CHAPTER III

G E O L O G I C A L S E T T I N G

The rocks of the Ramgarh-Mukteswar area, comprise parts of the two major tectonic units of Kumaon Himalaya - the Almora and the Krol nappes. The Almora nappe, made up of crystalline schists and gneisses, lies over the younger less metamorphosed quartzites, slates, limestones etc. of the Krol nappe. The entire sequence essentially a structural one, contains rock formations which could be correlated to the different horizons of the Jaunsar series of Pilgrim & West (1928). Two dislocations, the S. Almora thrust and the Ramgarh thrust, have brought a certain amount of structural complexity. The older Chandpurs have

been brought over the younger Nagthats by the S. Almora thrust, while the Ramgarh thrust is responsible for pushing the Deoban sequence over the quartzites of Nagthat age (Fig.III.1A & B). Merh (1968) while describing the structural and metamorphic history of the central Kumaon, ruled out any possible connection between the Almora thrust and the Ramgarh thrust. He has very clearly mentioned that neither the Ramgarh thrust comprises the north dipping southern flank of Almora thrust, nor the so called Ramgarh nappe in the sense visualised by previous workers exists. He found the entire sequence between Bhowali and S. Almora thrust to be univerted.

The author has elaborated and improved upon the work of Merh for the study area, and has suggested the following succession:

Almora Nappe	Crystalline schists, gneisses, flaggy quartzites and phyllonites	Chandpurs
	--------South Almora Thrust----------	
Krol Nappe	Quartzites interbedded with Phyllites	Nagthats(Lower)
	Limestones with slaty phyllites	Deobans
	Quartzites interbedded with slaty phyllites	
	Sheared and mylonitised, sericitic and chloritic granites, with quartzites, phyllites and epidiorites	
	--------Ramgarh Thrust----------	
	Pebbly quartzites with sills of metamorphosed mafic rocks	Nagthats(Upper)

Detailed mapping supported by subsequent laboratory studies have enabled the author to classify and subdivide the various formations into smaller units. These have been assigned local names for the facility of description. The enclosed Table (Table III.1) gives the detailed succession of the rock units of the area. Their distribution and field characters are given in the following pages.

ALMORA NAPPE

UPPER SCHISTOSE GROUP

Structurally, this group forms the topmost rocks and consists mostly of garnet bearing mica schists. These rest over the migmatitic gneisses, and the junction between the two groups is rather transitional. The mica schists show a considerable variation in the relative proportions of mica and quartz, and both micaceous and quartzose schists are present. The two varieties cannot be easily demarcated in the field. The minerals recognized with unaided eye are quartz, biotite, muscovite and garnet.

The garnet grains show a variation in size from pin head to as much as 3 mm in diameter, and are of typical pink colour.

The general trend of the foliation is seen to fluctuate between NNW-SSE to NW-SE, while the dips are variable though generally due NE.

Folded quartz veins showing 'S' shapes are quite frequent in the schists. The schistosity shows axial-plane relationship with these minor folds. Axes of these folded veins (often forming quartz rods) plunge due NNE at moderate angles. Another interesting feature of these schists is their microfolding. The schistosity is seen to have crinkled into tiny chevron folds, the fracturing of whose hinges has given rise to a distinct strain-slip cleavage which extends almost parallel to the strike of the foliation but dips very steeply due N. The axes of these microfolds and the associated puckering characterise the late lineation developed on the schistosity.

These schists grade imperceptibly into the underlying gneissic group, with increasing felspar content.

MUKTESWAR GNEISSIC GROUP

This group comprises two gneissic bands with an intervening band of mica schists. The strikes as usual are NW-SE, with fluctuations to as much as NNW-SSE. The dips are due NE. The more prominent southern band on which the town of Mukteswar is situated is made up of a coarse porphyroblastic gneiss, while the upper band which is of smaller dimensions, consists of somewhat less coarse augen gneiss. The intervening mica schists represent an unmigmatised relict. The gradation from the schist to gneiss is not much diffused, and the various intermediate stages are encountered rather in a quick succession. The different stages of migmatisation are ideally shown by the Mukteswar gneissic band, which on its both flanks exhibits gradation through augen-gneiss, permeation gneiss and felspathic schist to original mica schists.

