mass, though thin pelitic laminae are quite frequent.

(b) Garnetiferous quartzites:

The garnetiferous quartzites are dark coloured, medium grained, and compact rock, and occur as intercalated layers in the garnet mica schists. These are seen to consist mainly of quartz granules, mica - mainly biotite and pink garnet.

(c) Massive quartzites:

The massive quartzites are pink or buff coloured rocks with occasional thin pelitic laminae and micaceous partings. Mostly they consist of quartz grains, plagioclase and microcline with a small amounts of oriented mica.

IV. Crystalline dolomitic limestone:

These constitute a fine to medium grained hard and compact rock, and vary in colour from light grey to buff.

V. Quartz veins:

Quartz vein occurs in almost all parts of the area in varying abundance. They show rather sharp contact with country rocks. At many places they are seen folded.

(C) DISTRIBUTION AND FIELD CHARACTERS:

Pilkholi Series:

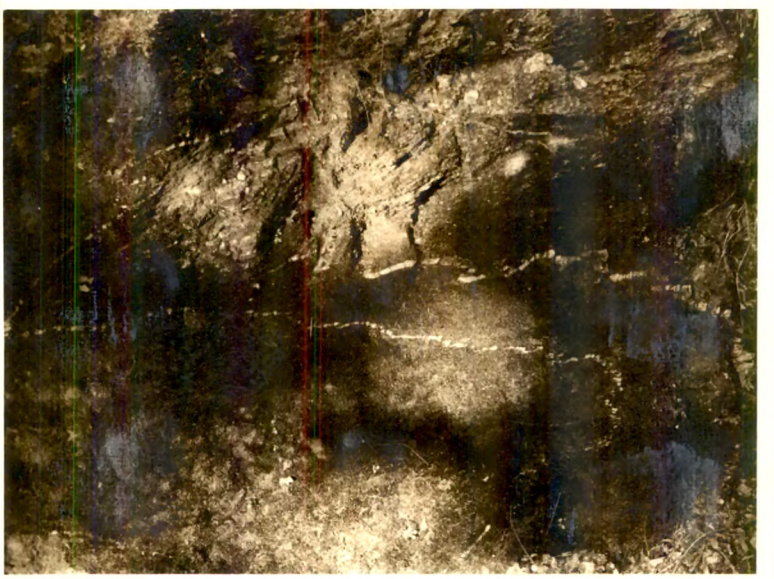
Chaubatia schists:

The schists of this group constitute

uppermost formation of the succession and form a thickness of about 300 to 400 meters. They rest on the Jhuladevi gneissic group and occupy northern part of the area. Based on the field study alone, this formation can be divided into two subgroups, the upper pelitic and the lower semi-pelitic. The upper group is highly micaceous with varying garnet content. The lower semi-pelitic group shows intimate interbedding of mica schists, siliceous schists and micaceous quartzites. The transition from pelitic to semi-pelitic type is rather gradual. The general trend of the strike of the rocks of this group is WNW-ESE, with moderate dips due NE, though variations in dips and strikes are quite frequent. Good exposures of this group are observed near Kalnon, Chaubatia, Ranikhet, Mallakhad and Deolikhet.

The typical pelitic schist is ideally exposed near Deholi. Coarse grained and bronze coloured, these schists are highly garnetiferous. The minerals visible in handspecimen are quartz, biotite, muscovite

PLATE I



A. Folded quartz veins in Chaubatia Schists; schistosity marking the axial plane.

B. Quartzite from Ranikhet showing S-shape recumbent fold.

and garnet. The garnets are big (0.7 mm. - 2 mm.) and are numerous. Typically pink, they are almandine type of garnets and are seen in abundance on the mountain slopes, released due to weathering. The garnets give somewhat spotted appearance to the rocks. The strike of the foliation is ESE-WNW and dips moderately (about 20° to 28°) due north. However, to the south of Deholi, the trend of the foliation becomes rather erratic and fluctuates sharply between NNE-SSW and ESE-WNW. The quartz veins present are mostly thin and are characteristically folded into small 'S' shapes (Plate I.A). The fold axis lineation plunges 10° to 20° due NNE. The lineation (L_1), due to oriented growth of tiny mica flakes is also occasionally recorded on the foliation planes. Its orientation is generally identical to those of the axes of folded quartz veins. Frequent north plunging lineation (L_4) due to faint puckers is also recorded from place to place. The schistosity shows axial plane relationship with folded veins, and psammitic layers. South of Deholi these schists become more

