CHAPTER 3

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

The Almora thrust in ~~the~~ Kumaon has been so folded that it outcrops more than once, and is recorded as several synformally folded remnants. The Almora nappe bounded by the South and the North Almora thrusts (Merh, 1968), forms a huge crystalline synform occupying a large area in Kumaon. The Baijnath nappe is a smaller synformal structure further north of the Almora nappe. The Someshwar area lies between these two synforms, and contains the younger rocks of the Krol nappe tectonically underlying the older rocks. Thus, the study area includes portions of three distinct tectonic units - the Almora nappe, the Krol nappe and the Baijnath nappe (Fig. 3.1 & 1a.)

The metasedimentary sequence of the Krol nappe forms an asymmetric anticlinal structure, between the North Almora thrust and the Kausani thrust. This structure has been designated by the author as the 'Someshwar anticline'.

The North Almora thrust in the southern part of the study area extends roughly NW-SE and dips due SW. The thrust is cut by an ESE-WNW reverse fault in its western part. This fault to the east extends along the crest of the anticline in the Krol nappe rocks. The author has referred to this fault as the 'Lod-Niral reverse fault'.

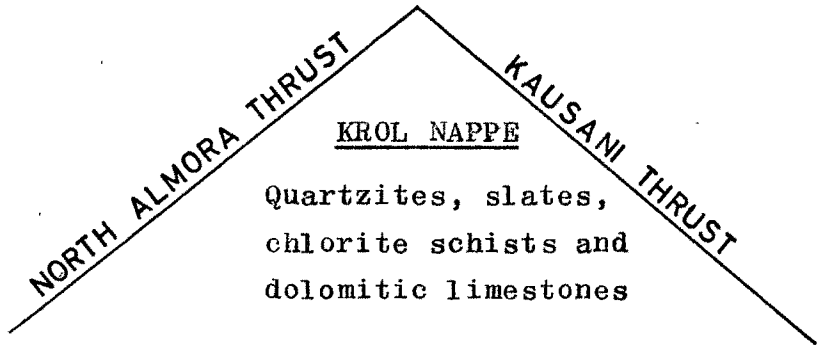
The North Almora thrust in the south separates the Almora and the Krol nappes, while the Kausani thrust in the north separates the Krol and the Baijnath nappes. The Kausani thrust and the North Almora thrust, dipping north-eastward and southwestward respectively are, infact, two flanks of the antiformally folded Almora thrust, and between these two flanks lie the rocks of the Krol nappe. Thus in the north, above the Kausani thrust, lie the older rocks of the Baijnath nappe, while to the south, the North Almora thrust separates the older Almora nappe rocks. The relationship shown by the various rock formations of the three tectonic units is as follows:

ALMORA NAPPE

Migmatitic gneisses, quartzites, phyllonites and epidiorites

BAIJNATH NAPPE

Migmatitic gneisses, phyllonites and epidiorites



The crystalline Almora and Baijnath nappes have been correlated to the Chandpurs (Auden, 1937; Heim and Gansser, 1939; Gansser, 1964 and Merh, 1968) while the Krol nappe comprises a Deoban-Nagthat sequence, both belonging to the Jaunsar Series (Cambrian-Ordovician).

ALMORA NAPPE

The constituent rocks of the Almora nappe within the limits of the study area are for the most part, migmatitic gneisses which have been extensively sheared along many narrow zones. In addition to these, there are also quartzites and phyllonites with two minor sills of epidiorites. From N to S the following ascending sequence is recorded:

3. Augen and Porphyroblastic gneiss with frequent narrow zones of mylonitised gneisses.

2. Quartzites

1. Phyllonites

-----North Almora Thrust-----

Phyllonites

All along the North Almora thrust, these rocks form a 600 metres wide band. The constituent rocks resemble strongly foliated greenish grey phyllites. Obviously, these rocks are derived by the intense granulation of the mica schists. In the present area, the original mica schists are not encountered but Vashi (1966) has worked out an ideal sequence of the retrogressive changes along the southern flank of the Almora thrust at Upradi (south of Ranikhet) and he has clearly established that the phyllonites are derived from the mica schists. Misra (1971) working along the Dwarahat area has also established a similar origin for phyllonites along the North Almora thrust.