The prophyroblastic variety is a coarse gneissic rock with abundant porphyroblasts (10 to 20 mm) of felspar. These big felspars are many a time, idiomorphic (Plate III.1.A). The porphyroblastic gneiss is ideally exposed around the Indian Veterinary Research Institute Office. Of course, similar good exposures are recorded

PLATE III.1A

Porphyroblastic gneiss (Loc. Near I.V.R.I. Office Mukteswar).

PLATE III.1B

Augen gneiss (Loc. About a mile in east of Bhulmaria)

at several places along the strike of the band. The augen gneiss occurs almost all along the two flanks of the above variety and is recognised by a profuse development of augens of felspars, enclosed within a foliated micaceous mass (Plate III.1.B). The augen-gneiss gradually grades into permeation gneiss with a progressive disappearance of augens. Instead, the rock is seen to contain small elongate grains of felspar (never exceeding 3 mm in length) along the mica foliae. Thin and somewhat less defined bands of the permeation gneiss occur at the south western flank of the Mukteswar band and also on the NE flank of the augen bearing northern band. The least migmatised rocks are represented by felspathic schists. These are almost like mica schists but with occasional felspar grains. This variety is quite common in the marginal portions of the two bands and is an important constituent of the relict mica schist band lying between the two gneissic bands.

From the point of view of the small scale structures, this group is less interesting. Except the gneissic foliation which is a derivative of the schistosity, no other planar structures are recognized, except in the gneisses nearer to the South Almora thrust which show some

shearing. A lineation mostly due to crenulation of mica flakes is quite commonly recorded. This mineral orientation shows the usual plunge due NNE and is related to the other similar lineations developed during the isoclinal folding. The felspar porphyroblasts have grown along the foliation, and thus show a striking parallelism.

BHULMARIA SCHISTS AND PHYLLONITES

Underlying the Mukteswar gneissic band, and coming in direct contact with the South Almora thrust is a descending succession of garnet-mica-schists to phyllonites. Good exposures of this retrograde sequence are encountered at Naya Latauli, Chhatuala, Bhulmaria, Jaspur, Chaupani and Sargakhet. The regional trend as usual is NNW-SSE with dips due ENE. On the basis of mineral composition and megascopic textural characters, the rocks can be divided into the following groups across the strike from NE to SW.

(i) Garnet mica schists,
(ii) Chlorite schists,
(iii) Phyllonites.

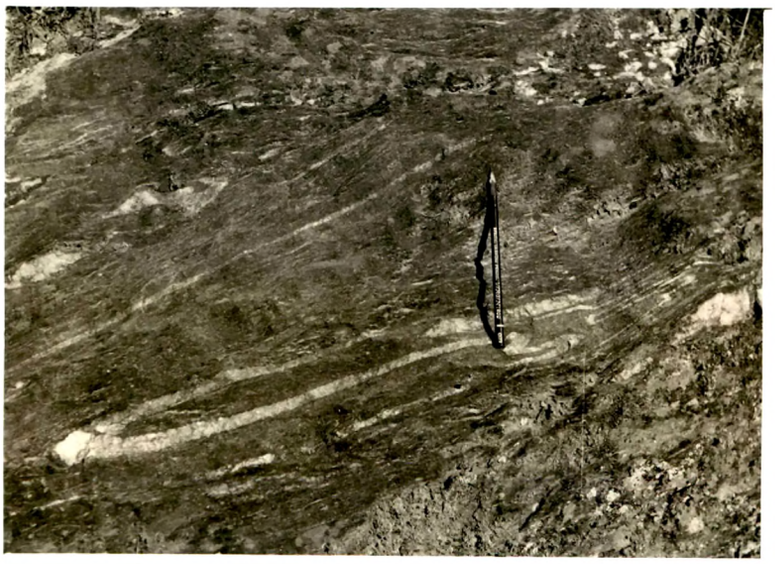
These varieties form narrow irregular bands roughly parallel to each other, and their junctions are rather

gradational and indefinite. The garnet mica schists grade southward into chlorite schists, and the latter in turn, grade into phyllonites in the immediate vicinity of the South Almora thrust.