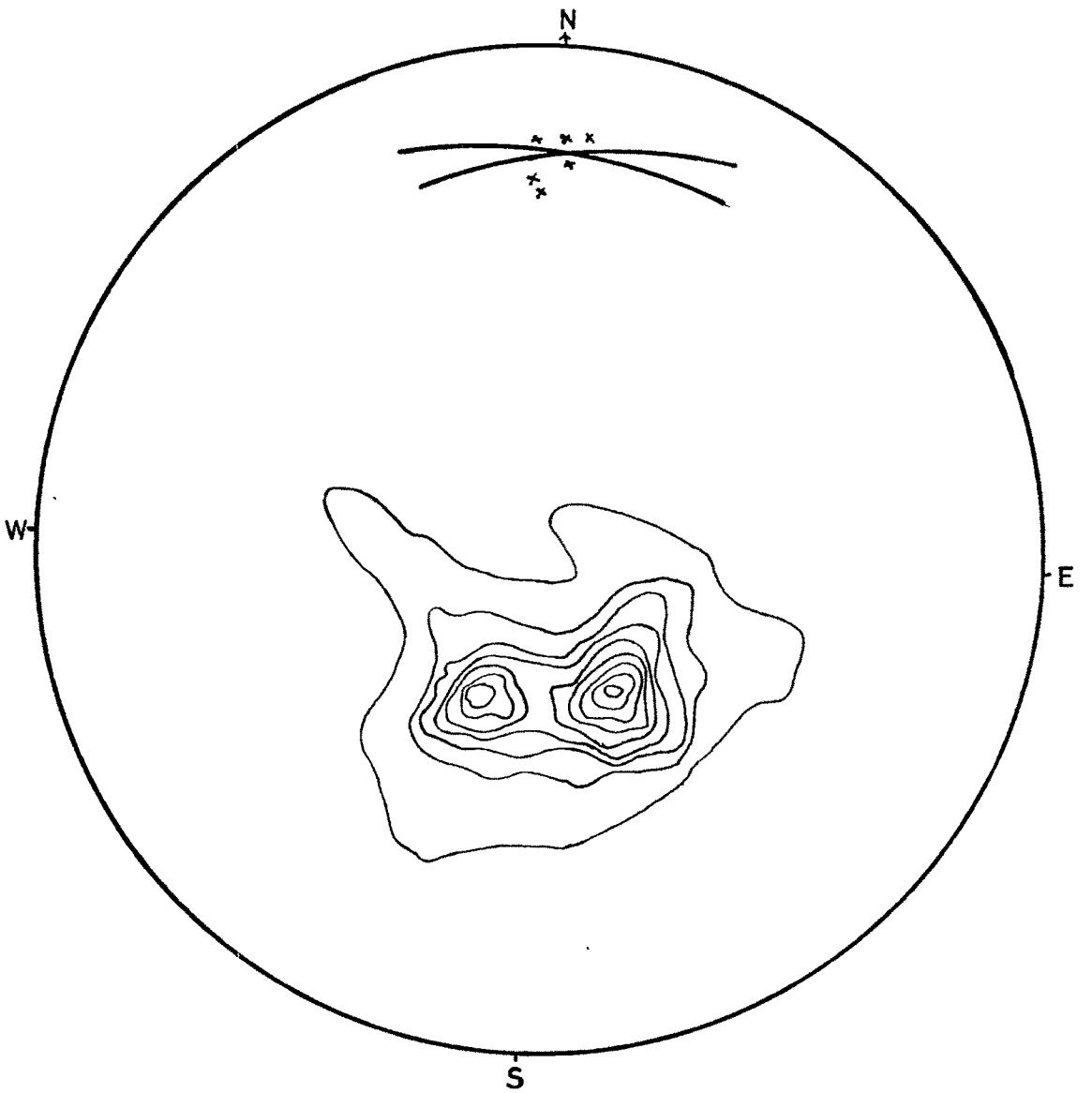


Fig 13

Contoured π diagram of the Chaubatia area

Foliation poles plotted - 200

Contours 0.4,8,12,16,20,24,28,32

× Lineation L_4

siliceous, and compact. Near Nagpani, the base of this schistose group is encountered and contain less garnets. Thin siliceous bands are quite common and these are forming small recumbent folds at a number of places, with their axial planes parallel to the schistosity (Plate I.B). On going west towards Chaubatia bazar, folded quartz veins become more numerous in the schists. Mineralogically the schists of Chaubatia are similar to those of Deholi. On going from Deholi to Chaubatia Bazar, a gradual swing in foliation from ESE-WNW to NNE-SSW is recorded, thus forming an open antiformal structure. The north plunging lineation (L_4) due to faint puckers are recorded (Fig. 13). The mica schists are ideally exposed at Chaubatia. The town is entirely situated on these rocks. The schists at Chaubatia are coarse grained, well foliated, grayish black in colour and highly garnetiferous. At number of places, weathering has imparted a characteristic bronze colour to these rocks. The minerals visible in handspecimen are quartz, biotite,muscovite and garnet. The garnets

range in size from 2 mm. to 5 mm. The foliation in the eastern part of Chaubatia is NNE-SSW with gentle dips to the north and this swings to ESE-WNW in the western part. This swing in foliation is on account of a synformal structure in the western part of Chaubatia. The late lineation (L_4) is marked in this part by faint puckers and plunges in north. The amount of plunge varies from 10°-18°. These schists contain numerous veins of quartz which are folded into small 'S' shapes. These folded quartz veins have given rise to typical 'quartz rods', whose orientation remains fairly steady throughout the area. The quartz rods which are in fact the fold axes, show a plunge of 10° to 20° due north. The schistosity shows axial plane relation with these folds. In Chaubatia garden, the schists are seen to contain a layer of about 50' thick black garnetiferous quartzite, and is ideally exposed in the nala. The occurrence of the garnet porphyroblasts in this quartzite, has imparted a spotted appearance of this rock. The strike here is ESE-WNW with a gentle dip

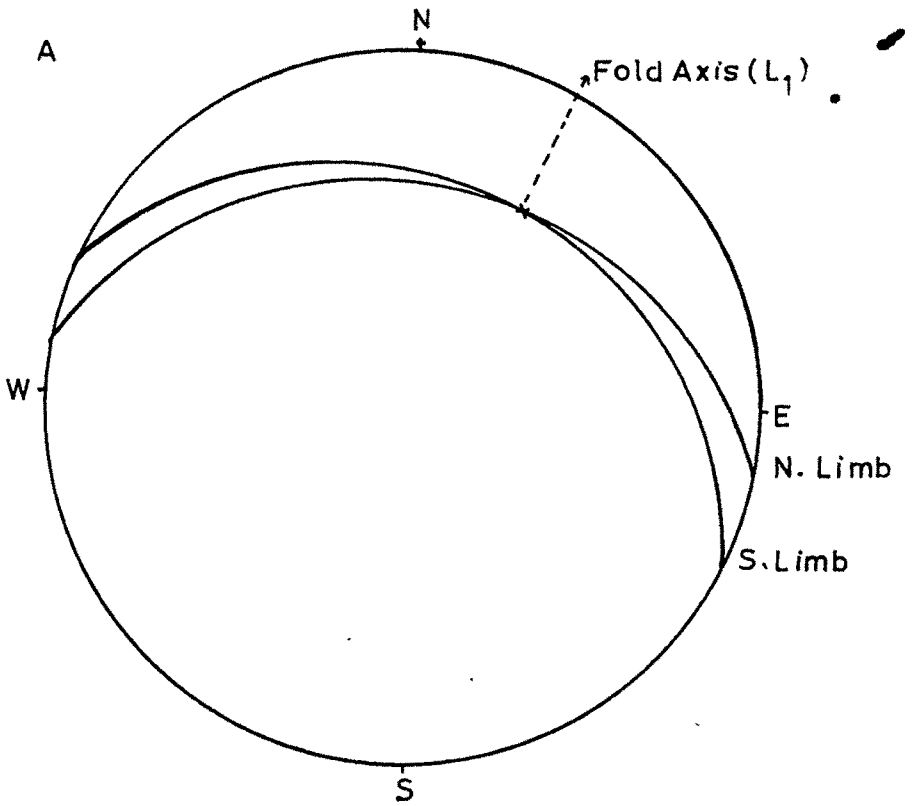
due north. To the north of Chaubatia at old Dhobighat, these schists are seen to be of rather darker shade, and less garnetiferous as compared to those of Chaubatia. Foliation here strikes ESE-WNW with a dip of about 20° due north. This remains fairly steady. In this part, at one place a small patch of muscovite schist, about 3 meter thick, is observed. This is well foliated and consists mainly of quartz, muscovite and magnetite. On going west and south of Chaubatia, the base of this schistose formation is gradually encountered. The rocks tend to become more siliceous.

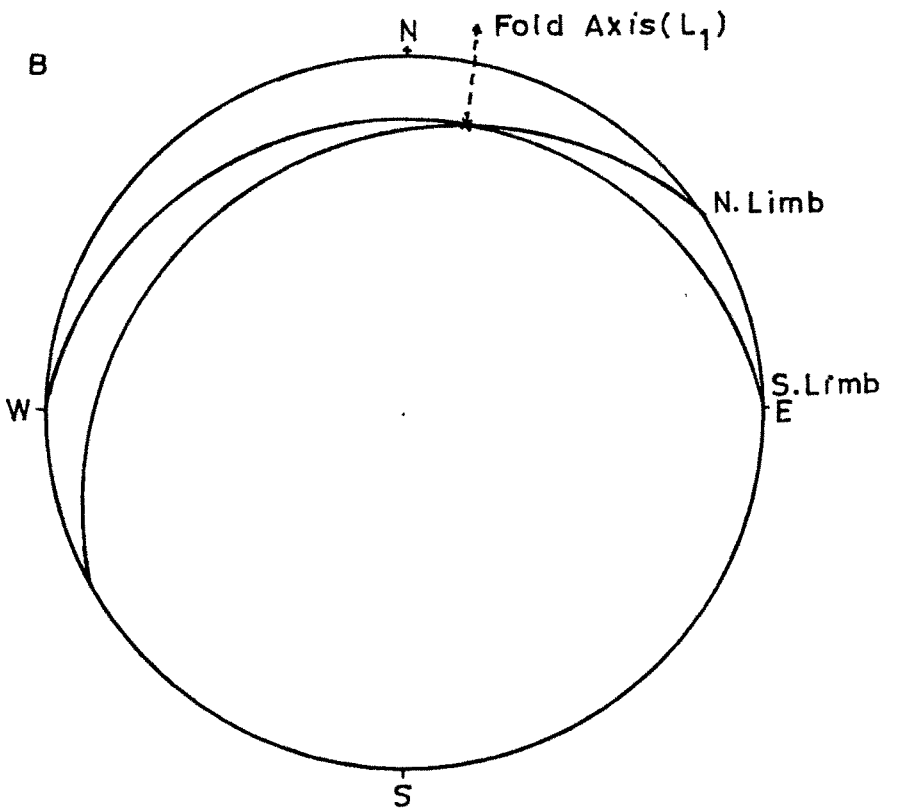
The garnet mica schist exposed at Ranikhet is almost identical to that of Chaubatia except that, garnets here are smaller and less numerous. The strike of the foliation in this part is generally ESE-WNW and is fairly steady. The quartz veins as usual are folded and show the axial plane relation with the schists. The fold axis lineation also remains the same, plunging about 10° to 12° due NNE.