The phyllonite band is ideally traced from E of Sunari for 8 km due NW where it is truncated by the Lod-Niral reverse fault. Due to lack of exposures, it is not possible

to record the presence of phyllonites in the area east and southeast of Sunari. Similarly, the exact nature of these rocks in the NW where they meet the reverse fault is also obscured due to paucity of outcrops. Within the phyllonites occur frequent lenses and bands of quartzites which quite often show overfolding. These folds are perhaps related to the thrust movement, and indicate folding due to drag effect. The axes of these drag folds plunge due SW. A large sill of epidiorite 2 km long occurs in the phyllonites and it is ideally seen south of Kangad.

The phyllonites contain linear structures of two generations. The early lineation of the nature of striations and axes of quartz veins shows conspicuous development and is seen plunging moderately due SW. Superimposed over this early lineation are, well defined puckers due to a faint crinkling of the phyllonitic cleavage. This pucker lineation shows a gentle plunge due SE.

Quartzites

Quartzites occur as a prominent band 300 to 800 metres thick, separating the underlying phyllonites from the overlying gneiss. This quartzite formation starts from Bhatgarh

in the SE and extends WNW upto Malonj. The constituent rocks are greyish white to yellowish quartzites, extensively sheared and rendered somewhat friable. The shearing is obviously an effect of the North Almora thrust. These quartzites do not show any minor structures, planar or linear, except the abundant shear planes.

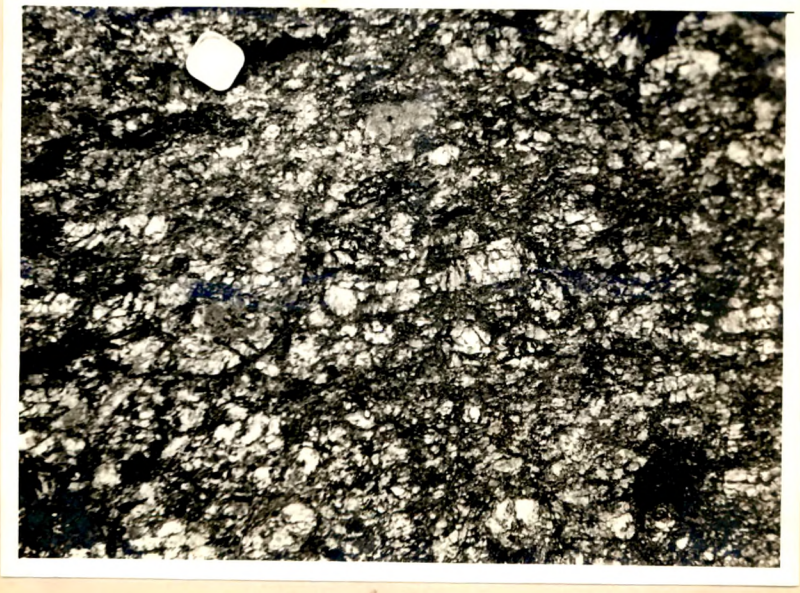
Migmatitic Gneisses

The gneissic rocks, resting structurally above the quartzites comprise the most prominent formation of the Almora nappe in the area. The entire gneissic formation is extensively sheared along numerous narrow zones. Along these shear zones, the gneisses are seen pronouncedly mylonitised and form a fine-grained streaky foliated greyish white rock (Plate 3.1). As a result of this shearing, the gneisses from N to S show intermittent bands of showing varying degrees of mylonitisation. On the whole, the degree and extent of shearing tends to decrease southward, and farther from the thrust, the original nature of the gneisses is better recorded (Plate 3.2). The author has designated them as migmatitic, because the metasomatic origin of the gneisses of Almora nappe has been conclusively established by Pande (1963), Merh and Vashi (1965) and Desai (1968).

PLATE 3.1

Mylonitised gneiss (Loc. north of Manan).

PLATE 3.2



Unmylonitised porphyroblastic gneiss
(Loc. south of Manan).

