# CHAPTER II

# BACKGROUND INFORMATION

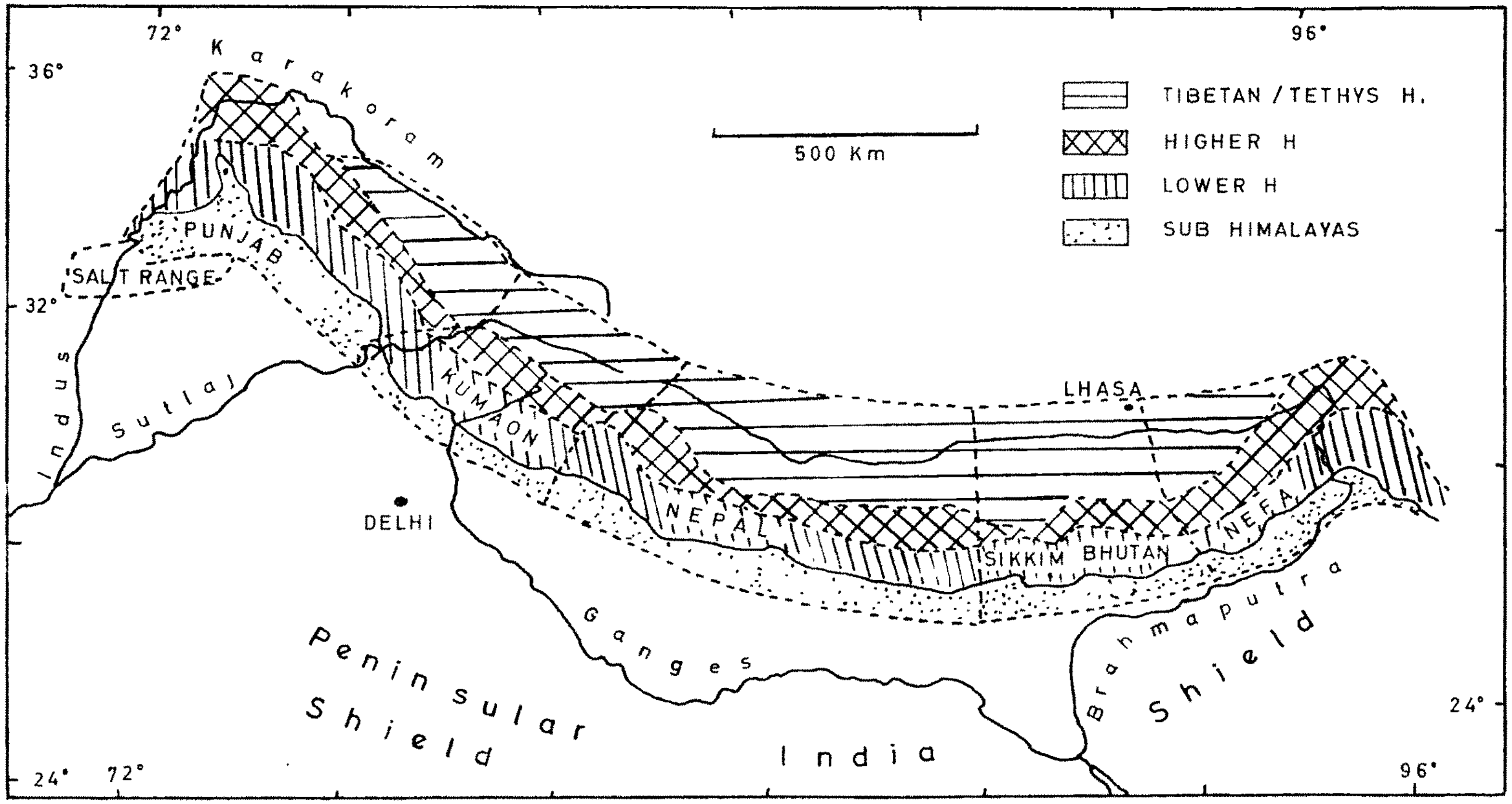
## HIMALAYAS IN GENERAL

### Geographic and geologic classification

Gansser (1964) has divided the Himalayan mountain chain into the following regional and geographical units (Fig. 2.1).

1. Punjab Himalaya: This 550 km long section of 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 region of the Himalaya.

Fig.2.1




THE GENERAL SUBDIVISIONS IN THE HIMALAYAS

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 Garhwal, 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 States of Sikkim and Bhutan, and measures about 400 km.

5. N.E.F.A. 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. Lying in the somewhat politically unsettled North Eastern Frontier Agency (N.E.F.A.) now known as Arunachal Himalaya, it is the geologically least known part of the whole mountain system.

Each of the above sections, is usually divided into following four longitudinal zones from south to north:-

(i) the foot-hills of the Siwaliks (also called the Sub-Himalaya or the Outer Himalaya).

