CHAPTER I

INTRODUCTION

The Himalaya has always posed a challenge to the geologists. The study of the geology of this enigmatic and gigantic mountain chain has been exciting, rewarding as well as baffling. And though, for about a century now, scientists have tried to unravel its mysteries, it still remains a controversial allure for all geologists. Hence, even today the various aspects of Himalayan geology—stratigraphic, petrogenetic, structural and geochronologic remain but, a matter of tremendous debate.

The 'backbone of Himalaya' or the Central Crystallines forming the basement for the Tethyan sediments in the northern Kumaun have received considerable attention. However, the granitoids occurring within the Higher Himalaya of Kumaun have remained a subject matter of considerable debate. The rocks of the Higher Kumaun Himalaya known as Central Crystallines are considered to be the 'root zone' for the various crystalline nappes found thrusted over the Lesser Himalayan metasedimentaries. The origin of the granitoids occurring within the nappes is also controversial. While some geologists consider them to be of igneous origin, others believe in their sedimentary parentage.

Several decades back, Read (1957) gave an excellent exposition of this fact and aptly stated that 'there are granites and granites'. The dictionary defines the granitoid rocks as a preliminary plutonic rock having more or less granitic composition (Bates and Jackson, 1979). Hence the term granitoid would include gneiss, migmatite, granite, granodiorites, tonalite etc.

There is actually no debate over the voluminous abundance of the granitoid rocks in the upper portion of the continental crust. Most rocks show presence of large number of plutonic bodies. Moreover, even the sedimentaries have bulk chemical composition quite similar to that of granitoids. The definition of 'granitoid' has changed over the years. During the 18th century the controversy existed as to whether the granitic rocks were igneous, sedimentary or metamorphic. Having decided the plutonic nature of these rocks the question arose regarding the 'room problem'. This led to the theory of metasomatic replacement or granitisation. This was challenged by the proponents of the magmatic emplacement as the granitoids exhibited clear cut intrusive relationships in the field. However, the experimentalists strongly believed in the fractional crystallisation from basaltic melts or direct anatectic melts. Finally, if the granitoids were largely 'magmatic' and 'primary' then what could be their source or the processes leading to the formation of granitoids ? Potential sources include almost every silicate rock from peridotite to granite itself including a wide variety of sedimentary rocks.

On the other hand, the processes of metasomatic transformation of pre-existing rocks under appropriate P-T conditions leading to the formation of granitic rocks, have also been invoked by several workers. The actual agencies and their role in bringing out the transformation have also been debated. Obviously, granitoid rocks could also originate by their soaking with granitising emanations. Thus, there are igneous granites and metasomatic granites.

With passing time, the status of 'granitoid' rocks has however become more confused. What are precise nature and the sources of granite magmas or granitising emanations ? If one is concerned with the petrogenesis of these rocks then the potential source include almost all silicate rocks as well as a wide variety of sedimentary rocks.

The granitoids of the Higher Kumaun Himalaya, forming a part of the "Central Crystallines" of Heim and Gansser (1939), are sandwiched between the Trans Himadri Fault (Valdiya, 1988) in the north and Main Central Thrust in the south, delimiting the boundaries of the Higher Himalaya in Kumaun. The genesis of these rocks has long been a matter of discord. The granitic rocks of the crystalline nappes occurring within the Lesser Kumaun Himalaya have also been interpreted differently.

