CHAPTER IV

S T R A T I G R A P H Y

GENERAL

The author has worked out a stratigraphy that is quite different from that suggested by most of the earlier workers (Fig. 4.1). In doing so, he has relied to a certain extent on the reinterpretation put forth by some recent workers (C.P. Shah 1973, Devendra Pal, 1973). The above named workers have investigated the areas to the north and west respectively under the guidance of Professor S.S. Merh (who has supervised the work of the present author also), and it is quite logical to extend latter's findings to the present area as well.

Structurally, the rocks form an anticline, the north-eastern limb of which is truncated by the Ramgarh thrust. As such, the actual successions on the two limbs of the anticline are rather different. The north-eastern limb shows the following sequence.

Sheared and mylonitised granites and granophyres

----------Ramgarh Thrust----------

Pebbly and bouldery quartzites

Foliated traps (Spilites etc.)

In this succession, the rocks that come above the thrust, are older to the pebbly quartzites, and obviously the succession is not a normal depositional one. On the other hand, the sequence on the south-western limbs is normal, uninterrupted and as under:-

Purple slates and quartzites

Trap flow

Quartzites with grey, green slates and lenses of limestones

Trap flow

Pebbly and gritty quartzites (sub-graywackes) with thin brown slaty layers (tuffaceous)

Bouldery quartzites

Foliated traps (Spilites)

The author has recorded that the underlying trappean rocks contain several lenses of pebbly graywackes and

similarly the slaty layers in the overlying quartzites are of tuffaceous nature. This very clearly points out to the fact that the basic igneous activity of spilitic affinity, formed the earliest event and an integral part of the depositional history of the overlying sedimentary sequence.

A synthesis of the sequences on the two limbs, has provided the following stratigraphic succession:

BHIMTAL-BHOWALI GROUP	Purple slates and quartzites
	Trap flow
	Quartzites with grey, green slates and lenses of limestones
	Trap flow
	Pebbly and gritty quartzites, (Sub graywackes) with thin brown slaty layers (tuffaceous)
	Bouldery quartzites
BHIMTAL TRAPS	Foliated traps (Spilites)
----------? Unconformity----------	
RAMGARH GROUP (Patel J.P.,1971)	Sheared and mylonitised granites, granophyres (within slaty and quartzite layers).

RAMGARH GROUP

The rocks lying above the Ramgarh Thrust and below the South Almora Thrust, comprise (Patel J.P., 1971) a sequence that has been considered equivalent to the Jaunsar of Simla (Bhargava, 1974).

Some of the earlier workers (Heim and Gansser,1939; Pande et al., 1963) believed that these rocks comprised a folded nappe of crystallines (Chandpur ?) lying between the quartzites and slates of Nagthat. Merh (1968), however did not agree with the above, and suggested that the entire sequence between the two thrusts is normal and uninverted. He correlated the succession as under:-

ALMORA NAPPE	Mica schists and migmatitic gneisses with quartzites	Chandpur
	Chlorite schists	
	Sericite schist (Phyllonites)	
----------Almora Thrust----------		Garhwal Thrust
	Quartzites with slates	Nagthat
	Dolomitic limestones with slates	Deoban
KROL NAPPE	Chlorite and talc chlorite schists (metamorphosed basic rocks) with quartzites	
	"Porphyries" (mylonitised granite)	Chandpur
	Talc chlorite schists (metamorphosed basic rocks)	
	-----Ramgarh Thrust---------	
	Quartzites and associated basic rocks (Bhowali traps)	Nagthat

Later on Patel J.P. (1971) and Merh et al. (1971) gave the following correlation:

Crystalline schists, gneisses and flaggy quartzites	Chandpur
----------South Almora Thrust----------	
Quartzites with phyllites	(?) Nagthat (Lower)
Limestones with slates, slates with interbedded quartzites	? (Deoban)
Sheared sericitic and chloritic migmatites	
----------Ramgarh Thrust----------	
Pebbly quartzites	(?) Nagthat (Upper)

In the present area, only the lowermost rocks of the Ramgarh Group sequence, viz. the sheared and mylonitised granites are encountered. Patel J.P. (1971, p.45) has aptly described these rocks in the following words:

"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

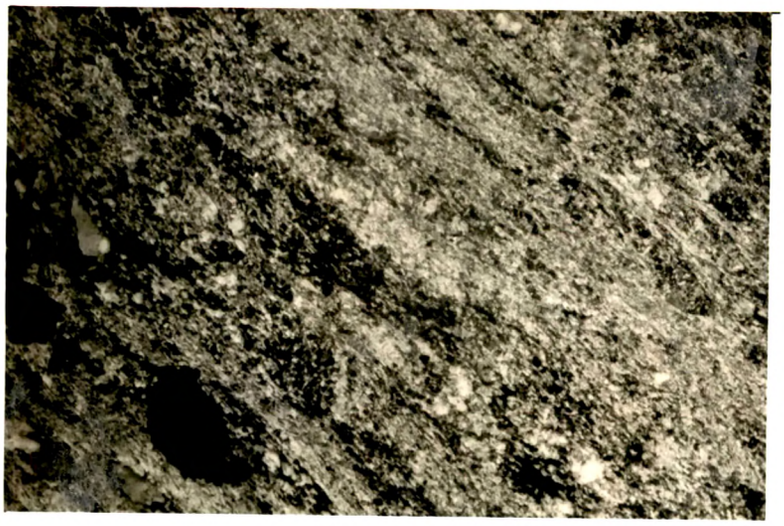
obliterated their original nature and mutual relationships. In a broad way, it could be stated that the upper portion of this group contains more phyllite and basic sills as compared to the lower portion; also the intensity of shearing decreases considerably on going away, from the Ramgarh thrust. It 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 original nature of the granitic rocks and their origin cannot be worked out in their existing mylonitised and metamorphosed state".

Shah C.P. (1973, p.52) who came across identical rocks above the Ramgarh thrust, further north near Khairna Bridge, found that some granophyric rocks were also associated with granites. According to him, "These sheared and mylonitised granitic and granophyric rocks form extensive exposures in the Ramgarh area in the SE, and J.P. Patel (1971) has studied them in much detail.... J.P. Patel (1971) has not mentioned granophyric rocks, but a scrutiny of thin sections of rocks from his area as well as those of the present area, does show that prior to shearing, in addition to granite, some "porphyries" also existed."

Within the limits of the terrain investigated by the present author, only a small area to the NE of Ramgarh thrust, is seen to contain these rocks. Apart from a few thin quartzites and phyllitic layers, the dominant rocks are soda granites in different stages of shearing. Some sheared samples also show granophyric texture.

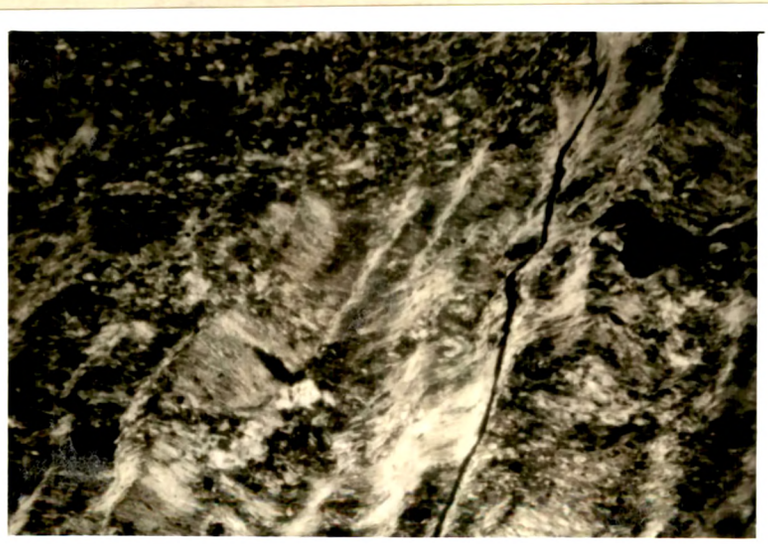
The greyish green strongly foliated rocks in the immediate vicinity of the Ramgarh thrust, show effects of shearing and granulation. In thin sections, they reveal a fine grained streaky mass consisting of sericite, chlorite and quartz granules. The sericite rich portions occur as elongated lenses and at some places it is quite obvious that they are after the original felspar (Plate 4.1). Crinkling of the foliation associated with an incipient strain slip cleavage is a very characteristic feature of these highly sheared rocks (Plate 4.2). On going away from the thrust, the intensity of shearing progressively decreases, and one comes across rocks which show the original nature. It is quite evident that the rocks before shearing were soda granites and granophyres. A rather unsheared coarsegrained rock revealed under microscope a granitic texture with felspars, quartz and

PLATE 4.1



Photomicrograph of sheared granophyre showing sericite rich lenses, after original felspars (cross nicols, X80).

