PART III : KROL NAPPE

CHAPTER 7

STRATIGRAPHY AND LITHOLOGY

As already mentioned earlier, the rocks of the Krol nappe are placed tectonically beneath the North Almora and Kausani thrusts, forming an asymmetric anticline plunging due WNW. The Krol nappe rocks are younger than those of the overlying Almora and Baijnath nappes. The structural complexities of the anticline have prevented the previous workers from visualising the correct stratigraphy of these rocks.

STRATIGRAPHY

Valdiya (1962) assumed that the calc-zone of Pithoragarh, which is the eastern extension of the

Someshwar rocks, showed an inverted sequence. According to him, the thick sequence of quartzites, that comes over the limestones, is in fact older (Berinag Quartzites) while the slate-quartzite formation below the calcareous and magnesitic horizon is younger (Sor slates etc.). He has suggested this inversion mainly on the basis of the attitudes of the stromatolites found in them. Observations made by Valdiya on cross-beddings and ripple marks of the quartzites of the Pithoragarh zone indicated again an inverted sequence. Gansser (1964, p.95) has, however, written that, "while some sections are undoubtedly inverted, I would not follow Valdiya in applying this concept to the whole sedimentary section of the inner zone in the Lower Kumaon Himalayas". The author fully agrees with the views of Gansser, and on the basis of his investigations in the Someshwar area, he has conclusively established that the sequence is not inverted. The author too has recorded stromatolitic occurrences from Someshwar and their critical field study has revealed that the inversion shown by these algal structures is always a local phenomenon observed on the inverted limbs of macroscopic folds related to the Someshwar anticline. To the author, it appears that in the Pithoragarh area the anticlinal structure is fairly tight and overfolded such that the true stratigraphic sequence is rendered confused. As Shah and Merh (1968) have rightly suggested, the entire calc-zone constitutes an asymmetrical anticline with a steeper southern limb in Dudatoli, Chaukhutia and Someshwar region, and which further southeast is so overturned that at Pithoragarh it forms an almost recumbent structure.

As regards the age of the various rock formations, the author has mostly followed Auden (1937) who considered the limestones of Dwarahat (a western extension of the limestones of Someshwar) to be equivalent to the Deoban limestone of Chakrata. The Deobans have been found to be "certainly Pre-Blaini" by Pilgrim and West (1928) and perhaps a part of the Jaunsar series (Cambrian-Ordovician). Gansser (1964,p.94) has correlated these calcareous rocks of Kumaon with the Kakarhatti limestones in the Simla slates and with the Shali limestones of the Shali window. Heim and Gansser (1939,p.220), though not sure regarding the stratigraphic position of these rocks, assigned with some uncertainty, a much younger age to this calc-zone, and according to them it was probably equivalent to the Krol series.

Following Heim and Gansser, Das (1966) also considered the limestones of Chaukhutia-Dwarahat to be Krol rocks of Permo-Carboniferous age, but according to Misra and Valdiya (1961,p.36) the limestone-slate series of Pithoragarh, "does not resemble and can not be correlated with the Krol series. The lithology and sequence of rocks are at considerable variance with those of the type area of the Krols. The lithology of the Pithoragarh calcareous zone has many things in common with that of the Deoban limestone of the Chakrata area. This formation is regarded as equivalent to the Kakarhatti- and Naldera-limestone of the Simla slates". Misra & Valdiya found that the similarity was not only in regard to the lithology, but also in respect of the presence of stromatolites, which were referred to by Pilgrim and West (1928) as "pseudo-organic structures".

The various lithological and organic evidences collected by the author have led him to correlate the Someshwar sequence with Deobans and Nagthats, and thus he has preferred to fall in line with Auden, Gansser and Valdiya.

Considering the structural pattern, and the extensive field data, the author has worked out the following stratigraphic sequence for the Krol Nappe rocks:-

	Rock Types	Equivalents	
Lod series	Quartzites	Nagthats	
------Unconformity------			
Someshwar series	Chlorite schists Upper slates Dolomitic limestones Lower Slates and Quartzites	Deobans	Jaunsars (? Cambro-Ordovician)

LITHOLOGY

In the following pages, a brief but critical account of the various aspects of the lithology of the rocks occurring at different horizons, has been given. The mineralogy, petrography and chemistry of the rocks have enabled the author to understand the original nature of the sediments of the Krol Nappe sequence.

Lower Slates and Quartzites

This formation, exposed around the Someshwar village and to its E and ESE, consists of interbedded slates and quartzites.

