CHAPTER VIII

RESUME

The author selected some parts of the Kumaun Higher Himalaya with a view to look for the evidences of the evolution of the granitoid rocks which comprise the dominant rock types of the Central Crystallines. Once the nature of these is known, it would be easier to compare and contrast the granitoids of the Lesser Himalayan crystalline nappes which are supposed to be the southern counterparts of the Central Crystallines, the root zone.

Though valuable data on the structural and metamorphic aspects of the rocks of Central Crystallines have been made available by the various previous workers, but a cohesive picture and concrete answers to the genesis of the granitoids has not been available. The author felt the need of a detailed and thorough study of these rocks, so that a succinct and convincing geological history could be reconstructed. In this thesis, the author has critically evaluated all the available data, which throw new light, not only on the structural and metamorphic aspects of the Central Crystallines but also present many interesting facts about the true nature of the granitoids of Higher Kumaun Himalaya in particular and Kumaun Himalaya in general.

The study area forms parts of the valleys of Sarju-Pindar, Ramganga, Goriganga and Darmaganga of Kumaun Higher Himalaya, delimited by Trans Himadri Thrust in the north and Main Central Thrust in the south, respectively. The rocks mainly comprise metamorphosed equivalents of pelitic, graywacke and psammitic sediments, intruded by basic rocks. These have preserved within them interesting and varied metamorphic and structural histories. Almost all the previous workers have postulated imprints of a Precambrian progressive metamorphism that synchronized with the main event of isoclinal folding, but very few have been able to recognise the true nature of the rocks that pre-existed this metamorphism. Not only the granitoids of Central Crystallines, but of various nappes have also been debatable. The question whether they are orthogneisses or granitised metapelites has remained a matter of discord.

The present study has provided information on the various unexplained problems of Central Crystallines in respect of the structural and metamorphic histories and has enabled the author to deduce the petrogenesis of the granitoid rocks.

1. The rock types of the study area, as categorised by the author are;

   i. Mica schists : Phyllonites and chlorite schists, garnet-mica schists etc.,
   ii. Micaceous quartzites,
   iii. Calc silicate rocks,
   iv. Metabasic rocks,
   v. Granitoids : Streaky gneisses, augen gneisses, porphyroblastic gneisses, granitic gneisses and granites.

The granitoids as observed in the field are well foliated, intimately associated with metapelites and psammites and show structural similarity with the country rocks. They show a gradual transition from metapelites to gneisses and then to granites. Variations in granularity, texture and mineralogy northward is a common phenomenon. The granitoids become richer in K-feldspar and do not contain xenoliths. Lack of forceful injection, absence of brecciated contacts, presence of relicts of host rocks, pods of feldspar in the relicts, presence of resistors, all these favour the view that they are remnants of the original rocks left untransformed by the process of feldspathisation.

2. Structurally, the area is most interesting and the author has reconstructed the tectonic picture of the area as under:

   a. The most prominent deformational structures are the wide spread isoclinal/reclined folds (F_1 and F_2). These are co-axial having identical geometry. There are ample evidences to show that prior to the first two foldings, the rocks had undergone a deformation which produced an earliest schistosity (S). However, the principal schistosity (S_2) characterizes the axial plane direction of the F_2 folds.

   b. Most of the granitoid bands and layers of quartzites ideally show F_1 and F_2 folds. The involvement of granitoids in F_1 and F_2 show that they perhaps constitute F_1 fold cores refolded on F_2.

   c. A thrust movement along the pre-existing lineament (MCT) pushed the crystallines over the Lesser Himalayan rocks. During this, considerable shearing and mylonitisation was brought about in the vicinity of the thrust. A new set of folds (drag folds) showing trend, similar to F_1 and F_2 folds point towards identical nature of movement directions.

   d. The next deformational episode is represented by open flexures. The various mesoscopic synformal nappes with asymmetrical to symmetrical parasitic folds and a striation lineation ('a') developed due to flexural slip are related to this fold episode.

e. The swing in the strikes of the foliation and the formation of gentle folds in NE direction are due to the last folding (F_4).