Chevron type microfolding of the schistosity (S_1) is occasionally recorded here. This folding has caused the development of fine strain-slip cleavage (S_3), which is identical with the axial plane of the microfolds of chevron. The lineation (L_3) related to this deformation is characterised by the fine puckers on the foliation which plunge moderately due WNW. At places it is sub-horizontal. On being traced north-westward these schists are seen to occupy the hill slopes upto Mallakhad where again the basal siliceous portion is exposed. The strike of the foliation in this part is NNW-SSE.

To the north of Ranikhet, a rather highly micaceous variety extends for a considerable distance being exposed along the dip slopes. Due to cultivation, the outcrops are scarce. However a good exposure of these schists is seen south of Uroli. Mineralogically these schists are identical to those of Ranikhet, though containing less garnets. The dips are as high as 30° to 40° due north.

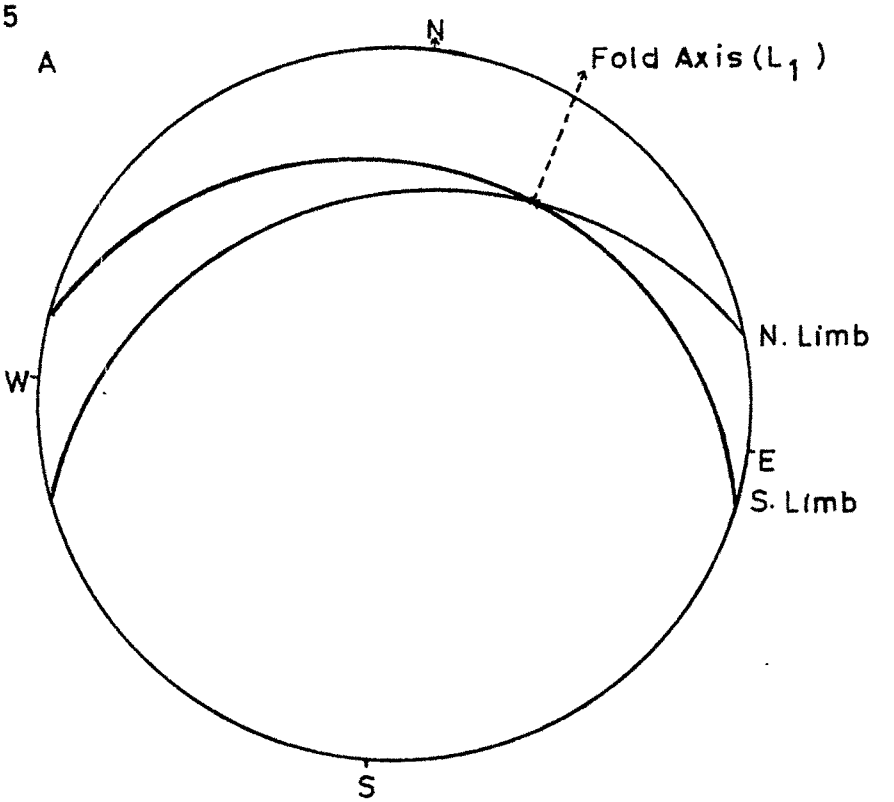
Fig 14


A
N
Fold Axis (L_1)
W
E
N. Limb
S. Limb
S


B
N
Fold Axis (L_1)
N. Limb
W
S. Limb
E
S

The lower and more siliceous group is ideally exposed at Jhuladevi, west of Chaubatia and below the Fruit Garden. Near Jhuladevi a regular gradation can be traced from upper pelitic to lower semi-pelitic type. On proceeding westward from Chaubatia Bazar towards Jhuladevi, the mica schists gradually contain more and more ribs and bands of quartzite. These bands, a few inches thick extend for several feet. The quartzites are rather micaceous and flaggy and can be easily split along parting planes. This semi-pelitic variety extends as far north as west view hotel and Dhobighat, and shows usually low dips to the north, at places being almost sub-horizontal. This inter-bedded semi-pelitic variety, which characterises the base of the Chaubatia schists is also exposed below the Fruit Garden of Chaubatia, Mallakhad, NW of Ranikhet and Deolikhet. Near Deolikhet the interbanding of quartzites and schists is ideally seen. Two quartzite bands as much as 7 to 9 meters thick are seen repeatedly overfolded, thus giving rise to a number of recumbent fold mullions plunging at 15° due NNE (Fig. 14.A & B).