The slates are brownish yellow, purple, grey and greyish green in colour. The variation in colour is so rapid and frequent that sometimes a single specimen may possess all the colours. These various hues are clearly due to the different degrees of oxidation of iron in the slates. Thus the factor controlling the colour of the slates is the ferrous and ferric iron content in them. According to Pettijohn (1964,p.347), "the red slates contain no more iron than do those which are black, grey or green. The colour differences reflect only the state of oxidation of the iron. Red shales are so coloured because of the presence of finely divided ferric oxide (hematite). In the green and black shales the iron is largely in the ferrous state".

In the following table (Table 7.1) the percentages of Fe_2O_3 and FeO for the slates of various colours are given:

TABLE 7.1

FeO and Fe_2O_3 percentages in slates

	FeO %	Fe_2O_3 %
Brown slates	2.4000	4.5216
Green slates	3.3660	3.5928
Purple slates	2.0400	3.5240

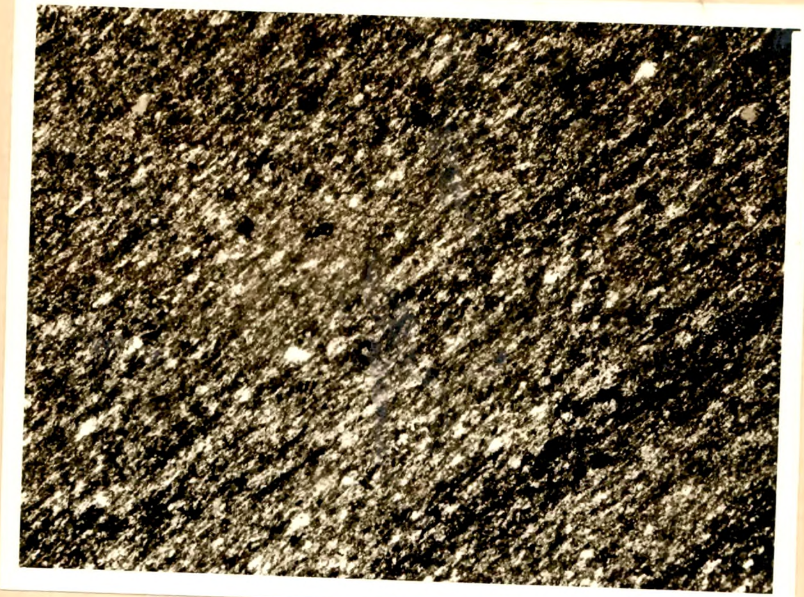
It is obvious that a predominance of Fe_2O_3 has been the prime cause of a red colouration while the green slates tend to contain a higher percentage of FeO.

The slates are highly cleaved and jointed. Under the microscope, the thin sections show a very fine-grained foliated mass in which tiny specks of muscovite, chlorite and tiny grains of quartz are just recognised (Plate 7.1).

The chemical compositions of the three representative colour types of slates are given in Table 7.2 and it is seen that the same corresponds well with the average composition of shales given by Pettijohn (1957,p.344).

The interbedded quartzites form 1 metre to 50 metres thick layers of fine-grained purple to cream coloured rock. The slaty cleavage is always parallel to these quartzitic layers. In thin sections, the quartzites exhibit an equigranular aggregate of somewhat rounded to sub-angular quartz grains, embedded in a fine argillaceous matrix (Plate 7.2). The individual quartz grains are surprisingly free from strain-shadows and this very clearly suggests that the strain was mostly taken up by the argillaceous layers.

PLATE 7.1



Texture of the slates from Lower slates and quartzites.
(Photomicrograph: Crossed Nicols X80)

PLATE 7.2

Texture of the quartzites from Lower slates and quartzites.
(Photomicrograph: Crossed Nicols X50).

TABLE 7.2

Chemical composition of slates

	Someshwar Area			Average C (Pettijohn)	Average E (Pettijohn)
	Green slates	Brown slates	Purple slates		
SiO_2	64.9294	72.5000	63.6560	60.15	56.30
Al_2O_3	12.8463	8.7144	16.1558	16.45	17.24
Fe_2O_3	3.5928	4.5216	3.5240	4.04	2.25 3.23
FeO	3.3660	2.4000	2.0400	2.90	3.66 5.09
Na_2O	0.4992	3.8064	1.9968	1.01	1.23
K_2O	3.9620	3.1152	1.4976	3.60	3.79
MgO	5.3919	2.1994	6.7076	2.32	2.54
CaO	0.8912	0.5608	1.1015	1.41	1.00
MnO	-	-	-	T	T 0.1
P_2O_5	-	-	-	0.15	0.14
TiO_2	-	-	-	0.76	0.59
Loss on Ignition	5.6050	3.0000	5.3500	-	-
Total	100.0748	100.7718	101.7393	100.46	100.00

C = Average of 51 Palaeozoic shales (Pettijohn,1957,p.344).

