CHAPTER II

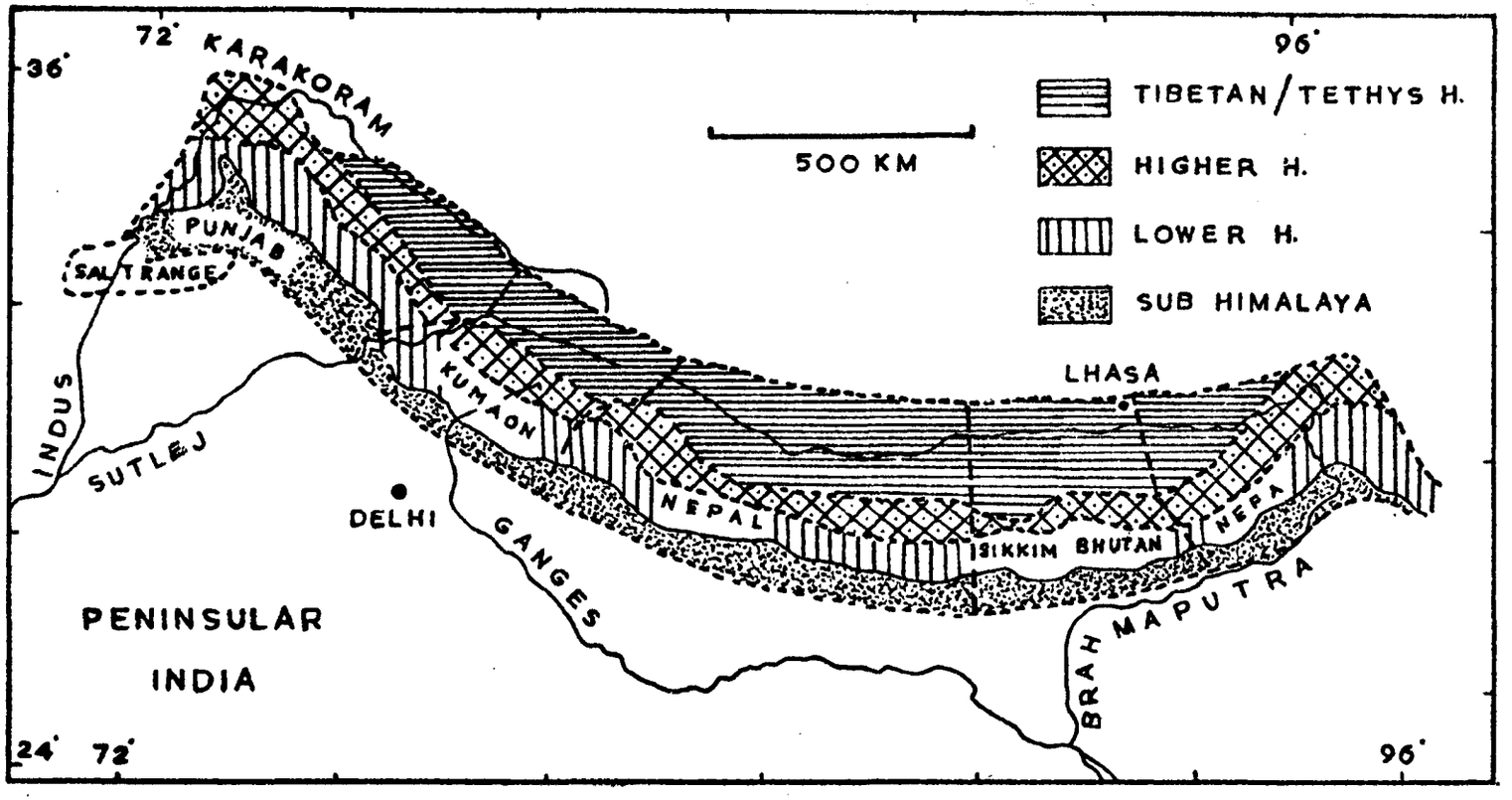
BACKGROUND INFORMATION

HIMALAYA IN GENERAL

Gansser (1964) has geographically divided the Himalaya into four major sections from west to east as under (Fig.II.1):

	Extent	Length in km
Punjab Himalaya	between the rivers Indus and Sutlej	560
Kumaon Himalaya	between the rivers Sutlej and Kali	320
Nepal Himalaya	between the rivers Kali and Tista	800
Assam Himalaya	between the rivers Tista and Brahmaputra.	720

FIG. 11.1



THE GENERAL SUBDIVISIONS IN THE HIMALAYAS

Longitudinally, the Himalaya is divided into four major zones from south to north (Fig. II.1) which strikingly correspond with the geological divisions. They are :

1. Sub-Himalaya or Siwalik foot-hills,
2. Lesser Himalayan Zone (Midlands),
3. Higher Himalaya or Great Himalaya,
4. Tethys or Tibetan Himalaya.

Apart from the above four divisions, there is a narrow zone in the extreme north, beyond the Tethys Himalaya, commonly known as the Indus Suture Zone which is well developed in western Himalayan region. This zone is supposed to delineate the Himalayan domain from the Trans Himalayan Region and also according to some authors, represents the plate boundary between the Indian and the Eurasian plates.