This schist-phyllonite sequence forms a 800 to 1,250 m thick band almost all along the fringe of the Almora nappe. Numerous thin lenses (30 m) of quartzites are frequently recorded in these rocks and these hard layers, in the thrust zone provide valuable data regarding the movement pattern along the thrust. Obviously, the intense shearing due to the dislocation has caused the transformation of coarser schists into finely foliated phyllonitic rocks. The phyllonites are very similar to sericitic and chloritic phyllites, but show intense granulation and metamorphic retrogression. In the field itself the garnet and biotite show a progressive decrease at the cost of increasing chlorite and sericite content.

The schists and phyllonites show planar and linear structures of two generations. The foliation of the schists in the upper part is identical to that of the rest of the nappe rocks and marks the axial plane cleavage related to the isoclinal folding. Small quartz rods and folded quartz veins (Plate III.2) typically indicate the

PLATE III.2



Quartz veins folded on F_1 showing axial plane relation with schistosity (Loc. Near 16th mile stone on Nathuakhan-Mukteswar cart road).

phenomenon, and their fold axes characterise the early lineation. The rocks nearer to the thrust plane have developed a strong shear cleavage (phyllonitic cleavage) due to differential slipping. This cleavage itself is seen drag folded whose axial planes are parallel to the planes of slipping themselves. Also the axes of drag folds show an orientation which is identical to that of the fold axes lineation described above. These observations clearly point out that the isoclinal folding and the Almora thrusting represent two connected events of a single deformational episode.

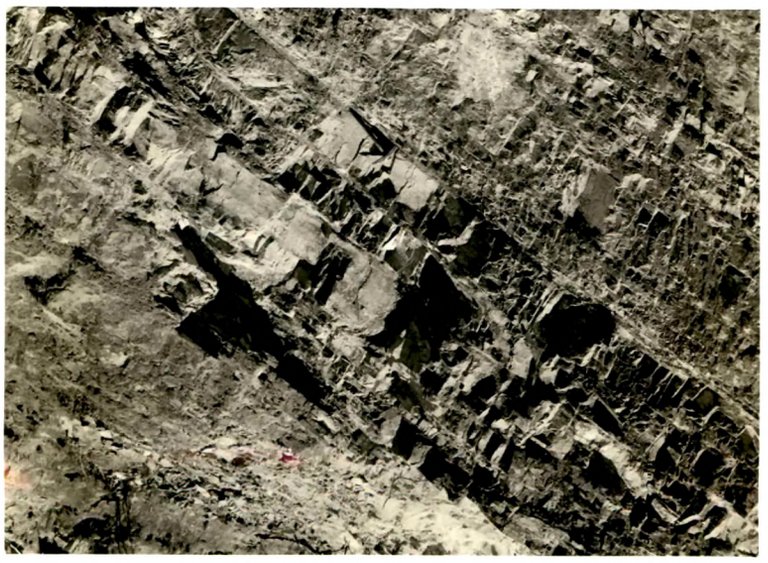
KROL NAPPE

NATHUAKHAN QUARTZITES AND PHYLLITES

This group correlated with Nagthats, lies immediately below the South Almora thrust. The constitutent rocks are dominantly quartzites with intercalated layers of phyllites (Plate III.3). These rocks comprise a continuous band of 2100 m thickness and show an unbroken exposure from NW to SE. The villages Kilaur, Nathuakhan, Chachadi and Chaukhutta are situated on these rocks.