In the present area, the transition of mica schists to coarse gneisses is not so well defined and most of the rock consists of coarse gneiss containing augens and well formed porphyroblasts of felspars. These are almost the end products, and the various early stages of migmatisation described by Merh and Vashi (1965) are not encountered.

The structural elements of the gneissic rocks comprise two S-planes and three linear structures. The main gneissic foliation represents the original schistosity and this structure has been found to be the axial plane of an early isoclinal folding by Merh and Vashi (1965). The shear planes in the mylonitised zones in gneisses (related to the North Almora thrust movement) represent another S-surface. Both the planar structures are parallel. Of the three linear structures, the earliest comprises fold axes of minor folds in quartzites (Plate 3.3), small quartz rods and boudins (Plate 3.4) and a lineation due to mineral orientation (Plate 3.5) - all related to the isoclinal folding. This lineation plunges at moderate angles due SSW to SW. Another lineation superimposed on the previous one is a fine puckering related to the microfolding of the schistosity, which developed at the time of the folding of the Almora thrust and the formation of the

PLATE 3.3

Drag fold in Almora nappe quartzites near the North Almora thrust (Loc. south-west of Sunari).

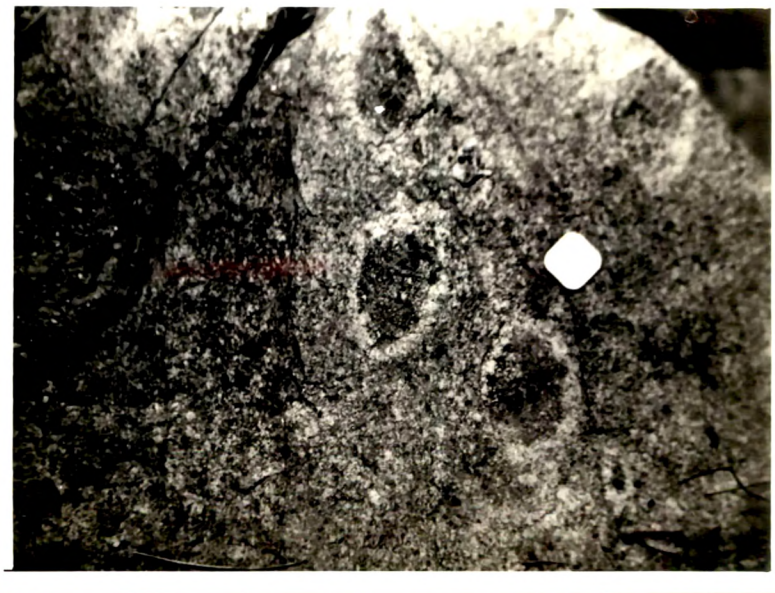
PLATE 3.4

Quartz rod in gneisses (Loc. north of Manan).

PLATE 3.5

Lineation due to mineral orientation in gneiss. (Loc. south of Manan)

PLATE 3.6



Ovoids of quartz-tourmaline in mylonitised gneiss. (Loc. north of Manan)

Someshwar anticline (Merh, 1968). Yet another linear structure, developed rather faintly, is the axes of open gentle flexures on mesoscopic scale, which tends to plunge due S to SSW.

A prominent 300 metres wide sill of epidiorite is seen to occur in the gneisses SW of Manan. It starts from a place 2 km south of Bamnigad and extends due SSE for about 3 km. This igneous body represents a late intrusion and is free from the effects of regional metamorphism. North of Manan, the mylonitised gneiss surfaces at places show 'ovoids' with a quartz felspar rim and a tourmaline rich central portion (Plate 3.6). These have been found to be spindle-shaped or elliptical bodies in three dimension.

A major fault striking SSW-NNE cuts the gneisses. Further north this fault is more prominent and also cuts almost all the formations of the Krol nappe. The author has referred to this fault as the 'Udyari-Chauthuli fault'. It appears that this fault extends for several km in SSW right upto Daulagad nala near Majhkhali.

