CHAPTER VII

METAMORPHISM IN RELATION TO STRUCTURE

The preceding account of the structural characters of the rocks has led the author to build up a succinct history of the tectonic evolution of the area. It is obvious that these rocks have been subjected to more than one deformational episode. The present study has also amply revealed that the various phases of metamorphism undergone by the rocks of the area, are intimately connected with the different deformational episodes.

Folding of the geosynclinal sediments and the accompanying progressive metamorphism:

After the deposition of the sediments (a sequence of sandstone/shale) in geosyncline, they were subjected to orogenic stresses which deformed them into a large isoclinal (reclined) fold (Episode I). Whether many more folds of this type were formed, cannot be definitely be stated at present. At least the Ranikhet area constitutes one such reclined fold. The geometry and the orientation of the minor folds and the linear structures related to this folding, indicatethat the reclined structure of Ranikhet closes to the west and its fold axis plunges moderately to the NNE. All the dominant linear structures viz. fold axes, quartz rods, lineation due to stripping and mineral orientation are genetically related to this folding, and could be considered to be of the nature of 'b' lineation. This folding synchronised with the progressive regional metamorphism of the rocks and the foliation S_1(schistosity) developed in the metamorphic rocks, in the axial plane direction of the folds. This axial plane foliation (S_1) is almost parallel to the bedding on the limbs of the fold, and to a casual

observer it could appear as a load schistosity. The accompanying regional metamorphism (progressive phase) gave rise to a number of mineral assemblages, characterising moderately high pressure and temperature. The fact that the garnets in schists rotated while growing indicates dominant role of shearing stress in the development of the metamorphic foliation. The author would suggest that this shearing originated due to the differential stresses, which folded the geosynclinal sediments.

Migmatisation in relation to folding:

The gneisses which occupy the core of the fold are of the nature of migmatites, and the migmatisation appears to have closely followed the regional metamorphism, the granitising solutions having invaded the rocks in the core of the fold. Their passage was facilitated by the axial plane foliation S_1. The fact that the quartzo-felspathic veins were drag-folded and involved in the folding, closely suggests that the folding was still in progress when the migmatising solution started affecting the rocks in the fold core. Thus in a broad sense migmatisation almost synchronised with the folding and the progressive metamorphism, and

possibly constituted an important event of the orogeny in this part of the Himalaya. In a recent paper, Sarkar and others (1965) on the basis of K/Ar dating, have assigned Lower Oligocene age to the metamorphism and granitisation of this region.

Thrusting and the related retrogression:

On account of the continued activity of deforming stresses, the Ranikhet overfold culminated into the Upradi thrust (Episode II), thus the older crystalline schists and gneisses were pushed over the less metamorphosed quartzites and slaty phyllites of Nagthats. The dislocation along the thrust caused intense crushing and accentuation of the existing foliation. The sudden slipping also drag folded the foliation itself. The geometry and orientation of these drag folds are identical to those of the minor folds recorded in the northern part of the area which clearly indicates that the minor folds in the quartzite etc. and the drag folds in the phyllonite were genetically related and were the products of the same deforming stresses. The progressive phase of regional metamorphism was closely followed by retrogressive phase. With the culmination of

the overfold into thrust, the rocks of the overlying sheet were metamorphically downgraded. The retrogression is characterised by the alteration of garnet and biotite to chlorite and muscovite to sericite. This has given rise to metamorphically inverted sequence consisting of garnet-mica-schists at the top in the north and chlorite-sericite-phyllonites at the bottom in the vicinity of the thrust.

Post-thrusting folding and the development of the strain-slip cleavage:

A post-thrusting fold movement folded the schistosity (S_1) giving rise to frequent chevron type folds and a strain-slip cleavage S_3. This folding and the accompanying strain-slip cleavage (S_3) probably developed at the time of the folding of the thrust into Upradi-Someshwar Synform (Episode III). This cleavage (S_3) is not frequently recorded in the present area, but it has developed in force as reported by Desai and Merh (1965) in the neighbourhood of Majkhali area. Such a cleavage is also reported by Merh (1965) in the neighbourhood of village Dharsala on the road from Khairna bridge to Almora. This

cleavage is seen to be almost vertical and striking east-west. The axes of the tiny folds as well as the related puckers which characterise the dominant lineations (L_3) dip gently to WNW or ESE or are subhorizontal. Little metamorphic changes are recorded to have accompanied this deformation except for some recrystallization of quartz and mica flakes.

Late North-South folding and faulting:

The entire area, at some late stage appears to have been affected by a gentle north-south folding (Episode IV). This has given rise to the development of open flexures of such dimensions which are better recorded in the accompanying geological map. Their characteristic recognition is based on the variation of the strike of the foliation. Faint puckers connected with this open folding, are quite frequently recorded throughout the whole area, on both sides of the thrust.

The last structural episode is that of fracturing and dislocation, which cannot be correctly dated. The last fold episode and the faulting could be as late as

Pleistocene or Recent (Auden,1948).

The author in the accompanying table has summarised the time-relation between the various structural and metamorphic episodes.

Table showing the time relation between structure and metamorphic events in the Pilkholi area

Structural events	Metamorphic events	Stages of regional metamorphism
(A) Deformation of the sediments into reclined overfold. Development of an axial plane schistosity (S_1) and lineation (L_1)	Progressive regional metamorphism- (i) Quartz-garnet-muscovite-biotite-(plagioclase). (ii) Quartz-biotite-plagioclase-clinozoisite. (iii) Quartz-biotite-plagioclase-garnet. (iv) Quartz-microcline-muscovite-(biotite). (v) Quartz-plagioclase-biotite-(muscovite)-garnet.	Progressive Staurolite-Almandine subfacies(Almandine-Amphibolite facies) (Turner & Verhoogen, 1960,pp. 545-46), Almandine zone(Barrow).
(B) Continued folding	Migmatisation along the core of the overfold, an early sodic phase followed by a potassic phase. (i)Quartz-plagioclase-(± microcline)-biotite-muscovite-(garnet). (ii)Quartz-plagioclase-muscovite-biotite-microcline-(garnet). (iii)Quartz-plagioclase-microcline-muscovite-biotite-(garnet). (iv)Quartz-microcline-plagioclase-muscovite-biotite-(garnet).	Migmatisation

Structural events	Metamorphic events	Stages of regional metamorphism
Later deformational force (? possibly during the Krol thrusting) has folded the earlier thrust, development of strain slip cleavage(S_3) and the related lineation (L_3)	No new mineral assemblages. Some recrystallisation of quarts and biotite marking the microfolds.	Recrystallisation
Late N-S folding and the development of related gentle puckers (L_4)	Nil	-
Faulting	-	-