PLATE 4.2



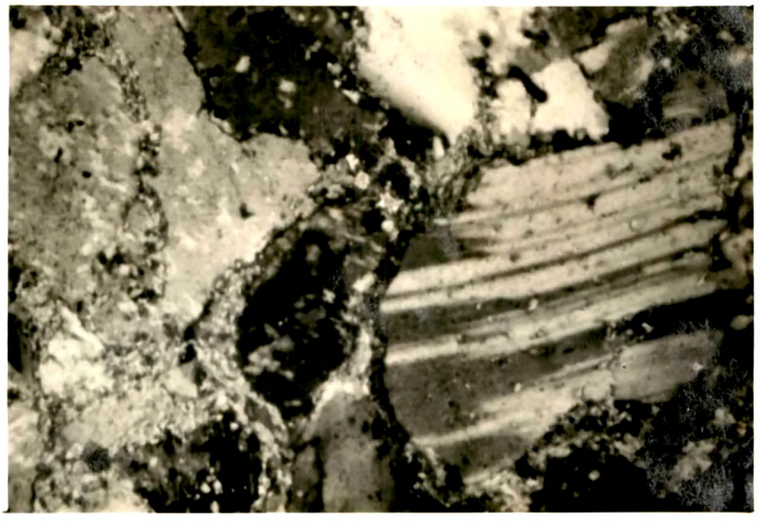
Photomicrograph of sheared granitic rock showing crenulation cleavage (cross nicols, X80).

green biotite. The dominant felspar is a plagioclase (oligoclase, An 18-26) and is easily recognised by its twinning, which is both of Carlsbad and Albite types. The potash felspar content is subordinate, and it occurs mostly as irregular cuspate interstitial grains or as inclusions in plagioclase. The biotite forms tiny flakes of green colour ($X > Y = Z$, X = greenish yellow, Y = Z = brownish yellow) and occurs in clusters and streaky patches. The plagioclase is abundantly altered to sericite. Other secondary minerals are, epidote, zoisite and calcite (Plate 4.3). Tourmaline, apatite, and altered magnetite occur as tiny grains and comprise accessory minerals.

The other unsheared rock is somewhat fine grained and shows granophyric texture (Plate 4.4). It comprises a fine to mediumgrained groundmass within which are seen embedded phenocrysts of felspars and quartz. Felspars are highly sericitised and generally difficult to identify. These phenocrysts of felspars are both of perthitic and sodic plagioclase. Quartz phenocrysts are typically corroded (Plate 4.5).

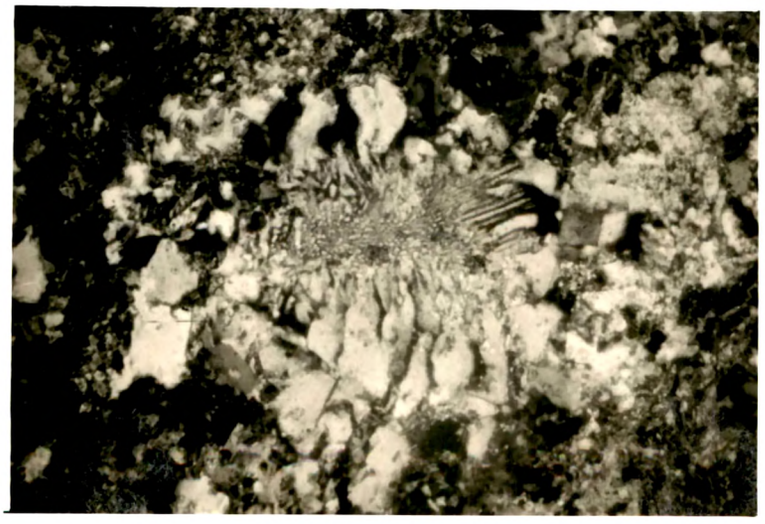
The author has also collected numerous samples of partly sheared granite and granophyre, and these clearly

PLATE 4.3



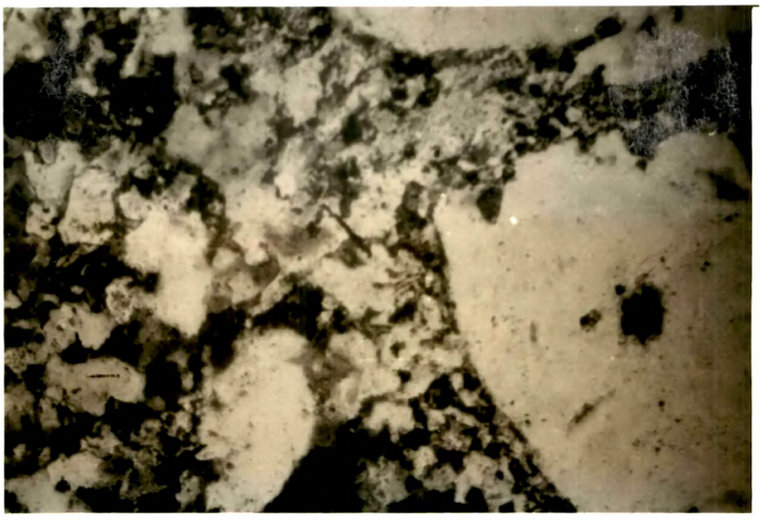
Photomicrograph of sodagranite (feebly sheared) showing coarse granitic texture (cross nicols, X80)

PLATE 4.4



Photomicrograph of unsheared granophyre showing typical quartz-felspar intergrowth (cross nicols, X80).

