CHAPTER II

BACKGROUND INFORMATION

HIMALAYA IN GENERAL

The Himalaya is a youthful mountain system, contemporary of the Alps. It comprises a number of successive nappes and in tectonic design, bears much similarity with the latter. Although vastly greater in dimensions, the Himalayan mountain chain is structurally far~~e~~ more simple~~r~~ than Alps. In the words of Wadia (1938, p. 117), "We cannot be so bold as to say that the Himalayas are built on the plan of the Alps, nor even that their architecture is individual. No doubt several tectonic features are common and the

Alpine-Himalayan axis of earth-folding originated in one common and continuous impulse. But the proportions are so vastly different, that the very magnitude of the earth-waves raised in the case of the Himalayas gave them a comparatively simpler tectonics, while the smaller convolutions at the other end of the axis may have more severely plicated the shallower surface folds; the one may be like an ornately built, delicately chiselled chapel, the other a huge sun-altar of rough-hewn blocks. Perhaps the old pioneers who worked before us recognised this fact and I hope those that follow will not entirely ignore this factor."

The Alps and the Himalayas have been referred to as Inter-continental mountain chains of the Mediterranean type, as opposed to the Circum-Pacific type. However recent studies in these mountain chains have indicated that in both, a combination of the two types exist one or the other predominating here and there. In regard to the Himalaya, Richter (1958, p.414) stated that this mountain chain has certain characteristics of the Pacific belt too, although exhibiting a lesser degree of seismic activity.

The Himalayan chain, omitting Salt Range and Karakoram, can be subdivided (Burrard and Hayden, 1932; Bordet, 1961) into the following regional geological and geographical units (Fig. 2.1):

1. Punjab Himalaya: This 550 km long section of the true Himalayan chain is bordered in the west by the Indus River and in the east by the Sutlej River. It includes Kashmir and Spiti region, geologically the best known area of the Himalaya.

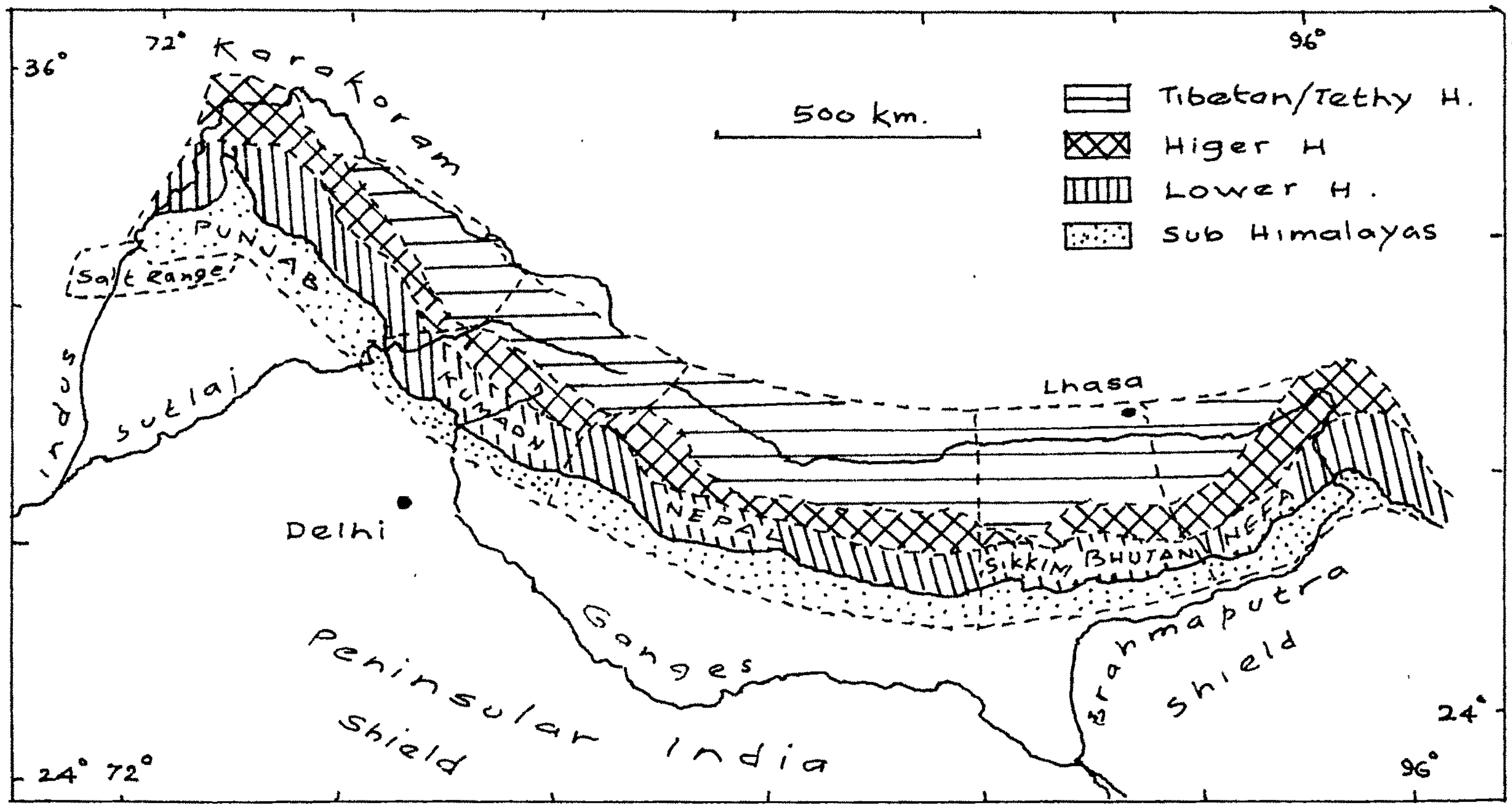
2. Kumaon Himalaya: From the Sutlej eastwards this section stretches for 320 km right upto the Kali river on the western boundary of Nepal. It includes the Himalayan ranges of Kumaon and parts of southern Tibet.