(ii) the Lesser Himalaya of unfossiliferous sediments and thrust sheets (also called the Middle Himalaya).

(iii) the Central Himalaya of the batholithic granite intrusions and root-zone (also called the Great Himalaya or Inner Himalaya).

(iv) 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 is supposed to have arisen out of two geosynclines parallel to and separated by the present crystalline axis. The northern geosyncline in the Tibetan Himalaya, where biogenetic conditions prevailed and permitted the preservation of a fully fossiliferous succession right 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. Wadia (1955,p.6) has designated the barrier separating the two major geosynclines as the Central Himalayan ge∅anticline. Pande and Saxena (1968) have contended that this barrier (the Central Crystalline Axis) came into existence towards the south of the geosyncline which gave rise to the Tibetan Himalaya, and was uplifted for the first time during the Ordovician. As a consequence of the rise of this central barrier, another geosyncline was formed towards the south of this axis at the close of the Palaeozoic Era. Thus, two geosynclines are postulated to account for the contrasting lithology, structure, stratigraphy and biogenic conditions as are obtained between the zones lying to the north and south of the central crystalline axis. This two geosynclines concept - the miogeosyncline to the south and an eugeosyncline to the north of the Central Crystalline Axis, has received considerable support from many recent workers (Pande, 1968).

Structure and Stratigraphy

Almost 110 years back, Medlicott (1864) gave the first connected account of the geology of the lower Himalaya, of the portion between the river 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, and these two series, classified further into various subdivisions, formed the following sequence:

1. Sub-Himalayan Series:

| | | |
|---|---|---|
| Upper | Siwaliks | |
| Middle | Nahan | Kasauli |
| Lower | Subathu | Dagshai |

2. Himalayan Series:

A. <u>Unmetamorphosed</u>

| | | |
|---|---|---|
| Krol | - | Limestone |
| Infra Krol | - | Carbonaceous shale |
| Blaini | - | Conglomerate |
| Infra Blaini | - | Slates |

B. <u>Metamorphics</u>

Crystalline and sub-crystalline rocks.

The works of Middlemiss (1887, 1888, 1890) in the Lower Himalaya of Garhwal and Kumaon, mark another landmark.

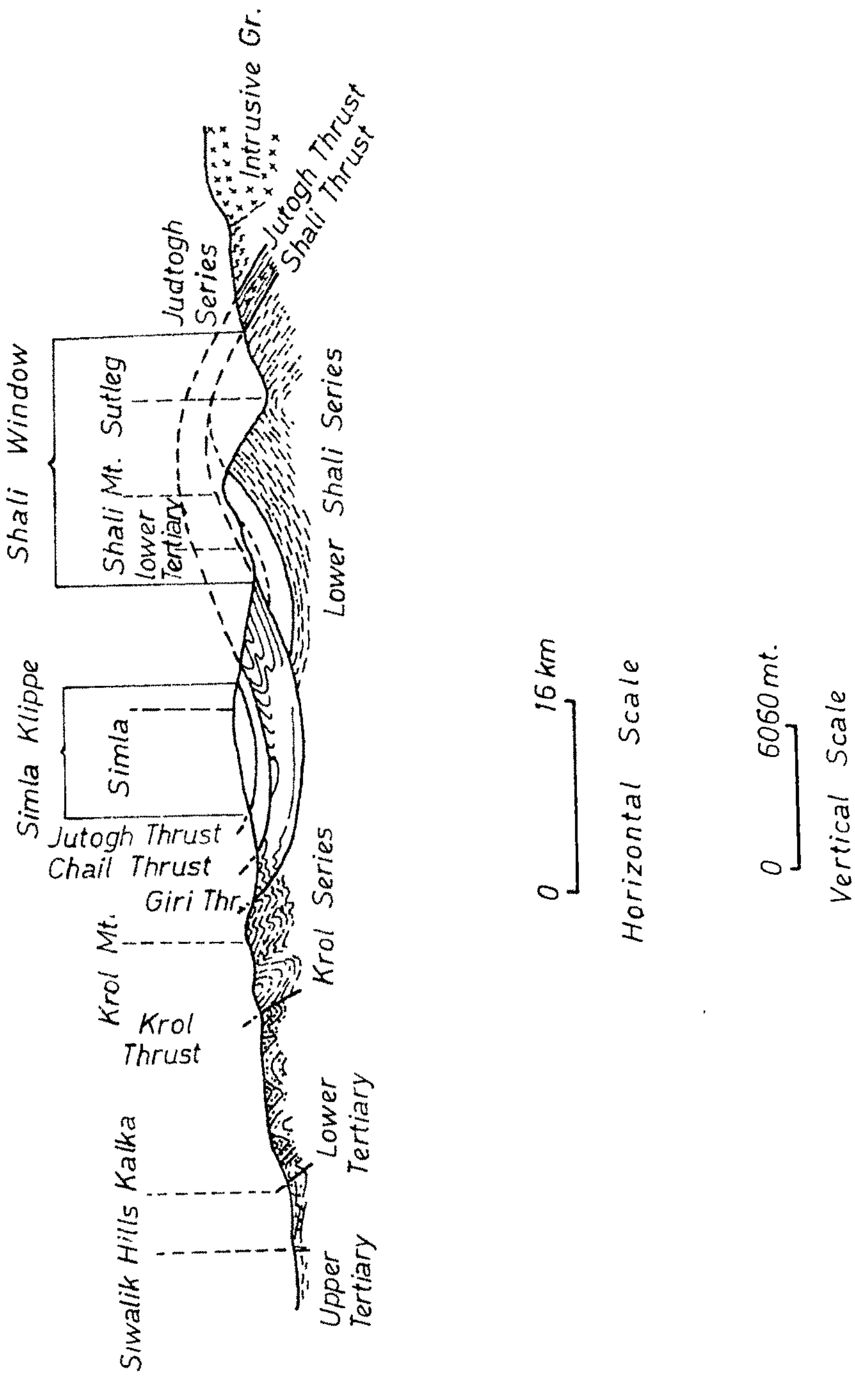
He established (1887) the following succession of the Garhwal rocks.