PLATE 4.5



Photomicrograph of corroded quartz phenocrysts in granophyric rock (cross nicols, X80).

reveal the true nature of the so called "porphyries" of Heim and Gansser (1939) and the "migmatites" of Pande (1963).

As regards the age of these rocks, the author is of the opinion that the entire sequence above the Ramgarh thrust could be broadly correlated with the Jaunsars. He is however reluctant to suggest as to which part of the Jaunsar sequence, these could be correlated. In his opinion it is not advisable to correlate these rocks to some definite horizon of the Simla Jaunsar viz Nagthat, Deoban or Chandpur etc. The granitic and granophyric rocks however do not belong to these Jaunsar rocks (? Late Pre-Cambrian or early Palaeozoic) within which they occur, but appear to have been intruded at a much later date. It is not unlikely that these were intruded at the time of the Krol thrust movement. Identical granitic rocks with an envelope of porphyries (= granophyres) occur to the south of the area near Amritpur-Ranibag (Fig. 3.2), and of late it is believed that these granitic rocks are related to the Krol thrust upthrow (Merh, personal communication; Chatterjee, 1973). The Ramgarh thrust which has sheared these granitic rocks obviously followed the Krol thrust.

BHIMTAL-BHOWALI GROUP

Succession

The rocks to the south of Ramgarh thrust comprise this group, and form the main anticline. The oldest rocks of this group are the foliated traps (Spilites), which occupy the core of the anticline. The sedimentary sequence that rests over these trappean rocks, forms an unbroken succession to the west, right upto Naini Tal. Earlier workers like Heim and Gansser (1939), Gansser (1964) and Thomas (1952) have correlated this sequence with Nagthat, Infra Krol and Krol. According to these workers, the quartzites that overlie the traps were equivalent to the Nagthat formations while the succession further up, of alternating slates and quartzites was Infra Krol.

Recently the above correlation has been considerably modified. Dutt (1955) reported the occurrence of Blaini from this area. Similarly Devendra Pal (1973) and Shah C.P. (1973) also suggested that the quartzites that overlie the traps could be equivalent to the Blaini. The present author too has adequate field evidence to believe that the Infra Krol slates and quartzites when traced downward merge into the pebbly quartzites, and thus there is no

tectonic or depositional break between the two. The quartzites that lie over the traps contain two prominent trap layers with layers of tuffaceous matter, and similarly within the green tuffs below occur pebbly graywacke type quartzites. All this very obviously points to a complete uninterrupted depositional event that started and synchronised with geosynclinal volcanism, was followed by the deposition of a graywacke suite which in turn gave place upward to a sequence of slates and quartzites (Infra Krol) of shallow water deposition.

The present author therefore is fully inclined to include the entire Bhimtal-Bhowali sequence to comprise lower part of a single group that started with the trap volcanism and ended with the deposition of the dolomitic limestone of Naini Tal (= Krol). Accordingly, he has described the rocks occurring within the study area as under:

Purple slates and quartzites

Trap flow

Quartzites with grey green slates and occasional limestone lenses

Trap flow

Pebbly and gritty quartzites (sub-graywackes) with thin brown slaty layers (tuffaceous)

Bouldery quartzites

Spilites, tuffs and tuffites

Lithology

Spilitic traps have been dealt with separately in Chapter VI. The rocks that overlie the traps are bouldery and pebbly quartzites. These coarse clastic rocks occur as lenses, such that at many places the overlying pebbly - and gritty subgraywackes rest directly over the traps. The bouldery quartzites are on the whole not as well developed as they are in the Khairna bridge-Garampani area to the north. Shah C.P. (1973) has described these rocks from the above area in the following words.

"The bouldery quartzites (Boulder beds) come over traps, and are ideally exposed along the Garampani scarp at Khairna bridge and in the Kosi valley on way to Bardau Malla along its northern bank. The rocks contain sub-rounded to sub-angular boulders, cobbles, pebbles and gravels of quartzite, graywacke, siltstone, slate, trap, chert, or vein quartz. The megaclasts are embedded in a gritty matrix consisting of quartz and felspar (both microcline and plagioclase), cemented by argillaceous material or resembles green volcanic tuffaceous material. Due to recrystallisation the cement is now seen to consist of sericite."