3. Nepal Himalaya: From the Kali river in the west to the Tista river in the east, it extends along the whole 800 km length of Nepal.

4. Sikkim/Bhutan Himalaya: This part of the Himalayan range is occupied by the autonomous states of Bhutan and Sikkim, and measures about 400 km.

5. NEFA Himalaya (former Assam Himalaya): This eastern part of the range (400 km long) leads from the eastern boundary of Bhutan to the cross gorges of the Tsangpo-Brahmputra rivers. Lying in the somewhat politically

fig 2.1.



The general subdivisions in the Himalayas unsettled North-Eastern Frontier Agency (NEFA-Arunochal) it is geologically the least known part of the whole Himalayan range.

Each of the above sections, is usually divided into four longitudinal zones from south to north, viz. the foot-hills of the Siwaliks (the Sub-Himalaya or the Outer Himalaya); the Lesser Himalaya of unfossiliferous sediments and thrust sheets (also called the Middle Himalaya), the Central Himalaya of batholithic granite intrusions and root-zones (also called the Great Himalaya or Inner Himalaya) and lastly the Thethys Himalaya of fossiliferous sediments (also called the Tibetan Himalaya). Beyond these four zones are the Ladak and Kailash ranges followed by the Trans-Himalaya ranges.

The Himalaya mountain chain arose out of two geosynclines parallel to and separated by the present crystalline axis. The northern geosyncline in the Tibetan Himalaya, where biogenetic conditions prevailed permitted the preservation of fully fossiliferous succession from the Lower Palaeozoic to the early Tertiary, while in the southern or the Lesser Himalayan geosyncline, prevailed environmental conditions inimical to the existence of life upto the Mesozoic, although the sedimentation in the southern geosyncline may have taken place at the same time as that in the northern. However, certain fossiliferous occurrences in the Lesser Himalaya indicate that the connections might have existed between the two major geosynclines. Wadia (1955, p.6) has designated the barrier separating the two major geosynclines, as the Central Himalayan geanticline ~~geosyncline~~ in the enbryonic Himalaya of the Eocene.

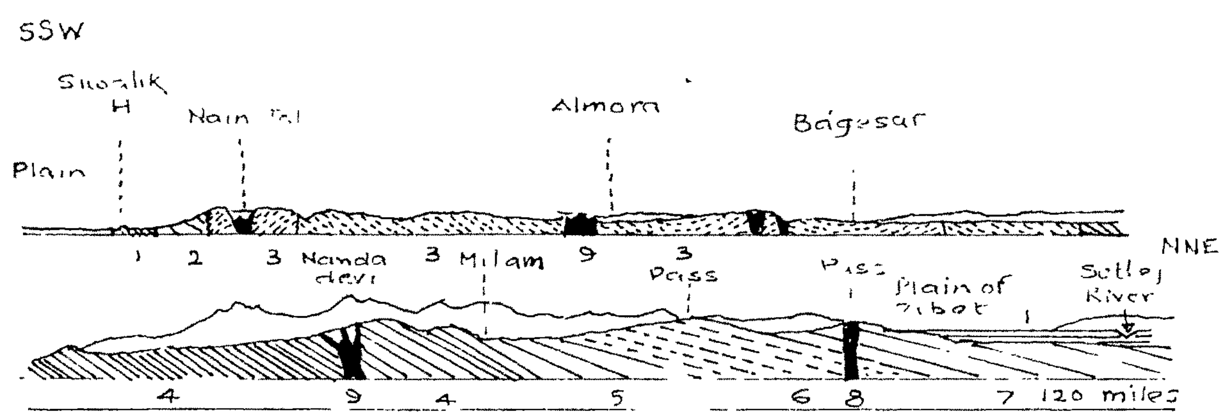
STRUCTURE AND STRATIGRAPHY OF HIMALAYA

The concepts of the structure and evolution of Himalaya have gradually developed in the course of last 150 years, and the existing knowledge of the geology of the different Himalayan areas, is due to the pioneering investigations of numerous earlier workers. As far back as the middle of the 19th century, Strachey (1851) conducted a number of traverses in the Central Himalaya and prepared interesting sections which though not showing any thrusting, could be considered a remarkable achievement for his times (Fig. 2.2).