The first report of the granitic rocks in Kumaun goes as far back as 143 years made by Strachey (1851). He considered them as intrusive bodies, rising and cutting right from below. In subsequent years passing references to these granites were made by Middlemiss (1880) and McMohan (1887). Several decades later Auden (1934) made a special mention of the foliated granites of Almora and thought that they were igneous. Subsequent workers have given fairly divergent views on the nature and origin of the granitoids. By and large, the granitoids of Almora Nappe have received maximum attention, and those of other Lesser Himalayan nappes as well as of Central Crystallines, remained more or less uninvestigated. To Heim and Gansser (1939) goes the credit of providing a fairly comprehensive picture of these rocks from all over Kumaun. According to these workers, the granitoids are concordant sheets of igneous origin intrusive into metasediments and referred to them as granites, orthogneisses and augen gneisses. Nautiyal (1944) too thought that the granites of Almora were of igneous origin. On the other hand Pande et al. (1963) were first to interpret these rocks of Almora and neighbouring areas, to be of metasomatic origin and called them migmatites. Pande and Powar (1968), Lal (1969), Das (1971), Agrawal et al. (1972), further developed the concept of migmatisation and invoked introduction of anatectic melt into the metasediments along the pre-existing metamorphic foliation ("privileged paths"). Sharma (1970) concluded that the oligoclase bearing granites of Kumaun were anatectic while the albite-bearing ones were of metasomatic origin. Gansser (1964), Sarkar et al. (1965) have also taken the Kumaun granites as products of syngenetic granitisation.

Valdiya (1980, 1983) believing in their igneous origin classified the granitoids into two distinctive types, (i) the granodiorite quartzdiorite type characterised by abundant biotite and quartz with intermediate plagioclase, texturally equigranular as well as porphyritic; these are syntectonic and (ii) leucocratic adamellite and granite devoid or poor in biotite, these are later or post-tectonic intrusives. Thakur (1983) categorized the granites into pre-Himalayan and Himalayan or late Himalayan granites. Powar (1983) suggested that the granitoids of the eastern sector of Kumaun are of S-type, resulting from permissive emplacement of anatectic melt into the mesograde sediments. According to Sharma (1983) the granitoids of Higher Himalaya were formed from anatectic melts generated during Himalayan orogeny. Merh and his associates (Merh and Vashi, 1965; Desai, 1973; Shah, 1972; Karanth, 1977; Chamyal, 1984) believed in the syntectonic migmatisation for the evolution of the granitoids of Kumaun.

However, Karanth (1977) classified the Almora granitoids into two main categories; (i) veins of intrusive granitic material and (ii) bands of granitised pelitic rocks with or without a median portion of intrusive granitic rock.

The controversy whether the granitoids are metasomatic or igneous, has remained unsolved. The author has therefore embarked upon this study on the granitoid rocks of Higher Kumaun Himalaya in detail and also made investigations on selected samples from the Lesser Himalayan crystalline nappes to dwell upon their petrogenetic aspects aiming at throwing more light on these interesting but controversial rocks. The present study is restricted to the granitoids of Higher Kumaun Himalaya in the valleys of Pindar, Sarju, Ramganga, Goriganga and Darmaganga. With a view to provide appropriate comparisons, the author also investigated the Almora, Baijnath, Askot, Dharamgarh and the Chiplakot nappes of the Lesser Kumaun Himalaya in a few selected traverses. The data on field relations, petrography and geochemistry are utilised in order to understand their petrogenesis.