A good account of the regional geology of Himalaya can be found in the works of Gansser (1964), Valdiya (1964, a, b, c ; 1973), Le Fort (1975), Pandey (1975), Jhingran et al. (1976) and many others. However, a very brief outline of the geography and geology of Himalaya is summarised below.

Outer Himalayan Zone or Sub-Himalaya or Siwalik Foot Hills

Extending continuously, along the northern border of the Indian plains, in the east from Brahmaputra to the Ganges and Indus river in the west, this zone includes the first group of hill ranges that rise from the Indo-Gangetic plain. This zone shows considerable variation in width, ranging from 8 to 50 km approximately, and rising to a maximum altitude of 1300 m from M.S.L. At places, these foot-hills are separated from the Lesser Himalaya by flat-bottom valleys called 'Duns' which are covered by recent gravels and alluvium. These foot-hills are thickly forested with tropical deciduous flora comprising mainly Sal (Shorea robusta) and Chir (Pinus longifolia) trees.

Geologically, this zone is occupied by fluvial and lacustrine molasse like clastic deposits of Upper Tertiary to Pleistocene age, consisting chiefly of sandstones, shales, pebble beds, conglomerates etc. At places rich vertebrate fossils have been found. The Siwaliks are divided into three divisions viz. Lower, Middle and Upper. The upper division contains coarser sediments than the lower horizons, indicating more violent upheaval of the Himalaya during the Upper Siwalik times.

Tectonically, the Siwaliks are separated from the Lower Himalaya by the Main Boundary Fault and along this tectonic plane there is visible southward advancement of the Lower Himalayan sediments over the Siwaliks. The Siwalik tectonic zone is characterised by broad open anticlines and synclines parallel to the length of the Himalaya. There are also several transverse structures in Siwaliks which have caused some amount of horizontal displacement.

Lesser Himalayan Zone (Midlands)

This is a zone of parallel ranges which form an intricate system of interconnected ranges with a milder topography as compared to the Higher Himalaya. The width of this zone varies from 60 to 80 km and the height variation ranges between 2000 to 3300 m.

The northern boundary of the Lesser Himalaya is delineated by the Main Central Thrust, while to the south, it is bounded by the Main Boundary Fault. A huge sedimentary succession of controversial age with very low grade metamorphism is characteristic of this zone with sporadic cover of Gondwana type of rocks and crystalline thrust sheets having their roots in the far north. The geology of this zone is most complicated because of thrusting, faulting, folding and nappes and schuppen structures.

Higher Himalaya or Great Himalaya

This is the northern and innermost line of the Himalayan range with perpetual snow-clad peaks. This zone rises abruptly in elevation from the Lesser Himalaya, the average height being about 6080 m and this is the very range where lie the majority of the majestic high peaks of the world including Mt. Everest (Sagarmatha).

The rocks of the Higher Himalaya consist of crystalline rocks - schists and gneisses, and these show a wide variation, ranging from chlorite to sillimanite zone of Barrovian type, with extensive development of migmatitic gneiss zone. These crystalline rocks have more or less continuous extension from Kashmir in the west to Dihang valley of Arunachal Pradesh in the east. The Main Central Thurst (MCT) marks the base of the Central Crystalline, and this major dislocation plane has caused the southward movement of crystalline rocks. These crystalline rocks have very large thickness of 15 to 20 km , and there is a sharp contrast in metamorphism and lithostratigraphy between the southern Lower Himalayan sediments and the crystallines to the north. The crystalline thrust-sheet is seen to lie below the thick sedimentary pile of the Tethyan domain, further north.

One of the important features of this Central Crystalline Zone is that unlike the sharp contrast with the Lesser Himalayan sedimentary pile, the overlying Tethyan sediments show a characteristic gradational contact in most sections. The metamorphism imperceptively decreases upward from the crystalline to the Tethyan sediments without any sharp break.

Tethys (Tibetan) Himalaya

This marine sedimentary zone has about 40 km average width and lies to the north of the Great Himalayan zone. The average altitude is about 3000 to 4300 m. The rocks belong to the Tibetan facies and comprise a sequence from Uppermost Precambrian - Lowermost Palaeozoic to Eocene. These marine sedimentary rocks have a good and well preserved fossil assemblages. According to Gansser (1974) the Tethyan sediments of the Tibetan Himalaya follow conformably on the Precambrian Crystallines of the Main Central Thrust-sheet. In Nepal, Ohta & Akiba (1973, P.243) however, envisaged an unconformable relation (possibly a thrust) between them.

The rocks of the Tethys Himalaya occur in isolated basins viz., from west to east as Kashmir, Lahaul - Spiti , Kumaon, Nepal and Tso-Lhamo region in Sikkim - Tibetan border. These basin - like areas are probably young structural features

caused by axial culminations and depressions during the orogenic movements and it has been envisaged that the constant sedimentary development suggests an originally large continuous major basin of sedimentation. Though a complete record of succession from Early Cambrian to Cretaceous - Eocene is preserved in these areas, several stratigraphic gaps indicating epeirogenic episodes have been reported from various localities.

GEOLOGY OF NEPAL

In the following pages, the present author has tried to give a somewhat elaborate account of the previous works in Nepal Himalaya. The author feels justified in doing so on the ground that though a large number of investigators have worked in Nepal dating back to as early as 1848, and a vast geological literature is available, the Nepal geology is still in its infancy. The various accounts are so much piecemeal and scattered that it is difficult to obtain a coherent and succinct picture. Thus, a complete and up to date preview of the geology of Nepal is much warranted.