In the Bhimtal-Bhowali region, the sub-graywackes of the nature of pebbly and gritty impure quartzites are most predominant (Plate 4.6). These contain numerous thin greenish grey and purple slaty layers. The sub-graywackes, under the microscope, reveal considerable immaturity. Megaclasts of mostly quartz of variable sizes, are seen embedded in a variable matrix, consisting of heterogeneous mixture of fine grained argillo-volcanic material and quartz grains. Also occasional fragments of jasper and purple slates are recorded. The megaclasts show a wide variation in shape, ranging from totally angular to sub-rounded (Plate 4.7).

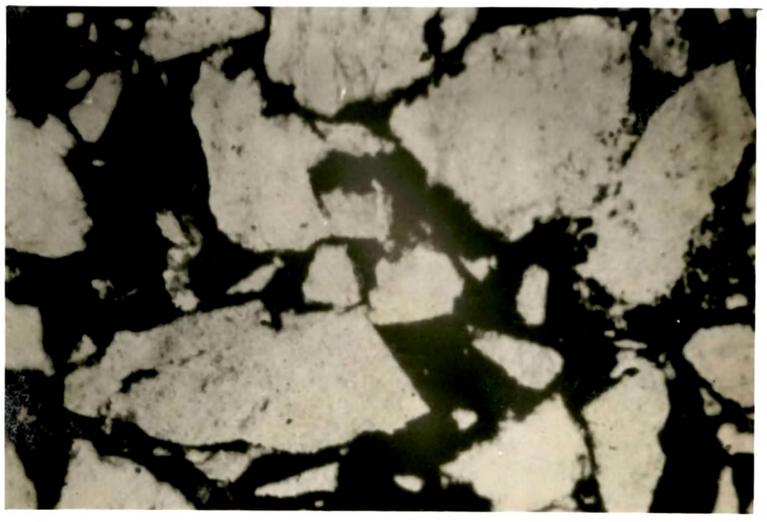
As the area has undergone deformation and a feeble metamorphism the matrix in most sections of the sub-graywackes shows some recrystallization to tiny flakes of chlorite and sericite, quite often revealing an incipient foliation. The effects of deformation in the megaclasts are rather less conspicuous except for some granulation of quartz fragments or development of strain shadows and Boehm lamellae.

Non pebbly sub-graywackes are predominant, and are seen to consist of quartz grains with subordinate

PLATE 4.6

Field photograph of Bouldery Quartzite (sub-graywacke). (Loc. Near Dungsil)

PLATE 4.7



Photomicrograph of angular megaclasts of mostly quartz of variable sizes, in an argillo-volcanic matrix (sub-graywacke). (Polarised light, X80).

felspar and jasper. These are cemented by a chocolate coloured almost opaque cement, perhaps some volcanic matter (Plate 4.8). At times, the grains are cemented by silica only, the textural pecularity being that in this variety the grains are rounded to sub rounded, welded together by silica such that the secondary over-growth of quartz is in optical continuity with the original grains (Plate 4.9).

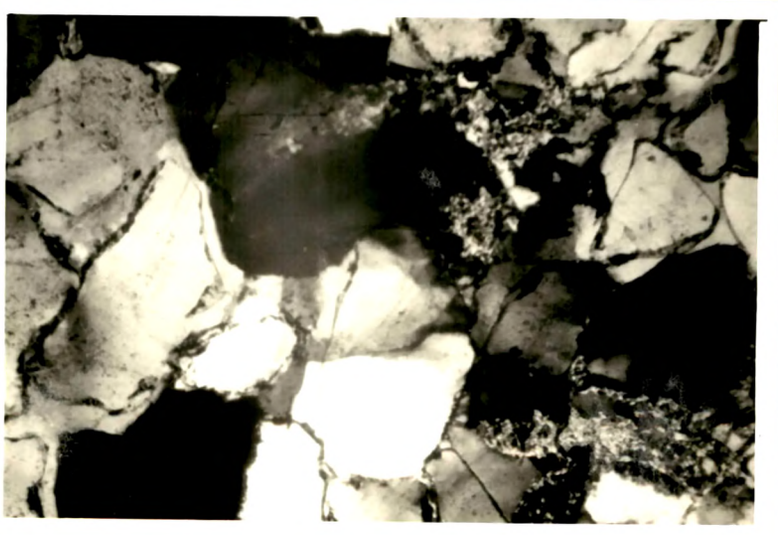
With increasing maturity, the sub-graywackes upward have changed over to pure quartzites with much less heterogeneity. Thin sections of this arenaceous rock (of the upper parts of Blaini) reveal aggregates of sub-rounded quartz grains with occasional felspar. The cement is silica, and some sericite (Plate 4.10).