THE STUDY AREA/LOCATION

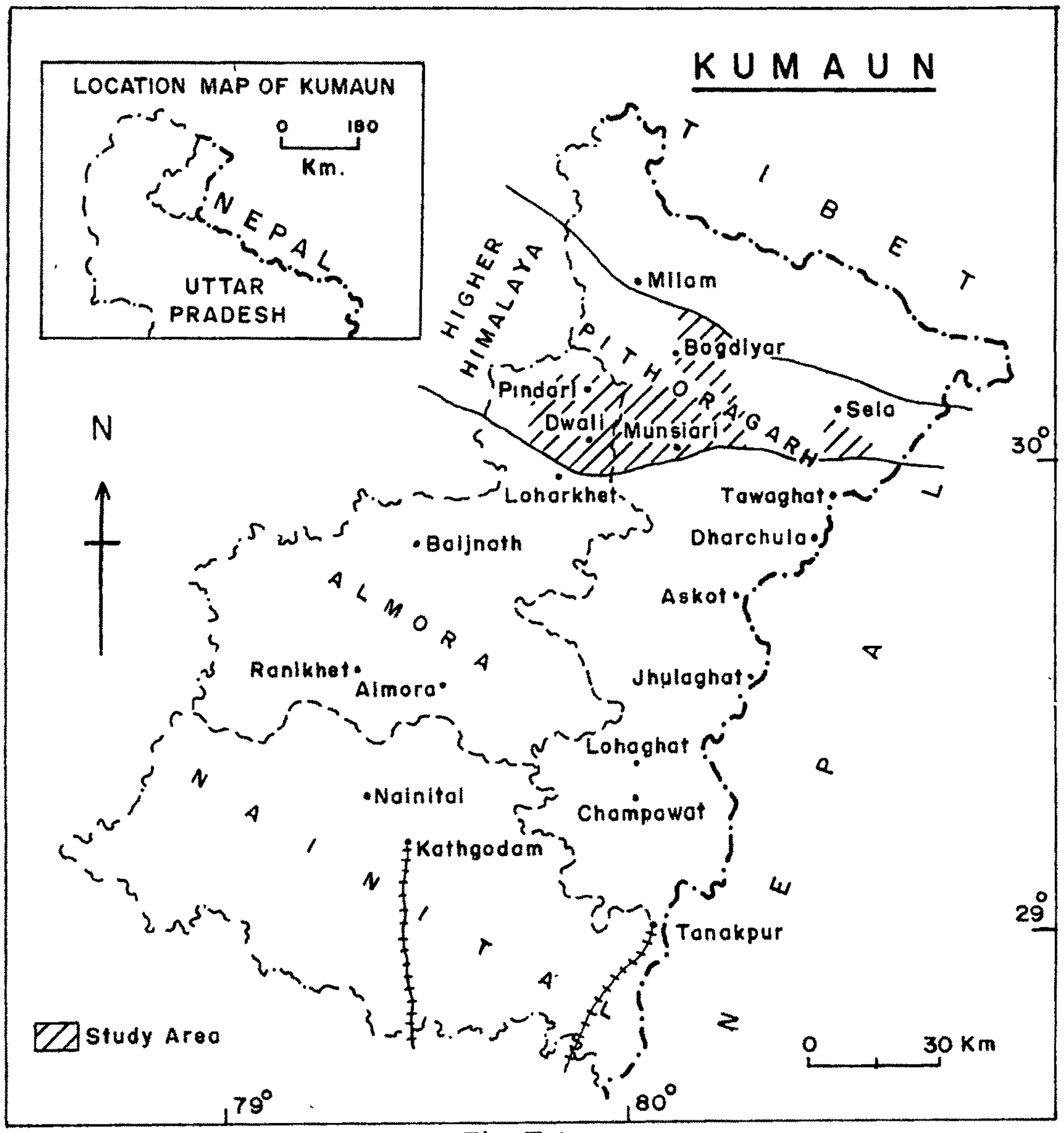
An area of about 2000 sq km in the Higher Kumaun Himalaya around Loharkhet, Dhakuri, Khati, Dwali and Phurkiya in the Pindar-Sarju valleys; around Hokara, Gogina and Namik in the Ramganga valley; around Munsiari, Lilam, Bagudiyar and Nahar in the Goriganga valley and around Tawaghat, Sobala and Nyu in the Darmaganga valley were studied in detail enclosing N latitude 30^0 0′ to 30^0 20′ and E longitude 79^0 55′ to 80^0 35′. Studies were also carried out in the Lesser Himalayan Crystalline nappes around Baijnath, Askot, Almora and Champawat to compare and contrast them with those of Higher Himalaya. Administratively, these areas lie within the Almora and Pithoragarh districts of Kumaun region in Uttar Pradesh (Fig. I.1).

COMMUNICATION

The entire study area is very well connected by all weather motorable metalled roads. However, the interior areas in the Higher Himalaya are connected northward to glaciers like Pindari, Kaphani, Ramganga, Milam and Panchchuli group of glaciers by mule cum foot tracks. The nearest railway station, Kathgodam is about 90 km to the south of Almora and about 300 km to the south of Munsiari. The nearest airports are at Pantnagar about 50 km south of Kathgodam and Pithoragarh very close to the study area.