The earliest work on Nepal geology was carried out by Hooker who visited the Tamur valley near Nepal-Sikkim frontier in 1848 (cf. Auden, 1935). Subsequently, Medlicott (1875) took a traverse from Amlekhganj through Kathmandu to

Nawakot. This was followed by a number of geologists who visited Nepal viz., Jones (1889), Oldham (1899), Diener (1912) Heron (1922) and Sutton (1933).

The first systematic geological investigation on Nepal is due to Auden (1935) who visited some parts of Eastern and Central Nepal. He gave a fairly good account of the geology of this part of Himalaya, and he is one of the earliest workers who attempted the correlation of the little known Nepal rocks with the better known rocks of Indian Himalaya. He divided the Siwaliks of Central Nepal into three sequences as in the Indian Himalaya. Regarding the pre-Tertiary rocks as of the Dhankutta-Chainpur in Eastern Nepal and Seopuri Lekh, north of Kathmandu, he wrote (1935, P.139) that these "..... are unquestionably, in my opinion, Darjeeling gneisses. The underlying phyllites of Taplejung (27^{o} $21^{'}$: 87^{o} $40^{'}$), Mulghat (26^{o} $56^{'}$: 87^{o} $20^{'}$), Deopur (27^{o} $45^{'}$: 85^{o} $34^{'}$) and near Nawakot (27^{o} $55^{'}$: 85^{o} $11^{'}$) may be regarded as Dalings. There is no doubt at all with regard to the correlation of the phyllites at Taplejung and Mulghat, and a very fair certainty about those north of the Nepal valley." Thus, he was the first worker to suggest the continuation of the Darjeeling gneiss and the Daling series westward into Nepal.

The rocks from Bhimphedi to Kathmandu section according to Auden (1935) were also Dalings. He collected some fossils from the non-metamorphosed limestones of Chandragiri Pass near Kathmandu valley and assigned Palaeozoic (Ordovician) age to these rocks. He further tried to correlate the limestones of Udaipur Garhi with the Upper Krol stage of Garhwal Himalaya.

When Auden revisited Nepal (Auden & Saha, 1952) , and worked around Narayangarh, Bhimphedi and Kathmandu, he gave the geology for Central Nepal as under :

Banded Phyllite Group

- - - - - - - Thrust - - - - - - - - - -

Dolomite Group

- - - - - - - Main Boundary Fault - - - -

Nahan Group

- - - - - - - Thrust - - - - - - - - - -

Siwaliks

He correlated with a question mark, the Dolomite Group with Krol-Deoban of Indian Himalaya and regarded the Banded phyllitic Group as pre-Krol.

A fairly good account of the geology of Westernmost Nepal is given by Heim & Gansser (1939). Their work comprises

an attempt to extend their structural concepts of Garhwal and Kumaon upto the western boundary of Nepal.

The most important and exhaustive studies on the geology of Nepal, were conducted by Tony Hagen in the fifties (Hagen, 1951, 1959 etc.) and his total work has been subsequently summarised in English (Hagen, 1968, 1969). He got an opportunity to work in the whole of Nepal and scaled every part of the country. According to Hagen (1969, P. 34) "As in the Alps, a number of nappe groups were found in Nepal, each of them consisting of several nappes of similar type of lithology and structure. Three of these nappe groups consist dominantly of crystalline formations, namely from top to bottom : the Kangchendozonga-Lumbasumba nappes, the Khumbu nappes and the Kathmandu nappes. Two of the nappe groups are dominantly formed of Paleozoic sediment-formations, with minor crystalline bodies (Hiunchuli nappes, Jajarkot nappes). A further two nappe groups contain mostly Carboniferous-Mesozoic formations (Bajang nappes, Nawakot nappes). The later group however, undergoes considerable change in lithology and stratigraphy in the direction of the strike. They show a kind of transitional character consisting, in the south and in central Nepal, dominantly of young formations (Permian-Triassic), while consisting in eastern Nepal almost entirely of Palaeozoic formations. The Nawakot nappes thus show a gradual development to the type of Kathmandu nappes".

In all, Hagen has postulated following 22 nappes :

Crystalline nappes	Kangchendzonga nappe	(1)
	Lumba sumba nappe	(1)
	Khumbu nappes	(3)
	Kathmandu nappes	(5)
Nappes of dominantly Palaeozoic sediments	Hiunchuli nappes	(2)
	Jajarkot nappes	(2)
Nappes of dominantly Carboniferous-Mesozoic sediments	Bajang nappes	(4)
	Nawakot nappes	(4)

He also gave a schematic sketch (Fig. II.2A) of the distribution of the various tectonic units and their correlation with each other. Geological cross-sections of Central Nepal by Hagen (Fig. II.2B) greatly differs from that given by Japanese workers (Fig. II.2C).

According to Hagen (1969), Auden's Darjeeling series corresponds to the Kathmandu nappe while his Krol rocks were identical with the Nawakot nappes.

