CHAPTER I

INTRODUCTION

The Himalaya - the Euphrates of Ptolemy - has not only fascinated those who love sages and adventures but has also attracted the attention of geologists from all over the world who have geologically investigated this youngest and loftiest mountain system forming a part of the Alpine-Himalayan chain of the globe.

The Himalaya (from the Sanskrit "Hima" meaning 'snow' and "alaya" meaning 'the dwelling place') forming a regular curved belt of mountainous country, convex towards south has a total length of about 2,160 kms measured along the chord of the arc or of nearly 2,400 kms measured along the arc itself. It has a width varying from 325 kms to 425 kms, the orientation of its western extremity, omitting syntactical adjustment with the continuing ranges further west, being generally NW-SE and that of its eastern extremity approximately WSW-ENE. Westwards this wide mountain belt terminates at the Jhelum gorge and the bend of the Indus. In the east, it imperceptibly ends at or a little beyond the Brahmaputra gorge locally known as the Dihong. On the north, there is
the vast plateau of Tibet dotted with a number of lakes stretching northwards to the Kuen Lun range having a general but irregular E-W strike (Pascoe, 1965).

Burrard and Hayden (1907-08, 1934) and Bordet (1961, vide Gansser, 1964) have subdivided the Himalayan chain including the Salt Range and Karakorum into the following seven transverse regional units (Fig. 1.1):

1) Salt Range: An intermediate structure between the Indian shield and Himalayan chain.

2) Karakorum: Over 400 kms long mountain chain bordering the western Himalaya to the north.

3) Punjab Himalaya: It is about 550 kms long and lies between the Indus and Sutlej rivers.

4) Kumaon Himalaya: It lies between the Sutlej and Kali rivers and has a length of 320 kms.

5) Nepal Himalaya: It lies between the Kali river, in the west, and Tista, in the east, and extends along the whole 800 kms length of Nepal.

6) Sikkim/Bhutan Himalaya: It measures about 400 kms and occupies the States of Sikkim and Bhutan.
Fig.11 Map of the Himalayas showing various sub-divisions (after GANSSE, 1964).
7) NEPA Himalaya: It extends from the eastern boundary of Bhutan across the gorges of Tsangpo-Brahmaputra and is about 400 kms in length.

Burrard and Hayden (1907-08) have divided the Himalayan mountain system from south to north into the following four, nearly parallel and longitudinal, zones from geographical and geological points of view (Fig. 1.1):

1) The Sub-Himalayan or Outer Zone (also called autochthonous zone bordering the Indo-Gangetic Plains).

2) Lower or Lesser Himalaya or allochthonous zone lying between the foot-hill zone and the central Himalayan zone.

3) Higher or Central Himalaya (crystalline zone of lofty peaks).

4) The Trans-Himalaya or Tibetan Himalaya lying north of the Central Himalaya.

Pande and Saxena (1968) subdivided the Himalaya into three longitudinal zones as follows:

1) The marine fossiliferous zones of Trans- or Tibetan-Himalaya consisting of a complete
succession of rocks from Cambrian to Palaeocene lying to the north of the main crystalline axis (This zone is also characterised by ophiolites).

2) A zone consisting of the Central Gneisses and other metamorphites.

3) The Himalayan zone lying just south of the crystalline axis which includes the Lesser Himalaya or the allochthonous zone and the foot-hills or autochthonous zone of Auden.

Geological investigations of the Himalaya were started in the middle of the nineteenth century and fairly good base has been laid by the pioneer workers like Stratchey (1851), Medlicott (1864), McMahon (1877, 1882, 1883, 1886), Middlemiss (1887, 1888), Oldham (1893), Burrard and Hayden (1907-08), Hayden (1907), Pilgrim and West (1928), Auden (1933, 1937) and others yet large tracts have geologically remained terra incognita till date. The factors like inaccessibility to remote areas, near absence of fossils in the south of the Great Himalayan range (or crystalline ridge - Pande, 1967), apparent paucity of economic minerals and complex structures have made the detailed investigations of the Himalaya very difficult and thereby many fundamental aspects of the geology have remained unsolved.
PRESENT WORK

A perusal of the geological literature on the Himalaya brings out the fact that detailed petrological, geochemical and structural investigations have not been carried out even in localised sectors so that some correlative parameters could be established. One of the important lithologic units which needs to be thoroughly investigated is the basic/metabasic rocks. The present work has been undertaken keeping in view the importance of such investigations and the area around Rampur was selected for this purpose. Some geological reports are available on the area but detailed investigations of the proposed type have not been done so far in the area under study.