The upper part of the Blaini, is dominantly an alternating sequence of quartzite and purple/green slates. In the study area the limestone band reported from the neighbouring parts is not so well developed. It only forms a few thin lensoid bands (siliceous) above the sub-graywackes. But the overlying purple slates however contain tiny lenticular patches of (5 to 10 mm long) calcareous matter (Plate 4.11).

PLATE 4.8

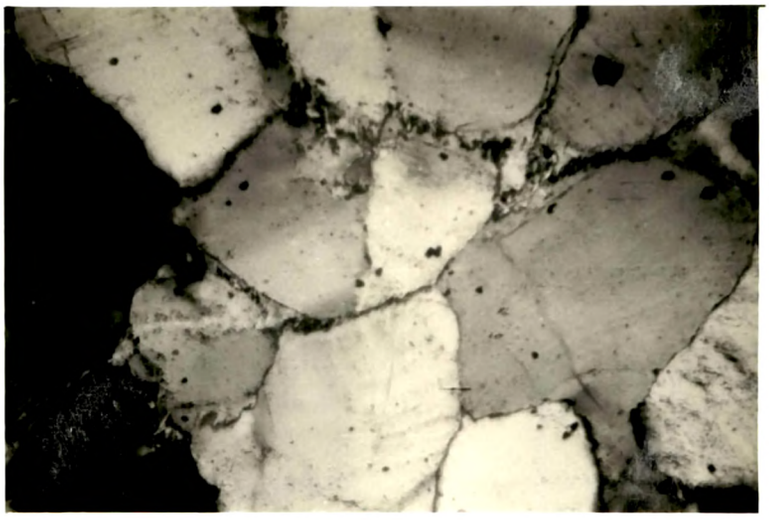
Photomicrograph of a typical non pebbly sub-graywacke. (cross nicols, X80).

PLATE 4.9



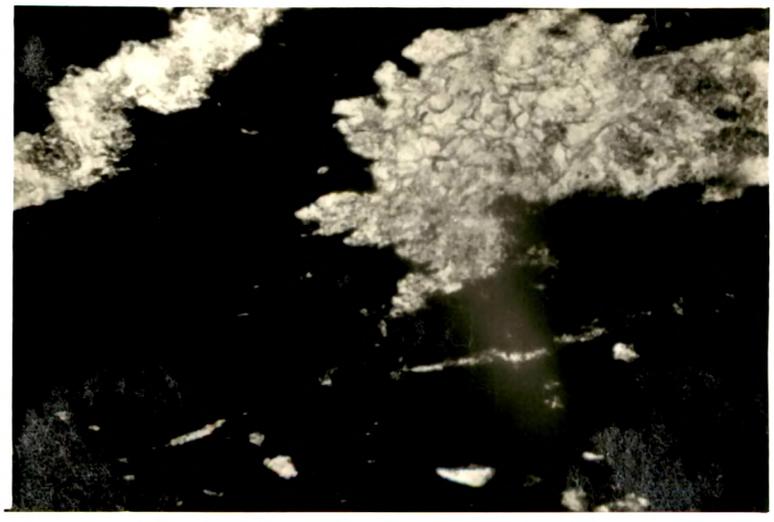
Photomicrograph of a sub-graywacke showing secondary overgrowth of quartz in optical continuity with the original quartz grains (cross nicols, X80)

PLATE 4.10



Photomicrograph showing the texture of a mature quartzite (cross nicols, X80).

PLATE 4.11



Photomicrograph showing patches of calcareous matter in purple slate (polarised light,X80).

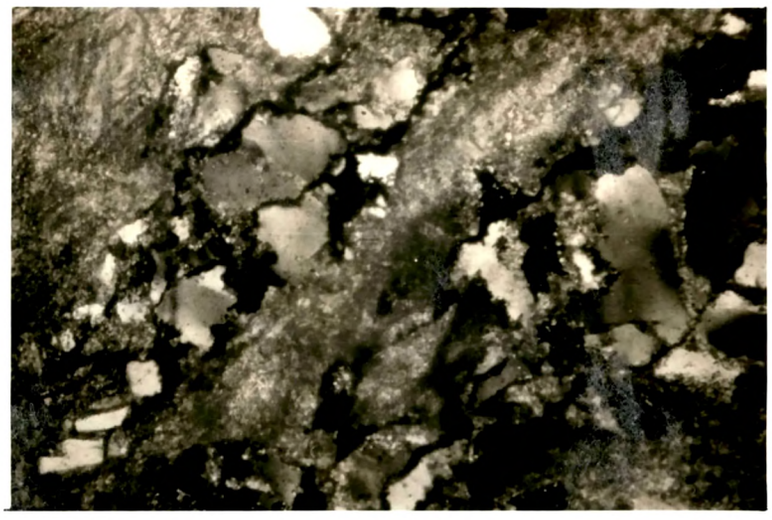
The limestone is of buff colour, fine grained and rather siliceous. Its thin sections reveal (Plate 4.12) a fine aggregate of calcite crystals interpersed with stray quartz grains. Quartz also occur as thin streaky aggregates. The quartzites, as stated above almost exclusively consist of quartz grains. The slaty layers of purple colour under the microscope do not reveal much. These are seen as almost opaque purplish brown mass with scattered tiny subangular fragments of quartz. These purple slates often contain thin layers of greenish grey variety. These light coloured layers show a foliated aggregate of sericite and quartz with some chlorite. The cleavage marked by the foliated mass often makes some oblique angle to the sedimentary layering (Plate 4.13).

