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 some similarity with the latter. Although vastly greater in dimensions, the Himalayan mountain chain is structurally far more simpler than the 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, combinations 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 Karakorum can be sub-divided (Burrard and Hayden, 1934; Bordet, 1961) into the following regional geological and geographical units (Fig. 2.1):-

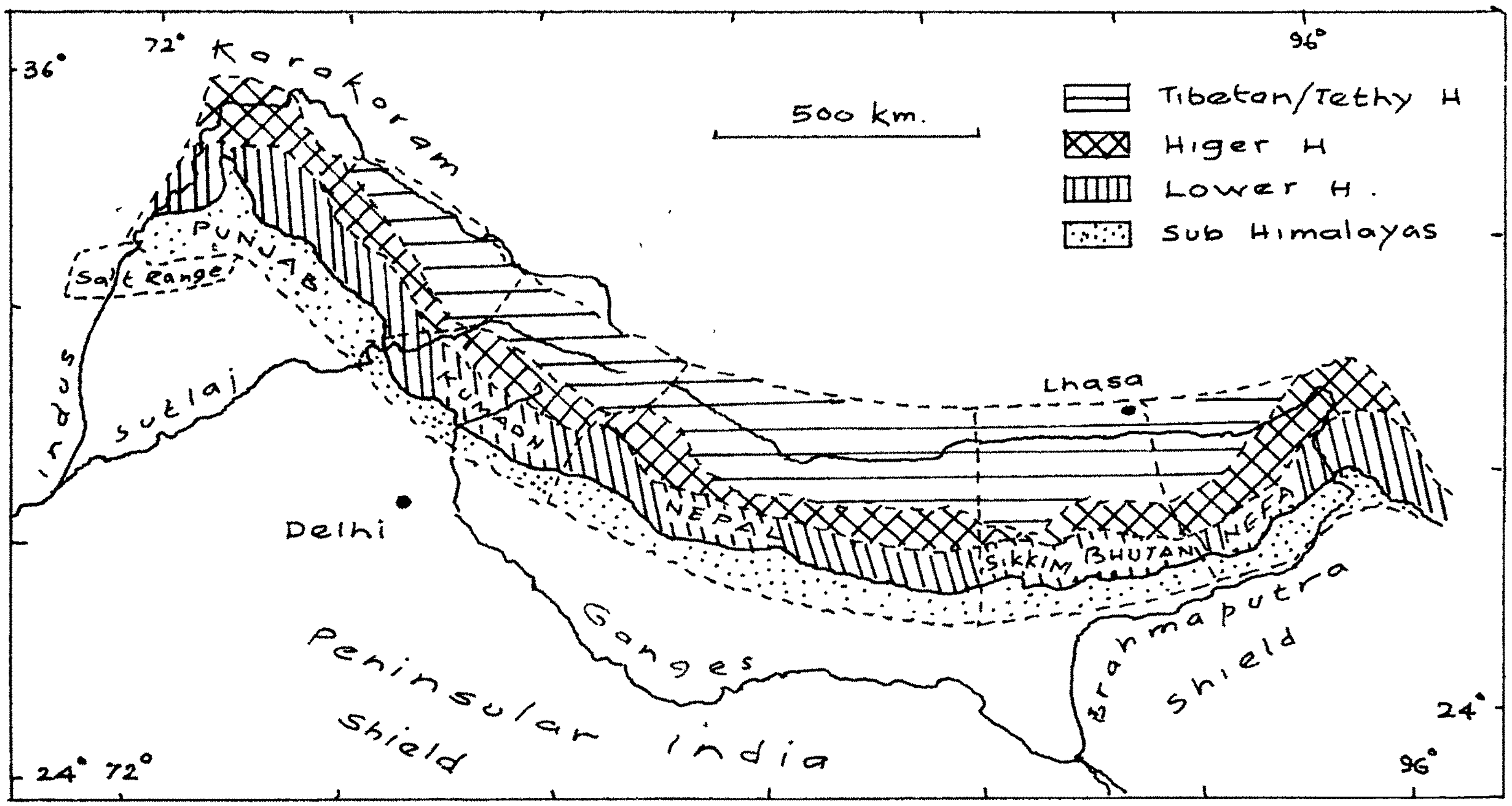
1. Punjab Himalayas: This 550 km long section of the true Himalayan chain is bordered in the west by the Indus River and in the east by the Sutlej River. It includes Kashmir and Spiti region, geologically the best known area of the Himalayas.

2. Kumaon Himalayas: 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 Garhwal, Kumaon and parts of southern Tibet.

3. Nepal Himalayas: From the Kali river in the west to the Tista river in the east, these extend along the whole 800 km length of Nepal.

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

Fig. 2 1.



The general subdivisions in the Himalayas

5. <u>NEFA Himalayas (Former Assam Himalaya)</u>: 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 unsettled North Eastern Frontier Agency (NEFA) it is the geologically the least known part of the whole Himalayan range.

~~The~~ Each of the above sections, is usually divided into four longitudinal zones from the south to the north, viz. the Foot-hills of the Siwaliks (also called 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 rootzones (also called the Great Himalaya or Inner Himalaya); and, lastly, the Tethys Himalaya of fossiliferous sediments (also called the Tibetan Himalaya). Beyond these four zones are the Ladakh and Kailash ranges followed by the Trans-Himalaya ranges.