LOCATION

The area under investigation forms a part of the Lesser Himalaya and lies in Simla district of Himachal Pradesh, India (Fig. 1.2). The area, covering about 75 sq. kms, falls in the northeastern corner of the Survey of India toposheet No. 53 E/11 (1" = 1 mile) and lies between the North latitudes 31° 25' and 31° 30' and East longitudes 77° 37' 15" and 77° 43' 36". Rampur (31° 27' 77° 38') town is situated on the left bank of the river Sutlej at the height of about 1,000 metres above the mean sea level.
FIG. 1.2. LOCATION MAP OF THE AREA
The area is easily approachable by an all-weather 141 kms long motorable road from Simla, the Northern railway terminus. It is also connected with Chandigarh via Simla; Kulu via Banjar; Kalpa (district headquarters of Kinnaur) and Pooh.

PHYSIOGRAPHY

Topography:

The area under study is characterized by rugged mountainous topography with a series of high precipitous ridges, steep escarpments and deep intervening valleys.

Shikar, the highest peak in the area, lies in the southeastern part of the map and is about 3,085 metres high while along the Sutlej valley, the recorded height is as low as 860 metres above the mean sea level, thus giving a local available relief of about 2,205 metres.

The study area is divisible into three units: (a) area to the south and east of the Sutlej valley, (b) area to the north and west of the Sutlej valley and (c) the Sutlej valley itself.

a) Area to the south and east of the Sutlej valley:
This area is typified by the following ridges and spurs
The Shikari Ridge (Dhar):

The main ridge - Shikari Ridge - commencing from 1,430 metres high peak, south of Rampur, firstly trends almost in the east-west direction passing through 2,741 metres height and thence swings towards ENE direction. It attains heights of 3,085 metres and 2,748 metres (peaks) in the map area. This ridge is characterized by escarpments on its northern side, i.e., towards the Sutlej valley and has a gentle slope towards the southern side. A number of spurs jut out from this ridge towards the flanks (Fig. 1.3).

Spurs on the Northern side of Shikari Ridge:

i) Kanech-Khaneri Spur is an off-shoot of the main Shikari Ridge on the northern side and juts into the valley of Sutlej. It forms a watershed between Rachuli Khad and Darshai Khad. The maximum height recorded on this spur is 1,577 metres.

ii) Shikar-Pashada Spur lying to the east of Kanech-Khaneri spur also juts into the valley of the Sutlej. The highest point on this spur is Shikar itself (3,085 metres). This spur runs in NNW-SSE direction exhibiting an escarpment on the eastern
FIG. 1.3 PHYSIOGRAPHIC FEATURES OF RAMPUR AREA
side and gentle slope on the western side.

iii) Banauri Thach Spur is a subsidiary spur on the northern side of the main Shikari Ridge and runs approximately in NNW-SSE direction. It forms a water-divide between Pashada Khad and Barauni Khad.

iv) Makrola Spur separates the Gharola Khad on the eastern side from the Barauni Khad on the west. It also runs in NNW-SSE direction and juts into the Sutlej valley.

Spurs on the Southern side of Shikari Ridge:

There are three main spurs on the southern side of the Shikari Ridge (Fig. 1.3).

i) Dansa Spur is an off-shoot of the main Shikari Ridge. It runs in N-S direction and juts into the Nogli stream (occurring to the south and outside the map area). The maximum height on this spur is 2,748 metres.

ii) Shikar-Shanjal Spur commences from 3,085 metres peak and trends in southerly direction. It is characterized by escarpments on both the sides.
iii) Parandli Spur commencing from the Shikar peak (3,085 metres) trends in southerly direction.
Sahneda Khad separates it from Shikar-Shanjal spur.

b) Area to the north and west of the Sutlej valley:
This area is characterised by the following spurs:-

i) Gaon Bel-Sisu Ser Spur runs in NW-SE direction and juts into the Sutlej valley. The maximum height on this spur is about 1,720 metres.

ii) Tonan-Zaghat Khana Spur lies to the NW of Rampur and runs in NW-SE direction. The highest point on this spur is about 1,824 metres.

iii) Ropru Spur occupying a small part of the map area to the SW of Rampur extends in WNW-ESE direction and juts into the Sutlej river. The Kasholi Khad separates it from Tonan-Zaghat Khana spur. The maximum height on this spur is about 1,368 metres.

c) The Sutlej valley:
In the map area, the valley formed by the Sutlej river varies in width (Plate 1.a) and the town of Rampur is situated on its left bank (Plate 1.b). The valley commencing from the northeastern corner of the map area runs in a NE-SW direction. Near Rampur it firstly curves towards WSW and then...
swings towards south. The relative relief of the valley is about 153 metres.