The entire group is seen to consist of the following four varieties:

PLATE III.3



Nathuakhan quartzites and phyllites (Loc. Near Bhatalia).

(1) Buff coloured massive quartzites,

(2) Yellow and grey quartzites with interbedded biotitic phyllites,

(3) White quartzites with interbedded green phyllites and foliated hematite.

It is so obvious in the field itself that the above varieties reflect the variation in the original sediments. The buff coloured massive quartzites, are encountered as a discontinuous band below the South Almora thrust. The distribution and occurrence of the varieties 2 and 3 are not so well defined and these occur at all horizons. The hematite bearing variety is confined to the basal portion in the immediate neighbourhood of the underlying calcareous horizon. Bedding is most conspicuous in the flaggy varieties, though well defined traces of recrystallised bedding are quite common in the buff massive variety also, which has preserved current bedding at several places. This current bedding clearly indicates that the quartzite sequence is uninverted.

The entire group conforms to the regional NW-SE trend with overall dips due NE. A variation in the strike direction, on account of late flexures, is from NS to WNW-ESE. In the immediate vicinity of the thrust zone,

the quartzites frequently show drag folds. The micaceous layers involved in such folds, have developed fine puckers whose orientation is identical to those of the drag folds. Small folds obviously related to the synformal folding of the Almora nappe, are quite common, and sometimes they are big enough to cause SW dips locally. The phyllite layers also contain the related microfolds and their axes characterise the dominant lineation. The phyllitic cleavage typically shows indications of shearing.

SAYALGAD LIMESTONE

This calcareous formation, lying below the Nathuakhan quartzite group, is stratigraphically also, older than the overlying quartzites. The latter grade into limestones through a narrow intermediate zone of increasingly calcareous rocks, and the author has all evidence to believe that the contact between quartzites and the underlying limestone is depositional and certainly not tectonic as postulated by Kashyap (1971).

The group consists of thickly bedded siliceous limestones of white,grey and greyish-black colour with interbedded thin grey slates. The limestone formation

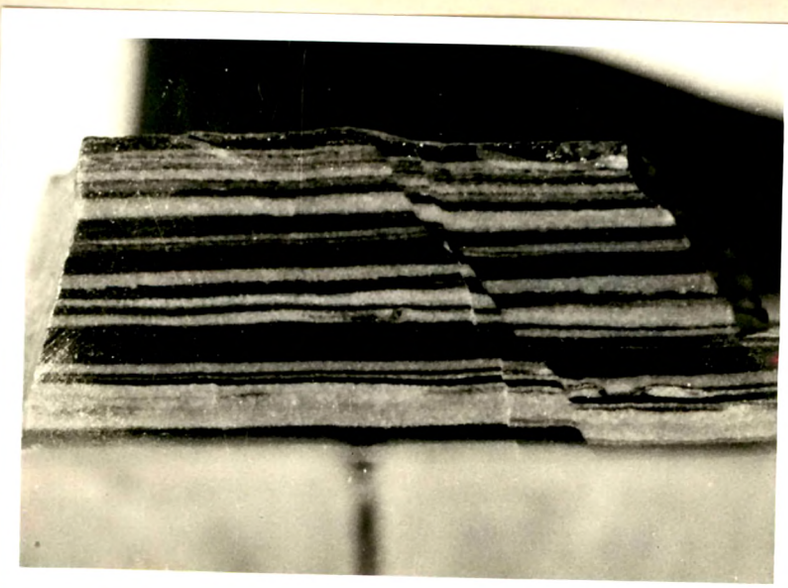
comprises an upper continuous band of increasing thickness from SE to NW (being 20 m to 300 m) and a few big lenses in the underlying slates and quartzites. In the SE, the lenses are small, 350 to 450 m long and of 20-30 m thickness. The two lenses in the NW are quite big, 150-200 m thick and extending for a few km. The main (upper) limestone band in the SE, near village Kamota is cut by a NS fault and the displaced counterpart is again encountered about 2 km further South at the village Chaukhutta. Original sedimentary bedding is very distinct, and depositional structures like contemporaneous folding (Plate III.4A) and microfaulting (Plate III.4B) are seen ideally preserved at many places. The entire formation is significantly free from effects of shearing.