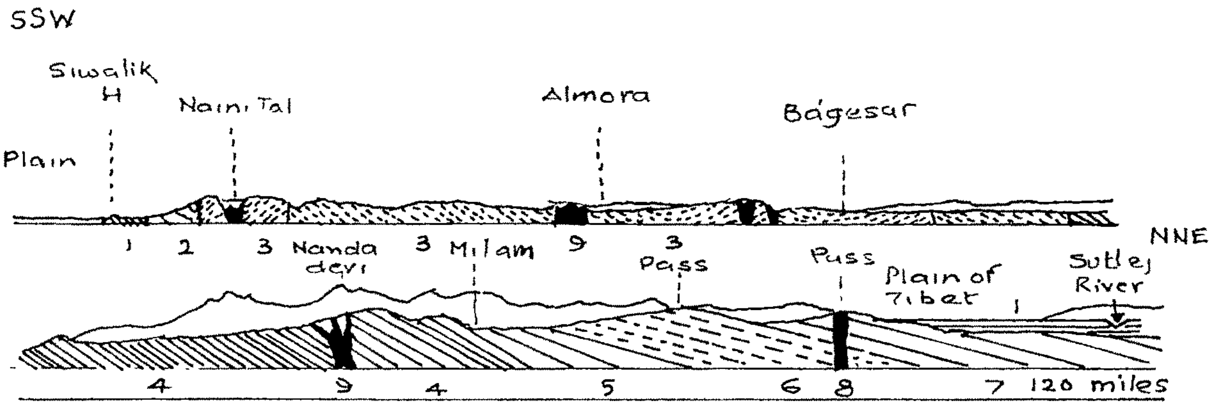
The Himalaya mountain chain arose out of two geosynclines parallel to and separated by the present crystalline axis. The Northern Geosyncline, in the Tibetan Himalaya, where biogenetic conditions prevailed permitted the preservation of a fully fossiliferous succession from the Lower Palaeozoic to the early Tertiary, while, in the southern or the Lesser Himalayan Geosyncline, the environmental conditions were 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 of Kashmir, Nepal-Sikkim and in the Eastern 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 in the enbryonic Himalaya of the Eocene.

STRUCTURE AND STRATIGRAPHY

The concepts of the structure and evolution of Himalaya have developed in the course of last 150 years, and the existing knowledge of the geology of the different Himalayan areas, is due to the investigations of numerous 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).

Fig. 2.2

The section across central Himalaya (after R. Strachey)



1 Tertiary
2 Secondary and Paleozoic 22
3 Metomorphic strata without fosils
4 Crystalline schists
5 Azoic slates
6 Palaeozoic
7 secondary
8 Greenstone
9 Granite

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 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 further into various sub-divisions, formed the following sequence:

1. Sub-Himalayan Series:

Upper	Siwaliks	
Middle	Nahan	Kasauli
Lower	Subathu	Dagshai

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 Professor 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.

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 the 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,