**Drainage:**

The drainage system of the area is formed by the river Sutlej and various Khads or streams (Fig. 1.3). The Sutlej is one of the most important antecedent rivers of the Himalaya which cuts across the NW-SE trending ranges. More than fourth-fifth of the area is drained by the Sutlej river system. Shikari Ridge acts as a watershed between the Sutlej drainage system and the Nogli stream; the latter lies to the south and outside the map area. To the SE of the Shikari Ridge, the remaining one-fifth of the area is drained by Khads and rivulets which flow towards SE and finally drain in the Nogli stream.

The main tributaries (Fig. 1.3) of the Sutlej are:

- (i) Gharola Khad,
- (ii) Barauni Khad (Plate 1.c),
- (iii) Pashada Khad (Plate 1.d),
- (iv) Rachuli Khad,
- (v) Darshai Khad,
- (vi) Sahnedra Khad,
- (vii) Kuni Khad and
- (viii) Kasholi Khad.

The streams (i) to (vi) drain the hill slopes of the left bank of the Sutlej river and flow towards NW except the sixth one which trends almost N-S. Khads (vii) and (viii)
The Khads or streams present a parallel drainage pattern which frequently becomes dendritic.

CLIMATE

The area experiences Cw(a) (Köppen) climate which is characterized by humid mesothermal conditions. The average annual rainfall in the district is about 175 cms. The variation in the seasonal rainfall is accentuated by the late or early arrival of monsoon. The monsoon usually sets in the middle of June and lasts till September. During the months of October to March, the area experiences snowfall in the hills. The summer season sets in the month of March and lasts till the middle of June.

METHODS OF INVESTIGATION

Field Investigations:

A reconnaissance survey was carried out in the study area during 1968-69 which revealed that the area has suffered polyphased metamorphism and deformation. With a view to systematically collect structural, petromineralogical and geochemical data, further work was carried out in different phases in the subsequent years. Geological
mapping was carried out on 1:15,840 scale enlarged from 1" = 1 mile toposheet No. 53 E/11 of the Survey of India. The mapping was done with a view to delineate the various lithologic units and attitude and nature of the various structures were studied, recorded and plotted on the field map. Each field season was followed by laboratory investigations. About 400 representative rock specimens were collected during the different seasons of field work. The sampling was done both along and across the strike direction depending upon the nature of the problem in hand. Finally, an area of about 75 sq. kms was mapped and selected for the present work. The results of the field investigations were used in the preparation of geological and structural maps of the area.

Laboratory Investigations:

a) The data recorded during each field season were studied in the laboratory. About 250 thin sections of the representative rock types were studied under the microscope with a view to determine the mineral constituents, their textural relationships and mineral paragenesis. The thin sections were cut oblique and perpendicular to the foliation of rocks. The determination of 2V was done by using Leitz 4-axis Universal Stage. Refractive indices were determined by liquid immersion method and Abbe's refractometer.
b) The various structural data recorded in the field were plotted on Schmidt's equal area net and contour diagrams were prepared to infer the symmetry of the structures and their mean trends.

c) In order to study the chemical changes suffered by the rocks of the area under study, representative samples were selected for chemical analysis on the basis of petrographic studies. The samples selected for chemical analysis were washed and dried. The clean samples were broken to pieces (approx. 1 cm size) on a hard steel plate. Care was taken to avoid contamination from smearing of hammer. The small chips were ground to adequate fineness in a percussion mortar. At this stage, the samples were reduced by coning and quartering. The samples taken for chemical analysis were pulverised in agate mortar till no grittiness (-200 mesh) was felt. In order to check oxidation of the samples, extreme grinding was avoided. The samples were dried over night at 110°C and were stored in dessicators. The chemical analysis was done by the 'Rapid method of silicate analyses' (Shapiro and Frannock, 1962) at the Geology Department, Panjab University, Chandigarh. The scheme involves the preparation of solution A for determination of $\text{SiO}_2$ and $\text{Al}_2\text{O}_3$ and solution B for the determination of $\text{TiO}_2$, total iron as $\text{Fe}_2\text{O}_3$, $\text{MnO}$, $\text{P}_2\text{O}_5$, $\text{CaO}$, $\text{Na}_2\text{O}$, $\text{MgO}$.
& K₂O using 0.1 and 0.5 gms of powder respectively. Oxides, such as, SiO₂, Al₂O₃, TiO₂, total iron as Fe₂O₃, MnO and FeO were determined by using the Hilger and Watts Uvispec spectrophotometer while alkalies (K₂O and Na₂O) were determined by EEL's flame photometer using Li as internal standard. For estimation of MgO and CaO titration method, using E.D.T.A. with murexide and eriochrome black T (+ methyl red) as indicators, was adopted. Ferrous iron was determined by volumetric method using potassium dichromate as the titrant and diphenylamine sulphonate as indicator. H₂O⁺ was determined by modified Penfield method. Trace elements, i.e., Pb, Cu, Ni, Co, Rb, Sr, Zn and Cr were determined by Atomic Absorption Spectrophotometer using Perkin Elmer Model No. 306 and Ba was determined by X-ray fluorescence spectrometry method in the laboratory of Mijnbouw Kunde, Technical University, Delft, Netherlands, during the author's stay there in 1973-74. To obtain optimum precision and accuracy same sets of glasswares and crucibles were used. The replicate analysis of USGS standards No. G-2 and No. BCR-1 were done by the author for correlation and precision. Different variation diagrams were plotted from the norms and parameters calculated from the chemical data which along with the petrographic studies help to decipher the geochemical changes in these rocks and to identify the parent rock composition.
PRESENTATION OF DATA