Two SSW-NNE striking minor faults, viz. the Bandalchak-Diyari fault and the Chunia fault extend for about 5 km each. While the former cuts across the gneisses, quartzites, phyllonites, the North Almora thrust and the Lod-Niral fault; the latter has shifted the western extremity of the quartzites northwards for about a km.

BAIJNATH NAPPE

Only a very small portion, (approximately 5 sq km) of the Baijnath nappe lies within the limits of the study area. The Kausani thrust which separates this unit from the underlying Krol nappe rocks, is, as stated already, the northern continuation of the North Almora thrust, and thus the rocks of the Baijnath nappe are identical to those of the Almora nappe except that they differ in their tectonic and geographic setting. Being on the northern flank of the antiform, they dip due NW. The NW dipping Kausani thrust is seen cut by a NS reverse fault at its western end and this fault has pushed the western side further north. This fault has been called as '*Bijoria fault*'.

The constituent rocks of this nappe are migmatitic gneisses, similar to those of the Almora nappe, but show more extensive shearing due to the nearness of the Kausani thrust. The Baijnath nappe migmatitic gneisses contain at places minor sills of epidiorite. These sills are quite small; the bigger ones never exceed a few metres in thickness and extend for small distances only - not more than 100 to 150 metres.

Structurally, the Baijnath nappe is less interesting. The gneisses show linear structures related to the early isoclinal folding only. These are drag folds and minor folds in quartzo-felspathic veins within the gneisses and show a moderate plunge due NW. Structural elements related to the later fold episodes are generally scarce.

KROL NAPPE

The rocks of the Krol nappe, placed tectonically beneath the Almora thrust, form an asymmetrical anticline the two limbs of which do not correspond. The folded and faulted metasedimentary rocks of the Krol nappe show the following stratigraphical succession:-

Lod Series		Massive quartzites
----------		Unconformity ----------
Someshwar Series	◊	Chlorite schists
	◊	Upper slates
	◊	Dolomitic limestones
	◊	Lower slates and quartzites

The above sequence of the Krol nappe is so folded that the upper cover of Lod quartzites forms a fairly open upright anticline, beneath which the rocks of the Someshwar

series show an overfolded anticline, the axial-plane of which is dipping due north. As already mentioned, the crest of the Someshwar anticline is faulted such that its southern limb has been downthrown and practically truncated.

Just underlying the SW dipping North Almora thrust and in a direct contact with it, is the SW dipping southern limb of the quartzitic cover. The quartzites show an almost east-west trend, and are greyish white, highly crushed and rather brittle rocks. The crushing is obviously, on account of the proximity of the North Almora thrust.

The SW dipping quartzites of Lod series appear at their western extremity near the villages Phalta and Bilori and pass eastwards and southeastwards almost parallel to the thrust through the villages Malakholi, Rautela, Tana, Paya, Okali, Bajel and Tapodiar.

As the crest of the Someshwar anticline is faulted and the southern limb of it downthrown, northward on crossing the southwest dipping quartzites, are immediately encountered the oldest formations of the Someshwar series - a group of purple, green and grey slates interbedded with quartzites. These have been termed as 'Lower slates and quartzites of the Someshwar series'. This formation is

highly folded, and good exposures are recorded at the villages Jaicholi, Phalia Bhanarat, Someshwar, Baigania, Bajel, Mahar, and Dhumangaon. The rocks,rapidly alternating slates and quartzites show tight asymmetrical folds on mesoscopic scale with gentler northern limbs and steeper southern limbs (Plate 3.7). The axial-planes almost invariably show steep dips due north and the fold hinges plunge moderately due NW with amounts varying from 25 to 45° (Plate 3.8). This folding of the slate-quartzite formation is clearly related to the Someshwar anticline, and the slaty cleavage shows a flexural-slip origin. This cleavage is parallel to the bedding of interbedded quartzites (Plate 3.9). The slates at places show distinct puckers obviously related to the NW plunging folds.