LAND-USE AND HABITATION

In the Almora and Pithoragarh districts, less area is available for cultivation owing to the rugged relief. However, in the recent years with increasing population most of the forest land



KUMAUN
LOCATION MAP OF KUMAUN
0 180
Km.
NEPAL
UTTAR PRADESH
TIBET
HIGHER HIMALAYA
PITHORAGARH
Milam
Bogdiyar
Pindari
Dwali
Munsiari
Sela
Loharkhet
Tawaghat
Dharchula
Baijnath
ALMORA
Askot
Ranikhet
Almora
Jhulaghat
Lohaghat
NAINITAL
Nainital
Champawat
Kathgodam
Tanakpur
NEPAL
N
Study Area
0 30 Km
30°
29°
79°
80°

Fig. I.1

has been encroached into agricultural fields. This has brought about severe depletion of forest cover resulting into considerable soil erosion and hence environmental imbalance. Because of poor irrigation facilities, cultivation is entirely dependent on precipitation. The Rabi and Kharif are the two crops obtained during the year. Wheat, barley and mustard are the chief Rabi crops while rice and mandua are principal Kharif crops.

People of the area are predominantly Hindus, speaking various dialects such as Hindi and Nepali, while Kumauni is spoken by almost all.

FLORA AND FAUNA

The altitudinal variations and peculiar physiography has resulted in specific climatic conditions in Kumaun, enriching it with spectacular and exotic botanical as well as zoological panorama.

Sal (*Shorea robusta*), Sain (*Terminoua tomenstoa*), Teak (*Tectona grandis*) etc grow upto an elevation of 1700 m. At altitudes higher than 2000 m Banj (*Quercus leucotrichophora*), Tilonj (*Q. dilatata*), Deodar (*Cedrus deodara*), Blue pine (*Pinus wallichiana*), Garhpipal (*Populus ciliata*), Bhojpatra (*Betula utilis*) and Phododendrons etc are common.

Among fruits, apple, apricot, orange, strawberry, blackberry, kaphal and fig are common. Potatoes, onion, tomatoes, cabbage, peas, cauliflower, palak and methi are some of the vegetables usually grown.

The common wild animals of the area are Tiger (Panthera tigris), Panther (Panthera pardus fusca), Wild dog (Cuon alpinus primaevus), Himalayan black bear (Setenarctos thibetanus), Fox (Vulpes bengalensis) and Wild boar (Susscrofa cristatus). Besides this, a wide variety of birds, snakes and lizards form an important part of forest fauna.

PHYSIOGRAPHY

Physiographically, the study area falls in the Higher Himalayan and the Lesser Himalayan domains of Kumaun Himalaya. The Lesser Himalaya rise in elevation from 1500 to 3000 m above msl. The terrain is rugged and dissected by numerous rivers and streams. The Higher Himalaya exhibit elevation from 3000 to 7000 m and the peaks are perpetually covered with snow. The terrain is extremely rugged with deep gorges and steep precipitous escarpments. This domain consists of the magnificent peaks of Nanda devi (7,816 m), Nandakot (6,661 m), Trishuli (7,120 m) and the Panchchuli group (6,994 m) which house the celebrated glaciers like Sundardhunga, Pindari, Kaphni, Milam, Surajkund etc.

Both the domains are dissected by the mighty Sarju, Pindar, Ramganga, Goriganga, Dhauliganga and Kali rivers. The river courses and drainage divide do not show any particular trend but are mainly controlled by the lithology and structural pattern. Hence, the overall expression is chaotic. The landscape generally is therefore the result of mechanical and chemical weathering by frost action, groundwater and rainwater.

CLIMATE

The altitudinal variations and the slope aspects have given rise to varying climate in different parts of Kumaun. The climate is generally cool and pleasant. Along the river valleys due to drop in altitude the climate is moist and tropical. However at elevations upto 1200 m the climate becomes sub-tropical, cool to temperate at 1800 m and cold-temperate between 1800-2400 m at still higher altitudes it becomes almost polar.

Average temperature in the southern parts during summer (May-June) upto 26^0 C and 5^0 C during winter (December-January), but it goes down to 0^0 C in winter and does not exceed 20^0 C in the summer at higher altitude.