Within the above sedimentary succession, occur two prominent trappean lava flows. These are definitely not sills. The author has found that these lensoid trap layers are also of spilitic nature.

STRATIGRAPHIC CONSIDERATIONS

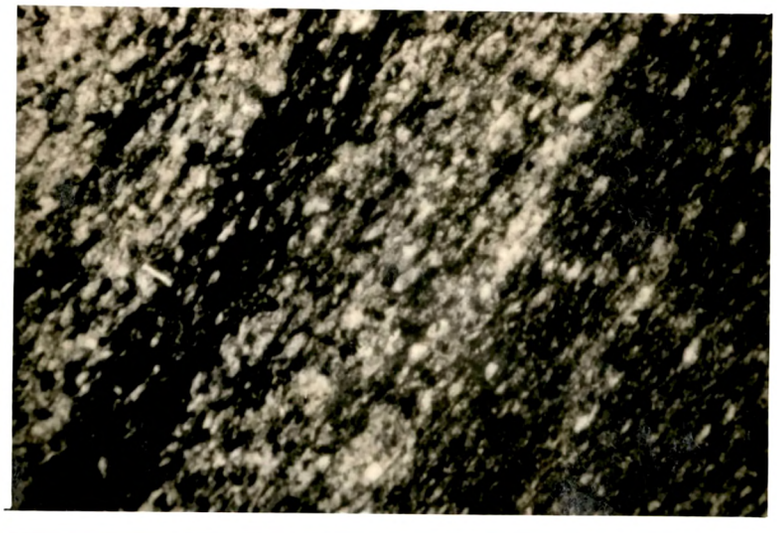
In the Simla area, Bhattacharya and Niyogi (1971) have included Blaini, Infra Krol and Krol into one group and found that the entire succession shows close

PLATE 4.12



Photomicrograph of limestone showing thin layers of interpersed quartz grains (cross nicols, X80).

PLATE 4.13



Photomicrograph of a purple slate wherein the cleavage makes a small angle with the sedimentary layering (polarised light, X80).

stratigraphic association, absence of marked unconformities, somewhat related environments of deposition and continuity of depositional history. According to these two workers, the Blaini does not appear to be glacial, or fluvioglacial. The bouldery and pebbly beds of Blaini, in all probability, represent slump deposits involving shallow water sediments. The angularity of pebbles and lack of sorting, do not represent glacial origin, but they indicate frequent submarine slides when portions of partly consolidated Blaini sediments together with a few extraneous pebbles contributed towards the formation of the pebbly mudstone. The presence of lensoid limestone also goes against the glacial origin; carbonate beds indicate warm shallow waters. Bhattacharya and Niyogi (op. cit. p.117) have, for the Blainis of Simla area, visualised "a shallow delta - front environment near the shore line where in local secluded clear-water pools, the carbonate lenses were formed." Rupke (1968) and Valdiya (1970) have also considered Blaini as shallow water turbidites.

The pebbly and bouldery beds of the Bhimtal-Bhowali area, typically resemble Blaini and the present author is inclined to suggest that these show considerable

affinity to graywackes. No unconformity is visualised between the quartzites and the underlying traps. Similarly, the formation upward gradually merges into an alternating sequence of quartzites with grey green and purple slates, which have been correlated with the Infra Krols by almost all previous workers. In view of the fact that no unconformity or any sort of break exists between the Infra Krols and the underlying sequence, it is not advisable to consider these rocks equivalent to the Nagthat. On the other hand, all the factors clearly indicate that these bouldery and pebbly rocks together with the overlying limestone and slates together with trap flow comprise the lower portion of the larger succession that is exposed to the west towards Naini Tal and which has been conclusively correlated with the Krol group. Under the circumstances, the present author is inclined to correlate these rocks with Blaini, taking them as equivalent to the early part of the Krol group of Bhattacharya and Niyogi (1971).