| Sub-Himalaya | Siwaliks |
|---|---|
| Outer formation | Nummulites |
| | Tal |
| | Massive limestone |
| | Purple slates |
| | Volcanic breccia |
| Inner formation | Schistose series with intrusives |
| | Gneissic granites |

Pilgrim and West (1928) 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 inverson (Fig. 2.2). 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 metamorphic rocks were

Fig. 2.2

SECTION THROUGH THE SIMLA HIMALAYA
(W.D. West)



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.

They gave the following stratigraphical sequence for Simla Himalaya:

| | |
|---|---|
| Dagshai Series | Lower Miocene |
| ----------Unconformity---------- | |
| Uppermost Subathu beds | Upper Oligocene |
| ----------Unconformity---------- | |
| Subathu Series | Middle Eocene |
| ----------Unconformity---------- | |
| Krol Series<br>Infra-Krol Series<br>Blaini beds | Lower Gondwana |
| ----------Unconformity---------- | |
| Shali limestone and slate | ? |
| Simla Series (Infra Blaini) | |
| ----------Unconformity---------- | |
| Jaunsar Series | Purana |
| ----------Unconformity---------- | |
| Chail Series | Purana |
| Jutogh Series | Archeans (?) |

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 Series

------------------------Giri Thrust------------------------

Krol Series

------------------------Krol Thrust------------------------

Subathu Series

Subsequent works of Auden (1934, 1937) 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

Solan 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. The sequence of formation in the Krol belt rocks of Simla-Chakrata area, as worked out by Auden is given in Table 2.1.

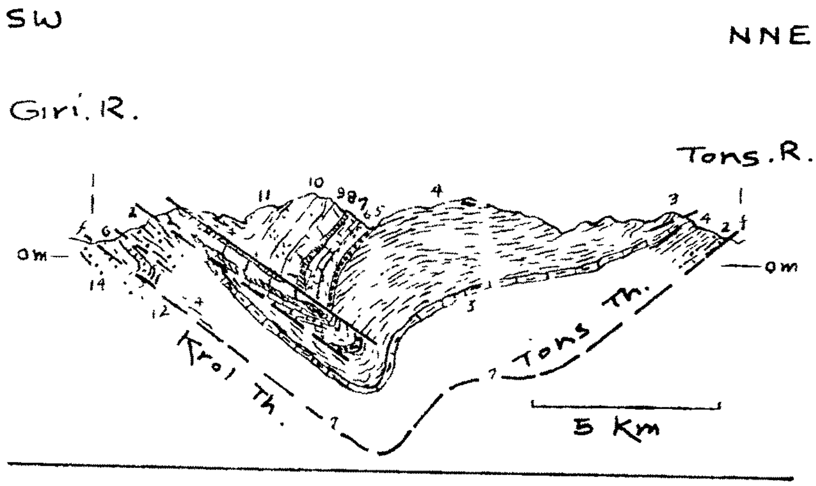
Auden visualised three main thrusts in the Krol belt : (i) the Krol Thrust, bordering the Sub-Himalaya and corresponding to the so-called 'Main Boundary Fault'; (ii) the Giri Thrust, paralleling the Krol Thrust approximately 6-8 km north-east of the former, and (iii) the Tons Thrust in the eastern area south of Chakrata, approximately 15 km north of the Krol Thrust. The Krol and Giri Thrusts are directed to the south and south-west respectively while the Tons Thrust rises to the north. According to Auden, the Krol Thrust and the Tons Thrust are one and the same, and the great syncline of Jaunsar rocks with overlying Krols and Tal rests as a nappe on a folded thrust plane (Fig. 2.3).