PURPOSE AND SCOPE OF THE STUDY

The Central Crystallines which are also referred as the 'Backbone of Himalaya', are a fine example of Precambrian metamorphosed rocks, and they have received considerable attention from geologists all over (who have studied them in great detail in all sectors viz - Kashmir, Garhwal, Kumaun, Nepal and Assam Himalaya) yet their origin remains highly controversial.

The granitoid rocks of Central Crystallines comprise massive granites, granitic gneisses, migmatites, porphyroblastic and augen gneisses and form an integral part of the Precambrian crystalline thrust sheet. A synthesis of the available literature (as given in the next chapter) points to the following facts : (i) the granitoid rocks comprise intrusive sheets, concordant with the regional foliation; the granitic melt being of anatectic origin (ii) a considerable proportion of these rocks, mostly gneisses are the product of granitisation of the metasediments, the metasomatic changes having been brought about by the emanations originating at depth. The controversy whether the granitoids are metasomatic or igneous, has unfortunately remained unsolved.

Hence, an attempt has been made by the present author to investigate the granitoids of Higher Kumaun Himalaya to understand the mode of origin of these rocks. The investigations comprised, mapping of the granitoid rocks, field characteristics, megascopic and microscopic details, providing geochemical indicators based on major, minor and rare earth interpretations, to find out temperature regime and thereby making an attempt to unravel the true nature of the granitoids of the study area. Various workers (detail as in next chapter) have pointed the Central Crystallines to be root zone or house of the Crystalline Nappes of Almora, Baijnath, Askot, Chiplakot and Dharamgarh presently found thrusted over the younger metasedimentaries of Lesser Himalaya. Thus, one of the aims of the author has been to provide correlation between the granitoids of the two domains using field petrographic as well as geochemical data.

The author spent an aggregate period of three months during two field seasons May-June, 1992 and November-December 1993. Traverses were undertaken along the Sarju-Pindar, Ramganga, Goriganga and Darmaganga rivers, walking along all possible foot-tracks. For mapping purpose original 1:50,000, Survey of India Topographical sheet Nos. 62 B/4, 62 B/8, 62 C/2, 62 C/3, 62 C/5, 62 C/6, 62 C/9, 53 N/16, 53 O/9, 53 O/10, 53 O/13 were utilised. About 250 fresh rock samples were collected from different horizons and locations. More stress was given on samples from the Central Crystallines whereas, only representative samples were collected for correlation purposes from the various crystalline nappes of Lesser Himalaya. The structural trends of these horizons were duly noted.

Thin sections of about 150 representative specimens of different lithotypes were studied in great detail giving stress to textural relationships and mineral assemblages. Mineral identification of one sample was confirmed by XRD analysis. The geochemical conditions that prevailed during the formation of these rocks have been ascertained by major, trace and rare earth elemental studies and chemical composition of minerals. Chemical analysis of 39 representative rock samples by XRF method was carried out for major elements, 24 and 10 representative rock samples by XRF and ICP for trace and rare earth elements respectively and 4 samples for mineral chemistry by EPMA, were carried out at W.I.H.G., Dehradun and N.G.R.I., Hyderabad.

SALIENT POINTS OF THE PRESENT STUDY

The present author has been able to provide substantial information not only on the overall genesis of the granitoid rocks of the Higher Kumaun Himalaya but has also made contribution in respect of the geology of the region encompassing, geological setting, structure and metamorphic aspects. On the basis of a detailed and careful field and laboratory investigations, the author has prepared elaborate geological map of the Higher Kumaun Himalaya (Fig. I.2). The detailed mapping was carried out in the Sarju-Pindar, Ramganga, Goriganga and Darmaganga valleys of the northern and northeastern Kumaun Himalaya (Fig. III. 1 to 8). While mapping emphasis was however given to the various granitoid bands and lenses. Based on the field mapping and considering the works of Chamyal and Manudip (1994), the author has suggested a tectonic succession for the rocks of the Higher Kumaun Himalaya commonly known as Central Crystallines (Table I.1). Detailed mapping of the granitoids and subsequent laboratory studies have enabled the author to classify and subdivide them into various types.