The most outstanding contribution to the geological studies of the Himalaya in the 19th century was that of Medlicott (1864). He gave the first connected account

Fig. 2.2

The section across central Himalaya (after R. strachey)



1 Tertiary
2 Secondary and Paleozoic ??
3 Metamorphic strata without fossils
4 Crystalline schists
5 Azoic slates
6 Palaeozoic
7 secondary
8 Greenstone
9 Granite

of the geology of the Lower Himalayas of the portion between the rivers Ganges and Ravee. His work not only laid the foundations on which our present knowledge of the Himalayan structure has been built and firmly established, but also his correlation and nomenclature of the rocks of Simla have undergone little alteration at the hands of the subsequent workers. He classified the Himalayan rocks of the area, into two series, (1) Sub-Himalayan series and (2) Himalayan series.

These two series, classified into various subdivisions, formed the following sequence:-

1. Sub-Himalayan series:

Upper Siwaliks		
Middle Nahan		Kasauli
Lower Subathu		Dagsai

2. Himalayan series:

A. Unmetamorphosed:

Krol	-	Limestone
Infra Krol	-	Carbonaceous Shale
Blaini	-	Conglomerate
Infra Blaini	-	Slates.

B. Metamorphics:

Crystalline and sub-crystalline rocks.

The work of Middlemiss (1887,1888,1890) in the Lower Himalaya of Garhwal and Kumaon, marks another landmark. He established (1887) the following succession of the Garhwal rocks:

Sub-Himalaya	Siwaliks
Outer formation	Nummulites Tal Massive Limestone Purple slate Volcanic breccia
Inner formation	Schistose series with intrusive Gneissic granites

The first modern section of thrust folding over the entire width of Himalaya, was presented by Loc'zy (1907). His section of Kanchanjangha showing an enormous overfold with huge reversed series, thrust for 150-200 km towards the Indian plains, has been more correct at least in principle.

Almost two decades later, an outstanding contribution towards the proper understanding of the complex structure and stratigraphy of the Himalaya came from Pilgrim and West (1928). These two officers of the Geological Survey of India, mapped the region around Simla, and found that the rocks of

Simla-Chakrata area lying to the north of Tertiary belt, are not in their normal position but they have undergone thrusting and inversion (Fig. 2.3). According to these two workers, the metamorphic rocks which are really a part of the belt of rocks forming the central axis of the Himalaya, have been forced southward for many miles along a nearly horizontal Jutogh thrust plane, so as to lie now on the top of unaltered rocks. These thrusted metamorphic rocks were named as Jutogh series on which the city of Simla is situated. They postulated existence of other thrusts also below the main Jutogh thrust, of which the Chail thrust was the most important. The sequence of events in Simla region as put forth by Pilgrim and West has been summarised as under:

(a) Deposition of Jutogh series

(b) Basic igneous intrusion as sills and dykes

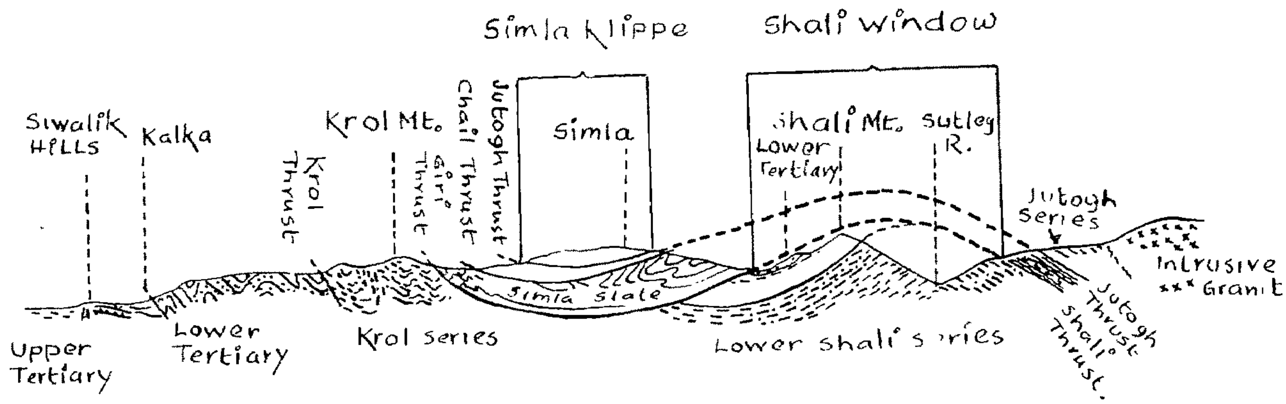
(c) Recumbent folding and metamorphism

(d) Intrusion of Chor granite at the close of folding and metamorphism.