Results obtained from the field and laboratory investigations form the subject-matter of the thesis. The text of the present work is divided into eight chapters. The first chapter gives an introduction and general account of the Himalaya, location and physiography of the study area. A brief review of the published geological works on the surrounding areas is also given. The second chapter deals with the geological setting of the area, lithological distribution and characters of the rocks observed in the area. The third chapter incorporates the petrographic details of different rock units. The fourth chapter deals with various types of structures observed in the area which have resulted on account of different phases of deformation. The fifth chapter deals with the geochemistry of the rocks. The sixth chapter includes a brief account of the various concepts of metamorphism and the description of the metamorphic facies deciphered in the present area. This chapter also outlines the different episodes of metamorphism. In the seventh chapter, stratigraphy of the area and its correlation have been attempted. A summary of the present investigations has been presented in the eighth chapter.
Previous Literature

Rampur area, being located in the interior of Himachal Pradesh, remained inaccessible for a long time. Except for some reports of the Geological Survey of India, no detailed geological literature is available on the area. Though the neighbouring areas like Simla and Shali have been investigated in some details by various workers (Pilgrim and West, 1928; West, 1934, 1935, 1939 and others) yet hardly any detailed investigation of the proposed type has been done so far on the area under study.

In the following pages, an attempt is being made to refer to geological works that have been published on the area in particular. A resume of the geology of some important formations occurring in the Punjab and Kumaon Himalaya is presented here to provide a comprehensive picture. Strachey (1851) prepared the first geological section across the length of the Himalaya. This geological section is too schematic to depict the structure of the Himalaya as it is understood today.

An examination of the geological literature shows that some significant contribution to the Himalayan geology has been made only after Strachey's work. Such contributions to the geology of Himalaya made in the later half of the
nineteenth century are due to Medlicott (1864), Stoliczka (1866), McMahon (1877-87), Oldham (1883-88), Middlemiss (1887-96) and Griesbach (1891).

Medlicott (1864) was one of the early pioneer workers who made an attempt to classify the rocks of Simla area and gave an authentic account of the structure and stratigraphy of the area lying between the Ravi and Ganges rivers. Though his classic work, published as a memoir, has undergone several modifications yet the classification proposed by him (Table 1.1) has served as a guide to all the students of Himalayan Geology.

TABLE 1.1
Classification of rocks of the Simla region after Medlicott (1864).

A  Sub-Himalayan Series:
   Upper  -  Siwaliks
   Middle -  Nahans
   Lower  -  Subathus

B  Himalayan Series:
   1. Unmetamorphic
      Krols
      Infra Krols
      Blini (Blaini)
      Infra Blini (Simla Slates)
2. Metamorphic Crystalline and subcrystalline rocks

Stoliczka (1866) described the petrography of the 'granitoid gneiss' of Wangtu which has been ramified by innumerable veins of albite granite containing quartz, mica and tourmaline. He further described most of the granites and gneisses extending from Hazara through Kashmir to Garhwal and Bhutan as 'Central Gneiss' which he considered to be forming the principal geological axis of the Himalaya and older than the Silurian period.

McMahon (1877, p. 215), while describing the Narkanda-Kotgarh-Rampur section, referred that "From the Nogli to Rampur and beyond, there is an extensive intrusion of trap which has tossed the rocks about a good deal. From Rampur to Nirth the dip, at first westerly, changes to east, then to south, and then back again to west." He (1882) opined that the traps of Drang and Mandi area are altered basaltic lavas.