3. The metamorphic history of the area is also fairly diverse and comprises several episodes. The author has very carefully studied and scrutinised the different textural and mineralogical criteria in working out the sequence of metamorphic events.

a. By and large, the imprints of the main metamorphism (M_1 and M_2) that synchronized with F_1 and F_2 foldings are the most obvious and almost all the metamorphic characters including texture and mineralogy of the granitoids and associated rocks, are related to these two metamorphic episodes.

b. The prevalent schistosity (S_2) that developed during the main metamorphism (M_2) shows axial plane relationship with the isoclinal/reclined folding (F_2), which obviously establishes the synchronization of M_2 and F_2. The resultant mineral assemblages during this metamorphism assign 'upper amphibolite facies'. The temperatures obtained are found to be consistent with those prevailing in the upper amphibolite facies.

c. Previous workers did recognise this metamorphism, but the pre-M_2 nature of the rocks have not been adequately studied. Karanth (1977) has however provided a complete metamorphic history of the similar rocks around Almora. The author has tried to unravel the pre-M_2 nature of the rocks and attempted to provide details of M_2 metamorphism. As pointed out by Karanth (1977) for the rocks of Almora nappe, data on the Central Crystalline rocks indicate that the rocks which were subjected to M_2 metamorphism were already granitised. The two generations of micas – one that developed during isoclinal/reclined foldings and the other that pre-existed and was tightly crinkled during F_2 confirms the above fact. On account of the tight microfolds the two micas (of M and M_1, M_2 generations) are mixed up. The garnets also reveal that they belong to two generations, while those grew during isoclinal/reclined foldings are rotated, and those pre-existed occur either as independent porphyroblasts or as cores within the rotated ones, indicating a static growth (Karanth, 1977). The evidences clearly point out that the rocks involved in the main metamorphic episode (M_2) were of the nature of garnet-mica schists.

d. The granitisation and formation of the granitoid rocks within the crystallines, comprised a phenomenon related to M_1 metamorphic event. Evidences do point out existence of a metamorphic event (M) prior to M_1. Extensive crinkling of mica flakes is conclusive indication of the existence of an early micaceous foliation, which was later on involved in F_1 folding. Previous workers did mention about this early metamorphism (M) and most of them took it to be primarily due to load. According to the present author the metamorphic episodes (M, M_1, M_2) are of Precambrian age.

e. The metamorphic episode (M_T) that followed the M_2 metamorphism, comprises diapthoretic changes on account of the Main Central Thrust movement. Obviously, the retrogression is due to the large scale movement of the Central Crystallines along the MCT. The down grading of the metamorphism is reflected even in the rocks which are away from the thrust zone.

f. The metamorphic event that synchronized with F_3 produced progressive metamorphic changes on a limited scale. The sericite and chlorite got recrystallised into porphyroblastic flakes of muscovite and biotite respectively, which show oblique relationship with the main foliation S_2 and define S_3. The last metamorphic event once again produced some of the biotite and muscovite flakes.

4. The granitoids are intimately associated with the country rocks and occur as concordant bands and lenses. In the hand specimens as well as under microscope, they very clearly reveal their foliated nature. They show a significant variation in the texture, granularity, mineralogy and chemistry. The schistose texture changes to gneissose (augen and porphyroblastic) to the north of the MCT. The granularity also increases northward and the size of the porphyroblasts or augens vary even within the same variety. The feldspar porphyroblasts become increasingly idiomorphic in the gneissic granites and granites. The granitoids show increase in feldspar content, particularly K-feldspar from south to north. The plagioclase dominates in feldspathic schists whereas the K-feldspars are found more in the other varieties of granitoids.

5. The K-feldspar of the granitoids has higher values of 2Vx and the development of cross-hatching is more conspicuous and frequent. The porphyroblasts are usually surrounded by plagioclase and myrmekite rim. The K-feldspars are seen replacing the plagioclase and its all stages are recorded. Contrary to Marmo's (1956) view, the replacing K-felspar is unhatched and is 'optically' monoclinic (Karanth, 1977). Some of such crystals are even twinned after Carlsbad law. However, the X-ray data revealed that the alkali feldspar in the granitoids is of potassic phase represented by intermediate

microcline triclinic type. A similar replacement phenomenon has been reported by Schermerhorn (1961). The muscovite predominates over biotite in the granitoids like the intercalated metapelites. The muscovite and garnets show characteristics similar to those of the mica schists, indicating the inheritance of this mineral from the metapelites. Zircon is subrounded and the tourmaline is commonly found in the granitoids.