The strikes fluctuate between NS to EW with easterly or northerly dips. Occasional small folds of a few metres in size, related to the synformal folding (Plate III.5A) and Ramgarh Thrust (Plate III.5B) are recorded.

PLATE III.4A

Limestone showing contemporaneous folding. (Loc. Near Dagar).

PLATE III.4B



Limestone showing microfaulting (Loc. Near Supi).

PLATE III.5A

Small folds in limestone related to F_2.
(Loc. About half a mile in the SW of Nathuakhan).

PLATE III.5B

Small monoclinal felxure in limestone related to Ramgarh thrust (Loc. About half a mile in the SW of Nathuakhan).

TABLE III.1

TECTONIC SUCCESSION OF THE RAMGARH-MUKTESWAR AREA

UPPER SCHISTOSE GROUP	Garnet mica schists with quartzites		
MUKTESWAR GNEISSIC GROUP	Porphyroblastic gneisses Augen gneisses Permeation gneisses Felspathic schists	CHANDPURS	ALMORA NAPPE
BHULMARIA SCHISTS AND PHYLLONITES	Garnet mica schists Chlorite schists Phyllonites		
----------SOUTH ALMORA THRUST----------			
NATHUAKHAN QUARTZITES AND PHYLLITES	Buff, yellow and grey quartzites interbedded with phyllites	NAGTHATS	
SAYALGAD LIMESTONES	Banded limestones with slaty phyllites		
LUSGAINI QUARTZITES AND PHYLLITES	Quartzites interbedded with phyllites	DEOBANS	KROL NAPPE
RAMGARH GROUP	Mylonitised granites with lenses of phyllites, quartzites and intrusive epidiorites		
----------RAMGARH THRUST----------			
TITOLI QUARTZITES	Quartzites with sills of epidiorites	NAGTHATS	
BHOWALI TRAPS	Foliated basaltic rocks	TERTIARY (?)	

LUSGAINI QUARTZITES AND SLATY PHYLLITES

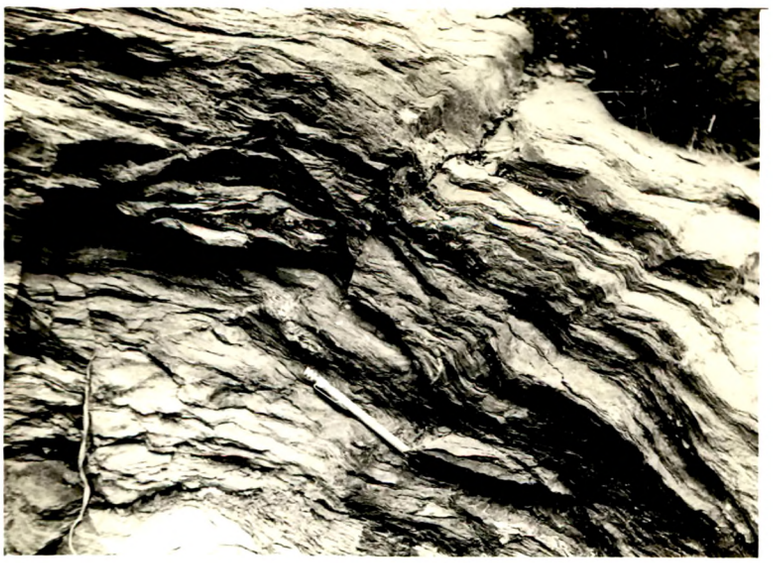
Lying stratigraphically below the limestones, this group comprises alternating layers of quartzites and slaty phyllites. The entire formation is very well developed and forms a wide and continuous band, whose thickness gradually decreases from NW to SE. In the NW, it is 1800 m thick while the least thickness is 300 m in the SE. Ideal exposures of these rocks are encountered at the villages Lusgaini, Galla, Dhakre and Satbunga. It is in this formation that the lenses of limestone mentioned above occur. The junction between the limestones and this group is fairly sharp and well defined.