As Hagen's Nawakot nappe 4 (uppermost) and whole of Kathmandu nappe are restricted in their root zones and are not found to the south in the Lesser Himalaya of Western Nepal (Fig. II.38), he has concluded that (1969, P. 70) "When considering the overthrust parts of Kathmandu nappes, we have to say that these nappes cover relatively small parts of the country (Plate 6). In two different zones only, crystalline masses of the Kathmandu nappes are thrust from the roots towards the south. The larger area is found in eastern Nepal, between the meridians of Kathmandu and Arun valley (Fig. 17 and Plate 6). The whole central area of the country lacks the thrust nappes. They occur again in western Nepal, only in the area of Jumla-Dailekh (Plate 6 and Fig. 34). In both of these areas, the Kathmandu nappes have been preserved from erosion in large synclines with axial depressions." (Fig.II.28). He further writes (PP. 70) "probably, the Kathmandu nappes formerly also existed between the sections of Kathmandu and Dhaulagiri, but have since then been eroded. The same situation appears to exist in western Nepal, west of the meridian of Saipal (Fig. 35). Further west, beyond Nepal, the overthrust masses occur again in the form of the 'Garhwal nappes' of J. B. Auden or the 'Almora Thrust' of Heim and Gansser". (Fig. II.38).

In a general way, Hagen has followed the stratigraphic correlation of Auden, but in details, it is observed that his

work on stratigraphy was quite inadequate. Because of this weakness as well as the multitudes of nappes, postulated by Hagen, his concepts were disputed by a number of subsequent workers and gave rise to the several present day controversies in respect of the tectonics of Nepal Himalaya.

Bordet and his associates have also worked in different parts of Nepal Himalaya. Their earlier work (Bordet, 1955, 1961, etc.) pertains to the Eastern Nepal and a substantial contribution to the geology of this region has been made by them. They broadly agree with the concepts of Hagen but differ in details. Later on, they also worked in Kathmandu area (Bordet, 1960 ; Bordet et al., 1959). They described the geology of the fossiliferous Phulchauki (Chandragiri) rocks and confirmed their Silurian age on the basis of Trilobite fossils. They extended their work further to the west in Central West Nepal (Bordet et al. 1964a , 1964b , 1964c , 1968 , 1972) and their contribution to the geology of this area and especially of the Tethys Himalaya is noteworthy.

Gansser (1964) was more or less convinced with the interpretations of Hagen. He has tried to give a regional tectonic picture of whole of Himalaya including Nepal Himalaya and extended his concepts of tectonics of Indian Himalaya to Nepal as well. But his description of geology and tectonics of Nepal is mainly based on the works of Hagen, Bordet, Lombard and others.

Bodenhausen et al. (1964) visited some parts of Central West Nepal Himalaya and discussed the geology of this region in broad perspective. Their main work comprised in providing a provisional stratigraphic scheme for the Tibetan Zone of this part of Nepal and correlating its rocks with the other well known sections of the Himalayan arc. These workers observed that the Tibetan Zone, together with the crystalline rocks of its base forms a huge overthrust unit, overlying the complex of the Lesser Himalaya to the south. They are more or less in agreement with the basic concepts of Hagen but are doubtful of the subdivision in the gneiss zone into a number of overthrusts as postulated by him. In the Lesser Himalaya, according to these authors, there were local indications of thrusting, especially in the north. Furthermore, the abrupt changes in metamorphic grades between the northern and southern parts of the Lesser Himalaya, have led them to suggest a possible tectonic contact.

An altogether new approach to the geology of Western Nepal was put forth by Nadgir & Nanda (1966), the two Geological Survey of India officers who, it seems did not believe in the nappe concept. They, envisaging major structural blocks bounded by thrust faults of considerable vertical slip component, have divided the Western Nepal Himalaya into following four major structural blocks :

1. The southern belt of Siwaliks
2. The belt of Suparitar autochthonous folds and thrusts with Ismakot Central massif of Bhimphedi type.
3. The Bhimphedi belt of the Main Himalaya
4. The Tethyan sedimentary zone.

The general stratigraphic sequence of the Western Nepal suggested by these authors is as follows:

7.	Mustang valley lake-fill, River terraces, Terai, Gangetic alluvium	- Mid Pleistocene to Recent
6.	Siwalik System	- Upper Tertiary to Mid Pleistocene
	- - - - - - - - - - Unconformity - - - - - - - - - -	
5.	Tansen Series (Mahabharat area)	- Cretaceous to Paleocene
4.	Granite, intrusive	- ? Mesozoic
3.	Thak Khola Rocks(Tethyan)	- Palaeozoic - Mesozoic
	- - - - - - - - - - Unconformity - - - - - - - - - -	
2.	Suparitar Series	- Precambrian ? (Delhis?)
1.	Bhimphedi Series	- Precambrian.

Similarly, Eremenko & Nomokonov (1967) were also of the opinion that the Himalaya was a block type mountain similar

to that of Tien Shien mountain and that there is an essential difference between the Alps and Himalaya in the tectonic style.

Austrian geologists, Fuchs and Frank, have contributed substantially to the geological studies on Nepal (Fuchs, 1967 ; Frank & Fuchs, 1970 ; Fuchs & Frank, 1970 ; Fuchs, 1975). They have worked extensively in the Central and Western Nepal and also in Kumaon and Garhwal Himalaya. Though agreeing with the nappe concept, they have preferred to correlate the Nepal stratigraphic and tectonic units with those of Kumaon Himalaya. Frank & Fuchs (1970 , P. 555) have commented on the work of Hagen and Bordet that "Both authors were misled by working without a reliable stratigraphical framework in the Lower Himalayas. They neglected the wealth of information collected from the Indian Himalayas." According to these authors "the stratigraphy given by Auden (1934) is applicable very well to Nepal and the tectonics described by Pilgrim and West (1928), and West (1939) are of a surprising similarity to those observed in Nepal." They have given the cross-section of Central West Nepal (Fig. II.3A) quite different than Hagen (Fig. II.3B).