So far as the stratigraphic age of Bhimtal-Bhowali group is concerned, the author has relied on the opinions of the previous workers on the age of the Infra Krol and Blaini formations with which these rocks have been correlated.

Pilgrim and West (1928) considered that the Krol group could be of Upper Palaeozoic to Mesozoic in age. They did not think that the sequence was Pre-Cambrian as suggested earlier by Holland (1896). Auden (1932) was not very certain, but thought the Krols to be Permian to Mesozoic, on the basis of the Blaini Boulder Beds being of Uralian (Upper Carboniferous) age. In a subsequent paper on the Krol belt, Auden (1934) suggested Blaini and Infra Krol to be of Upper Carboniferous, while equating the Krol and Tal with Permo-Carboniferous, and Jurassic and Cretaceous respectively.

In the course of last 20 years, numerous workers, have succeeded in obtaining microfossil evidences from Tal, Krol, and Infra Krol formations and their findings have thrown some light on this complex problem of age. Sitholey et al. (1954) and Lakhanpal et al. (1968) have reported plant microfossils from the Infra Krol carbonaceous slates of Naini Tal area, and according to these workers, the assemblage indicates affinity to the microfossil fauna from the Permo-Carboniferous Gondwana rocks. Ghosh and Srivastava (1962) on the basis of the occurrence of certain fossil spores in the Infra Krol, Krol and Tal near Mussoorie in Garhwal, have assigned a Triassic age of Krol formation. Bhargava and Srikantia (1967) have

also suggested that Krol must be of Mesozoic age. They have arrived at this conclusion on the basis of a precise and detailed mapping.

More recently Sah et al. (1968) have published another paper on the palynological assemblage from the Infra Krol carbonaceous slates of Naini Tal area. These workers have reiterated the earlier views of Sitholey et al. (op. cit.) and Lakhanpal et al. (op. cit.), and suggested that the dominance of non-striate bisaccate pollen in these rocks, points to the lowermost part of the Triassic.

Bhattacharya and Niyogi (1971) have more or less accepted the Upper Palaeozoic to Jurassic age for the Blaini-Krol sequence originally suggested by Auden (1934). They have written (op. cit.,p.200), "The Krols because of their normal sedimentary occurrence over the supposedly Upper Carboniferous Blainis were thought to represent the Permian and Triassic by earlier workers. Though the glacial origin of the Blaini boulder beds and their consequent correlation with the Talchirs can be challenged, a probable Upper Palaeozoic to Jurassic age for the Blaini-Krol sequence is still suggested by recent finds of

animal fossils and spores in the south-east extension of this belt."

In the most recent work on the Krol belt, Bhargava (1972) has also mentioned that the Krol group is Permo-Carboniferous to Lower Cretaceous. He has considered the Blaini formation to be of glacic-marine origin, having been deposited at the time of the Talchir glaciation. He has assigned Blaini an Upper Carboniferous age.

On the basis of what has been described above, the rocks of the Bhimtal area could be correlated as under:

BHIMTAL-BHOWALI GROUP	Purple slates quartzites	Uppermost part of Blaini or Infra Krol (Permian)
	Trap flow	
	Quartzites with grey, green slates and limestone	Blaini (Permo-Carboniferous)
	Trap flow	
	Pebbly and gritty quartzites (sub-graywacke) with thin brown tuffaceous layers	
	Bouldery quartzites	
BHIMTAL TRAPS	Spilites, Tuffs and Tuffites	Pre-Blaini (? Lower Carboniferous)

----------? Unconformity----------

RAMGARH GROUP	Sheared granites and granophyres with xenoliths of phyllites and quartzites and ~~intrusive spilites~~ within	Jaunsar (? Ordovician to Devonian)

The rocks of the Ramgarh group, occurring in the study area, viz. the sheared granites and granophyres, might be representing late intrusions into the Ramgarh group of metasediments. The author is not in a position to assign any conclusive age to these rocks. It is quite likely that these represent Tertiary acid igneous activity (Pre-Krol Thrust) to which belong the granophyres and granites of Amritpur-Ranibag (in the immediate south). Patel S.G. and Desai S.J. who are investigating the Ranibag-Amritpur area (personal communication), are however inclined to suggest that the granophyres which occur in close association with the foliated traps (spilites) could turn out to be metasomatised keratophyres. If this is true, then the sheared felspathic and quartzose rocks lying above the Ramgarh thrust, might be older in age and related to the mafic activity that gave rise to the trappean rocks of Blaini age.