Describing the brief sketch of the geology of the section from Simla to Wangtu, he (1886, p. 67) observed: "At the Nogli a beautiful milky-white quartzite that takes a high polish, and is sometimes mistaken for marble, appears dipping
south-west. This rock, which, I think, represents the Krol quartzite, is followed by trap." He further stated: "The volcanic rocks here displayed appear to me to occupy very much the same horizon as the altered basalts of the Dalhousie region, which occur between the silurian and the carbo-triassic series. Their relation to the white quartzite band at the Nogli, and to the quartzites interbedded with them, which presumably represent the Krol quartzite, would however seem to indicate that they are somewhat younger than the Dalhousie volcanic series. In this respect the Rampur lavas agree with those of Kashmir, where Mr. Lydekker observed that, in some instances, they pass up into his Kuling series, the equivalents of the infra-Krol series of the Simla region, and of the lower carboniferous series of Europe and Australia." He (1886, p. 79) also noted that: "Amongst the trap south of the town of Rampur, amygdaloidal specimens are not uncommon; the hornblende trap is intercalated with slaty beds, and about the middle of the series three bands of quartzites occur separated by beds of slate." He attributed the hornblende character of Rampur traps to metamorphic action.

Regarding the rocks occurring between Narkanda and Rampur, McMahon (1886, p. 86) observed that,"At Narkanda the oldest rocks are found at the point of highest altitude,
whilst at Rampur we have the younger rocks occupying the valley of the Sutlej. The dip is north-easterly; and, according to my view, the older rocks dip under younger ones, and we have a regular sequence of rocks between Narkanda and Rampur, beginning with the lower Silurians (or Cambrians?) at Narkanda, and ending, at Rampur, with the volcanic series of lower Carboniferous age."

Oldham (1883-88) described the geology between Simla and Chakrata in a series of papers. His later work in 1888 was mainly confined to Simla area. He suggested a glacial origin for the Blaini Boulder Bed and assigned an Upper Palaeozoic age to it. He noted the possibility of reverse metamorphism in the Simla Himalaya as due to heat applied from above by the intrusions of sheet of granite, now removed by denudation. He, however, opined that the metamorphism observed around Simla was due to a core of granite or other igneous rock having been intruded into the rocks but not yet laid bare by denudation. For the different grades of metamorphism exhibited by these rocks, he favoured the selective metamorphism.

Middlemiss (1888) carried out detailed survey in the Kumaon and Garhwal regions. He classified the lithological units of this region as: (a) the inner formation comprising
the schistose series with intrusive gneissose granites and (b) the outer formation (non-metamorphic) consisting of volcanic breccia, purple shales, massive limestone, tals and nummulites. He discarded the views of McMahon (1877) regarding the violent disruption during the intrusion of gneissose granites of the central axis during the Tertiary times.

Griesbach (1891) worked in Central and Lower Himalayan ranges and assigned the metamorphic origin to the gneisses of these areas. He also explained the possibilities of their gradual passage into schistose rocks.

Hayden (1904) gave an account of the geology of Spiti with parts of Bashahr and Rupshu which formed the basis for the classification and correlation of sedimentary rocks of the Himalaya. Further, he classified Himalayan granites as tourmaline granite, hornblende granite and biotite granite. According to him, these granites occur as intrusive igneous rocks. He also gave an account of Jaunsar, Simla Slate, Blaini and Krol Series.

Holland (1909) described the occurrence of striated boulders in Blaini Boulder Beds of Simla. He agreed with Oldham's views of glacial origin of Blaini Boulder Bed but assigned Cambrian age to the same.
Pilgrim and West (1928) gave a classic account of "the structure and correlation of the Simla rocks." Their contribution to the geology of Simla Hills forms a valuable guide for subsequent workers in this region. The thrusting hypothesis was, for the first time, applied to the rocks of Simla region, which also accounts for the reverse stratigraphy - an enigmatic problem for the earlier workers. They recognised a number of major thrust planes which separate the lithologic units of different ages. The following sequence (Table 1.2) has been established in the Simla Hills:

Table 1.2
Classification of the Simla rocks after Pilgrim & West (1928)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dagshai Series</td>
<td>Lower Miocene</td>
</tr>
<tr>
<td>? Unconformity</td>
<td></td>
</tr>
<tr>
<td>Uppermost Subathu Beds</td>
<td>Upper Oligocene</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Subathu Series</td>
<td>Middle Eocene</td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Krol Series</td>
<td>?</td>
</tr>
<tr>
<td>Krol Sandstone</td>
<td></td>
</tr>
<tr>
<td>Infra-Krol Beds</td>
<td>Lower Gondwana</td>
</tr>
<tr>
<td>Blaini Limestone</td>
<td></td>
</tr>
<tr>
<td>Blaini Conglomerates</td>
<td></td>
</tr>
<tr>
<td>Unconformity</td>
<td></td>
</tr>
</tbody>
</table>
Shali Limestone
and Slates - (Position uncertain)
Simla Series (Infra-Blaini) Dogra Slates
( LOWER Palaeozoic)

Unconformity
Jaunsar Series Purana
Unconformity
Chail Series Purana
Unconformity
Jutogh Series Archaean ?