According to Fuchs & Frank (1970), West Nepal from south to north comprised the following main structural units:=

1. The Tertiary Zone (Siwaliks)
2. The Tansing Unit.
3. The Rukum nappe.

4. The Chail nappe
5. The Lower and Upper crystalline nappe (Kathmandu nappe of Hagen)
6. The Tibetan or Tethys zone.

The concepts made out by Fuchs & Frank have been summarised as under :

1. The Tansing Unit shows a thrust contact against the Tertiary Zone all along the southern boundary (M. B. T.). The tectonic style of the Tansing Unit which contrasts with that of the higher nappes, led them to assume a parautochthonous character for that unit.

2. The Rukum nappe forms the lowest nappe of the Lower Himalaya. It was thrust horizontally over the Tansing Unit and is overthrusted by the Chail nappes. Whereas the Tansing Unit is nearly unmetamorphosed, the rocks of the Rukum nappe show metamorphism identical to that of the Chail nappe.

3. The Chail nappe of Simla (Pilgrim & West, 1928) is represented throughout the Himalaya. The Chail nappe has a large area of outcrop in the western part of Nepal and here it comprises entirely of Chail Formation.

4. The Crystalline nappe is also found throughout the Himalaya, the same thrust over the units of the Lower Himalaya. This nappe is comparable to the Kathmandu nappe of Hagen (1969) and the Central Crystalline Zone of Heim and Gansser (1939). The metamorphism dies out in the overlying formation of the Tibetan Zone.

The Russian geologist Talalov (1972) has interpreted Nepal geology quite differently. He believes that Himalaya formed as a result of block faulting instead of a geosynclinal folded mountains.

He has distinguished following structural units in Nepal Himalaya :

1. Siwalik foredeep,
2. Lower Himalaya of Nepal,
3. Higher Himalaya.

He summarised the geological history of Nepal Himalaya in the following lines.

The Lower Himalaya of Nepal is characterised by intermittent continuous sedimentation from the Proterozoic to the Lower Permian. Breaks in sedimentations are connected only with epeirogenic movements. At the boundary between the

Lower and Upper Permian the uplift of the region took place. At the time there developed broad box, coffer folds, nearly isometric, disrupted during the Permian time by a series of longitudinal faults of the north-western trend and transverse faults of the north-eastern trend. The faults emphasize the block rupture in the Archean basement, the movements along which were "inherited" in all subsequent geological epochs.

"The post Permian history is characterised by continuing uplift, erosion, block ruptures. And along the deep seated faults intrusions of granite at different periods took place. The Eocene is marked by the advance of the sea along narrow foredeeps and led to transitory deposition of limestones and then there followed abrupt block uplifts in which more northerly areas of the country were also involved. The formation of a very large foredeep filled with the Siwalik molasse formations of the Neogene age is related to these block uplifts of the Apline cycle." (Talalov, 1972 , P. 617).

The composite section of the Lower Himalaya of Nepal, as worked out by Talalov (1972) is given in table II.1.

According to Talalov (1972) the Higher Himalaya of Nepal is notable for continuous sedimentation from Proterozoic to the Cretaceous inclusive, and for pointing to a later beginning of the general uplift as compared with the Lower Himalaya.

The Japanese geologists on the other hand, have suggested rather a different geological framework for Nepal Himalaya. According to Ohta & Akiba (1973, P.6) the Alpine ultra-nappe concept could not be applied to Nepal, as "there is an essential difference in the geological structures between the Indian and Nepalese Himalayas." These authors believe that the essential structures of the Nepalese mountain range have resulted from the longitudinal block movements with vertical displacement and not from Alpine folding, and according to these authors, no nappe structures can be found in Central and Western Nepal. Some nappe structures do exist in Eastern Nepal, but they are of subordinate importance compared with the vertical movements.

The correlation of Nepal rocks with those of Kumaon as suggested by some of the workers is not acceptable to Ohta & Akiba, as they were not convinced of the desirability of comparing the lithologic units between remote areas more than several hundred kilometers apart from each other. To avoid such difficulty they attempted first to establish a large litho-stratigraphic subdivision for each of the surveyed areas separately, then correlated the rock units between the adjacent areas within the Nepalese territory, and only after establishing general lithostratigraphy they tried to correlate it to the successions known outside Nepal. From north to south, they have suggested the following tectonic

and litho-stratigraphic divisions :

- -

Tibetan Tethys sediments (early Paleozoic to Eocene) with the basement of Himalayan gneissess (Precambrian)

- $M_{\blacktriangledown}C_{\blacktriangledown}T_{\blacktriangledown}$ - - - - -

Midland meta-sediment group (Probably Eocambrian and older)

- -

Kathmandu group (early to middle Paleozoic)

- -

Younger sediments (late Paleozoic and Cretaceous to Eocene)

- M.B.T. - - - - -

Siwalik series (Miocene and Younger)

The Midland metasediment group is an enormous sequence of more than 15,0000 m thick, being divided into four subgroups based on the lithologic characteristics as follows:

Upper subgroup	... ...	calcareous succession,
Middle subgroup	... ...	siliceous succession,
Lower subgroup	... ...	arenaceous succession,
Lowermost subgroup	... ...	argillaceous succession.