Fig15


A
N
Fold Axis (L_1)
N. Limb
W
E
S. Limb
S

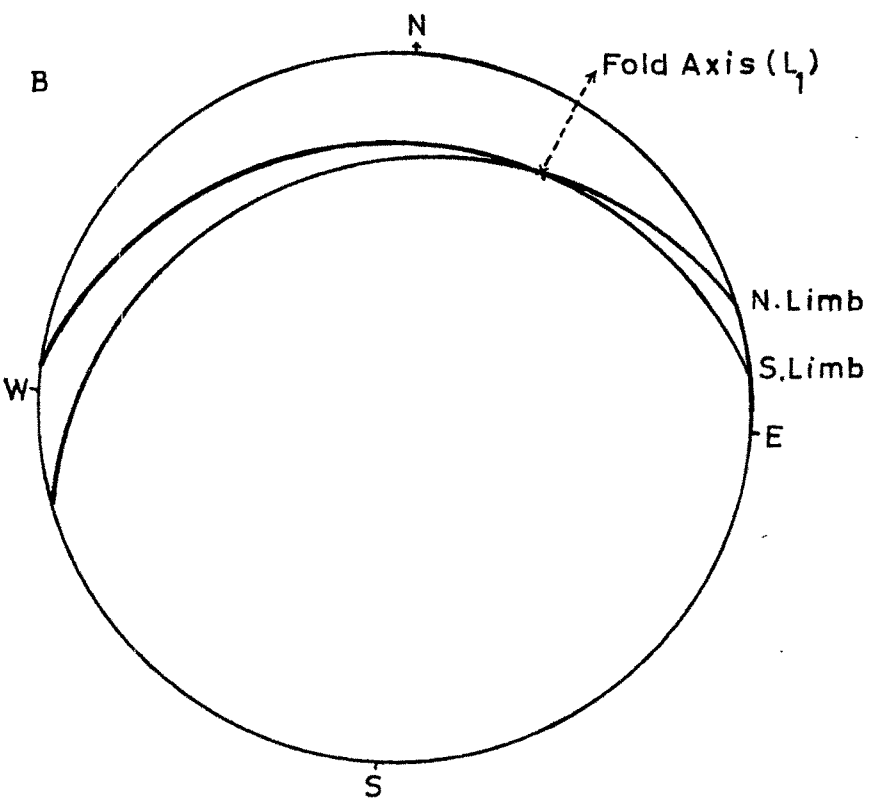
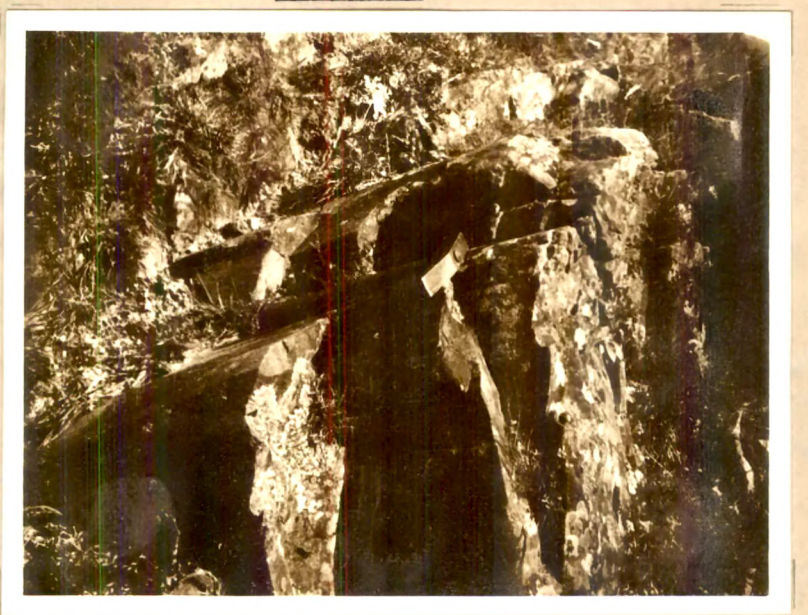

B
N
Fold Axis (L_1)
N. Limb
S. Limb
W
E
S

PLATE II



A. Quartzite from Upat nala showing mullion structure.

B. Recumbent fold in quartzites from Chaubatia.

The schists show the usual axial plane relation with the folded quartzites. Exposures of these rocks continue towards Upat in the NE. The strike and dip of the foliation remains almost the same. In the exposure immediately to the south of Upat, the schists show frequent folded ribs of quartzites. The interbanded schists show axial plane relation with the folded quartzites. The noteworthy point in these schists is the decreased garnet content. Conspicuous fold mullions are exposed in the nala below Upat which plunge as usual to NE at an angle of about 15° (Plate II.A, Fig. 15A). The lineation (L_3) mainly due to puckers is also recorded in schists and it usually plunges WNW with a fairly low plunge. The schists in this region are seen to contain thin streaks and pockets of graphitic material. This graphite bearing variety occurs near Chaukhani and Parade ground of Ranikhet. The strike of the foliation here is ESE-WNW with a dip of about 18° to 20° due north.

The base of these schistose series is clearly seen at Jhuladevi. About 80 to 100 meters thick,

to the SE of temple, lying immediately below schists, is recorded a quartzite layer of about 30 meters thick outcropping on the few isolated peaks, beneath which occur the underlying gneisses.

Jhuladevi gneiss:

The gneisses are exposed as two more or less continuous bands, extending NW-SE. The more prominant band occupies the region, immediately to the south of Ranikhet and extends from Ganiadoli in NW to Nagpani in SE. These rocks have thickness of about 200 meters near Pilkholi, but the thickness tends to decrease gradually north-westward. Near Ganiadoli the thickness is considerably reduced (about 25 meters). Possibly this outcrop pinches out and disappears further westward beyond the limits of present area. The junction between the gneisses and the overlying schists is not sharp, except where quartzite bands occur in between (as near Jhuladevi). It is obvious even in the field that the schists gradually merge into gneisses, and no sharp line of

demarcation can be put. The gneisses are exposed as a separate band in the NE corner occupying the valley area of Bhaludam and Deholi. This exposure is on account of the deeper erosion of the dip slopes of the overlying schists.

These gneisses are coarse to medium grained light coloured rocks and show considerable variation in textural details. Based on the field study alone the gneissic group can be classified into the following four types:

(i) Porphyroblastic gneiss.
(ii) Augen gneiss.
(iii) Permeation gneiss.
(iv) Felspathic schists.

(i) Porphyroblastic gneiss:

The porphyroblastic variety occupies the median portion of the principal gneissic band, and is ideally exposed near Jhuladevi temple, and along the scarp to the north of Pilkholi and Nagpani. Again on the NE valley portion, this variety is encountered at Bhaludam.

It is a coarsely foliated grayish rock with abundant porphyroblasts of felspars. The porphyroblasts generally range in size from 10 to 20 mm. but occasionally crystals as big as 40 to 50 mm. with fairly idioblastic outline are present. The ground mass consists of felspars, quartz and micas - both biotite and muscovite. The rock is farily rich in biotite and muscovite. The foliation is characterised by the parallel orientation of mica flakes which are uniformly distributed as streaks and tufts throughout the mass. The regional strike of the foliation is NW-SE, though from place to place, it shows considerable local variation. The strike and the dip of the foliation is almost parallel with schistosity and no crosscutting relationship is recorded. In the area NE of Pilkholi, the strike swings to as much as NE-SW. This swing in strike is due to an antiformal structure between NE of Pilkholi and Nagpani. Due to weathering, big porphyroblasts of felspars have been released and be scattered on the surface. The gneiss at Bhaludam is somewhat crushed and sheared, on account of the existence of a fault there.

(ii) Augen gneiss:

It occurs along the two flanks of the porphyroblastic variety. It lacks in the porphyroblasts of felspar which instead, occur as augens, varying in size from 5 mm. to 10 mm. The felspar augens are uniformly scattered and are invariably wrapped round by the selveges of biotite. The felspar appears to have grown as 'eye' shaped grains by pushing apart the micaceous folia. Felspar for the most part occurs as 'augens', but is also seen in the groundmass. The foliation, as usual is due to parallel mica flakes. The augen bearing variety is ideally exposed at Ranikhet, near West View Hotel, near Jhuladevi temple and also near Nagpani. About 100 metres, to the SE of Jhuladevi and SE of Chaubatia Bazar, the general trend of the foliation is NW-SE, which swings ~~due~~ to NE-SW near Giwal. These gently dip to the north but at places viz. near Ranikhet G.P.O. and near Jhuladevi they are almost horizontal.

The augen gneiss is seen overlain by flaggy quartzites. These and a few other occurrences where

the lenses of quartzites intervene between the gneiss and the overlying schists, clearly illustrates how quartzites have acted as barriers in the path of granitising emanations.

(iii) Permeation gneiss:

The augen gneisses gradually grade into a augen free variety which could best be described as permeation gneiss. This variety of gneiss contains felspar as small elongate grains (never exceeding few mm. in length) which are seen wrapped round by mica flakes. The strike of foliation is parallel to schistosity of neighbouring schists and is as usual NW-SE. This variety is well exposed on the scarps of Pilkholi, south of Chaubatia, near Dak Bunglow and near Deholi. At Deholi this type is rather fine grained and the relicts of the host pelitic rocks are found in it. These relicts occur more or less in the form of lenses of about 15 to 20 metres length, and also as thin ribs, surrounded by the gneisses. These remnants are always parallel to

the adjacent gneisses, and do not show any disturbances. All these characters strongly favour the view that they are the remnants of original rocks which have been granitised.

