CHAPTER-I

INTRODUCTION

The Himalaya, a part of the great arcuate Alpine-Himalayan orogenic belt, is considered to be the highest and youngest mountain range in the world. Convexing towards south, the Himalaya extends over 2,500 km from NW to SE. In the northern side, Indus-Tsangpo valleys separate the main Himalaya from the Trans-Himalaya. Towards the south it is fringed by the very low Gangetic plain. The clearest and most impressive border of the Himalaya range is its southern limit towards its foreland -- the Indian shield or Peninsular India. The Himalaya is divided, from west to east into three distinct regions: the Western, Central and Eastern Himalaya. From south to north, four major lithotectonic physiographic belts or zones of varying width, each having its own geological history have been recognised. They are designated as the Outer or Sub-Himalaya; the Lesser or Lower Himalaya; the Greater or Higher Himalaya; and the Tethys or Tibetan Himalaya. Further north lies the Trans-Himalaya which includes the Ladakh and Karakoram ranges. The immense structural studies in the Himalaya reveal distinctive tectonic architecture, lithostratigraphic and evolutionary history, episodes of magmatism and metamorphism of each of these belts (Thakur, 1992). Apart from the number of minor thrust planes, the Main Central Thrust (MCT) which separates the Higher Himalaya from Lower Himalaya and the Main Boundary Thrust (MBT) which lies in between Lesser Himalaya and the Sub-Himalayan Siwalik molasse sediments are the important prominent thrusts formed due to the collision of India with Asia during Tertiary time. A general outline map of Himalaya indicating the major tectonic divisions and mafic and felsic bodies from the Himalaya is presented in Fig. 1.

The Sub-Himalaya or Siwalik belt, which represents the last active phase of the movement responsible for the rise of the Himalayan mountain system, consists of Cenozoic sedimentary pile with a ruggedly youthful topography. The Sub-Himalayan zone is devoid
Fig. 1 Locations of the major mafic-ultramafic and granite-gneiss bodies in the Himalayas. Compiled from various sources. Base map after Gansser (1964). Ages of granites and granitic gneisses after Sharma (1983).
of magmatic activity. The Lesser Himalaya possesses a remarkable uniformity of height between 2000 and 3000 m and is characterised by unfossiliferous Precambrian and Paleozoic sediments. The Greater Himalaya consists of 15-20 km thick slab of crystalline rocks. This zone of crystalline rocks, known as the Central Crystalline Group (Gansser, 1964), occupies the axial zone of High Himalayan ranges. This zone is chiefly composed of Early Precambrian-Cambrian metamorphics that are intruded by Early Proterozoic-Early Paleozoic and Middle Tertiary granitoids (Sharma, 1983). The Tethys Himalaya contains a complete record of fossiliferous sediments from Cambrian to Tertiary. The sediments of this zone exhibit essentially marine facies, characteristic of an environment reminiscent of shelf to slope of the Tethys sea regime which is in sharp contrast to the sedimentary facies of the Lesser Himalaya. To the north of the Tethys Himalaya along the course of the upper Indus river is a tectonic belt comprising ophiolites, flysch wedges and molassic sediments. This belt is thrust towards south along the Indus Suture Zone (Gansser, 1964).

The present work is mainly concerned in and around the Kulu valley of Lesser Himalaya. The Lesser Himalaya, sandwiched between MBT in the south and MCT in the north, is built up of Precambrian and Paleozoic rocks. This Lesser Himalayan zone is an intricate arrangement of ranges lacking geological control as a result of intense and repeated tectonic activity undergone by this region. The rocks in this region are more or less completely unfossiliferous with autochthonous to parautochthonous sedimentary sequence. Three major tectonic nappes have been demarcated in the zone that imbricately cover the complex and strongly folded and broadly anticlinal autochthon of the Precambrian sediments. These Precambrian Lesser Himalayan sedimentary are now exposed in windows and half-windows in the inner belt, but uprooted and involved in imbricate thrusting in the outer sedimentary belt (Valdiya, 1984). These nappes consist of (i) the Precambrian-Lower Paleozoic sedimentary succession (Krol-Berinag nappes); (ii) the very low grade metamorphics associated with mylonitized and cataclasically deformed granitic porphyroid (Salkhala-Chail-Ramgarh-Daling-Sachi sheets); and (iii) the mesograde
metamorphics (Jutogh-Munsiari) intruded by granite-granodiorite plutons. The present area of study i.e., Kulu-Rampur belt broadly covers the paraautochthonous crystalline basement rocks, its sedimentsry cover and a thrust sheet of the crystallines exposed in the Kulu-Rampur window and its surroundings in the Lesser Himalaya. The Kulu-Rampur belt, a tectonic window extending up to Rakti Dhar in the east and Dhauladhar range in the west, is about a 100 km long linear stretch trending in northwest-southeast direction. A window is an exposure of the rock below a thrust sheet that is completely surrounded by rock above the thrust (Valdiya, 1984). In Kulu-Rampur belt, the younger volcanosedimentary sequence with a gneissic complex in its core is surrounded by thrust sheets of higher grade Jutogh-Chail rocks.