The investigations conducted by the author, have led to following conclusions:

1. The Trans Himadri Fault/Thrust in the north and Main Central Thrust in the south, delimit the boundaries of the Higher Himalaya in Kumaun, within which occur the granitoid rocks forming major part of the 'Central Crystallines'.

2. The granitoid rocks of Central Crystallines comprise massive granites, granitic gneisses, migmatites, augen and porphyroblastic gneisses and form an integral part of the Precambrian crystalline thrust sheet.

3. All along the Central Crystallines as observed in the Sarju-Pindar, Ramganga, Goriganga and Darmaganga valleys, the Main Central Thrust zone is marked by the presence of a thin horizon of highly sheared, crushed and retrograded phyllonites.

Table I.1 Lithotectonic succession of the Pindar, Sarju, Ramganga, Goriganga and Darmaganga Valleys, Higher Kumaun Himalaya

Pindar-Sarju Valley	Ramganga Valley	Goriganga Valley	Darmaganga Valley
		- - - Trans Himadri Thurst - - -	
		Porphyroblastic mica schists	
		Calc silicate rocks	
		Streaky, augen and banded gneisses	
		Carnetiferous augen gneisses and migmatites	
		Tourmaline and garnet bearing aplitic veins	
		Porphyroblastic gneisses and granitic gneisses	
Garnetiferous kyanite gneisses		Garnetiferous kyanite gneisses	
Garnetiferous augen gneisses and migmatites	Garnetiferous augen gneisses and migmatites	Garnetiferous augen gneisses and migmatites	
Micaceous quartzites	Micaceous quartzites	Micaceous quartzites	
	Streaky, augen and	Streaky, augen and banded gneisses	
Streaky, augen and	banded gneisses	banded gneisses	
Garnet mica schists	Garnet mica schists	Micaceous quartzites	Garnetiferous kyanite gneisses
Streaky, augen and banded gneisses	Streaky, augen and banded gneisses	Mica schists	Garnetiferous augen gneisses and migmatites
Mica schists	Mica schists	Streaky, augen and banded gneisses	Streaky, augen and banded gneisses
Streaky, augen and banded gneisses	Streaky, augen and banded gneisses		
Garnet mica schists	Garnet mica schists	Mica schists	
Phyllonites, chlorite and sericite schists	Phyllonites, chlorite and sericite schists	Phyllonites, chlorite and sericite schists	Phyllonites, chlorite and sericite schists
- - - - - - Main Central Thrust	- - - - - -	- - - - - -	- - - - - -
Loharkhet quartzites	Hokara quartzites	Girgaum quartzites	Deoban carbonates
Saling slates	Deoban carbonates	Deoban carbonates	
Deoban carbonates			

4. The schists northward exhibit increase in feldspathic content, passing into augen gneisses, which with gradual increase in feldspar and simultaneous decrease in the quartz content pass to migmatites, porphyroblastic gneisses, granitic gneisses and finally granite with homogenous appearance. The original gneisses are found to retain the relic fabric of the parent rocks.

5. The granitoids show no structural discordance with associated schistose and micaceous quartzite horizons and regionally exhibit similar trends. The micaceous quartzites have gradational contacts with associated gneissic horizons and locally show development of crude foliation. No evidences of forceful injection, complete absence of brecciated contacts, presence of relicts of horst rocks and resisters, all these indicate untransformed remnants of the original rocks.

6. The rocks of Higher Kumaun Himalaya have undergone polyphase deformation. The first two foldings (F_1 and F_2) are co-axial and are represented by the tight isoclinal/reclined folds. Most of the granitoid bands ideally show F_1 and F_2 folds at mesoscopic as well as microscopic scales. Perhaps, the granitisation precluded the F_1 and F_2 folds.

7. A thrust movement along the pre-existing lineament (MCT) pushed the Central Crystallines over the Lesser Himalayan

rocks. The Central Crystallines comprise a tectonic flake demarcated by MCT, a dislocation developed within the Indian Precambrian shield under collisional compressive slicing mechanism. The movement along this thrust has not only sheared the rocks but has also given rise to a new set of folds (related to the drag effect) superimposed over the Precambrian deformation.