The constituent rocks, viz. quartzites and phyllites, are never of great thickness and usually the individual layers never exceed 50 m in thickness. The quartzites are of grey and greenish colour, gritty and distinctly flaggy. Pande (1950) called these as greenstones. Sedimentary structures other than bedding are not seen, perhaps having been obliterated due to flexural slip. The metamorphic foliation essentially a shear phenomenon, characterised by the micaceous and chloritic minerals, is parallel to the bedding.

The grey quartzites are predominant and encountered almost all over the exposures of this group. The green variety is rather restricted and its outcrops are best seen at Dhakre on the Ramgarh-Nathuakhan road and near the village Galla. The phyllites are nearer to slate, of green and grey colour, and show a uniform lithology all throughout. The green phyllites are somewhat more chloritic, as compared to the grey variety. These are strongly foliated and show numerous minor structures related to the various deformations.

This interbedded quartzite-phyllite formation, generally conforms to the regional trend of the strike and dip. The dips are quite variable as the rocks are folded on account of the Ramgarh thrust. The quartzites extensively show a slickenside lineation which plunges due NNE to NE. The author has connected this lineation with flexural slip that affected this sequence during the Ramgarh thrusting, and genetically it has been classified as 'a' lineation. Another linear structure more common in phyllites, is a fine puckering (Plate III.6A & B). It shows sub-horizontal trend due NW-SE and characterises the axes of tiny microfolds that developed during the movement along the Ramgarh thrust. This lineation, which

PLATE III.6A



Pucker folds in phyllites related to the Ramgarh thrust (Loc. Near Lusgaini).

PLATE III.6B

Fine puckering in phyllites related to the Ramgarh thrust (Loc. Near Patli).

resembles very much the puckers related to the synformal folding, is clearly distinguished from the latter on the basis of the axial planes of the microfolds which characteristically dip due SW. These microfolds are typically associated with a well defined strain-slip cleavage at many places.

RAMGARH GROUP

Lying between the Lusgaini quartzites and phyllites and the Ramgarh thrust, is an interesting group of highly sheared rocks. A careful scrutiny has revealed that for the most part, the original unsheared rocks were granitic which occurred in association with phyllites and quartzites. In the present state, intense shearing has considerably obliterated their original nature and mutual relationships. In a broad way, it could be stated that the upper portion of this group contains more phyllite and basic sills as compared to the lower portion; also the intensity of shearing decreases considerably on going away from the Ramgarh thrust. It is so obvious that the shearing is related to the Ramgarh thrust movement.

Phyllites and quartzites perhaps represent the earlier rocks in which the granites were emplaced.

The basic sills which have intruded them, are clearly the youngest. The original nature of the granitic rocks and their origin cannot be worked out in their existing mylonitised and metamorphosed state.

In the field, following rock types in the Ramgarh Group have been identified and recorded:

(1) Mylonitised granitic rocks,

(2) Quartzites,

(3) Phyllites,

(4) Epidiorites.

The granitic rocks are the most dominant and show progressively increasing effect of shearing toward the Ramgarh thrust. Away from the dislocation, i.e. in the areas that come immediately below the Lusgaini quartzites and phyllites, the granite is seen as a less foliated rock, showing porphyroclastic texture (Plate III.7A). This variety is extensively recorded around Ramgarh, Jhutia, Sagana and Kona villages. The rock is biotite rich, quite coarse grained and contains "porphyroclasts" (2 to 10 mm in width) of felspar and quartz. On the whole, this rock is massive, though occasional bands showing greater shearing are not uncommon. To the W

PLATE III.7A

Partly mylonitised granite of Ramgarh group. (Loc. Near Jhutia).