The two lower subgroups mainly consist of an argillaceous succession followed by the sandstones. The middle subgroup contains thick orthoquartzite layers while the upper subgroup is characterised by the occurrence of stromatolite-bearing limestones. The Kathmandu group, developed in the centre of Nepal around Kathmandu valley, is supposed to overlie the upper calcareous subgroup of the Midland metasediments. The Kathmandu group forms a large synclinorium bounded by the injection gneiss zone from the north and the granite intrusion zone from the south. The total thickness of the Kathmandu group is about 7,200 meters. The younger sediments, including the Gondwana-type and the Cretaceous to Eocene sediments, fill the tectonic depression zones formed by later block movement.

As regards the age and correlation of the rocks of the Midland metasediment group, Ohta & Akiba (1973) have considered them as Eocambrian. They have correlated these rocks of Nepal with the Lower Himalayan rocks of Punjab and Kumaon as under :

Punjab and Kumaon (Valdiya,1964a)		Nepal (Ohta & Akiba,1973)
Argillo-calcareous		Upper calcareous subgroup
Arenaceous group		Middle siliceous subgroup
		Lower arenaceous subgroup

More recently, Remy (1975) has compiled his work of nearly eight years mainly in Western Nepal and has reinterpreted the geology and tectonics of this region. He is more or less in agreement with Bordet et al. (1964a) and Nadgir & Nanda (1966) and also with the Japanese authors at least in respect of the fact that this part of Western Nepal belongs to autochthonous to parautochthonous zone and does not form a part of nappes as postulated by Fuchs (1967), Hagen (1969) and Fuchs & Frank (1970). However, little west of Kali Gandaki valley, he has shown the nappe structures too.

Remy (1975a , b) has given the following lithostratigraphic tectonic units of this region arranged in a chronological order, the oldest being at the bottom, and the youngest at the top .

Quaternary
Siwalik Formation
Tertiary Formation
Tibetan Series
Nepal Nappe Series
Salyane Series
Nepalese Series

In his geological map, Remy (1975b) has shown the extension of the Calc Zone of Tezam and Calc Zone of Pithoragarh (Misra & Valdiya, 1961), far into the Nepal side to the

east, the two zones being separated by the Askot crystallines. According to him, the Nepalese Series and the Nepal nappe series are equivalent to old formations which outcrop at Kumaon. Their age thus being Precambrian and Lower or Middle Palaeozoic. But, he correlates Salyane series, with that of Blaini-Krol-Tal assigning the age of Carboniferous, Permian and Mesozoic. Thus, Remy differs with Fuchs (1967) and Fuchs & Frank (1970) in correlating these rocks of Western Nepal with Kumaon Himalaya and in the interpretation of tectonics and stratigraphy of the region.

Sharma (1975), a Nepalese geologist has worked extensively in Nepal Himalaya for more than a decade, and he is of the opinion that instead of nappes, the faults and high angled thrusts have controlled most of the structural pattern of the Nepal Himalaya. He has also envisaged block faulting as the main mechanism of evolution of Nepal Himalaya. The conspicuous inverse metamorphism, supposed to be the backbone of nappe theory, according to Sharma (1975) is related with the intrusion of granites. He has also postulated a uniform lithological sequence extending from the east to the west of Nepal. In Lesser Himalaya of Nepal, except the Permo-Carboniferous (Gondwana) of Barahachhetra (Auden, 1935), Silurian formation of Phulchowki (Rimal, 1959, Bordet, 1961) and Cretaceous and Eocene formation of Masem, Dang and Dailekh not much stratigraphic controls are found. Therefore, he has

put the unfossiliferous Lesser Himalayan metasediments into his Mahabharat Limestone Group of Precambrian to Cambrian age. He has put forth the stratigraphy as per table II.2.

For Eastern Nepal, a rather noteworthy contribution has come recently from Jaros (1976) and Jaros & Kalvoda (1978). These workers have recognised two stages of nappe thrusting: the earlier stage of Middle Tertiary and later stage of Quaternary age. Their main conclusions are as under:

(a) The Pre-Neoid basements of the Himalayan area (except for the Indus Suture Zone) was built by a substratum of continental type. Two units of this substratum are observed in the suprastructure of the Himalayan mountain range; the first unit - probably Precambrian in age (the Arun group in the Lesser Himalayan Unit, the Barun group in the Higher Himalayan Unit) the second unit probably Palaeozoic in age (the Tumlingtar and Sanguri Formations in the Lesser Himalaya and the Chomolongma group in the Higher Himalaya).

(b) The Zone of eugeosynclinal type stretched in the north upto the Indus Suture Zone while the Tibetan

(Tethys) Himalaya can be interpreted at the best as a miogeosynclinal zone with uninterrupted sedimentation from Palaeozoic to Lower Tertiary. The Himalayan area proper was a fore-land of this geosyncline which was not incorporated into the Neoidic remobilization until the young Cenozoic Evolution phase.