The Bandal gneissic complex (=Bandal granitoids+ basic rocks+phyllites+chlorites+schists and interbedded quartzites), which is exposed in the core of the Kulu-Rampur window, is the main focus of the present study. The gneissic complex, covering an area of about 500 sq km, extending from Garsah valley in the north to south of Sarahan in Sutlej valley is encompassed between latitudes 31° 30' and 31° 55' and 77° 05' and 77° 35' longitudes. The Bandal granite pluton is well developed in Shainshar, Shangarh and in east of Bandal. V.P. Sharma (1977) presented a comprehensive account of the geology of Kulu-Rampur belt with particular reference to its stratigraphy and structure.

1.1. Purpose of Study

The Himalaya has been a source of inquisit to earth scientists for a very long time. The growing interest in the evolution of this mountain has prompted many Geoscientists to study the continent-continent collisional orogenesis as a part of a complex set of processes acting both beneath and on the surface of the earth.
The occurrence of the granites, granite gneisses and migmatites make a spectacular feature of the lithologies of the magnificent Himalayan mountain. The phenomenon of granite as a widespread formation in the earth’s crust, and particularly in mountain ranges, has been a leading subject of discussion throughout the history of the science of geology. The role played by granitic bodies and the question of their origin remained problematic, despite realization of their unique importance in stratigraphy and geometry of the orogens. Since the inception of the study on Himalaya very less work has been done on granites in particular. One of the main reasons being most of the areas in Himalaya has been inaccessible and hence remained unattended. Unlike the other areas, the Kulu-Rampur belt has been subjected to an intensive examination by various geoscientists aimed at the exploration and exploitation of economic potentials such as uraninite, silver, and copper.

Because of the complex tectonic history of the region, the geology of Kulu-Rampur belt has been under debate for several years. The occurrence of number of shear zones and its proximity to the MCT has generated lot of interest among structural and economic geoscientists. However, no attempt has so far been made to study the geochemical aspects of Bandal granitoids; geochemical data on the magmatic rocks of the area is rare. Detailed study on petrogenesis of basic and felsic rocks other than the mere Rb, Sr trace element contents of few rock samples (Thoni, 1977) has not been carried out. The impetus for this specific study on Bandal area arose from a broader investigation of the characteristics of surrounding rocks of the Bandal batholith (Thoni, 1977; Sharma, 1977; Bhat and LeFort, 1992; Rao et al., 1995). Their studies revealed large, remarkably systematic regional variation in different lithologies.

The main purpose of the present study is to study the granitoids and associated metabasics with a view to understand their petrogenesis. Further, one of the unifying themes in the thesis is that the models, proposed for the tectonic evolution of the Kulu-Rampur belt can be strongly constrained by the currently generated geochemical data. The
study is also directed to document the petrological variations within the plutons of a large batholith, and with the purpose of formulating an internally consistent genetic model. A large number of geological data have been collected and these are discussed in the forthcoming chapters along with information on the field relationships and the characteristics of individual lithologies. Based on petrographical, geochemical studies combined with field observations of Bandal granitoids and associated rocks the effects of the granite intrusion, if present, would be clearly evaluated vis-a-vis the basement nature of the gneissic complex.