(iv) Felspathic schists:

The gneissic band near its contact with the overlying as well as underlying schists grades into a schistose rock.

Near their junction with the schists the gneisses have given rise to narrow zones which can best be called as felspathic schists. These transitional rocks are more or less schistose, highly micaceous and contain small felspar grains. These zones, narrow and irregular, are ideally exposed near Ranikhet, Pilkholi, Nagpani and Deholi. About 100 metres to the south of Ranikhet Bazar, near the military school, a solitary basic dyke forms a small elongated 8 to 10 metres high ridge. About 10 metres wide and extending for about 30 to 32 metres due ENE-WSW, the dyke appears to have been intruded in

the gneissic rocks. The rock is readily recognised in the field because of its colour, freshness, hardness and the ringing sound it emits when struck with a hammer. It shows typical spheroidal weathering, its disintegration has given rise to a thin mantle of brown soil seen in the surrounding area.

Paniali schistose group:

This group of schistose rocks which occur below the Jhuladevi gneiss, occupies the area to the south of Chaubatia and Ranikhet, and its good exposures are found at Pilkholi, Paniali, Ganiadoli, Tana, Chamoli, Bhargaon and Siwali. In conformity with the previously mentioned formations, rocks of this group also extend roughly NW-SE and its foliation dips moderately to the NE. On being traced across the strike from north to south, following varieties are encountered:

(i) Biotite-muscovite-chlorite-garnet schists.

(ii) Chlorite-muscovite-garnet schists.

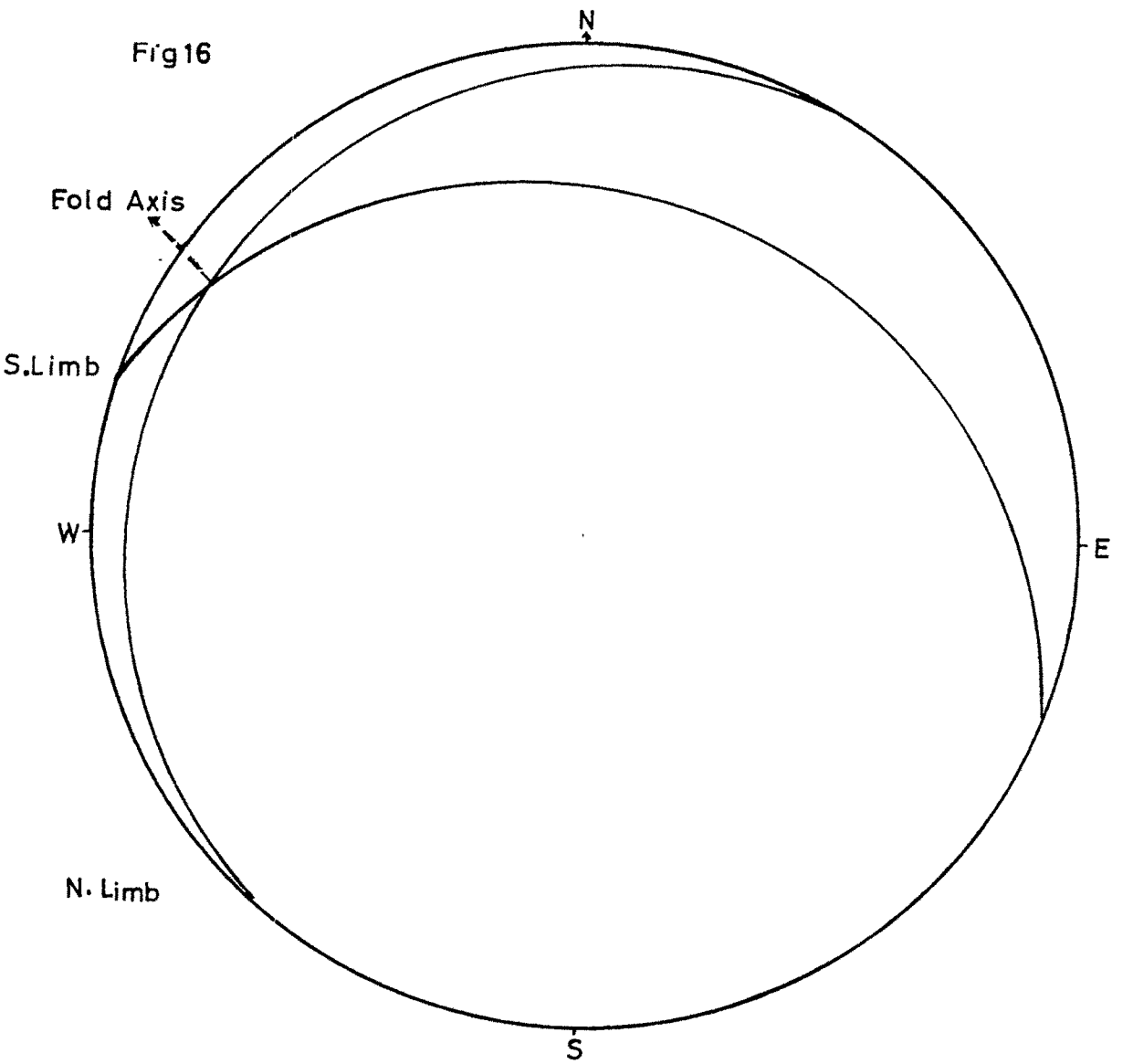
(iii) Sericite-chlorite-garnet phyllites(phyllonites).

These types occur as narrow bands parallel to each other and their junctions are rather gradational and indefinite. On being traced from north to south, the biotite-muscovite-chlorite-garnet schists inperceptibly grade into chlorite-muscovite-garnet schists and ultimately to sericite-chlorite-garnet phyllites (phyllonites). This gradual downgrading of garnet mica schists to phyllonitic rocks is obviously connected with the south Almora thrust which flanks this schistose formation to the south.

(i) Biotite-muscovite-chlorite-garnet schists:

These are medium to coarse grained brownish green schists, the green shade being due to the presence of chlorite. It is noteworthy that its garnet content steadily decreases on being traced away from the gneissic contact. This variety is well exposed in the section along the road from Pilkholi to Ganiadoli and also near Bhargaon and Siwali. Near Ganiadoli, strike of the foliation

Fig 16



is as usual WNW-ENE, the dip being about 25° to 32° to north. The rock is extensively traversed by quartz veins. The contact between overlying gneissic rocks and these schists are seen near China view. Proceeding southward from China view along the road, the strike of the foliation rapidly fluctuates between ESE-WNW and NNW-SSE. The folding of the quartz veins has given rise to 'quartz rods', (L_1) which plunge with an angle of 10°-20° due north 10°-15° east. (Fig. 15B). Accessible exposures of this variety are seen extending from Dak Bungalow to Pilkholi on the road. The quartz rodding, striations and puckering appear to be identical to the fold axis lineation of the Chaubatia schists. Occasionally another type of gentle puckering is recorded in this location which plunges very gently to the WNW to W. Two sets of lineation (L_1 and L_3), on the same exposure show that one which plunges gently to W or WNW (L_3) is later one and superimposed on the earlier one. This lineation (L_3) is due to folding of the schistosity (S_1) into chevron type folds (Fig. 16). Proceeding towards Pilkholi the outcrop of this type tends to

become a little narrow, and further east near Giwal it strikes WNW-ESE and forms an open synformal structure. Beyond Giwal to the east the foliation again swings to WNW-ESE, and forms an antiform. The quartz veins in this part are more numerous, are invariably folded, and show the foldaxis lineation (L_1). The fracture cleavage in quartz veins is perpendicular to the plane of schistosity.