In a later work, Auden (1937) gave an excellent structural interpretation of the Garhwal Himalaya (Fig.2.4). He worked out the following sequence of rocks in Garhwal:

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<br>Dagshai | | Dagshai | |
| Oligocene<br>Eocene | Subathu (Nummulitic) | | Subathu (Nummulitic)<br>never in contact | |
| ? Cretaceous and Jurassic | Absent | | Tal | Upper Tal<br>Lower Tal |
| | Krol Lime-stone | Krol E<br>Krol D<br>Krol C | Krol lime-stone | Upper Krol limestone |
| ? Permo-Carboni-ferous | Krol Series | Krol B<br>(Red shales) | Krol Series | Red Shales |
| | | Krol A | | Lower Krol limestone |
| | Krol sandstone | | | |
| | Infra-Krol | | Infra-Krol | |
| Upper Carboni-ferous | Blaini | | Blaini | |
| ? Devonian and Silurian | Jaunsar with possible Mandhali | | Nagthat stage<br>Chandpur stage<br>Mandhali stage | Jaunsar series |
| ? Lower Pal-aeozoic and pre-Cambrian | Simla slates with Kakarhatti limestone | | Deoban limestone<br>Simla slates (Morar-Chakrata beds) | |
| Miocene (and older) | Dolerites | | | |