E = Average of 33 Pre-Cambrian slates (Pettijohn,1957,p.344).

Dolomitic Limestones

These can be broadly classified into two main varieties, viz. stromatolitic and non-stromatolitic.

The non-stromatolitic variety is more prevalent and is recorded almost in all parts of the limestone horizon. It is a cream coloured or bluish fine-grained rock, which typically shows distinct lamination and bedding at most places. These sedimentary structures are locally obliterated. In a broad way, the samples from the eastern part show poor bedding or lamination but those from the western half have ideally preserved these structures. The rock is seen to contain frequent nodules of chert.

Under the microscope, this limestone is seen as alternating layers of fine-grained and coarse-grained calcite, and some dolomite (the presence of dolomite could be checked only by staining the slide with Alizarin-S red). Fine grains of quartz are always present, and quite often they form distinct streaks.

The stromatolitic variety, though only occasionally recorded, is of considerable importance. The rock is of greyish white colour and shows less well defined stratification. The bedding planes are rather uneven and mostly marked and identified by the zone of stromatolites. In cross sections, the lines joining the convex surfaces of the stromatolites could be taken as the depositional bedding.

The stromatolites show a laterally linked hemispheroidal column form and can be favourably compared with the type LLH of the code letter classification of Logan et al. (1964). These hemispheroids are closely linked at most of the places but show occasional spaced linkage giving rise to an LLH-C type transitional into LLH-S. The space intervening between the columns and sometimes between the laminae is filled with broken chert. Apart from this cherty material the stromatolites consist almost entirely of ferron dolomite which gives sky blue stains when etched with HCl fumes and treated with Alizarin-S red.

In plan, the stromatolitic laminae show round to oval parallel sections indicating a concentric vertical stacking, corresponding to type SS-C of Logan et al.(1964). The diameter of the stromatolites varies from 10 cm to 15 cm but at places is as much as 25 cm (Plate 7.3).

PLATE 7.3

Stromatolitic structure showing well developed hemispheroids (Loc. east of Mala).

The basal radii for individual colϕumns, however, are more or less constant. The stromatolite axes show an inclination of nearly 75° to 80° to the bedding plane in most of the cases. They compare favourably with the type <u>Collenia coloumnaris</u> (Fenton & Fenton) described by Valdiya (1969, p.8) from the calc-zone of Pithoragarh and by Dixit (1960, p.87) from the Girichhina area, east of Someshwar.

Under the microscope, the stromatolitic variety of limestones is seen to consist of a greyish, dense, fine-grained mass. The rock exhibits alternating layers of lighter and darker colours. The lighter layers are relatively coarse while the denser ones are extremely fine-grained. The dominant mineral is, of course, calcite, though quartz is mostly present and shows a variable proportion and often forms patches. Pyrite crystals are quite common, scattered throughout the rock mass.

The chemical analyses of two typical samples of stromatolitic variety - one free from cherty material and the other containing nodules of chert, are given in Table 7.3.

TABLE 7.3

Chemical composition of limestones

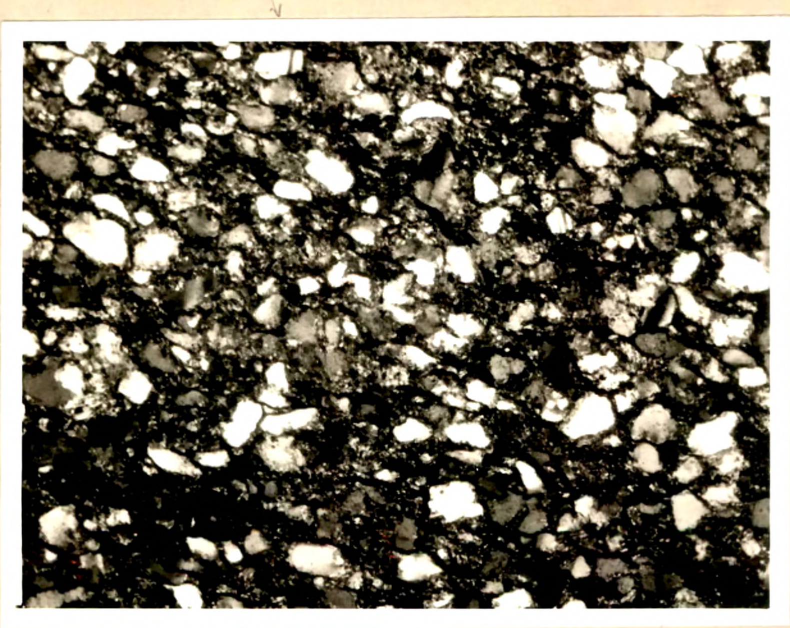
	Variety free from chert	Variety containing chert nodules
SiO_2	11.5400	36.9500
Al_2O_3	5.6454	3.6748
Fe_2O_3	0.8636	0.5748
FeO	1.2000	1.6400
Na_2O	3.1208	5.5606
K_2O	0.3120	0.4368
MgO	23.1231	11.2940
CaO	36.3536	20.4692
MnO	-	-
P_2O_5	-	-
Loss of Ignition	21.3060	21.7540
Total	102.4816	102.3756