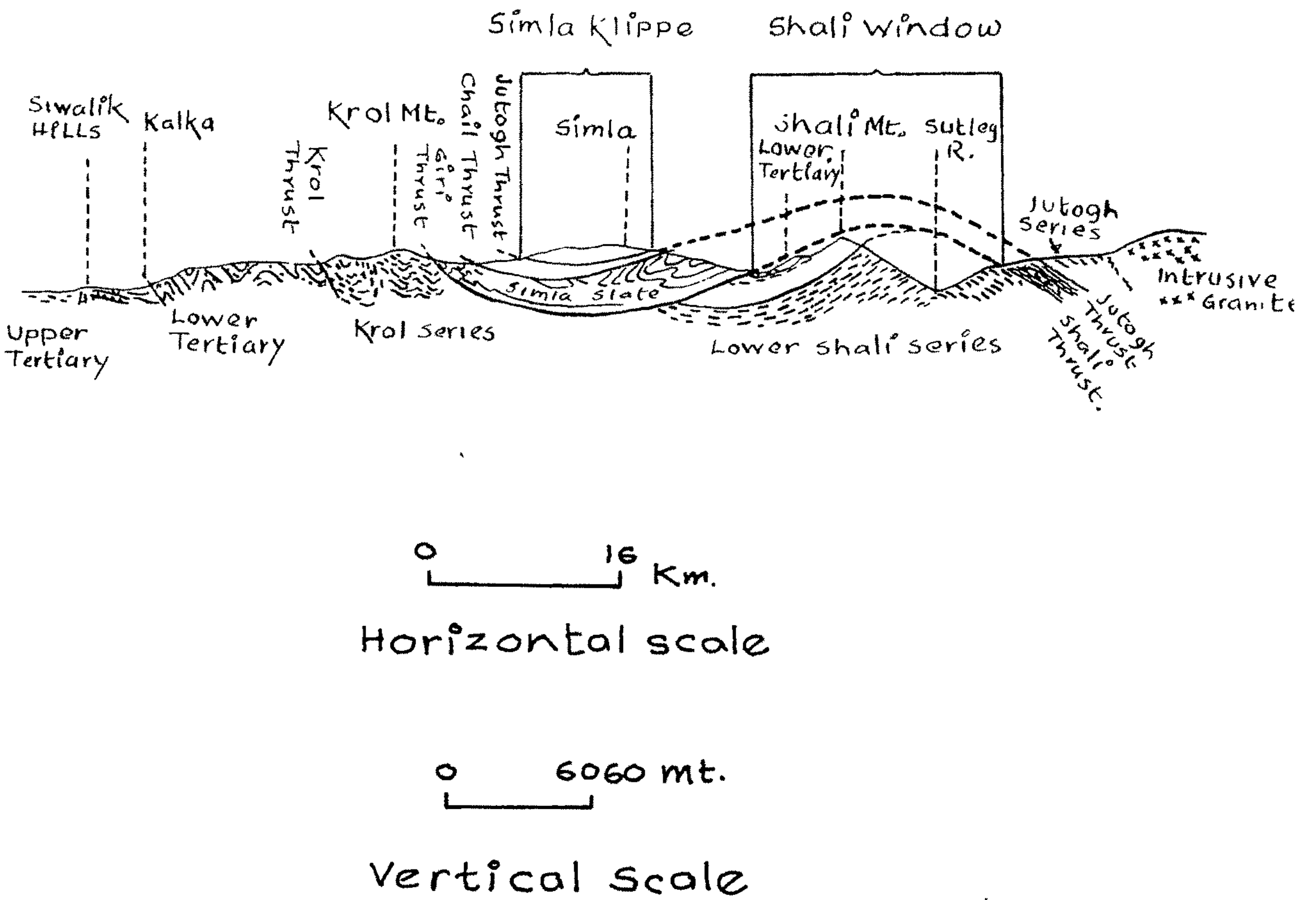
(c) Recumbent folding and metamorphism,

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

Fig.2.3

SECTION THROUGH THE SIMLA HIMALAYA

(W.D. West.)



They gave the following stratigraphical sequence of Simla Himalayas:

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

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

Jotogh 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 of Punjab Himalaya constitutes another important milestone in the progress of the Himalaya's geological studies. He pointed out the most striking feature of the N.W. Himalaya - the way in which the ~~strike of the~~ strike of the mountains, after following an arcuate SE-NW direction from Assam to Kashmir, makes a great bend in Hazara, rapidly curving round through an E-W to N-S 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 N.W. 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:

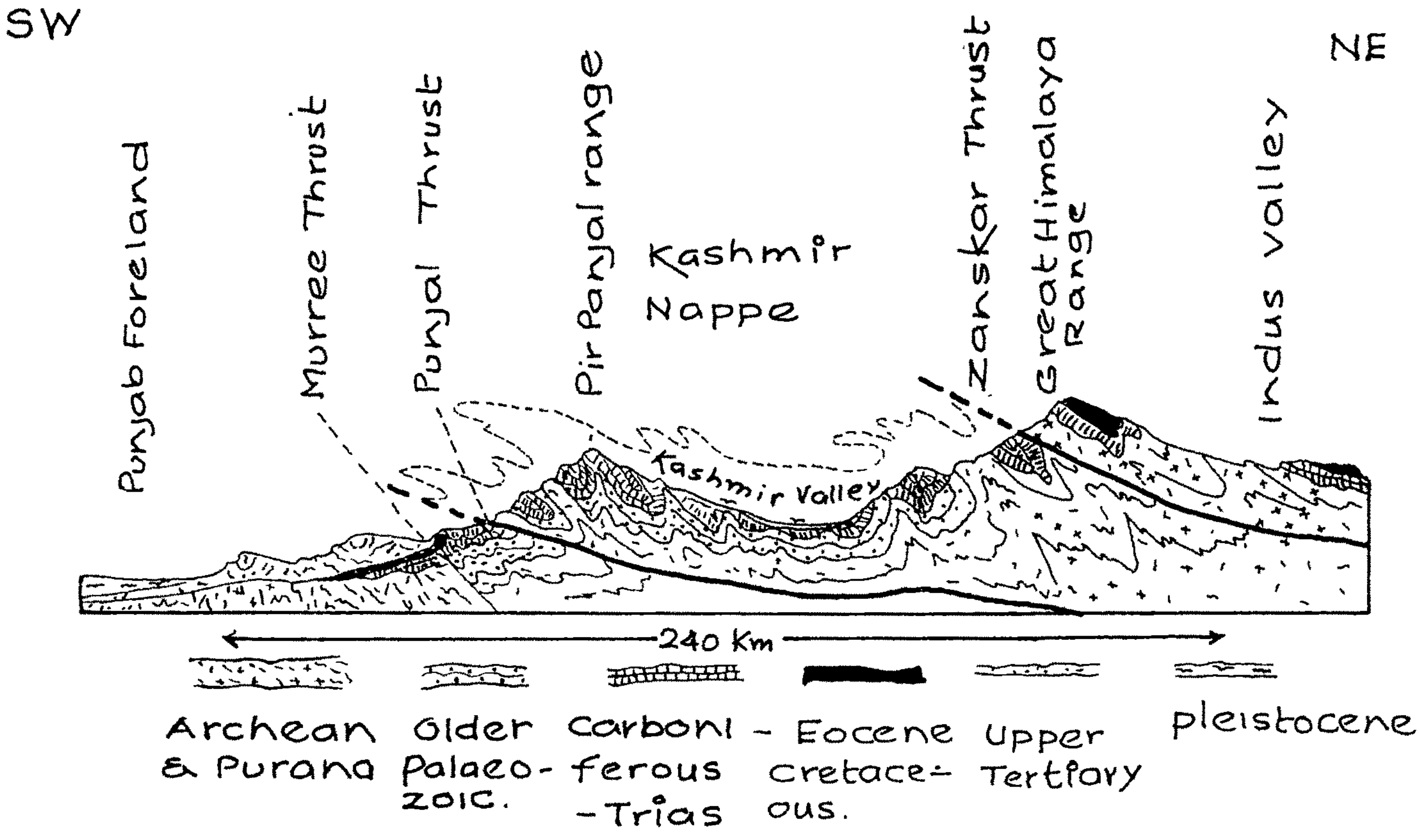
1. The tongue of the Foreland, its peneplaned surface being burried under a thick cover of Murree sediments.
2. The belt of Autochthonous, mainly recumbent folds consisting of rocks ranging in age from carboniferous to Eocene, thrust against and over the Foreland covered under the Murree series (Murree 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 (Panjal 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 round the syntaxial bend from Hazara to Dalhousie. Of these two thrusts, the inner (Panjal thrust) is more significant, involving large horizontal displacements. The