Fig. 2.3

SECTION THROUGH THE SIMLA HIMALAYA

(W. D. West.)



Horizontal scale

Vertical Scale

They gave the following stratigraphical sequence of ~~sequence of~~ Simla Himalaya:

Dagshai Series		Lower Miocene
------------------	Unconformity	------------------
Uppermost Subathu beds		Upper Oligocene
------------------	Unconformity	------------------
Subathu series		Middle Eocene
------------------	Unconformity	------------------
Krol Series Infra-Krol beds Blaini beds		Lower Gondwana
------------------	Unconformity	------------------
Shali Limestone and slate Simla Series (Infra Blaini)		?
------------------	Unconformity	------------------
Jaunsar series		Purana
------------------	Unconiirmity	------------------
Chail series		Purana
Jutogh series		Archaeans (?)

On account of large-scale thrusting and inversion, the above formations show the following structural sequence:

Jutogh Series

.... Jutogh Thrust....................

Chail Series

.... Chail Thrust ....

Jaunsar Series

.... Jaunsar Thrust...................

Simla Slates

.... Giri Thrust ....

Krol Series

.... Krol thrust ....

Subathu series

The classic work of Wadia (1931) in the Kashmir area os Punjab Himalaya constitutes another important milestone in the progress of the Himalaya's geological studies. He pointed out the most striking feature of the NW Himalaya - the way in which the strike of the mountains, after following an arcuate SE-NW direction from Assam to Kashmir, makes a great bena in Hazara, rapidly curving round through an EW to NS direction, and producing thereby a great re-entrant angle in the alignment of the mountains between Abbotabad on the SW and Kashmir valley on the NE. Wadia's (1931) work in the south of this syntaxial area has shown that both from structural as well as from stratigraphical point of view, there is a complete geological continuity around this re-entrant. The structure and stratigraphy on the Hazara side of the syntaxis is the mirror image of the structure and stratigraphy of the Kashmir side. Wadia concluded that there had been a single Himalayan movement from the north which came up against some underground obstacle around which it was been forced to diverge. He suggested that a tongue of the ancient and stable Peninsular rocks extended upto the NW, beneath a covering of Cenozoic rocks, and that this formed the obstacle to the folding movement coming from the north, so that the original north and south direction of movement was resolved into a NE-SW direction in Kashmir and a NW-SE in Hazara. In that part of Kashmir area, Wadia defined three structural elements:

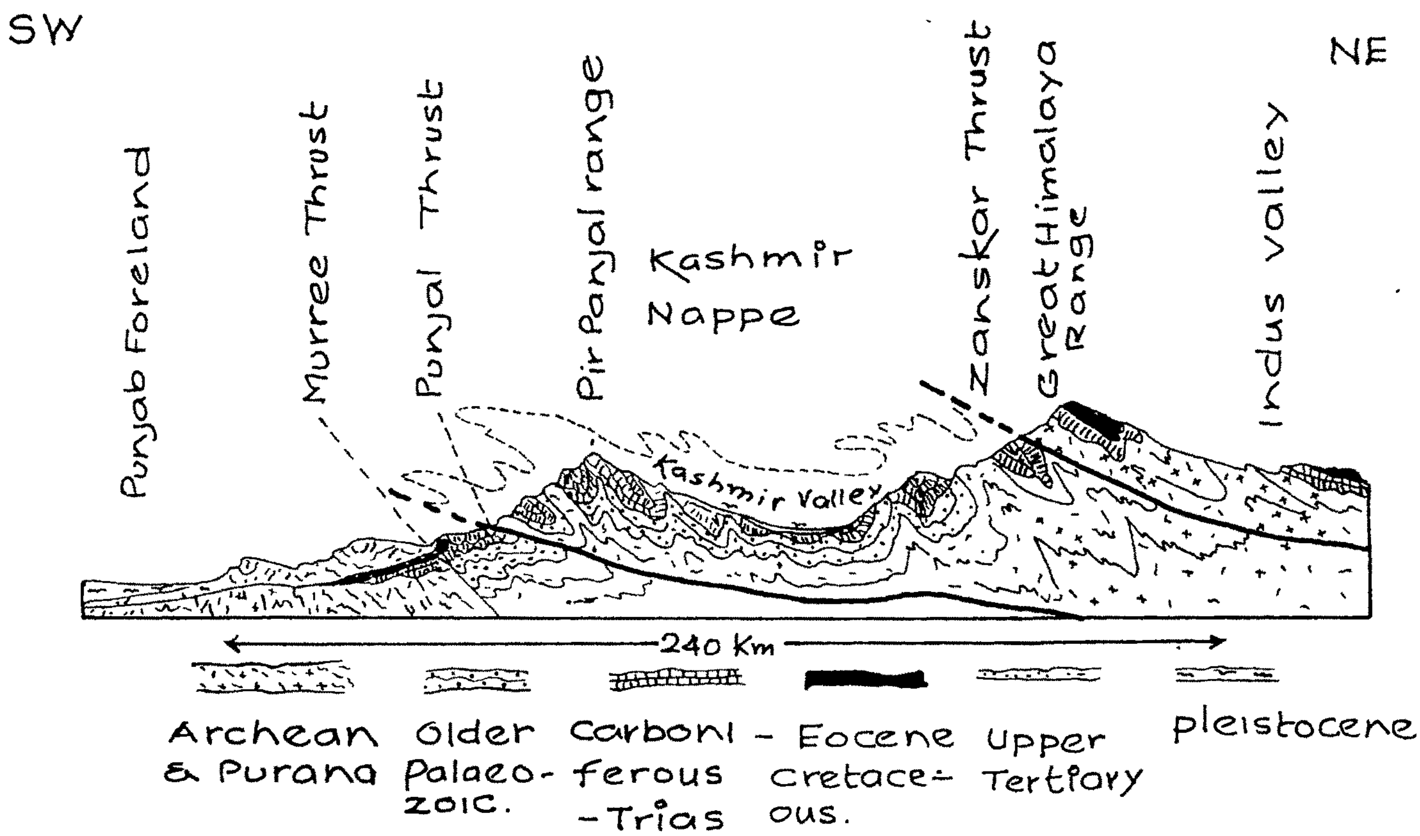
1. The tongue of the Foreland, its peneplaned surface being buried under a thick cover of Murree sediments.