PLATE III.7B

Mylonitised granite showing drown out streaks of quartz and sericite-quartz. (Loc. Near Pachhil Tanda).

and SW, with increasing nearness of Ramgarh thrust, these granites show progressively increased shearing, and pass through a gneissic to almost totally schistose variety. Partly broken augen shaped "porphyroclasts" superficially resemble metasomatically grown porphyroblasts, and in the past quite a few workers have mistaken this rock to be a product of progressive migmatisation. Ideal exposures of "augen" bearing gneiss are encountered all around the villages Holi, Kimunkhet, and Umagarh. Highly foliated light green intensely sheared derivative of these granitic rocks occur just above the Ramgarh thrust. With a progressive dimunition in the size of the porphyroclasts and increased shearing, the augen-gneiss pass into the chloritic and sericitic streaky rocks. Drawn out streaks of quartz and sericite-quartz indicate the stretching, shearing and destruction of earlier coarser quartz and felspar grains (Plate III.7B). Biotite is seem to have changed over to chlorite. Good exposures of this variety are recorded all along above the Ramgarh thrust.

Quartzites form a big lens within the granite and are ideally exposed near the Talla Ramgarh bridge. These are seen as hard and compact rocks with very distinct

sedimentary bedding. The maximum width of the quartzite lens is 250 m and it extends for 5200 m. Near Hartola in the NW, these quartzites come immediately below the younger group of quartzites and phyllites, but toward SE, granites occur inbetween. Phyllites are confined to a few thin lenses never exceeding 40 m in thickness and are seen to be more common in the upper portion. Good occurrences of these phyllite lenses are recorded from Ata Bircha and Somerford Orchard. In their present state, they are seen as highly foliated greyish rocks. Their contact with granites are fairly sharp and well defined. Sills of basic rocks, relatively free from any effect of shearing, and more or less epidioritic occur at two places in granites. These appear to have been emplaced after the Ramgarh thrust, having arisen along the foliation of the granites.

The strike of the foliation is in conformity with the regional structure, and fluctuates between NW-SE to E-W. The dips are always in the NE sector, except at a few places where the dips are due SW, on account of local flexures. The variation in the amount of dip is considerable, and the foliation is seen showing steep to very gentle dips.

The most striking planar and linear structures developed in these rocks are those related to the Ramgarh thrust movement. The rocks show a strong development of 'a' lineation - the slickenside (Plate III.8A), which shows a plunge due NNE to NE. It is very clear in the field that differential slipping along the foliae of the thrusted block, gave rise to this lineation. Another lineation is a fine puckering characterising the axes of the monoclinal angular microfolds developed due to a drag effect during movement along the Ramgarh thrust plane. This pucker lineation shows the usual sub-horizontal NW-SE trend. The intensity of the development of these structures increases towards the thrust. An important and conspicuous planar structure developed in these rocks is a distinct strain-slip cleavage which dips moderately towards the thrust and is generally parallel to the axial planes of the microfolds.

Intense shearing of the rocks nearer the thrust has also resulted into development of numerous 'drag-boundins' - obviously stretched and broken fragments of quartz veins (Plate III.8B).

PLATE III.8A

Slicken type 'a' lineation in mylonitised granite (Loc. Near Sagana).