(c) The origin of the main Himalayan nappes can hardly be explained by gravitational glidings from elevation. At the time of origin of nappes there was no large mountain elevation. In the northern part of the geosynclinal area deformations appeared in the Upper Cretaceous and in the Eocene. In the foreland of the geosyncline in Himalayan area proper they are Neogene in age.

(d) With regard to the development of Himalayan area of Eastern Nepal, the thrust planes of nappes and scales should be interpreted as relief thrust and the bodies of nappes as relief nappes.

The present author has included two schematic cross-sections of Nepal Himalaya compiled by Terman (1974), that provide ideally the geological framework of Nepal (Fig. II.4).

In addition to the various major contributions on the regional geology of Nepal discussed above, there are numerous investigators who have mapped various parts of Nepal on specific problems. For want of space, their works have not been reviewed here. However, for the purpose of reference few of them are listed below :

Lombard (1958), Bordet et al. (1965), Krummenacher (1961, 1966, 1967, 1971), Khan & Tater (1970), Colchen (1971, 1975), Singh (1973), Kalvoda (1973), Fort (1974, 1976), Le Fort (1971, 1975), Leroy et al. (1975), Pecher (1975), Bouchez & Pechov (1976), Tewari & Gupta (1976), Lasserre (1976) Mascle & Peacher (1977), Maruo & Pradhan (1977), Ravindra Kumar et al. (1978), Krummenacher et al. (1978).

PREVIOUS GEOLOGICAL INFORMATION PERTAINING TO THE STUDY AREA

References to the geology of the study area and its neighbourhood, comprising the Kali Gandaki section of the Midland, are found in the works of Gandotra (1962), Bordet et al. (1964a,b,c), Nadgir & Nanda (1966), Fuchs (1967), Frank & Fuchs (1970), Fuchs & Frank (1970), Nanda (1973), Sako et al. (1973), Remy (1975a,b) Sharma (1975) and others. Of course, none has given a detailed account. It is also observed that the structural and stratigraphic details have been variously interpreted, depending on the concepts and

bias of the individual worker. As a result, considerable confusion and controversy prevail in respect of the geological framework as available in literature. The present author has summarised below the salient points of the previous work, to provide a suitable background.

Gandotra, V. M.

Gandotra (1962) who was an officer of the Geological Survey of India, visited the Kali Gandaki valley area in connection with gold investigation. He took a traverse from Butwal to Baglung, wherein the traverse from Riri Bazar to Baglung was all along the Kali Gandaki river valley. His work, though a preliminary one with a traverse map showing the distribution of the various lithological units, gives a fairly good account of geology and metamorphism of this area. According to this author, the rocks like shale, slate, quartzite and dolomite exposed south of Jyamireghat (near Phalebas) appeared to be similar to the Suparitar Series occurring between Suparitar and Bhainse Dobhan villages in the type area of Central Nepal (south of Kathmandu). The rocks between Jyamireghat and Baglung, consist of interclations of dark biotite schists, greenish chlorite mica schists, greenish and gray gritty schists and quartzites and white hard quartzites, indicate a higher grade of metamorphism than that of the rocks of the southern area. He has therefore, correlated these rocks with the Bhimphedi series of Central Nepal. He also found that there was

a progressive increase of metamorphism from south to north.

Nadgir, B. B. and Nanda M. M.

The first comprehensive work on the geology and tectonics of Kali Gandaki valley area is found in the unpublished works of Nadgir & Nanda (1966) and Nanda (1973), the two officers of Geological Survey of India. According to them the rocks of the study area lie within the Suparitar Series and show a stratigraphically younger sequence from north to south as under :

Banded limestone, fossiliferous Carbonaceous shales with black to Khaki sandstone		Cretaceous-Palaeocene	
- - - - - - - - - - Unconformity - - - - - - - - - - - - -			
8. Carbonaceous shales with dolomitic limestone			
7. Stromatolitic dolomite, cherty in upper part			
6. Purple formation -	Calcareous Argillaceous Arenaceous	Shallow water continental facies	Pre-Cambrian ?
5. Grey shales grading into the Purple formation			
4. Crystalline limestone and phyllites			
3. White quartzite, with discontinuous basal pebble-beds			
2. Basic volcanic facies, Submarine (?)		Precambrian	
1. Grits and phyllites with occasional limestone and basic igneous bands : flysch			
- ?			
? Bhimphedis			

These authors have divided the Suparitar terrain of this area into four structural blocks separated from one another by both normal and thrust faults as under :

(a) Ismakot - Tansen block

(b) Dhorpatan - Galkot - Keware block

(c) Jugja Pahar - Beni - Nawakot block and

(d) Gurjakhani - Dana - Pokhara block.

According to these workers (1966) "In the Suparitar basin, an initial subsidence in what is now the Pokhara anticlinorium led to the deposition of a great thickness of grits and volcanics. Similar rocks were also deposited around the Ismakot of Central massif. The subsidence was later shifted to the south in a narrow belt between Central Himalayan and Ismakot massif and to another belt south of the latter, leading to the deposition of a great thickness of the shallow water purple formation and biostromal dolomite. According to the latest radiometric dating the Suparitars are equivalent to a post-Delhi age, i.e. Precambrian". "The Tansen Series was deposited in a faulted graben - syncline on the eroded Mahabharat anticline and is contiguous with the Eocene formation further west."