Fig 23 

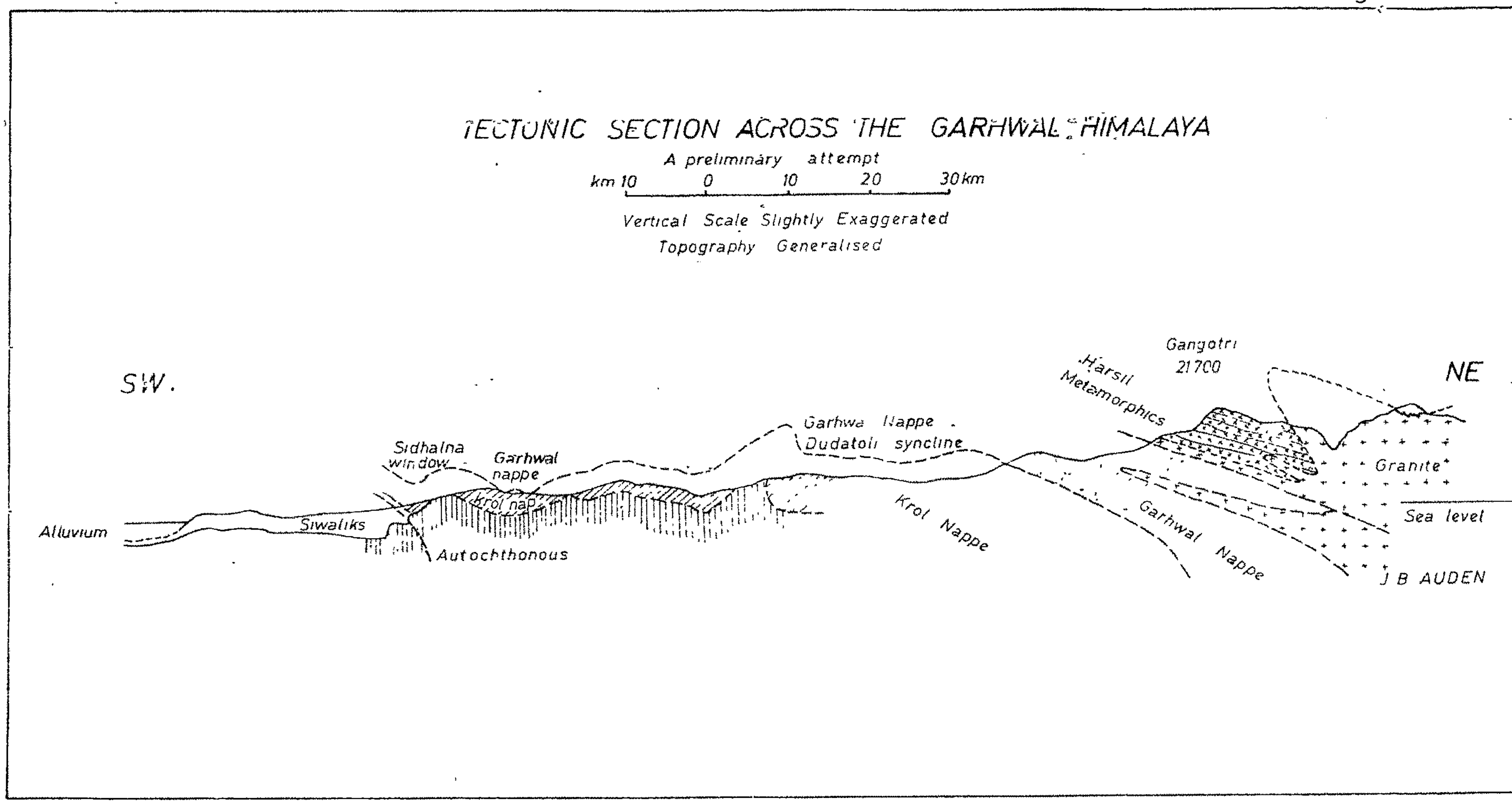



1. Simla slates
2. Mandhali
3. Bansa limestone
4. Nagthat and Chandpur
5. Blaini
6. Infra Krol
7. Krol A
8. red shales, Krol B.
9. Upper Krol limestones
10. Lower Tal
11. Upper Tal
12. Subathu (Eocene)
13. Dagshai-Kasauli (Murrees)
14. Nahan (Lower Siwaliks)

SECTION THROUGH THE KROL BELT

(after: AUDEN)

Fig. 2.4


TECTONIC SECTION ACROSS THE GARHWAL HIMALAYA
A preliminary attempt
km 10 0 10 20 30km
Vertical Scale Slightly Exaggerated
Topography Generalised
SW.
NE
Alluvium
Siwaliks
Autochthonous
Sidhalna window
Garhwal nappe
Krol nap
Garhwa Nappe
Dudatoli syncline
Krol Nappe
Harsil Metamorphics
Gangotri 21700
Granite
Garhwal Nappe
Sea level
J B AUDEN

| Formation | Thickness | Probable age |
|---|---|---|
| Siwalik | 16,000' | Upper Miocene to Pleistocene |
| Nummulitics | - | 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 to Precambrian |

According to Auden (op.cit.), the abovementioned rocks are tectonically arranged to show the following structural succession:

| | |
|---|---|
| Garhwal Nappe | Chandpur (metamorphosed) |
| | ——Thrust—— |
| | Nagthat, Chandpur: little metamorphosed |
| | Boulder beds, slates and limestones of uncertain stratigraphical horizon occur in one outlier below metamorphosed Chandpurs |

——Garhwal Thrust——

| | | |
|---|---|---|
| Krol Nappe | Nummulitics | |
| | Tal | |
| | Krol | |
| | Blaini | |
| | Nagthat | Metamorphosed and |
| | Chandpur | unmetamorphosed |

------------------Krol Thrust----------------------------

| | | |
|---|---|---|
| Autochthonous | Dagshai | |
| | Nummulitics | |
| | | Siwaliks |
| Simla Slates | | |

He made a comparison of the structure of Garhwal with that of Eastern Himalaya and 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 thrust upon Gondwanas or their equivalents.

Auden (1951) suggested an upper Miocene to Pleistocene age for the Krol and Garhwal thrusts. The pioneering work of Heim and Gansser (1939) forms another landmark. They have dealt with various geological aspects such as petrology, stratigraphy and tectonics of Kumaon, NW part of Nepal and Tibet Himalayas.

In a more recent paper, Wadia and West (1964) have briefly discussed the structure of the Himalaya. 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 granitic intrusion in root zone. This movement appears to have taken place at the beginning of Lower Siwalik (Mid-Miocene) deposition. The final orogenic activity came at the end of Siwalik (Lower Pleistocene) times.

Valdiya has (1964) ideally synthesized the work of many investigators in different parts of Himalaya, and has suggested the following structural framework:

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

2. The Para-autochthonous Lesser Himalayan Zone of early Tertiary formations beneath the overthrust Krol Nappe.

3. The Krol Nappe system mostly unfossiliferous sediments comparable to the Helvetic nappes of the Alps.

4. The Kashmir Nappe system which embraces the Kashmir, Jutogh, Garhwal and Kathmandu Nappes, all built of Precambrian crystallines and characterised by huge recumbent folds. Those could be compared with Pennine nappes.

5. The Tethys Himalaya, consisting of Cambrian to Eocene fossiliferous sediments, comparable to the East-Alpine nappes.

## Tectonics of evolution

Wadia (1931) postulated a compression from the north for the folding and uplift of the Himalayan sediments. According to him, the Asian continental block moved southward and came up against some underground obstacle around which it was forced to diverge. According to him 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 NW-SE in Hazara. On the other hand, the advocates of the Continental Drift, have suggested a northward drifting Peninsular Indian block that pushed the geosynclinal pile into a series of folds that progressively rose higher and higher as the landmass moved onwards (Holmes, 1965).