(ii) Chlorite-muscovite-garnet schist:

The rocks described above when traced southward gradually tend to become more chloritic and finer grained. Bottle green in colour, this chloritic rock shows a perfect schistosity and is seen to contain chlorite, fine muscovite (sericite) and tiny (rather altered) garnets. Forming about 100 metres wide band, almost parallel to the previous one, this variety forms good exposures near the villages Dhamaljar, Saroli, Bithar and Siwali. The foliation shows the usual northernly dip, the strike of the foliation near Dhamaljaris NW-SE. The usual folded quartz veins

mark the lineation (L_1) which is plunging gently to NNE. Proceeding SE, towards Bithar the strike of the foliation swings to SSE-NNW and again further southeastward it swings back to WNW-ESE near Saroli. Garnets are diminished in size and number and are altering to chlorite. Pucker lineations of the two generations as discussed earlier, are recorded. One tends to be almost subhorizontal or sometimes plunges very gently to west or northwest (L_3) while the other (L_4) plunges due N5°E at an angle of about 10° to 20°. Towards south of this, rock becomes more chloritic and dark clots of magnetite gradually increase in frequency. The junction of these chloritic rocks with the overlying chlorite-mica schist and the underlying phyllonites is gradual.

(iii) Sericite-chlorite-garnet phyllites(Phyllonites):

The chloritic schists further southward gradually merge into a sheeny, grayish green phyllite looking rock. After a detailed investigation of the nature of these highly cleaved rocks, the author has preferred

to call them as phyllonites. The shining silvery colour is obviously on account of its sericite content. The origin of these rocks is connected with the adjoining Upradi thrust. This phyllonite band runs all along the northern side of the thrust, and its ideal exposures are seen around the village Tarswar, Kanela, Pakhura, Gari and Kharkani. The strike of the foliation remains same and is roughly WNW-ESE. The foliation shows usual northerly dip. South of Dhamaljar, these phyllonites are crumpled on all scales. The axes of these minor crumples characterise the dominant lineation (L_2) which shows a plunge of about 15° to 20° due N15°E. These crumples are in fact the effect of drag during the thrust movement. It is interesting to note that the trend of this crumpling lineation is identical to fold axis lineation (L_1), so common in Ranikhet-Chaubatia area. While in the latter area it forms the axes of the minor folds, whose axial plane is coincident with the schistosity, the crumples near the thrust have folded the schistosity itself. Obviously the deformational stresses which

operated at the time of the development of the regional foliation were themselves responsible for the crumpling of the foliation near the front. It thus appears that the stresses which folded the rocks at Ranikhet (thus giving rise to the axial plane schistosity and the minor folds) were at a later stage responsible for the thrust, (and the accompanying drags). Proceeding further southward, towards Tana and Tarswar the rock becomes more chloritic and sericitic, probably due to nearness of the thrust. Proceeding eastward, beyond Janoli School the strike of the foliation swings from EW to NNE-SSW. Crumpling, drag folds and folded quartz veins are very common. The axes of the crumples, drag folds etc. characterises the dominant lineation (L_2) which show a plunge of about 18° to 20° due N15°E. The later lineation (L_3) is marked by gentle puckers and is either subhorizontal or shows a plunge of about 5° to 10° to the WNW. Around Kanela and Gigari the strike fluctuates very rapidly between EW and NE-SW . The quartz veins are more numerous and have developed drag folds. Some of them are stretched into lenses. The strike is almost EW near

Kharkhani and Chauna. This rock type in general becomes more and more finer towards south near the thrust contact. Exposures are poor in the vicinity of the thrust, and the dislocation is marked by the zone of crushed and broken rock material.

Upradi Thrust:

The thrust is ideally recorded on the road side, about a furlong (200 metres) further north. It marks a narrow zone, about 10 to 20 metres wide, characterised by the occurrence of crushed rocks. The thrust zone has been traced to run approximately WNW-ESE. On account of cultivated fields, its exposure is rather discontinuous. Its trend has been deciphered on the basis of a number of exposures along its strike. It is well recorded at Kharkani in the E, and at Tarswar in the west. Further NW of Tarswar, about 3½ kms., in a prominent stream-bed, the thrust zone is seen affected by a fault. At Kharkani and Upradi, the drag folds associated with the thrust are abundantly recorded. At Tarswar, the drag folds are scarce, and the thrust zone is marked more by an intense

crushing. Considering the dips of the phyllonitic rocks and the trend of the crushed zone, it is very obvious that the thrust plane is inclined moderately (about 30°) to the N or NE.

Bajina Series:

Below the thrust to its south occur a group of interbedded quartzites and phyllites and dolomitic limestone which the author has designated as Bajina series. These rocks belong to Krol nappe, and have been correlated by previous workers with Nagthats (Auden, 1937). Structurally, the rocks of Pilkholi series (? Chandpurs) are resting over the much younger and less metamorphosed rocks of the Bajina series (? Nagthats and Deobans).

This underlying Bajina series mainly consists of pink and buff coloured, massive or flaggy quartzites with intercalated phyllites. On lithological consideration, it can be subdivided in the following four broad divisions:

4	Buff massive quartzites (50 to 60 metres)	Bajina Series
3	Quartzites interbedded with green phyllites(400 to 600 metres)	
2	Pink quartzites with bands of slaty phyllites(200 to 250 metres)	
1	Crystalline dolomitic limestone (about 10 metres)	

Buff massive quartzites:

These buff massive quartzites form a narrow band of about 50 to 60 metres thick lying immediately below the rocks of Pilkholi series. Coming from Ranikhet along the road, the abrupt change in lithology and marked appearance of these quartzites immediately draw one's attention. In the vicinity of the thrust these quartzites show intense crushing and drag folding. These quartzites contain thin intercalation of pelitic material. These are well exposed near Pandekota, valley below Tarswar and Chamoli. Near Chamoli the strike of these quartzites varies between NE-SW and ESE-WNW. The pucker type of lineation (L_3) is recorded which plunges 20° due NW. The crushing in quartzites near Chamoli is due to the fault zone which runs

PLATE III

A. Folded quartzite near Upradi thrust.

B. Drag fold in quartzite near Upradi forming a mullion.

ENE-WSW. In the area further west of Chamoli, the strike fluctuates very rapidly between ESE-WNW and NE-SW. This variation is due to a number of flexures developed in them. Again westward the strike becomes ESE-WNW due to synclinal folding. Near Upradi village the strike is as usual WNW-ESE with moderate dips due north. Quartzites are drag folded near Upradi whose fold axes plunge from 12° to 29° in N35°E and is possibly due to thrust (Plate III A&B). Just half a furlong (100 metres) south of Upradi, fold axes in quartzites show a plunge of 22° due NW. To the west of village Upradi, the strike fluctuates sharply. Fold axes lineations are also same as those discussed near Upradi. Proceeding northwestward towards Pandekota the rocks show NW-SE strike dipping uniformly due NE. The lineations due to puckers (L_3) is seen plunging 20° due NW. Here the quartzites are seen displaced by another NE-SW fault.