Fig. 2.4.



DIAGRAMMATIC SECTION ACROSS THE KASHMIR HIMALAYA, SHOWING THE BROAD TECTONIC FEATURES (D.N.Wadia) 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"; the Giri thrust, paralleling the Krol thrust approximately 6-8 km north-east of the former, and the Tons thrust in

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	Nagthat stage Chandpur stage Mandhali stage (Jaunsar series)
? Lower Palaeozoic and pre-Cambrian	Simla slates with Kakarhatti limestone	Deoban limestone Simla slates (Morar-Chakrata beds)
Mocene (and older)	Dolerites	

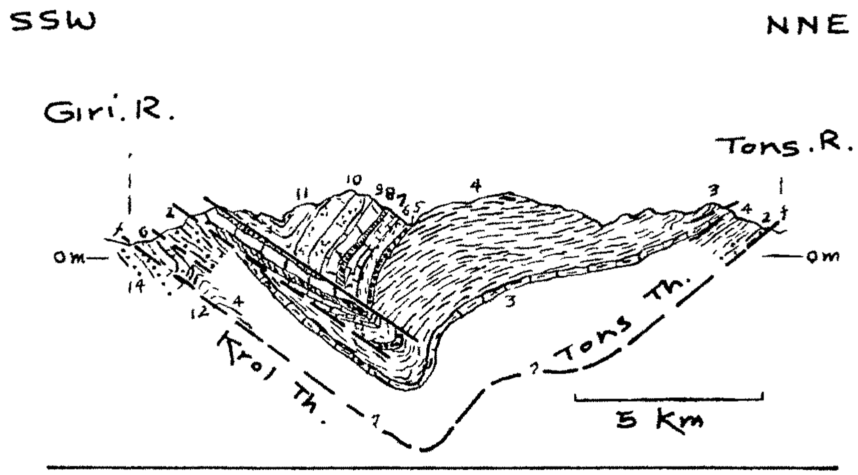
the eastern area south of Chakrata, approximately 15 km north of the Krol thrust. The Krol and Giri thrusts are directed to the south and south-west respectively, while the Tons thrust rises to the north. According to Auden, the Krol thrust and the Tons thrust are the same, and the great syncline of Jaunsar rocks with 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

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

Fig 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)