2. The belt of Autochthonous, mainly recumbent folds consisting of rocks ranging in age from Carboniferous to Eocene, thrust against and over the Foreland covered under the Murree series (Murree thrust). Southward overfolding and thrusting with a dominant north-east dip was the prevalent structural tendency of this region.

3. The Nappe zone of inner Himalayan rocks which has travelled far along an almost horizontal thrust (Punjal thrust) so as to lie fitfully sometimes against a wide belt of the autochthon, at other times almost against the foreland. The Kashmir nappe is composed mostly of Pre-Cambrian sediments (Sulkhala series), with a superjacent series (Dogra slates), forming the floor of the Himalayan geosyncline that has been ridged up and thrust forward in a nearly horizontal sheet-fold. On this ancient basement lie synclinal basins containing a more or less full sequence of Palaeozoic and Triassic marine deposits in various parts of Kashmir (Fig. 2.4).

The most important feature of this region described by Wadia is the occurrence of two great thrusts delimiting the autochthonous belt. These thrusts have been traced

Fig. 2.4.



DIAGRAMMATIC SECTION ACROSS THE KASHMIR HIMALAYA, SHOWING THE BROAD TECTONIC FEATURES (D.N.Wadia) round the syntaxial bend from Hazara to Dalhousie. Of these two thrusts, the inner (Panjal thrust) is more significant, involving large horizontal displacements. The outer, the Murree thrust, shows greater vertical displacement and is steeper in inclination.

Kumaon Himalaya has received maximum attention of Auden (1934, 1937) and his works, in fact provide the most lucid and convincing account of the Himalayan rocks of Simla, Garhwal and Kumaon. He studied in great detail the 270 km long sedimentary belt of Mesozoic rocks lying to the north of the thrust which has brought these rocks over the younger Subathus of Tertiary age, extending from Solon in the NW to as far as Naini Tal in the SE. He called it as 'Krol belt' and gave the name Krol thrust to the dislocation that separated these rocks from the underlying younger Subathus. According to Auden (1934, p.364) his work was a continuation of the work started by Pilgrim and West. The sequence of formations in the Krol belt rocks of Simla-Chakrata area, as worked out by Auden, is given in Table 2.1.

Auden visualised three main thrusts in the Krol belt: the Krol thrust, bordering the Sub-Himalayas and corresponding to the so called "Main Boundary Fault";

TABLE 2.1

Auden's sequence of Formations in Simla-Chakrata Hills

Age	Solon neighbourhood	Tons river neighbourhood
Miocene	Nahans (only at Kalka)	Nahans
Lower Miocene	Kasauli Dagshai	Dagshai
Oligocene Eocene	Subathu (Nummulitic)	Subathu (Nummulitic) never in contact
? Cretaceous and Jurassic	Absent	Tal: Upper Tal / Lower Tal
? Permo-Carboniferous	Krol Series: Krol limestone: Krol E, Krol D, Krol C, Krol B (Red Shales), Krol A Krol sandstone Infra-Krol	Krol series: Krol limestone: Upper Krol limestone Red Shales Lower Krol limestone Infra-Krol
Upper Carboniferous	Blaini	Blaini
? Devonian and Silurian	Jaunsar with possible Mandhali	Jaunsar series: Nagthat stage Chandpur stage Mandhali stage
? Lower Palaeozoic and pre-Cambrian	Simla slates with Kakarhatti limeston	Deoban limestone Simla slates (Morar-Chakrata beds)
Miocene (and older)	Dolerites	