Upper Slates

The formation, resting over the limestones, is dominently slaty with a few occasional quartzite layers. The slates are quite identical to those below the limestones and show greenish and greyish colours. Purplish or brownish slates are also recorded, and thus from the colour point of view, these slates are quite variegated. An interesting feature of this slaty formation is the axial plane relationship shown by the cleavage with folded sedimentary laminations at many places. The dominent rock is a fine grained slate, but occasional patches of coarser sandy argillites are seen to occur.

Petrographically, the variegated slates of this horizon are in no way different from those of the lower slates and quartzites below the limestones. The more argillitic portions show a higher proportion of bigger quartz grains (Plate 7.4). The chemical composition of the argillites is given in Table 7.4.

PLATE 7.4



Texture of a quartose argillitic patch in upper slates.
(Photomicrograph: Crossed Nicols X30)

TABLE 7.4

Chemical composition of sandy argillites

SiO_2	69.5000
Al_2O_3	7.2124
Fe_2O_3	2.6756
FeO	3.2000
Na_2O	3.1824
K_2O	0.4992
MgO	2.3123
CaO	3.3648
MnO	-
P_2O_5	-
TiO_2	-
Loss on ignition	6.0000
Total	99.9067

It is interesting to note that the chemical composition of these apparently more quartzose patches infact differs very little from that of the average shale. Thus it is inferred that these patches reflect only a grain-size variation of the original shales.

Chlorite Schists

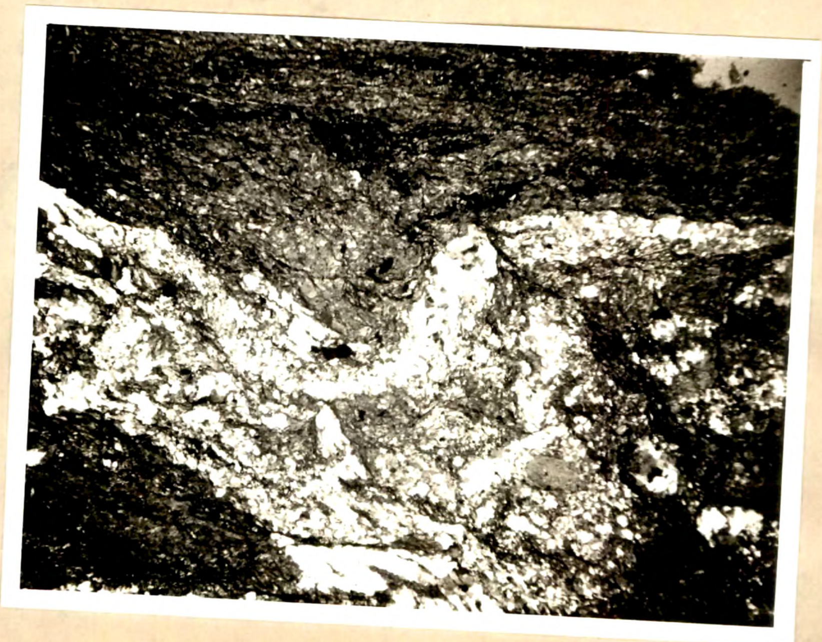
These are dull green foliated rocks consisting of fine micaceous material with intervening streaks of mainly fine-grained quartz. Somewhat coarser aggregates of quartz are also quite common.

Under the microscope, the finely foliated mass is seen to consist of quartz, chlorite, biotite, muscovite with some albite and epidote. Well defined layers of crystalline quartz alternate with those of chlorite-biotite. The schistosity is quite often deformed (Plate 7.5) especially in the samples collected from the western portion. Occasionally, tiny albite grains with rims of quartz are also seen developed.

Chemically, these schists show the composition given in Table 7.5.