Efforts have been made to establish the nature of basement for the Bandal gneissic complex by integrating the already available facts and current observations. Different geochronological and tectonic studies of the surrounding rocks in Bandal area indicate that the meta-sedimentary rocks in which the Bandal granitoids were considered to be intruded are older. The age of the Bandal granitoids is assigned as \( \sim 1900 \) Ma by Frank et al. (1977). Based on geochemical and isotopic studies Bhat and LeFort (1992) characterise the Rampur volcanics (part of the surrounding volcanosedimentary sequence of the Bandal granitoids) as rift related continental tholeiites and have assigned an Sm-Nd age of \( 2.51 \pm 0.09 \) Ga for these volcanic rocks. Believing that the above age of Rampur volcanics is correct, the scenario that emerges is that the 2.5 Ga volcanosedimentary rocks are intruded by 1900 Ma granites. Obviously, under such conditions the marked effects of such a large granite intrusion on the surrounding rocks should be conspicuously seen in terms of contact aureoles and metamorphism, development of hornfelsic texture etc. However, in contrary to these effects, the features like intensive shearing, pulverisation of rocks and development of fold patterns which can be related to thrusting, are observed at the contact. With the help of detailed field and geochemical studies, the present investigations have also been directed to workout an alternative possibility of the Bandal Gneissic Complex being the basement for the extensive development of mature quartzites and their associated rift-related volcanics as a supracrustal volcanosedimentary sequence.
In this context, the detailed studies carried out by K.K. Sharma and his coworkers (Rao et al., 1995) in Wangtu Gneissic Complex (WGC) which is an adjacent area to Bandal Gneissic Complex (BGC) have revealed that the core part of the WGC is occupied by an Early Proterozoic (1895 ± 64 Ma) granite body which has not been affected by Himalayan deformation. The main lithostratigraphic units of BGC, like Early Proterozoic granites with abundant aplite and pegmatitic network and associated amphibolitic intrusives closely resemble with the adjoining rocks (i.e., WGC). With this in view, an attempt has also been made in the present study to correlate these two gneissic complexes.

1.2. Geography of the Area

The Bandal granitic batholith which lies in the Kulu-Rampur belt, is one of the most fascinating segments of the Himalayan arc. This belt forms a part of the western Lesser Himalaya and lies between the Dhauladhar range to the west and the Central Himalayan range to the east.

The area has striking features, such as diversified relief with outstanding high mountains, deep valleys, steep slopes, escarpments and cliff faces. There is a great variation in altitude from 800 m above mean sea level near Luhri in Sutlej valley to more than 6000 m in Rakti Dhar area in Sainj valley. The great difference between the elevation of beds of the rivers and the height of the ridges suggests a very young immature topography and indicates a very young uplift. It is the geology of the area which has a crucial role in the attractive topography of the area. The most resistant rocks like quartzites form precipitous cliffs and escarpments as in Jari-Kasol - Manikaran area in Parvati valley and Dalasni-Aut-Thalat section in Kulu valley, whereas the less resistant rocks like slate, phyllite and schists form gentle to moderately steep slopes.
The two rivers Beas and Sutlej drain the Kulu-Rampur belt and are separated from each other by the ridge connecting Augan Dhar with Jalori Pass which forms the watershed between these two rivers. The river Beas drains along the periphery of Bandal batholith. The Parvati river, the Hurla nal and the Sainj Khad which are the principal tributaries of the Beas, have carved out deep and narrow traverse valleys, often punctuated with waterfalls.

The areas under investigation are generally thickly forested. The forests are mostly of oak coniferous. Important trees found in the area are pine, deodar, kail, oak, etc. At higher elevations, the vegetation is mostly of dry alpine sarup type and consists of only grass, herbs and shrubs forming broad and beautiful lush green meadows and pastures. During rainy season these meadows bloom with beautiful multicoloured flowers. Being a richly forested area, the Kulu-Rampur belt is also endowed with wild and varied fauna.

The area enjoys very pleasant and bracing temperate climate. The normal temperature during summer goes up to 20°C. Winter from October to March is severe and the area experiences moderate to heavy snowfall. Kulu is well connected with Pathankot, Chandigarh and Simla by metalled roads via Mandi. Kulu is also connected with Banjar by metalled road, which has been extended up to Luhri in Sutlej valley. Bhuntar, situated 10 km south of Kulu on Kulu-Mandi high way, is connected with Chandigarh and Delhi by a bi-weekly air service during summer and late autumn months. From Bhuntar a few other roads branch off to places like Manikaran and Garsah-Thela. Small roads connect Larji with Sainj in Sainj valley and Banjar with Bathad in Bathad valley.
1.3. Methods of Study

For a better understanding of the tectonic history of the region and the petrogenesis of granites and associated rocks, the main tool that has been used in the present study is "Geochemistry". However, the other important aspects like structural data, field investigations, petrography, regional stratigraphy and metamorphism have also been given due importance to obtain a comprehensive information about the study area. When incorporated into a tectonic model, their collective values become more apparent as each can provide better insights to a general model for the tectonic evolution of an area.