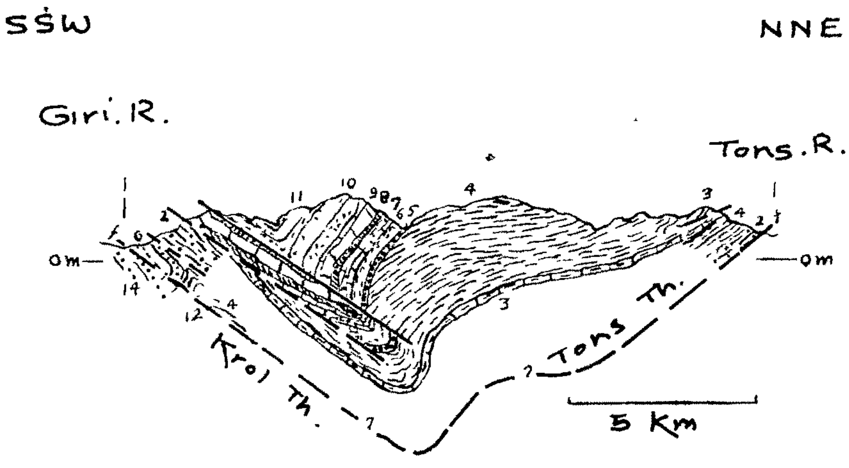
the Giri thrust, paralleling the Krol thrust approximately 6-8 km north-east of the former, and the Tons thrust in the eastern area south of Chakrata, approximately 15 km north of the Krol thrust. The Krol and Giri thrusts are directed to the south and southwest respectively, while the Tons thrust rises to the north. According to Auden, the Krol thrust and the Tons thrust are the same and the great syncline of Jaunsar rocks overlying Krols and Tals rests as a nappe on a folded thrust plane (Fig. 2.5).

In a later work, Auden (1937) has given an excellent structural interpretation of the Garhwal Himalaya (Fig. 2.6).

He gave the following sequence of rocks in Garhwal:

Formation	Thickness	Probable age
Siwalik	16,000'	Upper Miocene to Pleistocene
Nummulitic	-	Eocene
Tal	6,500'	Upper Cretaceous
Krol	4,000'	Permian to Triassic
Blaini	2,000'	Talchir (Uralian)
Nagthat	3,000'	Devonian
Chandpur	4,000'	Lower Palaeozoic Pre-Cambrian

Tig 2.5



1. Simla slates
2. Mandhali
3. Bansa limestone
4. Nagthat and Chandpur
5. Blaini
6. Infra Krol
7. Krol A
8. red shales, Krol B.
9. upper Krol limestones
10. Lower Tal
11. upper Tal
12. Subathu (Eocene)
13. Dagshai - Kasauli (Murrees)
14. Nahan (Lower Siwaliks)

SECTION THROUGH THE KROL BELT

(after: AUDEN)

According to Auden, the above mentioned rocks are tectonically arranged to show the following structural succession:

	Chandpur (metamorphosed)	
	-----------Thrust-------------	
	Nagthat	Little metamorphosed
Garhwal nappe	Chandpur	
	Boulder beds, slates and limestones of uncertain stratigraphical horizon occur in one outlier below metamorphosed Chandpurs	

------------------- Garhwal thrust -------------------

	Nummulitic	
	Tal	
	Krol	
Krol nappe	Blaini	
	Nagthat	Metamorphosed and unmetamorphosed
	Chandpur	

-------------------- Krol thrust --------------------

	Dagshai Nummulitic	
Autochthonous		Siwalik
	Simla slates	

He made a comparison of the structure of Garhwal with that of Eastern Himalaya. According to him, in the Eastern Himalaya, there are two following main thrusts:

1. The thrust causing the Gondwana rocks to lie upon Siwaliks, and

2. The thrust separating the Daling series from the underlying Gondwanas.

These two thrusts are analogous to Krol and Garhwal thrusts of the Kumaon Himalaya. In both the areas schistose rocks are thrusted upon Gondwanas or their equivalents.

The work of Heim and Gansser (1939) forms another landmark. Their geological observations on the Central Himalaya formed a part of the Swiss expedition to Himalaya. They have dealt with various geological aspects such as petrology, stratigraphy and tectonics of Kumaon, NW part of Nepal and Tibet Himalaya. They traversed in Siwalik border region of Kumaon, the great thrust fold region of Darjeeling, the central high range of Nandadevi and Badrinath, the northern range of Tethyan Himalaya and the Tibet Himalaya. Their identification of rocks, regional correlation and tectonic interpretation are so perfect that their work will remain unique for many years to come.