In their present state, these chlorite schists reveal very little about their parentage. Munshi, Misra and Merh (1972) working in the nearby Dwarahat region to the west, have come across some clear evidences of these rocks being originally igneous. It is quite likely that these rocks were originally lava flows or sills, and under conditions of extensive shearing during folding,

PLATE 7.5



Contorted silliceous bands in chlorite schist.
(Photomicrograph: Crossed Nicols X30)

TABLE 7.5

Chemical composition of chlorite schists

	I	II	III
SiO_2	61.5500	60.4900	62.9400
TiO_2	-	-	-
Al_2O_3	16.1338	11.4348	11.4232
Fe_2O_3	3.9346	3.6438	5.7160
FeO	2.2000	4.4400	5.7000
Na_2O	4.4928	4.2432	4.2542
K_2O	4.1184	0.9984	2.4960
MgO	3.7841	5.9053	3.8200
CaO	0.8912	0.9814	0.7010
Loss on Ignition	3.1200	3.7000	3.0000
Total	100.7718	100.1199	99.6214

have metamorphosed into chlorite schists. Moorhouse (1964, p.165) writes, "Immense thicknesses of flows and sills of basic lavas occur in some of the earliest known formations (Keewatin and similar Pre-Cambrian Series), and have formed at various periods since, down to the present. These thick piles of flows have formed on the continents (Plateau Basalts), on the ocean floors (e.g. Hawaian Islands), and in geosynclines, associated with sediments such as greywackes and slates".

The microscopic and chemical characters of these rocks do not help much. The relatively higher percentage of SiO_2 to the author appears to be due to admixture of mafic rocks with the sandy sediments. It could also be due to the abundance of quartz amygdules in the original rock. The extensively present fine streaks of quartz are perhaps crushed and stretched amygdules.

Lod Quartzites

The quartzitic rocks that lie unconformably over the Someshwar series, are seen as coarse to medium-grained gritty rocks. In hand specimen, these show buff to dirty white colour in which bedding is difficult to recognise. In thin sections, the quartzites are seen to consist of elongated grains of quartz embedded in a fine-grained quartzose matrix. While the bigger grains of quartz show strain effect, the quartz grains of the matrix are quite fresh and unstrained (Plate 7.6).

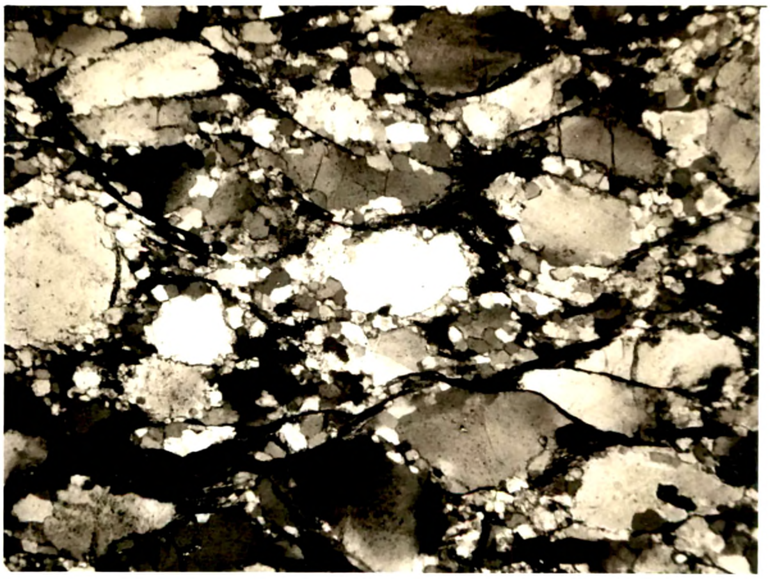
METAMORPHISM OF THE KROL NAPPE ROCKS

Metamorphically, the Krol nappe is less interesting, and shows a rather low grade of regional metamorphism. The metamorphic grade is as high as of 'chlorite zone' and the various mineral assemblages indicate that the rocks belong to the 'quartz-albite-chlorite subfacies' (Green-schist Facies) of Turner and Verhoogen (1960).

One fact that stands out is that the entire metamorphic impress howsoever feeble, was intimately connected with the differential slipping during the fold episode that gave rise to the Someshwar anticline. Differential slipping took place by flexural-slip in the lower slates and by axial-plane-slip in the upper slates.

The metamorphism and the slaty cleavage developed in argillaceous layers thus show a close relationship with the F_2 folding.

PLATE 7.6



Texture of the quartzites of Lod series.
(Photomicrograph: Crossed Nicols X30)