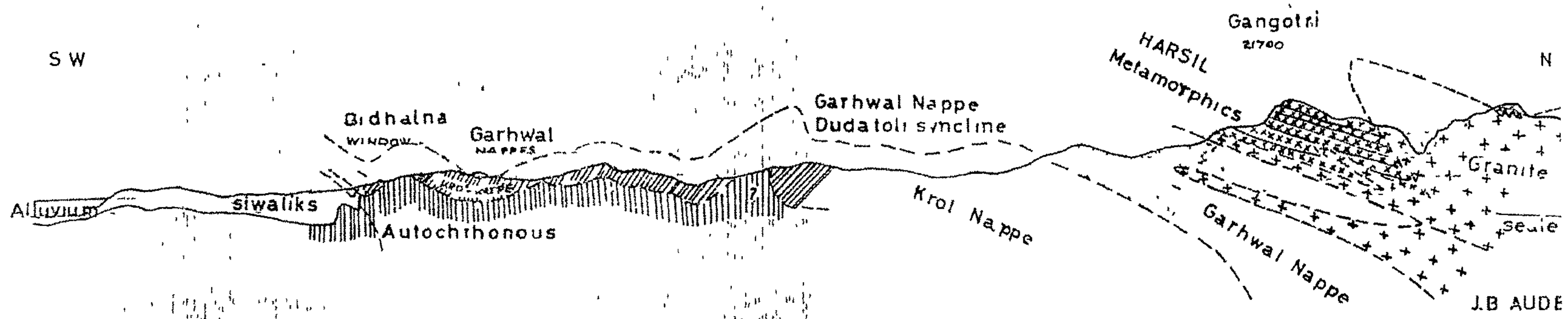
Fig. 2-6

TECTONIC SECTION ACROSS THE GARHWAL HIMALAYA

A preliminary attempt

Vertical Scale Slightly Exaggerated

Topography Generalised



Garhwal nappe	Chandpur (metamorphosed)	
	----------Thrust--------------	
	Nagthat	Little metamorphosed
	Chandpur	
	Boulder beds, slates and limestones of uncertain stratigraphical horizon occur in one outlier below metamorphosed Chandpurs	
------------------ Garhwal thrust ------------------		
Krol nappe	Nummulitic	
	Tal	
	Krol	
	Blaini	
	Nagthat	Metamorphosed and
	Chandpur	unmetamorphosed
------------------ Krol thrust ------------------		
	Dagshai	
	Nummulitic	
Autochthonous		Siwalik
	Simla slates	

He made a comparison of the structure of Garhwal with that of eastern Himalayas. 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 Garhwal Himalaya. In both the areas schistose rocks are thrusted upon Gondwanas or their equivalents.

The work of Heim & Gansser (1939) forms another land mark. Their geological observations on the central Himalaya formed a part of the Swiss expendition to Himalayas. They have dealt with various geological aspects such as petrology, stratigraphy and tectonics of Kumaon, NW part of Nepal and Tibet Himalayas. 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 British 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 anticlines below crystallines.
Overthrust sheet of Dudatoli-Ranikhet-Almora	Crystalline, Almora thrust zone.

A few years later, Auden (1951) 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 Garhwal area 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 foot hills, 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 ~~with~~ the molasse zone of the Alpine border.

2. The <u>parautochthonous Lesser Himalayan zone</u> of early Tertiary formations beneath the over-thrust 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 NAINI TAL AND ITS NEIGHBOURHOOD

Geologically, the Naini Tal area lies at the south-eastern extremity of ~~the~~ Auden's Krol belt. As compared to Simla and Garhwal, this area has received somewhat less attention. Of course, considerable work has been done around Naini Tal, mainly to its north and north-east, but most of the attention has been paid to the crystalline rocks of Almora nappe (= Garhwal nappe) which rest over the Krol belt rocks. Though in the course of last 100 years, the Naini Tal and Almora region has from time to time been visited and described by a number of workers, yet the major bulk of investigations particularly in the recent decades, has confined to the problems of structure, metamorphism and granitisation of the older crystalline Almora thrust sheet.

The earliest reference to the geology of Naini Tal is made by Strachey (1851) in his sections across Kumaon (see Fig. 2.2). Quite a few workers in the later part of 19th century visited Naini Tal to study the origin of the various lakes there. Middlemiss (1890) who spent several years in the foot-hill region of Kumaon, mapping the area between Ganges and the hills around Naini Tal, remarked, "The geology of Naini Tal, in its purer scientific aspects is neither very attractive nor very instructive, as larger part is filled up with large blocks of mountain slides". He established that, "At Naini Tal the rocks encountered were a continuation of ~~that~~ those in the border region of Simla. The thrusted syncline of Naini Tal recalls the border of the syncline of Mussoorie." He described the geology of Naini Tal for the first time and suggested that the various lakes in that area originated "due to differential uplift and subsidence along groups of fractures which cannot be demonstrated in the field, aided by solution of the local limestones". Earlier Ball (1878) had suggested the origin of Naini Tal lake due to landslip. Oldham (1880) believed that the barrier that gave rise to the Naini Tal lake was formed of a slipped block of limestone with associated debris. On the other hand Theobald (1880a) thought the lake to be of glacial origin.

After a gap of about 50 years, Heim and Gansser (1939) published some more information on the Naini Tal area. Though, these two workers did not study this area in detail, but their's is a fairly detailed account of its geology and structure. They have suggested that stratigraphically the rocks here comprise a sequence of Nagthat-Infra Krol-Krol, and form a syncline. They have described the Naini Tal area in the following words,

"The result of our rapid investigation within a few days showed us first that a larger part of the country than that indicated by Middlemiss is sliding or filled up with blocks of mountain slides, and that even the Ayarpatha mountain (7716' = 2350 metres), with its stratified southern limestone face, is generally broken up in such a way that it is impossible to design a correct tectonic section."

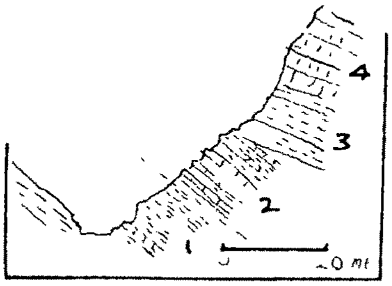
"Besides this broken Ayarpatha mountain, a large area is covered by what is unquestionably off from the walls of the crest, extending from China peak (8563'= 2600 metres) towards the south over Deopatha (7987') to the Bajiyun Pass. The structure of this crest is fairly well visible. The unfossiliferous limestones with shaly layers probably belonging to the Krol series. As already considered by Medlicott, form the syncline of Deopatha."

"The sequence of China peak seems to be cut off by a fault from the main limestone (Krol) series, which is at least 600 and probably 1000 metres thick."