West (1949) while summarising the work of Auden in Tehri and Garhwal, mentioned that the structure of the Garhwal Himalaya is essentially the same as that of Kumaon Himalaya, and the two areas could be compared as below:

Garhwal Himalaya (Auden, 1939)	Kumaon Himalaya (Heim & Gansser,1939)
Thrust at the foot of main Himalayan range forming the NE boundary of the "Chamoli window".	Central thrust
Garhwal series in "Chamoli window"	Tejam Calc-zone, occurring in anticline below crystallines
Overthrust sheet of Dudatoli-Ranikhet-Almora	Crystalline Almora thrust zone

A few years later, Auden (1953) suggested an upper Miocene to Pleistocene age for the Krol and Garhwal thrusts.

In a more recent paper, Wadia and West (1964) have briefly and lucidly discussed the structure of the Himalayas. They wrote that in Simla and Garhwal areas the geological evidence suggests more than one period of orogeny. The earliest is pre-Eocene, as Subathu sediments are found resting unconformably on the strata of Palaeozoic and Mesozoic ages. A large-scale post-Subathu movement resulted into translation of sheets of rocks southward along low angle thrusts in a series of 'nappes', possibly with granite intrusion in root zone. This movement appears to have taken place at the beginning of Lower Siwalik (Mid-Miocene) deposition, giving rise to a change in the deposition from arkoses to conglomerates containing Krol belt pebbles in the foothills, though the latter was affected by the final orogenic activity at the end of Siwalik (Lower Pleistocene) times. The 'nappes' belt also moved further southwards at this time, coming to rest directly against Siwalik sediments in places.

Valdiya (1964) has ideally synthesised the work of many investigators in different parts of Himalaya, and has suggested a somewhat modified structural framework, as given below:

1. The autochthonous Siwalik zone, comprising Jura type simple open folds affected by steep reverse faulting which resembles molasse zone of the Alpine border.

2. The <u>parautochthonous Lesser Himalayan zone</u> of early Tertiary formations beneath the overthrust Krol nappe.

3. The <u>Krol nappe system</u> - mostly unfossiliferous sediments comparable to the Helvetic nappes of the Alps.

4. The <u>Kashmir nappe system</u>, which embraces the Kashmir-, Jutogh-, Garhwal-, and Kathmandu nappes, all built of pre-Cambrian crystallines and characterised by huge recumbent folds. These could be compared with Pennine nappes.

5. The <u>Tethys Himalaya</u>, consisting of Cambrian to Eocene fossiliferous sediments, comparable with the East-Alpine nappes.

PREVIOUS WORK ON THE GARAMPANI AND ITS NEIGHBOURHOOD

No worker in the past has investigated the study area proper, though considerable geological data of all the neighbouring areas, is available. It is not clear to the author, why none visited this area in the past. Had some one investigated this area earlier, many unexplained facts about the stratigraphic and structural complexities of this part of Kumaon Himalaya would have been solved.

Heim and Gansser (1939) were the first workers to correlate the quartzite rocks of Bhowali with Nagthat and it was assumed by them and many of the subsequent workers that the hilly terrain lying within the study area, also comprised Nagthat quartzites.

Another work which has direct relevance to the study area is that of Pande (1950) on the Ramgarh area. As the northwestern extension of the Ramgarh thrust and the rocks above and below it, also occur in the Garampani area, the views expressed by Pande could also be considered applicable to the rocks of the study area. He has more or less supported Heim and Gansser, and suggested that "the Ramgarh thrust may be the eastern extension of the Garhwal thrust or may be equivalent to it in age. He correlated the rocks above the Ramgarh thrust with Chandpur stage and those below with the Nagthat stage of Jaunsar series. Pande in this paper invoked an igneous activity to explain the occurrence of "gneissic quartz porphyries". Subsequently in a later publication, Pande (1956-57) has referred to the "porphyries" as migmatitic rocks, having originated by the metasomatic replacement of phyllites. In a more recent paper dealing with the migmatitic rocks of entire Kumaon, Pande (Pande et al. 1963) has shown that the Ramgarh thrust does not extend beyond the Kuchgad stream, but turns back to form a synclinal nappe.

Tiwari and Mehdi (1964) have also shown on their map a synformally folded Ramgarh nappe. According to these workers, the rocks of the study area, all comprise quartzites of Nagthat age.