1.4. Previous Work

Hayden (1908) produced the first ever geological account of the Northwest Himalaya. The first geologist to explore in detail the Kulu-Rampur region was Auden. During his investigation, he made number of traverses in the region and made certain interesting observations. Again it was Auden (1948) who's pioneering work indicated the existence of tectonic windows at Larji in Beas valley. The subsequent studies by Berthelsen (1951) and Jhingran et al. (1952) have confirmed the earlier observations by Auden and added that these tectonic windows also extend to Rampur area in Sutlej valley. Shukla and Srivastava (1957) in their investigations along Kulu-Larji-Banjar road, have suggested that the Kulu-Aut-Larji-Banjar area is covered by the Chail series consisting of phyllite, slate and calcareous quartzites. The dolomite limestones exposed near Larji were considered as calcareous quartzites by these workers.

Dass and Srikantia (1962) mapped the area lying on either side of Bhuntar-Banjar road. They have divided these rocks into: (i) Larji and (ii) Banjar series. According to them, the Larji series mainly consists of massive dolomites with rarely interbedded pink limestone and quartzite; subordinate slate and chlorite occur as 'tectonic' window.
surrounded by the Chail series in the west and Banjar series in the east. A part of the Parvati valley has been mapped by Sehgal (1963). He divided the rocks of Parvati valley into: (i) the quartzite phyllite series called as Jari series and (ii) the schistose series. According to Dass (1964), the group of rocks comprising slate, phyllite, massive quartzite, conglomerate and conglomeratic quartzite etc. exposed in Naraul-Gobha area form part of the Banjar series. Venugopal (1964) proposed that the Larji series which occurs as a 'window' between the Chail and Banjar thrust, extends up to Mahul Khad, 3 km north-west of Buntar. According to him, the carbonaceous phyllite with bands of limestone forms part of Larji series.

Gansser (1964) has shown in his map that the Kulu-Rampur area is covered by Salkhlas and Jutogh rocks. All these rocks have been assigned Precambrian age by him. Larji and Banjar area was investigated by Singh (1965) who believes that the younger Shali formation forms the tectonic base over which two nappes are superposed one over the other. The upper nappe consists of Sarahans (Jutoghs), Chails and Jaunsars. The lower nappe is composed of Chodls and Tarale Formation. Kathiara (1967) mapped the Bathad-Sarahan area and divided the rocks into three units namely: (i) the Rampur series (ii) Chail series and (iii) the Jutogh series. All the three series form independent tectonic units which are separated from each other by thrust planes. According to him, the Bandal gneisses belong to Jutogh series and are thrust over the Rampur series. Petrofabric analysis of the Bandal gneisses were carried by Parthasarathy (1967, 1969). His work indicate that these rocks are characterised by F, F/1, F/2 and F/3 fabrics where the F and F/1 fabrics are superimposed by F/2 fabric. The F/2 fabric is the resultant of tectonic stress which resulted in the introduction of new minerals like potash feldspars as porphyroblasts. This was followed by F/3 fabric which represents the culmination of the processes in the formation of the gneisses.
Extensive geological information about the area has been accumulated during the work carried out in early seventies. Significant contributions include investigations of Dass and Srikantia (1972), Bhargava et al. (1972) who have contributed mainly towards lithostratigraphy, structure and tectonics. In the year 1977, a group of German geoscientists have investigated a part of Kulu-Rampur window, particularly in the Kulu valley (Frank, 1977; Thoni, 1977). They have given more emphasis on geology, structural evolution and metamorphic zoning in the Kulu valley but very little has been discussed about the geochemistry. Their observations indicate that the Crystalline nappe overthrusted above the relatively less metamorphosed sequence of the Larji-Kulu-Rampur Window. At the base of the Crystalline nappe a very thin rock sequence with a special lithology has been observed on a regional scale. They call this as 'Bajaura nappe' and consider it as a separate unit.

Sharma (1977) has mapped about 2,500 sq km area and has given a comprehensive account of the geology of Kulu-Rampur belt. He brought out a consolidated geological account of this little known area, where geological work has been sporadic; he also established a standard stratigraphic sequence. Further studies (Bhargava and Ameta, 1987) indicate that the Rampur Window, which was earlier considered to be closed at Nogli in southeast, extends up to Karcham in the Sutlej valley.

Following an introductory chapter on Himalaya, each chapter is devoted to a specific subject of study. Pertinent tectonic models and different concepts of the area are reviewed, all the available data are summarized. The second and third chapters review geological background and petrographical characters of different rock units, respectively and these two important topics are integrated throughout the rest of the thesis. The final three chapters are based on geochemistry that deals with the petrogenesis and tectonic setting of the area. By applying all of the preceeding material, a tectono-magmatic model for the evolution of the Kulu-Rampur area is presented.