6. The geochemistry of the granitoids of the Central Crystallines as well as the crystalline nappes reveal the following facts:

   a. Their high peraluminous nature (A/CNK > 1.1), moderate normative corundum (2 – 3%) furnishes the fact that these rocks are derivatives of a sedimentary source.

   b. The Niggli value plots all reveal a common source for the granitoid rocks.

   c. Harker diagrams reveal that there is an increase in K_2O with increase in SiO_2 while Na_2O remains more or less constant. All other major oxides show negative correlation. Enrichment of K_2O is revealed clearly by the variation diagram.

   d. AFM diagram as well as log(CaO/Na_2O+K_2O) versus SiO_2 plots further reveal their calc-alkaline nature and all fall in the granite field in the ternary diagram of O'Connor (1965).

e. In the Na_2O/Al_2O_3 versus K_2O/Al_2O_3 and K_2O versus Na_2O diagrams these rocks (granitoids including schists and quartzites) fall in the sedimentary field while the amphibolites plot in the igneous field.

f. Complementary diagram of de la Roche (1978) clearly distinguishes the granitoids as having been derived from an arkosic fields and the molar Al_2O_3 (Na_2O + K_2O) versus Al_2O_3 (CaO + Na_2O + K_2O) highlight their continental collision granite zone.

g. Trace elements Cu, Co, Ni and Ga show low concentrations and compare well with those of continental crust.

h. K and Rb furnish positive correlation and Rb concentrations are high generally predominating over Sr. Rb/Sr and Rb/Ba ratios are indicative of a pelitic source and are much higher than those of the continental crustal ratios. Low K/Rb ratios strengthen the role of fluid interaction processes.

i. Trace element variation diagrams reveal that while Zn and Zr decrease, Y and Ga remain unchanged with increase in SiO_2. Increase of Rb and Sr, with decreasing MgO and increasing CaO respectively confirms compatible nature of both Rb and Sr.

j. In Rb-Sr diagram the granitoid rocks all plot in the S-type field of granites. Trace elements assign a syn-COLG field for these rocks.

k. The REE patterns correspond to those representative of the continental crust and their deviation from average continental crust REE abundances can be attributed to mobility during the metasomatic phase.

7. Based on the above observations the facts that have emerged as regards the stages of granitisation could be summarised as under :

a. The first stage of granitisation i.e. the Na_2O metasomatism is marked by the development of plagioclase grains in the metapelites (feldspathic schists).

b. With the formation of the plagioclase grains, they have increased in size and formed augens and porphyroblasts. The early formed plagioclases are replaced by K-feldspars. Thus forming K-feldspar porphyroblasts. It seems that the Na_2O metasomatic phase was followed by the K_2O metasomatism. The large size K-feldspar porphyroblasts confirm the increased intensity of the K_2O metasomatism.

c. The late Na_2O metasomatism once again formed the plagioclase and also resulted in the formation of the myrmekitic rim around the K-feldspar. The last stage of granitisation comprised debasification of the country rocks along its junction with the gneissic rocks which was accompanied by tourmalinization.

Similar sequence of granitization has been invoked for the granitoids of Almora nappe (Merh and Vashi, 1965; Desai, 1968; Patel, 1971; Shah, 1972 and Karanth, 1977). Excepting Karanth (1977) all others envisaged that the granitic rocks occupy the core of reclined folds and the granitisation took place along S_1 (S_2 of the present author). They visualized that the granitization commenced during F_1 episode (Syn-F_1) and it even outlasted this event. Karanth (1977) however contradicted this and invoked pre-F_1 origin for the granitoids of Almora nappe. According to him the Almora granites were involved in F_1 folding (F_2 of the present author) and the granitisation took place along pre-existing foliation S but not along S_1. The author tends to agree with Karanth (1977) as the effect of deformation during F_2 (F_1 of Karanth) is clearly seen in the different minerals of the granitoids of even Higher Kumaun Himalaya. It thus appears that the granitic activity precluded F_1 (reclined folding). The absence of contact aureole, intense granitization with the addition of K-feldspars formed under upper amphibolite facies metamorphic condition support the authors views. The author is convinced that the granitisation took place prior to the main isoclinal/reclined fold event (F_2) and it is hard to believe their development during main Himalayan orogeny. They belonged to the late Precambrian orogeny that affected the rocks to the south of Himalaya and formed the basement for the deposition of the younger Himalayan sediments. The geochronological data also supports this contention.