"An interesting exposure of detail at the base of the limestone walls of Ayarpatha is passed on the road to Naini Tal below point 6913' (Fig. 2.7a). Possibly the limestone series SW of Naini Tal is repeated by concealed thrust-sheets dipping to the north-east (Fig.2.7b)."

"The region SE of Naini Tal is extremely complicated by crushing, crumpling and numerous local faults of different directions. The variegated clay shales with

Fig 2·7a.



BASIS OF THE LIMESTONE WALL OF AYARPATA, NAINITAL

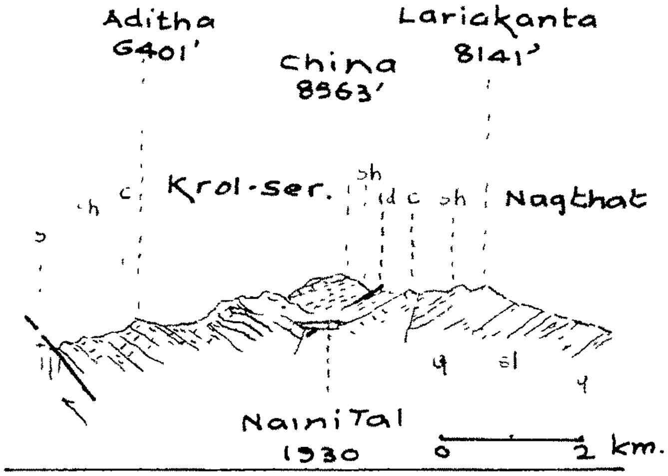
(HEIM & GANSSER)

1. Greenish shale with limestone layers
2. 15 meters of violet clay shale with about 12 beds of greenish dolomite, each 5-30 cm at every 0.5 – 1 meter slight unconformity
3. 10 meters of gray shales passing into
4. about 300 meters of bluish limestones and marls forming the S.W wall of Ayarpata.
   a) about 80 meters of blue marls with limestone layers
   b) 50 meters brown weathered lime stone
   c) 100 meters thin-bedded bluish limestone
   d) 100 meters of yellowish weathered limestone and dolomite, well bedded and 'banded'.

Fig 2·7 b

SECTION ACROSS NAINITAL AREA

(HEIM & GANSSER)



sh.	shale.
c	carbonates, mainly limestone, incl. marble
s.	sandstone
id.	igneous, dioritic
q.	quartzite
sl.	slate

quartzite along the road to Ranikhet (Gainthia and Bhumia Dhar) may partly correspond to the Nagthat series of Tehri Garhwal."

"If we try to establish a normal sequence of the formations, we start from China peak, the snow view point and highest summit of Naini Tal 2600 metres. There, as already mapped by Middlemiss, a limestone bed is exposed within the shales or slates. It is of a peculiar aspect, made of small lenticular scales of yellow dolomite and bluish grey limestone. Several slices under the microscope showed no trace of micro-organisms".

"The best stratigraphic series with a regular dip of 25-35° to SW is obliquely traversed from China peak along the crest of Sherka Danda-Lariakanta."

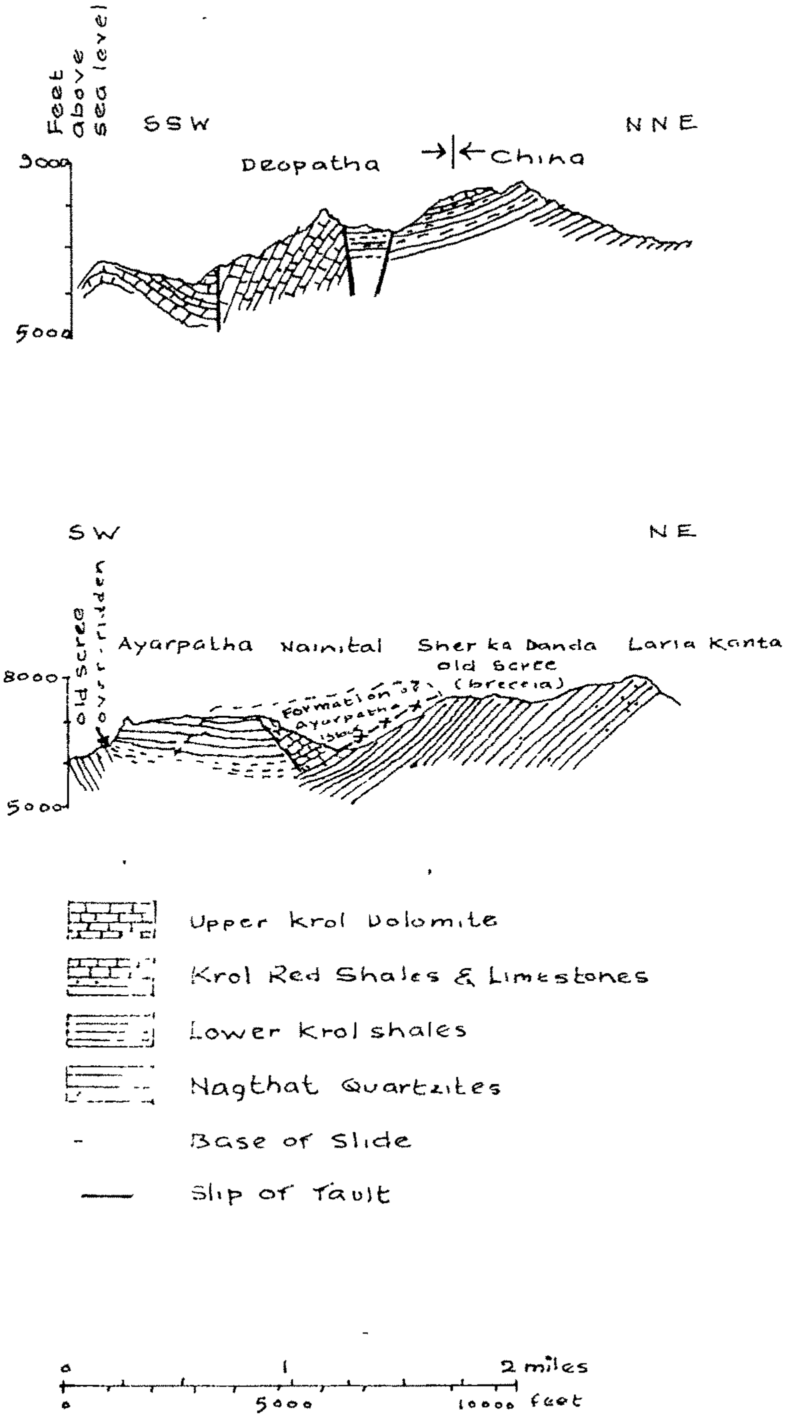
"Interpretation: The first question is, whether we can regard the mighty sequence on the north side of Naini lake as being one stratigraphic unit. The regularity seems to confirm a normal position, but it may be questioned if the limestone of China peak No.7 is a repetition of No.5 of Sherka Danda. In this case the series would be repeated above a thrust plane on the top of No.5. However that may be, the slaty gray to purple series reminds us of the lower Krol of Simla district and Tehri. If so, the quartzite of Lariakanta might correspond to the Nagthat of Auden and others. We searched in vain for the Blaini conglomerate above the quartzite."