Quartzites interbedded with green phyllites:

Southward the quartzites grade into an underlying group of interbedded quartzites and phyllites. This

transition is rather graded and it is very difficult in the field to put a definite line of demarkation between the two groups. The foliation strike ESE-WNW with uniform northernly dips. The green colour of the phyllites is due to chlorite. They characteristically look like the phyllonites of the above lying series. These are garnet free chlorite-sericite-phyllites. The minerals visible in handspecimens are fine granules of quartz sericite and chlorite. This group is best exposed near Bajina, Pipalkhand, Silangi, Kothian and covers much of the southern part of the field. Near Bajina the strike of the foliation is more or less NW-SE and lineation (L_3) due to puckers is coarse and well marked. It moderately plunges to NW. North of Bajina, the strike swings from NW-SE to NNE-SSW and further west it again gradually swings back to ESE-WNW. Near Pipalkhand, folds are seen in quartzites. The fold axes (L_3) are plunging about 20° to 25° due NNW. Quartzites here are well exposed on the hill tops and on the slopes while the low lying area is seen occupied by phyllites.

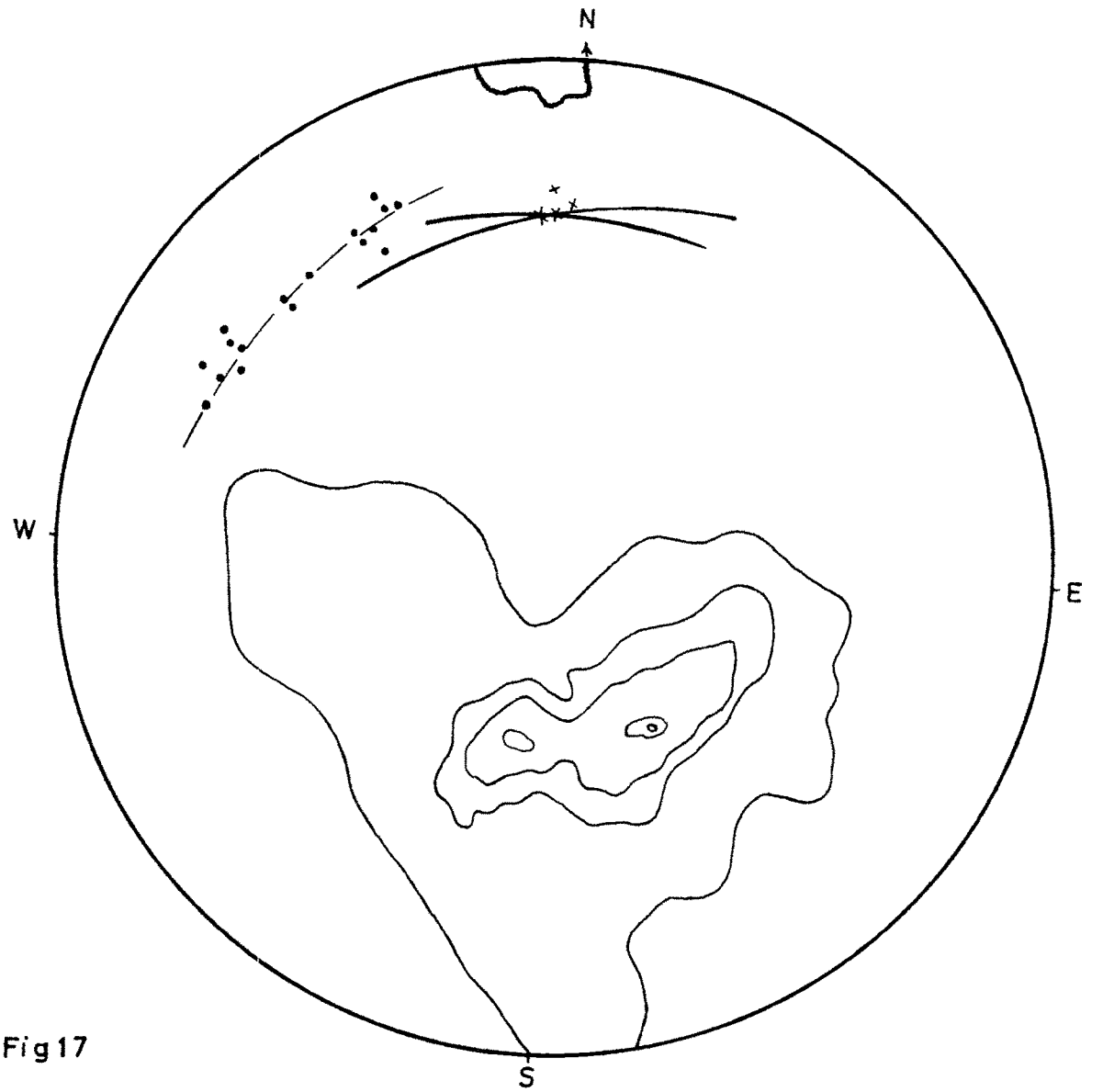


Fig 17

Contouted π diagram of the area west of Bamsyum

Foliation poles plotted – 250

Contours 0, 4, 8, 12, 16

•Lineation L_3 ×Lineation L_4

The lineation (L_3) due to puckering is quite prominent and steadily plunges gently to NW or NNW. On going northwestward these phyllites look more greenish possibly due to more chlorite content. The increase in the chlorite could be linked with the nearness of the thrust.

Pink massive quartzites:

These coarse to medium grained massive quartzites occurring below the above formation. This quartzitic group contains occasional thin bands of dark slaty phyllites, and are best exposed near Bamsyum, Ruma and Tipawla. The quartzites form an anticlinal structure in west of Bamsyum. The strikes being ESE-WNW near Bamsyum and NE-SW in west of Bamsyum. The lineation(L_3) due to puckers plunging 5° to 10° to the NW while the lineation (L_4) due to puckers is also observed, which plunges gently to the north (Fig.17).

Crystalline dolomitic limestone:

This dolomitic limestone (? Deobans) below the above discussed pink quartzites is exposed as a thin band of about 5 to 10 metres thick in the Kuchgad nala below Bamsyum. It is a siliceous dolomitic limestone consisting of buff and dark gray bands and is traversed by a number of calcite veins. At some places viz. just near Bamsyum nala it is intricately chevron folded. The foliation is WNW-ESE with moderate dip

due north.

STRATIGRAPHY AND CORRELATION

A correct stratigraphical account of the rocks of Pilkholi area is rather difficult. Though, the area looks structurally quite simple at first sight, it reveals on a deeper probe, a complex structural pattern, which in turn has rather complicated the stratigraphy too. The author has no intention of getting into controversy or arrive at definite correlation of the various rock groups of his area. The following account therefore should be considered as only an essential background for the purpose of the present study. Based on a close study of the various minor structural elements, supplimented by an exhaustive study of metamorphism, an attempt has been made here to decipher the correct stratigraphical sequence of the various rock units. The complete absence of fossils and the obliteration of original sedimentary structures, have made the work of correlation difficult.