Pilgrim and West (1928), while summing up their investigations, postulated the following sequence of events in Simla rocks:

a) Deposition of Jutogh Series
b) Intrusion of basic sills and dykes (now hornblende schists)
c) Recumbent folding and regional metamorphism
d) Intrusion of Chor granite towards the end of (c)
e) Intrusion of olivine dolerites probably soon after (d)
f) Deposition of Chail and Jaunsar Series
g) Deposition of Simla to Krol Series
h) Deposition of Subathu Series
i) Folding in of the Subathu with the Jaunsar, Simla and Blaini Series
j) Main overthrusting with low grade metamorphism

k) Cross faulting and warping of the overthrust planes.

Chatterjee (1929), in a short note, referred the rocks of Chor and neighbouring areas as Infra-Elaini. According to him, the Chails and the Jutoghs represent only the different metamorphic products of the Infra-Elaini slates and sandstone bands.

Wadia (1932, 1938) confined his work mostly to the Punjab Himalaya in general and Kashmir area in particular. He published an account of the geology of Poonch State and also a number of papers on the geology of northwestern Himalaya including Nanga Parbat. He proposed the famous syntaxial bends of the Himalaya, as formed due to bending of sediments of the Himalayan geosyncline, around two tongue-like projections of the Peninsula which was drifting northwards.

Auden (1934, 1937, 1951, 1952) carried out geological investigations both in Simla and the Kumaon Himalaya. He published his valuable work entitled: "The Geology of the Krol belt" in 1934, which has gone a long way in solving the various baffling problems regarding the
structure of the Himalaya. Discussing the structure of the Himalaya in Garhwal, he (1937) evoked the theory of nappe sheet and thereby he explained the reversal of the stratigraphic succession and metamorphism. He also compared the rock types and structures observed in the area with that of Simla area as proposed earlier by Pilgrim and West (1928).

West (1934-35, 1937-38, 1939) worked in the Sutlej Valley and observed that the gneissic rocks around Luhri have intruded into the Chail Formation in the form of sill-like bodies without any remarkable contact effects. While describing the geology and structure of the Shali Window, he (1939) proposed that the Shalis form the autochthonous zone and crop out in the form of tectonic window under the Chail nappe sheet. The Chails and the Shalis were separated by the Shali thrust which was post-Miocene in age as it overlies the rocks belonging to Dagshai Series (Miocene).

Heim and Gansser took extensive traverses in the Central Himalaya and summed up their results in the form of a memoir entitled: "Central Himalayas" (1939). Their work is classic and covers many aspects of Himalayan geology like structure, lithology, correlation, tectonics, etc. Gansser (1964) made a significant contribution by compiling the investigations carried out on the geology of Himalaya.
He (1966) suggested a northward shift of the Indian Shield as a possible cause of the Himalayan orogeny.

Misch (1949) demonstrated the process of granitization in the Nanga Parbat area. Linking the high-grade metamorphism with synorogenic granitization, he expressed that the granitising solutions were responsible for regional metamorphism in the upper part of the earth's crust which took place in the early Tertiary period.

Pande (1950, 1956-57, 1967, 1975) carried out geological investigations in the various parts of the Kumaon and Garhwal Himalaya. He (1956-57) referred to the quartz porphyries of Ramgarh (Heim and Gansser, 1939) as migmatite. He stated that they were formed as a result of permeation of granitising solutions along the privileged paths constituted by the schistosity of the metasediments and assigned a Tertiary age to the migmatization. He discussed the geological history of the Himalaya in his paper (1967) entitled: "Palaeo-tectonic evolution of the Himalaya." He proposed two geosynclines separated by the Central Crystalline Axis. According to him, southern or the Himalayan geosyncline was responsible for the development of the Himalaya. Pande and Saxena (1968) discussed the geotectonic evolution of the Simla Himalaya by 'translation'
and advocated the theory of two geosynclines. Pande (1975) discussed the metamorphic history and deformation of the Himalaya in general and recognised at least three phases of deformation accompanied by metamorphism during the Tertiary Himalayan orogeny.

Berthelsen (1951) indicated the existence of a tectonic window around Rampur in the Sutlej Valley. He described from this area a thick sequence of chlorite phyllite and quartzite, which he designated as the Rampur Series tectonically overlain by the metamorphics with their roots in the Higher Himalaya. He (1967) also discussed the structures and the stratigraphy of the Lower and Higher Himalaya of the Simla-Sutlej section.