Working in the Nepal Himalaya, Hagen (1959) attributed the evolution of the great nappes to the uplift of the crustal blocks along deep fractures and faults. Pande and Saxena (1968) have also suggested a concept of vertical uplift, and according to them, through great tensional faults that were formed in the Indian Peninsular Shield in consequence of the fragmentation and drift, and aligned parallel to or across the Himalayan trend, there was vast outpouring of lavas. The northward movement of the shield and its intermittent sinking as a result of volcanic activity resulted in repeated underthrusting of the shield into the sedimentary prism of the southern Himalayan geosyncline, and consequent translation (slipping) against the Central Crystalline barrier which was lifted up progressively, the pre-existing faults providing the planes of slippage. Recently, Mehdi, Kumar and Prakash (1972) have advanced the hypothesis of successive generation of grabens and horsts in the Kumaon Himalaya, their progressive uplift and subsequent deformation of the accumulated sediments in grabens purely as a consequence of vertical uplift along faults which have now become inclined to assume the posture of thrusts.

The most recent theories to explain the Himalayan uplift are based on the Concept of Plate-Tectonics. Fetch (1970) suggested convergence of the Indian and Eurasian plates at shallow depths along the Himalaya mountain front. Dewey and Bird (1970) have conceived the origin of the Himalaya as resulting from the collision of the blocks of the Indian Peninsula and the Asian continent. Gansser (1973) has invoked northward movement of Indian continental plate and its subduction beneath the Eurasian plate, the Indus-Suture Line with its exotic blocks and ophiolites marking the subduction zone between the two plates.

## KUMAON REGION

### General

It is not possible for the author to include all the works on Kumaon, and he has mentioned here only those publications which have a direct bearing on his research problem.

Heim and Gansser (1939) extended Auden's concepts eastward into Kumaon, and named the crystalline thrust unit corresponding to the Garhwal Nappe as 'Almora Nappe'. They suggested that the Almora nappe was a huge syncline bounded by thrusts on either side, called by them as North Almora Thrust and South Almora Thrust respectively to the north and south.

They were, however, not clear about the exact location of the South Almora thrust. They have shown two thrusts dipping to NE between Bhowali and Ranikhet and they thought that the thrust near Ramgarh possibly joins up with the North Almora thrust (South Almora Thrust).

After Heim and Gansser, the Kumaon Himalaya received little attention from geologists till Pande (1949, 1950, 1956, 1963) started his investigations, and devoted a great deal of his time in unravelling the complexities of the structure and metamorphism.

Pande (1963), summarising the results of his investigations established four general metamorphic episode in Kumaon, viz. load metamorphism, progressive regional metamorphism, dislocation and retrogressive metamorphism, and granitisation- in that order. Pande for the first time unequivocally suggested a migmatitic origin of the gneissic rocks of Kumaon. Later on, Sarkar et al. (1965), working in the Almora area, also suggested the granitic rocks of the area to be a product of granitisation. Sarkar considered the age of regional metamorphism and granitisation in this part of the

Himalayas as Lower Oligocene. Pande and Powar (1968) and Das (1966), working under the guidance of Pande, worked out the details of the metamorphism and granitisation process at Almora and Chaukhutia respectively.

Important contributions to the Kumaon geology have come from Merh and his associates (Merh and Vashi, 1965, Desai and Merh, 1965, Merh, 1968). These workers have studied the structural and metamorphic aspects of Kumaon rocks in a great detail, and on the basis of minor structures, worked out a complete sequence of structural events and correlated them with the metamorphic history.

A short note published by Merh (1968) on the structural and metamorphic aspects of the Central Kumaon gives a clear picture of the geological evolution of the Kumaon region. Merh has found that some of the structural observations of Heim and Gansser are not valid and according to him, the thrust at Upradi is the South Almora Thrust, which joins up synformally with the North Almora thrust in the north.

In the same paper Merh has suggested that the Central Kumaon region has been affected by three deformational episodes. The earliest deformation appears to have folded the geosynclinal sediments into several large reclined isoclinal structures. The folding synchronised with the progressive phase of the regional metamorphism. Later, these overfolded rocks ruptured and this resulted in the Almora Thrust. The superimposed second folding gave rise to the major structures like the synform at Almora and the anticlines at Bhowali and Someshwar-Dwarahat-Chaukhutia. The third major folding has been along a NNW-SSE to N-S axis.

Rocks to the north of North Almora Thrust

The rocks to the north of the North Almora Thrust, have been included in the Deoban-Tejam belt by Gansser (1964), and this belt can be traced from the Simla area in the north-west to the border of Nepal in the South-east for about 350 km. The belt comprises the Garhwal Series of Auden (1949), Chamoli-Tejam Zone of Heim and Gansser (1939) and the Calc Zone of Pithoragarh of Valdiya (1962). Recently, Mehdi et al. (1972) have suggested the name Garhwal group to these rocks.