The structural succession of the various rock types, as seen in the field is as under:

8 Garnet mica schist with quartzite bands.

7 Migmatitic gneiss.

6 Garnet-mica-chlorite.schist.

5 Chlorite schist.

4 Phyllonites.

3 Quartzites.

2 Phyllites interbedded with quartzites.

1 Dolomitic limestone.

The area exhibits an ideal case of apparent metamorphic inversion. It is only when the existence and effect of the thrust at Upradi, is recognised, that the true position of the various rock groups is understood. The Upradi thrust constitutes the most striking feature of the area, which has brought highly metamorphosed crystalline rocks (? Chandpurs) over the less metamorphosed younger rocks (? Nagthats). It is interesting to note that the apparent metamorphic inversion in the area, is in fact a case of retrogressive dislocation metamorphism, and metamorphic convergence. The overlying schists have been metamorphically

downgraded into sericite-chlorite schists (phyllonites), and the underlying slates have slightly progressed in metamorphism.

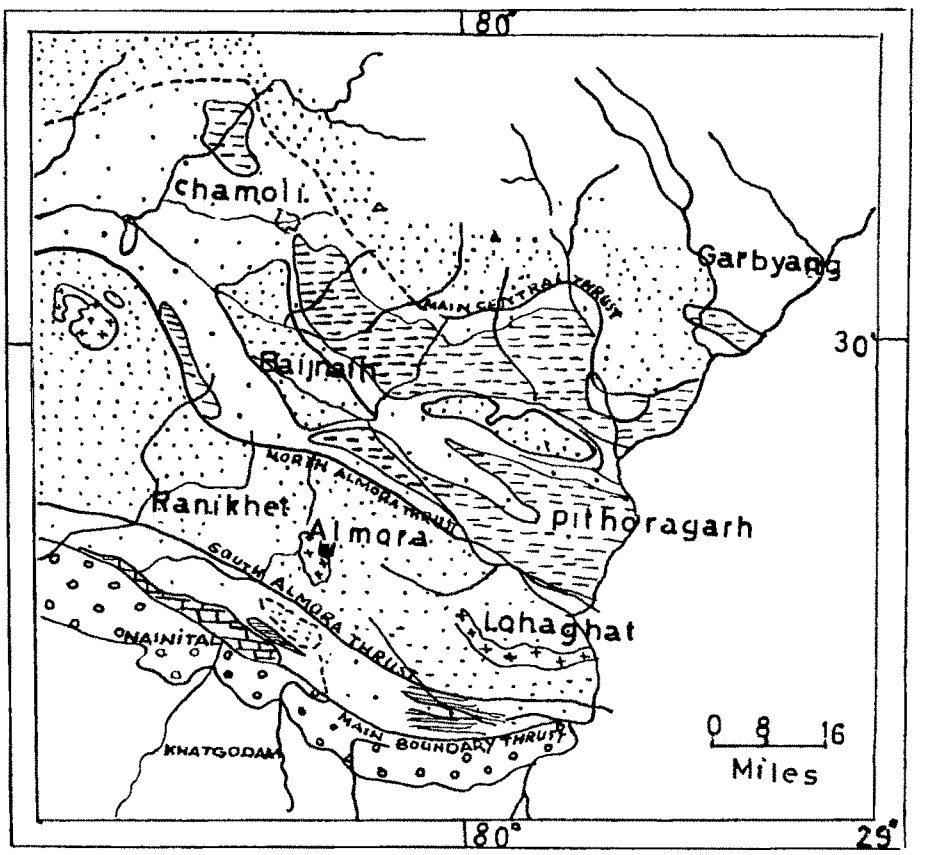
Once this fact is understood, the rock units can be properly arranged in a stratigraphic order which willbe as under:

(iii)	Slaty phyllites interbedded with pink massive quartzites.	? Nagthats (? Devonian)	Krol
(ii)	Buff and grey dolomitic limestone.	? Deobans (? late pre-Cambrian & Ordovician)	Nappe
(i)	Garnetiferous mica schists of various types with interbedded quartzitic flags and migmatites.	Chandpurs (? pre-Palaeozoic)	Garhwal Nappe

Garhwal Nappe:

The oldest rock group in the area consists of a thickness of garnet mica schist and its derivatives, flaggy quartzites which occur as interbedded with above schists and gneissic rocks. This is separated by Upradi thrust from the underlying younger group of quartzites and phyllites. This group has been taken as Chandpurs (? pre-Palaeozoic).

Fig 18



Regional tectonic map of kumaon (after Auden (1937), Heim and Gansser (1939) and Valdiya (1962).

Auden (1937,p.428) working in Garhwal reported similar schistose and gneissic rocks. He considered the schistose formation as equivalent to Chandpurs, into which the gneissic group was intruded. Heim and Gansser (1939) studied the schistose group of Ranikhet-Almora, and called them as crystalline metamorphics (pre-Palaeozoic) and correlated them with Chandpurs of Garhwal, described by Auden (1937) (Fig.18).

Middlemiss (1887) has also reported similar formations in Garhwal as Inner Schistose Series and considered them to be pre-Palaeozoic.

Das (1962) considers similar schistose rocks and migmatites in Chaukhatia area in Kumaon belong to Chandpurs. Pande (1964) described the schistose rocks and migmatites of the western Kumaon as Chandpurs.

Relying on the previous workers' correlation the author, for the purpose of this thesis has

correlated his Pilkholi series to be equivalent to Chandpurs (pre-Palaeozoic).

The present thickness of the group is mainly on account of a repetition due to overfolding. Thus, the schists above and below the gneissic group are one and the same forming two limbs of reclined overfolded structure.

Krol Nappe:

The younger group of rocks which occur right below the Upradi thrust, are described in this work as Bajina series. Based on a study of the current bedding recognised at several places within the limits of the present area (as well as in the areas beyond), it has been established that the succession to the south of this thrust is uninverted and normal. Thus in this group, the limestone marks the lowermost formation while the quartzites in the vicinity of the thrust form uppermost beds.

In Garhwal, Auden (1937) has described similar phyllites and quartzites below the Garhwal thrust as Nagthats, and considered them to be of Devonian age.

Pande (1950, 1963) too considers the phyllites and quartzites of Ramgarh area to be Nagthats. On the basis of physical and lithological similarities with the Nagthats, phyllites and quartzites of Jaunsars (Auden 1934, pp. 372-373), and that of Pande (1950), the author is inclined to fix the age of the group of phyllites and quartzites of present area to be Nagthats(? Devonian).

The rocks which are found below the above discussed group consists of dolomitic limestone. These limestones and slaty rocks on their physical and lithological similarities, are tentatively considered by the present author to be equivalent to Deobans.

Auden (1936, pp. 133-134) while taking traverse from Ranikhet-Dwarhat to Tehri-Garhwal reported similar limestone along the Alaknanda with northward dip,

which he correlated with eastern Lobah limestone and the Deoban limestone of Chakrata. He has assigned the age of Deoban limestone of Chakrata as (?) lower Palaeozoic andpre-Cambrian.

Considerable divergence of views prevails in respect of the stratigraphic position of the Deoban limestone andits equivalent in different parts of the Himalayas. According to Pilgrim and West (1928), Deobans are equivalent to Kakarhatti and Shali limestones, and their age could be anywhere between Jaunsar(? Purana) and Blaini (upper Carboniferous).

Valdia (1961) considers similar limestone in Pithoragarh area of eastern Kumaon to be equivalent to Naldera and Kakarhatti of Simla, and assigning them an age between late pre-Cambrian and early Ordovician.

Much more work in the neighbourhood of these limestones is required before a proper and correct correlation of the rocks of this area can be suggested. Till then, the author would refrain from giving his definite views on the subject.