Above the slates and quartzites is a prominent band of cream coloured and grey, cherty, dolomitic and magnesitic limestones termed the 'Dolomitic limestones of the Someshwar series'. At places, the limestone beds show numerous folds, related to the major anticline (Plates 3.10 and 3.11). The limestone band extends roughly ENE-WSW and abuts against the Lod-Niral fault, just south of the village Diyari. Thus the limestone band constitutes the northern limb of the anticline. The villages Khari, Jal, Jaloli, Mala, Khakoli

PLATE 3.7

Overfolded slates and quartzites (Loc. NW of Someshwar).

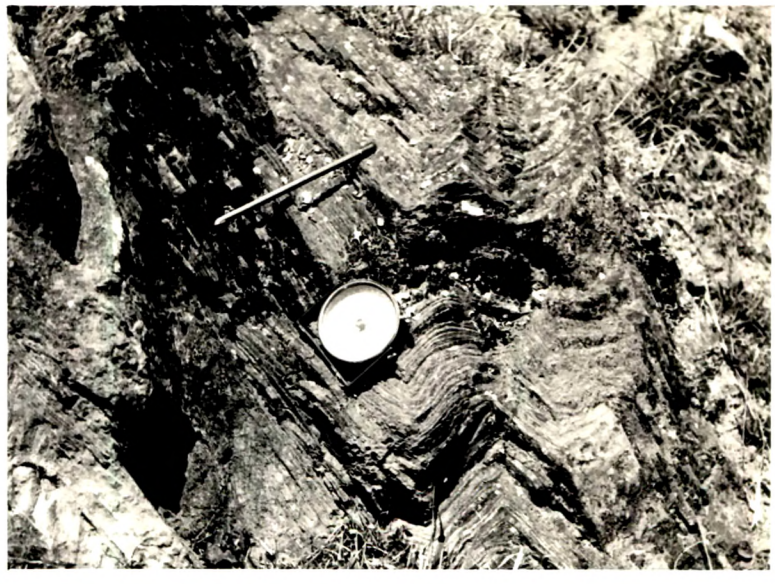
PLATE 3.8

Mesoscopic F_2 fold hinge in Lower slates and quartzites (Loc. east of Someshwar).

PLATE 3.9

Slaty cleavage parallel to the quartzite bedding (Loc. east of Someshwar)

PLATE 3.10



F_2 folds in limestones (Loc. Near Jal)

PLATE 3.11

F_2 folds in limestone (Loc. near Jaloli)

and Chauthuli are situated on or near the limestones. Near Chauthuli, they are cut by the Udyari-Chauthuli fault such that the eastern side shows a lateral displacement of about 1.5 km southward. This faulted counterpart passes through the villages Banora, Digra, and Kakrai. Minor folds are recorded at some places and these show folding with moderately plunging axes and near vertical axial planes. Near the villages Jaloli and Mala, the limestones contain stromatolites of the type Collenia coloumnaris in the form of laterally linked hemispheroids (Plates 3.12 and 3.13) and vertically stacked hemispheroids (Type LLH-C. SH-V of Logan et al.,1964). The attitude of the stromatolites points to an univerted position of the limestones.

The slaty rocks that overly the limestones are definitely younger and have been termed the 'Upper slates of the Someshwar series'. These consist of variegated, cleaved argillaceous rocks with occasional thin layers of quartzites. The slates are greenish, purplish and grey, and quite often show clear preservation of original sedimentary laminations. The slaty cleavage, though at most places makes small angles to the laminations, in some folded specimen typically exhibits folding due to slip along planes that mark the axial plane (Plate 8.1).

PLATE 3.12

Stromatolites as seen on bedding plane in limestones (Loc. east of Mala)

PLATE 3.13

Stromatolites as seen across the bedding plane in limestone. The bedding plane is shown by the trend of the pencil. (Loc. east of Mala)

These slates form a rather prominent and continuous exposure entering the study area in the east and extending beyond Someshwar in W where they get truncated by the Lod-Niral fault near Balot.

The outcrop extent of these rocks is quite variable mostly on account of folding into local anticlines and synclines. These folds, recognised by the outcrop pattern, are difficult to put on the map due to obliteration of laminations and a strong development of slaty cleavage of axial plane type. The cleavage shows variable dips.