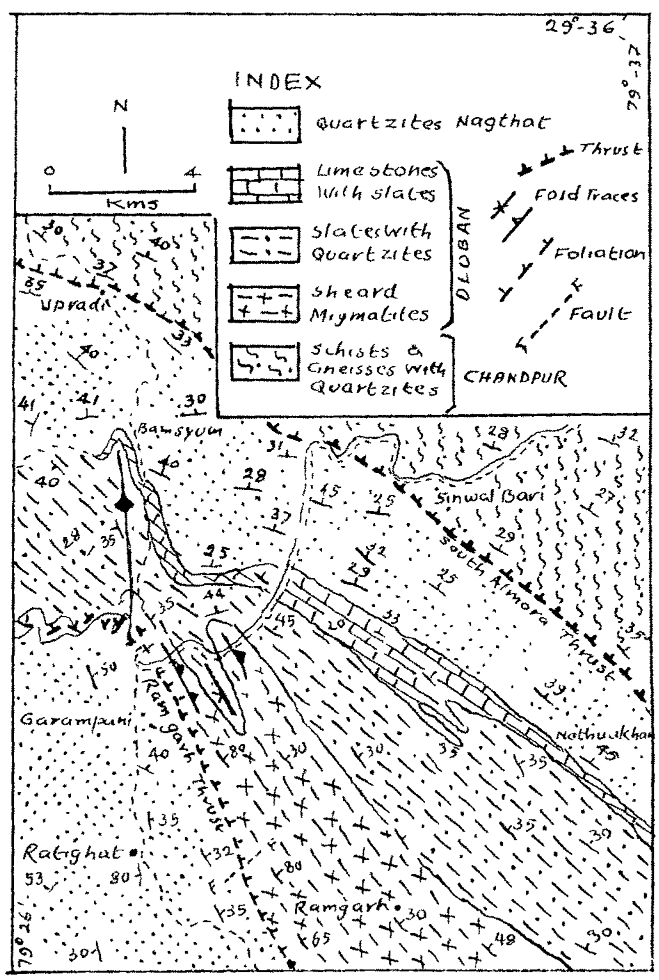
More recently Merh (1968) gave an altogether new interpretation to explain the nature and stratigraphy of the Ramgarh thrust and the overlying rocks. He was of the opinion that the Ramgarh thrust was not a folded continuation of the Almora (= Garhwal Thrust) and that "the uniformly NE dipping rocks hardly show any evidence to suggest the possibility of a folded thrust open or tight to form the so called Ramgarh nappe." According to Merh, the Ramgarh thrust was of a date later than the Almora thrust, had affected only Krol nappe and was in some way connected with the synformal folding of the Almora thrust sheet and Krol thrust movement. He further suggested that the rocks above Ramgarh thrust comprised a Nagthat-Deoban-Chandpur sequence and the quartzites underlying the Ramgarh thrust were in fact the upper part of Nagthats pushed below the older rocks by the thrust.

Merh in another paper (Merh et al. 1971) on the nature of Ramgarh thrust, has for the first time, given a sketch geologic map which includes the study area also. In this map, the authors have shown (i) the Ramgarh thrust meeting the Kosi river at Khairna, and then following the river valley further west, and (ii) the rocks to the north on Kosi Valley were Deobans while those to its south were Nagthat (Fig. 2.7).

An entirely new approach to the geology and structure of this part of Kumaon has been made by Devendra Pal and O.K. Shah (both personal communications). Devendra Pal, working in the adjoining area in the south, around Naini Tal, has radically modified the pre-existing concepts in respects of the structure and stratigraphy of the Naini Tal-Bhowali-Garampani area. He has established that the so called 'Nagthats' of Heim and Gansser (1939) are in fact, typically Blainis and Infra-Krols. According to him, the rocks of the present area too contained a fig. 2·7

GEOLOGICAL SKETCH MAP OF THE REGION BETWEEN RAMGARH & RANIKHET IN KUMAON HIMALAYA

(S S Merh, N M Vashi & J P. Patel.)



Blaini-Infra Krol sequence to the west of Ramgarh thrust. Devendra Pal has also worked out a fold history comprising three episodes, (i) F_1 - related to the folding that gave rise to Almora synform and the Bhowali anticline, (ii) F_2 - superimposed over F_1 folds are E-W structures related to the Krol thrust movement and (iii) F_3 - the NS or NNE-SSW open flexures superimposed over all pre-existing structural features including the Krol thrust.

The work of O.K. Shah in the Bhowali-Bhim Tal area too has important bearing on the author's interpretation of the geology and structure of the study area. Earlier, Merh (1968) had suggested that the formation of Bhowali anticline and Krol thrust comprised a single tectonic event, and Ramgarh thrust also originated during this event. O.K. Shah on the other hand has established that the Ramgarh thrust is a very late dislocation unconnected with the development of the Bhowali anticline, and according to him (i) Bhowali anticline is older than the Naini Tal syncline, and (ii) the Ramgarh thrust cuts across the folds related to the Naini Tal syncline.

The present author has mainly relied on the works of Merh, Devendra Pal and O.K.Shah in establishing the stratigraphy and structural geology of the study area.