Gansser has divided the Deoban-Tejam Zone in the eastern Kumaon, into two belts, separated by the

Askot-Baijnath crystalline thrusts. In the south, occur the Badolisera-Pithoragarh Zone, while in the north it is known as Chamoli-Tejam Zone. According to him (op. cit. p.95) "The Badolisera-Pithoragarh Zone follows just north along the north-thrust border of the Almora-Dudatoli crystalline. The deepest outcrops visible in a steep, fan-shaped 'anticline' without corresponding limbs, consist of highly contorted thin quartzites with dark grey slates grading upwards into more greenish and reddish types. Northwards and apparently upwards some limestones begin, alternating with quartzites".

In an earlier work on the Pithoragarh, Misra and Valdiya (1961) and Valdiya (1962) have suggested that the entire Calc-Zone sequence shows a structural inversion. Gansser (op. cit.), is of the opinion that the sequence is uninverted.

Mehdi et al. (op. cit. p. 487), also who have mapped the Pithoragarh area do not agree with Valdiya's interpretation and in their opinion, there is no overturning in the Pithoragarh formation.

The western extension of this Calc Zone in the Almora (around Someshwar) has been mapped by Munshi (1971), and the present author's work deals with similar rocks further west around Chaukhutia. Munshi at Someshwar observed that the inversion shown by stromatolitic occurrences were only sporadic and indicated locally inverted small folds. Munshi has visualised in Someshwar a regional anticlinal structure that extends both east and westward and which was faulted along its crest. Earlier, Merh (1968) had invoked a reverse fault running along the anticlinal crest to explain the peculiar outcrop pattern of this belt, and to which Heim and Gansser (op. cit. p.43) gave the name "false anticline".

## The Problem of North Almora Thrust

The 'North Almora Thrust' in the Kumaon has intrigued all previous workers. As per Heim and Gansser (1939) and Gansser (1964), it comprises the south dipping northern flank of the synformally folded Almora thrust (equivalent to the Garhwal Thrust of Auden). This tectonic plane is supposed to separate the overlying crystalline rocks of the synformally folded Almora-Dudatoli thrust sheet. Valdiya (1962) has more or less accepted this concept and has correlated the Saryu Thrust of Pithoragarh area with North Almora Thrust. Vashi & Merh (1974) was however not very sure whether the junction between crystalline and the metasedimentaries to the north was Almora thrust and he therefore suggested a fault that had pushed down the Almora thrust.

The recent work of Mehdi et al. (1972), and Agarwal and Gopendra Kumar (1973) do not support the concept of the folded Almora thrust, and all these workers have invoked a mechanism of uplift and subsidence along deep seated vertical fractures to explain the tectonic framework and have practically ruled out the existence of large thrust sheet and nappe. Ghosh (1973) has a somewhat similar explanation to suggest, but he invokes considerable horizontal squeezing also, and development of thrusts during the later stages of the squeezing, when the rocks of the infrastructure glided over the sedimentary rocks of the suprastructure.

Chaukhutia and its neighbourhood

Oldham (1883), it appears, was the first worker who recognised the faulted contact between the gneisses and the metasedimentaries at Chaukhutia. As his account is nonillustrated and the various localities mentioned do not find any place in the present map, it is difficult to follow his description. Similar mention of "the abrupt fault contact of the granite and schistose rocks of Dudatoli with massive limestone to the east" has been made by Auden (1935, p. 135). In a later paper, Auden (1937) has shown this fault contact to be a great thrust plane delimiting the schistose and granitic rocks of Dudatoli (belonging to his Garhwal Nappe) from the underlying limestones.

Heim and Gansser (1939, p.46-48) have given a fairly detailed description of the Chaukhutia-Dudatoli tract. They have written, "We also have come independently to the conclusion that this fault line marks the line of a great thrust coming from the north-east".

"We begin at Ranikhet. This pretty and important place (1700-1900 meters) is situated on mica schists and white orthogneiss of gentle northern dip".

"Descending northward to the Gagas river, a series of mica schists, quartzites and gneiss is traversed. The dip increases up to 40° to NE. A carbonaceous layer too was encountered about half way down (Graphitic phyllitic schist of Auden). The dip remains unchanged as far as the crest of Chaura where the garnetiferous mica schists form a symmetrical syncline of WNW strike".

"At an angle of 45° the mica schists overlie an imposing mass of coarse granite. It contains muscovite and biotite, and forms the rugged hill south of Dwarahat. This important village with its schools, missions and numerous old Hindu temples is situated on a peneplain of 1500-1600 meters, formed of deeply weathered white gneiss, rich in muscovite, but with little biotite".