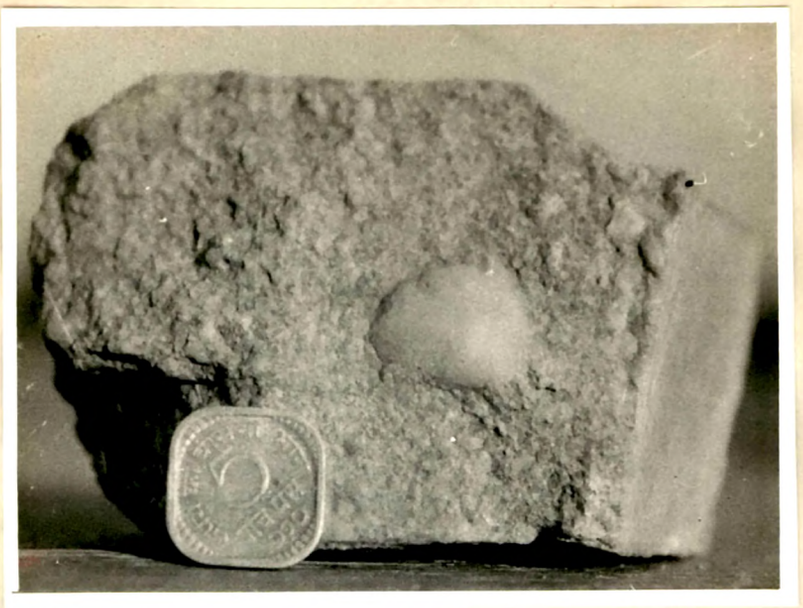
PLATE III.8B

Boudinaged quartz vein in phyllites. (Loc. Near Kona).

TITOLI QUARTZITES

These quartzites lie below the mylonitised granites, and the Ramgarh thrust separates the two. The thrust has brought the older granitic rocks over the younger quartzites of Nagthat age. This quartzite formation is very prominent and extends right up to Bhowali in the SW beyond the area's limit. The uppermost layer of the quartzites is pebbly in nature, and is a compact light pink rock with pebbles of quartz (Plate III.9A). The Ramgarh thrust cuts this pebbly horizon irregularly. The non-pebbly massive quartzites, which comprise the main bulk of the formation are of yellowish white colour and show faint but distinct traces of bedding planes. Gritty layers showing faint graded bedding are also quite common (Plate III.9B). At several places thin sills (2 to 5 cm thick) of basic rock are seen intruding these quartzites along bedding planes. In the extreme SW corner of the area, is encountered the foliated trap which forms the core of the Bhowali anticline. The other limb of this anticline, made-up of these quartzites is again seen only 2 km further west. The trap which occurs in the core of this big fold is seen as dark green foliated rock. It occupies only a very small portion of the study area near the village

PLATE III.9A



Pebbly variety of Titoli quartzite (Loc. Near Holi).

PLATE III.9B

Graded bedding in Titoli quartzite. (Loc. Near Titoli).

Kaichi. It is worth mentioning here that the Ramgarh thrust and the underlying quartzites are cut by a ENE-WSW fault, such that the Ramgarh thrust has been exposed on the Kaichi-Garampani road, where the trap is seen in contact with the mylonitised granites.

The quartzites dip due E or NE and do not contain those structural elements which the rocks above the Ramgarh thrust contain. The strikes and dips of the bedding show some variation, which have been found to be due to the effects of an E-W folding. This E-W folding is more strongly developed in Nainital and Bhowali, and is quite faint in the study area.

DISCUSSION

From his detailed mapping of the area, the author could easily establish and locate the two major dislocations, South Almora thrust and the Ramgarh thrust which are responsible for all the stratigraphical complications. While the South Almora thrust has pushed the crystalline rocks (Chandpurs) over the younger and less metamorphosed Nagthat quartzites, the Ramgarh thrust has made it possible for those quartzites to appear again below the mylonitised granites. One most

important fact that emerges out of this mapping is that the entire succession between South Almora thrust and the Ramgarh thrust is uninverted and also no recumbent fold exists in these rocks. Also, there are ample evidences to prove that the Ramgarh thrust and South Almora thrust are two distinct dislocations, and the former is much younger to the latter. The author found the interpretations of Merh (1968) quite valid to a certain extent, but in details, as will be evident in the forthcoming chapters, the structure of the area is rather different.