Kedar Narain and Dass (1959-60), while working in the Narkanda, Rampur and surrounding areas, described the rocks from north to south as belonging to the Sarahan Series, Rampur Series, Simla Slates and the Narkanda thrust sheet. They further observed that the rocks of the Rampur Series are exposed in the form of a window.

Bhargava (1961-62) observed that the quartzites of Rampur area, which show ripple marks and current bedding, are suggestive of shallow water conditions during their deposition.
Das and Pande (1963-64, 1964-65) described the occurrence of garnet in garnet from the metapelites of the Chaukhutia area in Kumaon Himalaya. They referred the two zones to two different episodes of metamorphism. They also recognised five episodes of metamorphism in the Kumaon region.

Valdiya (1964a, b, c) discussed the geological history of the Himalaya and the age of unfossiliferous rocks of the Kumaon Himalaya as well as the Himalaya in general.

Gupta (1967) studied the granitization trends of the Chandpur metamorphites (Algonkian ?) in the Dhauladhar Range and assigned Tertiary age to the granitized rocks.

Fuchs (1968) pointed out that the Jutogh (Pilgrim and West, 1928) and Almora nappes (Heim and Gansser, 1939) belong to a single unit. A similar view has also been expressed by Pande and Saxena (1968). He further mentioned that Simla Slates are older than the Chails and that the reversed metamorphism observed in the lower part of the crystalline complex is related to the tectonics of the area.

Kumar (1968) investigated the structure and tectonic history of the Halog area and described three phases of
deformation. Kumar and Pande (1972) described the mesostructures in the Simla Hills as belonging to three phases of deformation.

Saxena and Pande (1969a, b) described the Blaini Tillites from the type area and concluded that these are indicative of wet base glaciers which deposited them in Permo-Carboniferous times. They (1969b) also discussed the granitic rocks of the 'Central Crystalline Axis' and their relationship to the orogenic phases in the Himalaya.

Pande and Kumar (1969) as also Pande and Virdi (1970a) described basic intrusives from the Chail Formation of Arki and Narkanda areas respectively. Their finds disfavour the earlier generalization that Chails are completely free from basic intrusives (Pilgrim and West, 1928). Pande and Virdi (1970a) concluded that the occurrence of basic rocks in Chails, though a rarity, cannot be used as a criterion to demarcate them from the Jutoghs in which the basics are very common. Pande and Virdi (1970b) reported the occurrence of upper Shali rocks in the form of a small 'tectonic window' around Chareota in the Sutlej Valley under the Chail Thrust Sheet. According to them, the Shali Series continues underneath the thrust sheet towards NE and the gneissose rocks, forming the base
of the Chail Thrust Sheet, are migmatites and not igneous intrusives as reported earlier (West, 1939).

Pande and Singh (1971) describing the polyphal growth of garnet in the metasediments of Sarahan area concluded that the development of garnet in garnet in this area is related to migmatization phase and the development of the 'outer garnet' is due to iron metasomatism. They further opined that this development of garnet in garnet is a function of polyphased metamorphism and is not due to the difference in grades of zones of metamorphism.

Ray and Naha (1971) concluded that the rocks of the Jutogh Series in the Simla area have been involved in deformation in three impulses interspersed with metamorphism in two stages. The rocks of the Chail Series show partly independent trends of metamorphism and deformation. The Jutogh-Chail contact represents a thrust. Further, Naha and Ray (1972) cited evidences for overthrusting in Simla Himalaya and concluded that the overthrusting preceded third phase of deformation.

Sharma and Gupta (1971) observed that the Dogra slates are intruded by lava flow, sills and dykes of spilites and keratophyres. They (1972), while discussing the spilite-keratophyre rocks of Thanamandi area, observed
that these rocks occur as sills, dykes, lava flows and ash beds which are confined to the metamorphic allochthonous zone of Kashmir Himalaya, south of Rattanpir Range of Rajouri district. These rocks exhibit alkalic character and appear to represent the initial stage in the magmatic episode.

Virdi (1971) carried out investigations in Narkanda area and recognised five different metamorphic episodes in the rocks of this area.