In a paper on the origin of the Kumaon Lakes, Thomas (1952) has taken into consideration also the geology of the area. But in his account, the Infra-Krols do not find any mention. In the text of his paper he has referred to the rocks below the lower Krol slates as Blaini series (Banded carbonaceous slates), but in his sections (Fig. 2.8), the Blainis have nowhere been mentioned. He has taken the quartzites underlying the Blainis as Nagthats.

As regards the structure of the Naini Tal area, Thomas has written, "The whole series appears to be thrown into folds aligned in a NW to SE direction. Ridges of Pre-Nagthat green-stones with this trend are seen at Bhowali and to the north and south of Bhim Tal. The overlying Krol slates are folded into a generally synclinal area about Naini Tal, with a pitch

Fig 2.8

SECTION AFTER THOMAS (1952)



to the west. Between Deopatha and Khurpatal there is a series of steep folds in the Krol Dolomites. The main syncline under Deopatha has a steep northern limb, which is cut off by a fault. North of the fault, Krol shales and Krol Red shales within limestones are to be seen dipping gently southward from China peak."

"The Ayarpatha dolomite mass lies along the strike of the steeply folded Deopatha syncline, but there is no sign of the steep folds or even of a synclinal arrangement of the beds. Gentle northerly dips appear of a synclinal arrangement of the beds. Gentle northerly dips appear to prevail over most of the mass and a few southerly dips on the northern side are clearly connected with post-tectonic slipping. In the great cliff which forms the southern face of Ayarpatha there appears to be a low angled thrust hading towards the west, within the dolomites. Several similar thrusts have been suggested by Dr. J.B. Auden within the Krol slates west of China peak and along the ridge to Sherka Danda. Apart from field indications of these low-angled thrusts, he points out that the great apparent thickness of calc-slates here as compared with elsewhere requires some degree of repetition.

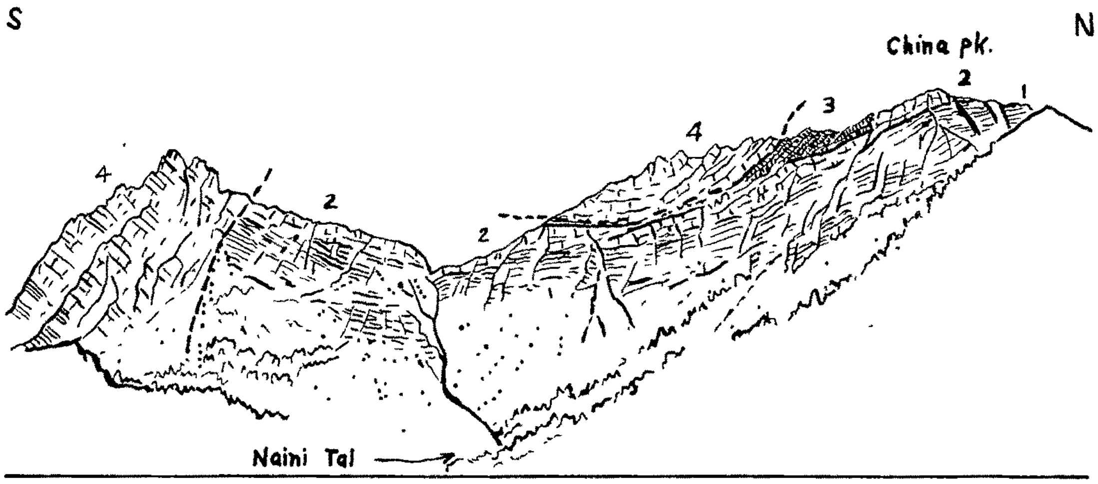
From many point of view therefore the tectonic structure of Ayarpatha suggests that it is continuation of China peak rather than of Deopatha."

