# CHAPTER VIII

# R E S U M E

## ROCK TYPES AND STRUCTURE

The rocks of the Almora area, belonging to the Chandpur stage of the Jaunsars, mainly comprise garnet mica-schists with lenses of graphitic schists and flaggy quartzites. The schists occasionally show development of staurolite. Schists also contain thin lensoid bands of calc-silicate rocks comprising quartz, garnet and actinolite. Various transitional types between schists and quartzites are also present. The granitisation of schists has given rise to gneissic rocks which form distinct bands within the schists.

The granitised rocks show a complete range from felspathic schist to gneissic granite through the intermediate varieties like augen gneiss and porphyroblastic gneiss. Structurally, the area shows macroscopic folds, belonging to more than one fold episodes. The earliest folds are seen as repeated isoclinal reclined structures ($F_1$). On these, have been superimposed synforms and antiforms of two generations - $F_2$ and $F_3$. $F_2$ synformally folded the Almora nappe and in the NE corner, the main hinge of this synform (Dinapani-Kaparkhan synform) is encountered. Most of the Almora area lies on the north dipping limb of the synform. On this limb are seen developed two smaller $F_2$ structures (viz., Sual antiform and Guna synform). The superimposition of $F_3$ flexures on this synformal limb has further complicated the structural pattern. A rather large NNE-SSW ($F_3$) antiform (Matela antiform) in the western half of the area, has arched up the rocks and considerably affected the earlier structures. It is interesting to observe that during $F_2$ and $F_3$, the schists developed microfolds and crinkles at many places.

## STRUCTURAL AND METAMORPHIC HISTORY

In the preceeding chapters, the author has discussed in detail the structural and metamorphic aspects of the Almora area. He has worked out the evolutionary history of the terrain, and has established that the rocks have evolved during a connected sequence of metamorphic changes, which in turn closely synchronised with the various deformational events. The various processes of metamorphism, granitisation and deformational episodes essentially comprised important orogenic events that affected this part of the Himalayan geosyncline.

It appears that after the deposition of one or more graywacke-sub-graywacke-arkose sequences, the sediments underwent the earliest metamorphism. This metamorphism was perhaps of the load type, having been impressed on the sediments by the factors of plutonic heat and vertically directed pressure in a sinking geosynclinal basin. Only a few evidences of this early metamorphism are at present preserved, and the existence of this metamorphic event is suggested by the bedding schistosity (S) and the occasional presence of tight microfolds in micaceous schists.

With the first main orogenic upheaval, the metasediments were subjected to severe deformational stresses resulting into a series of reclined isoclinal folds ($F_1$). During this episode, the existing metamorphic characters for the most part were impressed on the rocks, and the mineral assemblages characteristic of the Almandine and Staurolite zones of the Amphibolite facies of Turner developed. The metamorphic foliation - the main schistosity, was the result of this progressive regional metamorphism and marked the axial-plane direction of the reclined folds. The rotated garnets grew during this metamorphism. These facts clearly bring out the close synchronisation of the progressive metamorphism with first folding. The isoclinal folding event finally culminated in the Almora thrust and thus the Almora nappe came into existence.

In the Almora area, the retrogressive metamorphic event connected with the Almora thrust is not recorded. As the area is somewhat far from the dislocation, its rocks do not show the retrogressive changes and metamorphic inversion worked out by Vashi (1966) and Patel (1972) along the south Almora thrust, and by Munshi (1972) along the north Almora thrust.

The next deformational event of importance was that of the synformal folding of the Almora nappe ($F_2$). This fold event gave rise to a number of smaller antiforms and synforms in the study area. Microfolding and crinkling of the $S_1$ giving rise to a new crenulation cleavage ($S_2$) were an important effect of this folding. The metamorphic changes that accompanied this fold event consisted of (i) bending and breaking of earlier mica flakes and their subsequent recrystallisation (ii) granulation of quartz grains and their recrystallisation (iii) formation of a new static garnet, and (iv) the growth of new muscovite, biotite and chlorite porphyroblasts oblique to the main schistosity ($S_1$).

The last conspicuous deformational event is characterised by a late folding ($F_3$) whose axial-plane fluctuated between NNE-SSW to NE-SW. Several folds of this generation were superimposed on the $F_1$ and $F_2$ folds, and the interference of $F_1$ and $F_2$ with $F_3$ has been mainly responsible for the existing outcrop pattern. The earlier planar ($S_1$ and $S_2$) and linear ($L_1$ and $L_2$) structures were considerably affected by this $F_3$ folding, and their present orientations are

mainly due to the effect of $F_3$. Little metamorphic changes accompanied the $F_3$ flexures.

GRANITISATION

The granitisation of garnet mica-schists has given rise to the gneissic rocks, and the various gneissic bands in all probability represent early (reclined) fold cores. The most conspicuous exposure of gneissic granite of Almora, viz., the Dyolidanda hill forms a horse-shoe shaped outcrop and looks like a rootless reclined $F_1$ structure. The southernmost Chaunsali band of augen bearing and porphyroblastic gneisses has also been taken as a reclined fold core forming a part of the Ranikhet-Siahidevi-Mukteshwar gneissic band.

The granitisation closely synchronised with the regional metamorphism and appears to have preceded, synchronised with and outlasted the main deformational event $F_1$. The process was initiated before the $F_1$ folding set in and it was quite predominant during the folding and its porphyroblastic phase continued even after the folding had ceased to be effective. In this respect, these granitised rocks could be considered as 'synkinematic'.

The transformation of schists into gneisses and gneissic granites is seen to have been brought about by a process of slow permeation and metasomatic action of emanations rich in alkalies. The relative proportions in which the two alkalies $Na_2O$ and $K_2O$ got fixed during the process of granitisation, not only depended on the length of time of granitisation but also on the tectonic levels at which the fixation took place. The augen gneiss (and porphyroblastic gneiss) of the Chaunsali band and other smaller bands, showing relative richness in $Na_2O$, indicate granitisation farther from the deepseated source of emanations. The fixation of $Na_2O$ which travelled faster and farther as compared to $K_2O$, into the metamorphic rocks at shallower levels, gave rise to plagioclase rich augen gneisses. On the other hand the gneissic granite mass of Dyolidanda which is rather potassic and rich in K-felspar, reveals a course of transformation at a greater depth, where the dominant alkali was potash.

Thus, the granitised rocks of Almora belong to two main groups, each representing distinct plutonic condition of origin and characterising granitisation at different energy levels. While the former comprise

granitised metasediments in a moderately high metamorphic environment, the latter (i.e. Dyolidanda gneissic granite) represents a deepseated product having been lifted up as a 'rootless' fold core.

## CONCLUDING REMARKS

In the foregoing pages of the present thesis, the reader will not only find geological details of the Almora area, but he will also come across numerous observations and conclusions which are of great importance from the point of view of the structural and metamorphic evolution of the Almora nappe as a whole. The Almora area, contains in a nutshell, almost all the salient features of the metamorphic and structural evolution of the Almora nappe synform. The present study fills many important gaps in the knowledge of the Kumaon region.

The Almora area has ideally preserved the imprints of all the fold episodes at macroscopic, mesoscopic and microscopic scales. The rock types typically reveal the close relationship that existed between the successive metamorphic events and fold episodes. The granitised rocks of the Almora area

are perhaps one of the few occurrences that illustrate the phenomenon of granitisation at different energy levels.

The author hopes that more detailed work by future investigators will further develop the ideas and concepts put forth by him in this thesis.