Ashgirei (1972) opined that the Himalayan granites originated not by palingenesis and anatexis but by deep juvenile processes. He further described that the granitization of the Chail nappe sheets in the Nirth synform took place at a depth only 1-1.5 km below the landscape surface which was in existence at the time of granitization. He further concluded that granitizing fluids in the Himalaya ascended only along deep-seated tectonic zones from a very deep-seated source. He (1972) also described the geological section across the Himalaya from Kalka and Simla to Nirth and Babeh Pass (Fig. 1.4). He pointed out that the roots of nappes lie to the north of Nirth synform and has recognized four roots between Nirth and Babeh Pass. He (1975) discussed the thrust
FIG. 1.4 - GEOLOGICAL SECTION ACROSS THE HIMALAYAS FROM KALKA AND SIMLA TO NIRTH AND BABEH PASS

(AFTER - G.D. ASHIREI, 1972)
tectonics of Himalaya and is of the view that the uppermost thrust sheet unit in the Lower Himalaya, viz., Chail Unit and Jutogh Unit, especially more metamorphosed rocks of the Jutogh Unit must have their roots in close neighbourhood with graben synclinorium related with the axial deep-seated faults. He further concluded that Jutogh metasediments represent rocks belonging to the amphibolite facies. These sediments were deposited during the initial stages of geosynclinal evolution, the exact nature of which is not yet known. The absolute age determinations have affirmed the older geologic age (900 m.y., 730 m.y. and 728 m.y.) of upper thrust sheet units which are composed of granite gneisses and crystalline schists, younger age for the crystalline schist thrust sheets of Jutogh units (325, 314, 250, 172 m.y. but also 50, 37 and 13 m.y.) and still younger age of metamorphism for the rocks of lower thrust sheets unit which is composed of phyllites and greenschists formation of Chail Unit (139, 107, 86, 84, 79 m.y. but also 32 and 28 m.y.). According to him, the Chail Group shows metamorphism of phyllitic and greenschist facies (Chail Thrust) and these rocks may represent deposition during early period of geosynclinal evolution. He mentioned that the lowermost thrust sheets distributed only in the Lower Himalaya (Auden, 1934) are composed of almost unmetamorphosed rocks. These thrust
sheets were squeezed out of the geosynclinal thick sequences deposited somewhere in the bordering areas of Higher and Lower Himalaya. He further pointed out that the absence of metavolcanics in the lowermost thrust sheets shows that they belong to miogeosynclinal sediments. In the rocks of Chail and Jutogh, there are numerous remnants of metamorphosed volcanics which are sometimes highly granitized. Thus, the upper tectonic thrust sheets are the representatives of eugeosynclinal sediments. The discovery of metavolcanics in the thrust sheets of Chail and Jutogh imparts the vital conclusion in favour of developing hypothesis about the existence of eugeosyncline in the Upper Himalaya.

Chadha (1972) studied the Jutogh metamorphites and associated metabasics of Chaur area. His study of metabasics in the Chaur and adjacent areas reveals that there had been intrusion of more than one igneous suites.

Mehta (1972), while working in Kulu area, established three main phases of deformation accompanied by five episodes of metamorphism.

Pareek (1973) observed that the Darla trap shows a chemical gradation between tholeiitic and alkali basalts. The rock types are basalt, palagonite-basalt, diabase,
spilite, actinolitic ferruginous schistose rocks and rhyolite.

Patwardhan and Bhandari (1974), while discussing the petrogenesis of the spilitic rocks of Mandi area, Himachal Pradesh, have opined that albite and consequently the soda content of these rocks are primary. They are of the view that basic rocks attaining spilitic composition on account of post-magmatic processes may be referred to as spilitic rocks.

Varadarajan (1974) observed that the massive metabasites of Bhimtal-Bhowali area have given rise to contrasting but complementary rock types as a result of degradation of the original basaltic rocks and metamorphic differentiation during load metamorphism.

Bhatia (1975) observed that the rocks of Dalhousie-Chamba area have been subjected to at least three phases of deformation.

Kapila (1975), while describing the deformation and metamorphism of Mukteswar area, concluded that the rocks have undergone at least three phases of deformation accompanied by five phases of metamorphism.
Desai, et al. (1976) observed that the rocks in the area to the south of Bhimtal as far as the Main Boundary Fault comprise a complete consanguineous suite of spilitic-keratophyre-soda-granite. They are of the opinion that the porphyries of Ramgarh are also of keratophyric nature and appear to be genetically related to the spilitic rocks of Bhimtal.

Shah and Merh (1976) established that the basic rocks of Bhimtal comprise a spilitic suite and classified them into three main types, i.e., 'spilitic diabase', 'spilitic basalts' and 'tuffs and tuffites'.

Sharma (1977), while describing the geology of the Kulu-Rampur belt (H.P.), concluded that the rocks of the belt belong to the Jutogho, Banjar and Larji formations and show progressive increase in the grade of metamorphism from shale-slate stage in rocks of the youngest Larji Formation to kyanite-sillimanite stage in the older rocks of Jutogho Formation. He concluded that the metamorphism in the area is essentially of regional type.

Singh (1977) observed that rocks of Sarahan area have undergone three phases of deformation and five main episodes of metamorphism.