The slaty rocks show a distinct cleavage bedding intersection and this lineation plunges moderately due NNW.

Overlying the slates are the youngest formation, viz. the Chlorite schists of the Someshwar series, with a thickness of 500-700 metres. In the field, these dull green foliated rocks are seen to contain thin streaks of quartz. These outcrop all along from the eastern boundary right upto Lod in the west, where the Lod-Niral fault truncates them. The Ladhyura and Lakhnari faults cut this formation in the western half and show a NW shift of the faulted block. These are essentially chloritic schists and in the western

half, show tiny folds of two generations which are typically preserved in the quartzitic streaks. The axes of earlier folds show a NW plunge while the late flexures plunge due NE. The foliation is seen to dip at moderate angles northward except in the western extremity where the dips are rarther gentle.

Lod series - a thick sequence of quartzites rests unconformably over the chlorite schists and dips due NW to NE, forming the north dipping limb of the anticline. These occupy a large tract in the northern portion of the area, and make up almost all the high peaks and ranges of the region. The quartzites, as already stated, are gritty to massive and rarely show sedimentary bedding. As compared to the southern limb, these quartzites are hard, compact and relatively free from the effects of shearing. No minor structures, planar or linear, are recorded. The general strike of the formation, is ESE-WNW in the east and centre, while in the western part, west of Bhatina Camping ground, the strike is almost NW-SE. The dips are due NNW and NE respectively and thus the quartzite cover forms a synformal structure around Bhatina. This fold has been referred to as the 'Bhatina synform'. The Ladhyura and Lakhnari faults cut these quartzites also.

SUMMARY

From the above account of the field characters, distribution and structure of the different rock formations of the three tectonic units, it is evident that the Someshwar area has a complicated metamorphic and structural history. The two nappes, Baijnath and Almora- indicate somewhat different evolution as compared to the Krol nappe. Each nappe is characterised by distinctive lithological and structural features (Fig. 3.2), and the author has synthesised the data furnished into a connected sequence summarised below.

The earliest event in the orogenic activity was the large scale isoclinal folding 'F_1' during which geosynclinal metasediments were lifted up as numerous isoclinal folds. It was with this folding that the main progressive phase of regional metamorphism coincided, and as a result the principal foliation (schistosity) characterises the axial plane of the folding.

This deformation was responsible for the development of the small folds in the quartzites and quartz veins of the Almora and Baijnath nappes.

The isoclinal folding culminated into the Almora thrust, and the movement of rock masses along this thrust induced

intense shearing and granulation in the rocks, and as a result a strong shear cleavage developed in the mylonitised gneiss and the phyllonites. Retrogressive changes leading to breakdown of several high grade minerals into chlorite and sericite are quite obvious in the field itself.

The Almora thrust sheet at some later date was folded into a number of synforms and antiforms. This folding F_2 gave rise to the Someshwar anticline such that the northern flank of the Almora thrust now characterises the Kausani thrust, while its southern flank is known as the North Almora thrust. The Almora nappe rocks of the study area lie on the south dipping limb of the huge synform. The effects of this folding (F_2) are quite varied. In the Almora nappe, the crystalline schists have developed a distinct crenulation cleavage, though in the study area its development is sporadic. In the rocks of Krol nappe, this folding has given rise to a flexural-slip type cleavage in the lower slates and quartzites while an axial plane type slaty cleavage has developed in the upper slates.

A superimposition of NNE-SSW folding F_3 is the next important event preserved in the rocks. This gentle folding gave rise to the Bhatina synform which was responsible for imparting a NNW plunge to the Someshwar anticlinal structure.

Considerable complexity was impressed upon the Someshwar anticline by a regional dislocation - the Lod-Niral reverse fault - which has affected a part of the anticlinal crest and also the North Almora thrust in the west. It is the recognition of this fault that has elucidated the structure of the area.

The last event of orogenic upheaval is revealed in the form of several faults cutting the various rocks and affecting all the three nappes.

In the Part II and Part III of the thesis, the author has given a systematic account of the abovementioned geological evolution in detail.

PART II : ALMORA AND BAIJNATH NAPPES