8. The next fold events (F_3 and F_4) are essentially related to the Himalayan uplift. The F_3 has even folded the crystalline thrust sheet into various synformal nappes. The F_4 which is the last fold episode has only imparted waviness to the regional foliation trends. The transverse faults (the last deformational event) have even dislocated the MCT and other thrusts all over the Himalaya. The F_1 and F_2 are assigned Precambrian ages whereas the F_3 and F_4 are of Himalayan to Late Himalayan ages.

9. Petrographic studies of the granitoid rocks of the study area reveal that excepting the granites all the other varieties are foliated and including granites show marked difference in the texture, granularity and mineralogy.

10. The granularity in the granitoids which increases northward from streaky gneisses to porphyroblastic gneisses and enrichment of K-feldspar and several other characteristics

like preponderance in muscovite over biotite, subrounded nature of the zircon, presence of garnet and tourmaline, replacement of plagioclase by K-feldspar and a high 2Vx values, all point towards their metasomatic origin.

11. The granitisation through fluid medium and active participation of liquid diffusion in rocks appear to have played the dominant role in the evolution of the granitoids of Kumaun Higher Himalaya.

12. The rocks of the Higher Kumaun Himalaya exhibit metamorphic characters that indicate mainly two progressive phases followed by retrogression. The mineralogy, texture and structure of these rocks reveal metamorphic changes that synchronise with the successive deformational events, pre-Himalayan as well as Himalayan.

13. The granitic activity precluded F_1 (reclined folding). The total absence of contact aureole, intense granitization with the addition of K-feldspars indicate that most granitoids were formed under upper amphibolite facies. The temperatures obtained by geothermometry are also in conformity with these metamorphic conditions.

14. The geochemistry of the granitoid rocks reveal their high peraluminous nature and moderate to high normative corundum.

The overall bulk geochemistry compares well with the average sedimentary compositions but, for the predominance of K_2O over Na_2O indicating alkali enrichment.

15. The granitoids are calc alkaline in nature and show progressive enrichment in alkalies with a concommitant depletion in magnesia and total iron. A common source of their origin is indicated by Niggli values.

16. The granitoids and all other associated rocks barring amphibolites fall in the sedimentary field confirming their S-type nature.

17. Trace elements in the granitoid rocks (Co, Cu, Ni, V and Ga) show low concentrations and compare well with those of the crustal granites. High Rb, low Sr and <1000 Ba concentrations and considerably high Rb/Sr ratio indicate that these granitoids are derived from pelitic sources.

18. Both Rb and Sr are found to increase with decreasing MgO and increasing CaO respectively, indicating the compatibility of these elements and thereby confirming role of both potash as well as soda activity.

19. The major and trace element chemistry, indicate the tectonic environment of the granitoids as that of Syn-Collision Granite

(syn-COLG) type which is defined as those exhibiting features associated with S-type granites.

20. The REE patterns for the granitoids correspond well with the representative REE patterns of the continental crust and the deviation from the average continental crustal values is attributed to the mobility of these REE'S during metasomatism.

21. The overall characteristics point to the formation of granitoids by the process of metasomatism. The first stage of Na_2O metasomatism is marked by the development of plagioclase grains in the metapelites, which with increase in size formed augens and porphyroblasts. The replacement of plagioclase by K-feldspar indicates K_2O metasomatism and is confirmed by the large size K-Feldspars. The Na_2O metasomatism was followed by K_2O metasomatism and the subsequent Na_2O metasomatism formed plagioclases and myrmekitic rims around the K-feldspar.

22. The granitisation took place prior to the main isoclinal/reclined fold event and it is hard to believe their development during main Himalayan orogeny that affected the rocks to the south of Himalaya and formed the basement for the deposition of the younger Himalayan sediments. The available geochronological data also supports this contention.

23. The environment pointing to collision tectonics, as revealed by granitoids has obviously to be considered as Precambrian, and looking to the widely accepted fact that the Crystallines of Himalaya form the northern extension of the Rajasthan Precambrians, the phenomenon of collision could be correlatable to that visualized by several workers in Rajasthan.