"With 30°-40° SW dip the gneiss is conformably underlain by sericite schists with garnet, below which follows slaty quartz porphyry. On the eastern side of the brook are some exposures of variegated shale recalling the Krol formation. The dip there is, on the contrary, towards NE. The walls up to the Dunagiri (fine view point, 7549') are made of limestone or dolomite and quartzites with a general dip more or less corresponding to the slope i.e. towards SW".

"Along the valley towards NW, quartz porphyry schists are exposed on the south-western side, dipping 30°-50° SW. A fine place for studying these igneous rocks is Chaukhutia, situated on the border of the fertile alluvial plains".

"A highly interesting structure is found about a mile north of Melchauri, where the Ramganga has cut an epigenetic gorge through the folded limestone series".

"The limestone series interbedded with quartzite and green schists is intensely folded, the general strike being still to the NNW, conforms to the longitudinal valley, but with local deviations. Proceeding further to the NW and rising from Lohba to Diwali Khal, the crystalline series is seen overlapping the sedimentary folds".

"Middlemiss considered the abrupt contact to the unmapped limestone series to be a straight fault. However, this 'fault' contact is far from being straight, nor is it vertical. Looking from Salana to Diwali Khal, it plainly appears as an overthrust shearing off the folded sedimentaries. Thus, the great synclinal region of gneiss and mica schists of the Dudatoli mountains is swimming. We may call it the Dudatoli thrust mass".

According to these two workers (op. cit., p.220) the complex sedimentaries, north of the Almora Crystalline Zone, extend south-eastward to Someshwar-Barichina-Badolisera, and the limestone occurring in it is non-metamorphic and resembles Krol and accordingly the large overlying quartzites could be Tal.

As regards the rocks to the south west of the thrust, they have been reported to be metamorphic quartz porphyry by Heim and Gansser. They have written (op. cit., p.57), "The sprinkling of feldspar and quartz of the gray schistose rock is recognized even macroscopically. Under the microscope the quartz forms large rounded grains of intense undulatory extinction. The orthoclase is perthitic, more or less idiomorphic and in parts reticularly albitized and calcitized. The plagioclase (oligoclase andesine), if present, shows calcite secretion. The fine ground mass is chiefly quartz, sericite and brown biotite".

"The texture is porphyroblastic, the structure lenticular. The mineral composition too is that of a quartz-porphyry, similar to the quartz-porphyry gneiss of Ramgarh. In both cases they are probably old intrusions, like those of gneiss. At Chaukhutia it may be prophyritic marginal facies of the gneiss".

A rather detailed work exclusive on the Chaukhutia area, is due to Das (1966), who carried on his doctoral research on the rocks of the two structural units around Chaukhutia. The North Almora Thrust of the previous workers has been referred to by him as Chaukhutia thrust and he has put the rocks into three main groups as under:-

| | | |
|---|---|---|
| Ganai Group | (25) | Crystalline dolomitic limestone |
| | (24) | Slates |
| | (23) | Flag-Quartz-sericite-chlorite flags |
| | (22) | Ganai quartzite |
| | (21) | Violet and purple slates |
| ----------------Khastari Nadi dislocation (Chaukhutia thrust) | | |
| Chaukhutia group | (20) | Phyllonite and mylonite |
| | (19) | Pink-micaceous quartzite with basal graphitic phyllonite |
| ----------------Nagar Nala Dislocation---------------------- | | |
| | (18) | Garnetiferous-biotite schist (bluish-grey schist) interbanded with quartzitic flags |
| | (17) | Pink quartzite with at times thin layers of red mica schist |
| | (16) | Garnetiferous-mica schist interbanded with quartzitic flags |

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| Migmatite Group | (15) Feldspathic-garnetiferous mica schist with at places patches of quartzitic flag |
| | (14) Medium grained foliated migmatite |
| | (13) Feldspathic garnetiferous mica schist |
| | (12) Sub-Augen Migmatite |
| | (11) Feldspathic-garnetiferous mica schist |
| | (10) Sub augen Migmatite |
| | (9) Feldspathic garnetiferous mica schist |
| | (8) Streaky migmatite |
| | (7) Garnetiferous flag |
| | (6) Medium-grained foliated migmatite |
| | (5) Sub-augen migmatite |
| | (4) Feldspathic-garnetiferous schist |
| | (3) Coarse grained foliated migmatite |
| | (2) Augen Migmatite |
| | (1) Feldspathic garnet-mica-schist alternating with bands of quartzitic flags |

According to Das, the Migmatite and the Chaukhutia Groups belong to the Almora Nappe while the Ganai Group form a part of Krol Nappe. The limestone of the Ganai Group have been considered to be equivalent to the Krol.