Thomas agreed with Heim and Gansser that the whole region south of Naini Tal lake has been affected by post-tectonic sagging. Explaining the exact mechanism of the southward slipping of Ayarpatha block, he has likened it to the 'slipped blocks' of Harrison and Falcon (1934)- an example of "Gravity collapse structures". He wrote, "On the north and south flanks of Ayarpatha are outcrops of Krol Red shales which form the 'plastic' horizon over which the block must have slipped. The base of the slide is discordant over the underlying formations and the junction at the discordance is clearly exposed in the cuttings of the new road from Kathgodam to Naini Tal. Below the base of the dolomites the underlying shales are contorted and broken up and contain angular fragments of the overlying dolomites ranging from pebble size to large blocks several feet in diameter. It is clear that this junction is not an unconformity. The observed facts seem to indicate a sliding forward of the Ayarpatha dolomites over the Krol Red Shales."

Thomas ruled out the various pre-existing theories about the origin of Naini Tal Lake and instead connected the lake formation with the bodily slipping of the Ayarpatha from China peak. He wrote, "The enormous hollow between China peak and Deopatha on one side and Ayarpatha on the other side, and which was formerly much deeper, cannot be explained as a normal erosional feature. It requires the bodily removal of a large mass of dolomite, of which fragments now remain in the detatched masses of Handi Bandi Hill and the Sukha Tal ridge." According to him, "After the folding and thrusting of the Krol-Nagthat belt, erosion succeeded in isolating an inclined block of Krol dolomite lying south-eastward along the strike from China peak and separated from it by dip-faults throwing to the south-east. This inclined block was tilted south-westward and lay on top of the potentially plastic Krol Red shales. Under the influence of gravity, and assisted by late earth movements the inclined block moved southward towards lower ground, buckling the underlying beds and coming to rest in a horizontal attitude as the broken dolomite mass of Ayarpatha. An enormous chasm was left between Ayarpatha and its neighbours, and has since been partly filled by landslip, scree and outwash."

Gansser (1964, p.92-93) in his recent work on the Himalaya has briefly touched upon the geology of Naini Tal area. He has more or less agreed with Thomas and wrote, "The relatively high Naini Tal mountains bordering the low-lying Siwaliks along a main thrust are full of tectonic complications, and conspicuous post tectonic slips and mass gliding. We have here, a fine example of how gravity gliding can follows major tectonic effects as a kind of adjustment movement but not be the prime cause of the structural picture. Thomas was able to prove how secondary fracture lines, strongly oblique to the main boundary thrust, do coincide with a change in direction of the latter. This change may have been caused by a forward-thrusting of the Krol nappe over an erosional gap, and structural disturbances in the Siwaliks and the secondary fracture lines could well be related tear faults." Gansser's section of the China peak - Deopatha is quite interesting (Fig. 2.9) and shows some departure from his earlier views (Heim and Gansser, 1939).

Sarkar et al. (1967,p.14) investigated Naini Tal from the point of view of its tectonic evolution. They analysed the various linear and planar structure



1 Green (tuffaceous) shales.
2 Lower Krol limestones.
3 Green and red shales with dolomites.
4 Upper Krol limestones.

THE GEOLOGY OF CHINA PEAK, NAINITAL KUMAON HIMALAYA (after A. GANSSER) statistically and then kinematically analyses indicated that "Deopatha syncline (-fold) is formed by horizontal squeezing along NE-SW, accompanied by slight rotation of the B-axis. Minor folds and imposed folding due to rotational movement along N.15° - N.195°, (anti-clockwise sense when looking NW), B' axes orientation being chiefly controlled by WSW dipping main fold limb and the B' movement plane. The angles between mean B and B' axes are 35° in Sector I and 50° in sector II. In the Siwaliks corresponding mean B and B' axes orientation and their angular relations are different. These kinematic episodes appear to be successive phases of one orogenic cycle (Himalaya orogeny)."

In two recent notes on the structure of the area NE of Naini Tal, Merh (1968, 1971) has worked out the sequence of various fold events and their time relationship with the Krol thrust. He has suggested (1968, p.5-6) that the Almora thrust was folded into the Upradi-Someshwar synform at the same time as that of the formation of Bhowali anticline, and these folds developed due to drag effect during the Krol thrust movement. According to him (1971, p.382) the Ramgarh thrust, which Heim and Gansser (1939) and Pande (1950) thought to be folded continuation of Almora (= Garhwal thrust), is more of the nature of a big reverse fault, originating from the Krol thrust.

AUTHOR'S NOTE

The author has given above in somewhat detail a full background of all the existing data relevant to the present study. He has not mentioned many workers on Kumaon but the omission does not belittle the importance of the work of the various investigators. He has quoted only those references which have directly or indirectly been used by the author in building up his thesis.