Regarding the tectonics of this area, they have stated, "Hagen's nappe theory is rejected for this part of Nepal Himalaya and an alternative theory of development of

folds and thrusts, variously directed, by intense relative uplifts and subsidence of blocks is put forward."(Fig.II.5A).

Fuchs, G. and Frank, W.

These Austrian geologists in a series of papers (Fuchs, 1967, Frank & Fuchs, 1970 ; Fuchs & Frank 1970) have given in fair detail the geology and tectonics of this part of Kali Gandaki valley. These authors have envisaged a NW-SE thrust dividing the area into two tectonic units, the Chail nappe in the north resting tectonically over the Tansing Unit (Parautochthonous Krol Unit) (Fig. II.3A). They have assigned almost identical stratigraphy for both the Units. They write (Frank & Fuchs 1970 , P. 556) "The nearly unmetamorphosed Krol Unit is over-ridden by the Chail Nappe in Alpine times, the stratigraphy of which corresponds to that of the Krol Unit, but generally it is metamorphosed in the lower greenschist facies."

Stratigraphically both tectonic Units have been taken by them to comprise the following sequences.

Stratigraphy of the Chail Unit.	Stratigraphy of the Tansing Unit
7. Lower Gondwana Beds	10. Dagshai (Lower Miocene)
6. Shali Slates	9. Subathu (Up Paleocene-Eocene)
5. Shali	8. Tal Formation
4. Blaini	7. Krol and Shali
3. Nagthat	6. Riri Slates
2. Chail Formation	5. Infra-Krol and Shali Slates
1. Simla Slates	4. Blaini
	3. Nagthat
	2. Chandpur
	1. Simla Slates

Sako, S. and others

Sako et al. (in Ohta & Akiba, 1973) worked in detail in the Dhaulagiri region of Nepal Himalaya mainly on stratigraphy and tectonics. Also, they tried to correlate the rocks of Dhaulagiri region with those of the adjacent areas. The main findings of these authors are as under :

1. The Midland metasediment zone has been subdivided into seven geological units, and in their words (P. 192) "The midland meta-sediments compose of a remarkably thick sequence, barren in fossils,

except for the stromatolite bearing limestone layers. The nummulites have been reported from a few localities in this region (Fuchs & Frank, 1970), however, they are from the younger sediments burying the depression zones cut into the Midland metasediment terrain by later disturbances."

2.. The geologic structure of the region is essentially the same as those of the Pokhara-Gurkha region in the east (Fig. II.5B). The Dhorpatan zone is an important tectonic zone separating the Midland of Central Nepal into two; The Buri Gandaki-Kali Gandaki area in the east and the Kali Gandaki-Bheri Khola in the west. The folded structures remarkably differ between the Tibetan Tethys zone and the Midland zone. The folded structures in the main part of the Midland are very gentle with the WNW-ESE striking axes. The Arkha synclinorium, once considered as nappes by Hagen (1969) and Fuchs & Frank (1970), is not a nappe structure but an autochthonous synclinorium having a deep root. The Dhorpatan and Baglung zones are peculiar because of their position oblique to the general structural trend of Midland.

3. Regarding metamorphism, the change in metamorphic grade of the Midland meta-sediments corresponds to

a progressive series from the south to the north, although this transition is disturbed by some longitudinal faults. The trend of the isograde of some index minerals is more or less concordant to the general frame work of fold structures in the Midland.

Sharma, C. K.

Sharma (1975) has also given some details of the geology of the study area. He proposed the following tentative stratigraphy of the Lesser Himalaya of Western Nepal (excluding younger rocks) :

Age	Formation	Equivalents	Lithological characteristics
Cambrian to Pre-cambrian	Mahabharat limestone group	Arenaceous formation (Sungur Khal series)	Quartzites, sandstone, sandy calcareous phyllite
		Calcareous formation (Deoban limestone)	Cherty delomite, stromatolitic limestone and dolomite, purple to green slate & quartzite
		Argillaceous formation (Ranimatta series)	Green phyllite,lead grey phyllite,epidiorite and quartzite

According to Sharma (1975) the Argillaceous formation consists of chlorite phyllite and phyllitic quartzite, the Ranimmata hill of Surkhet-Dailekh being the type locality. Here, these have been thrust over the Calcareous and Eocene formations. This Argillaceous formation in turn, has been thrust over by the Arenaceous formation in Sungurkhal region. The Calcareous formation (which is well developed in the study area) has been divided into three members :

1. Ripple mark bearing dolomite
2. (a) Purple shale and white quartzite (repeated)
   (b) Fine grained, massive, pinkish white or buff coloured quartzite interbedded with thin layers of green to black marly slate and dolomite.
3. Green to black, chocolate coloured shale highly fractured slate with bands of white quartzites.

Stocklin, J. and Bhattarai, K. D.

Most recently, Stocklin & Bhattarai (1977) working under the HMG/UNDP Mineral Exploration Project in Nepal have given the geology of Lesser Himalaya of Central Nepal in a fair detail. Though their main work is based on photogeological interpretations, the new tectono-stratigraphic subdivisions and nomenclature proposed by them is an important contribution relevant to the study area. They have classified the Midland

rocks that lie beneath the Kathmandu Nappe of Central Nepal into following two main groups :

Name of the Unit	Main lithology	Approximate thickness in m	Age
- - - - - - - - - - - Mahabharat Thrust - - - - - - - - - - -			
UPPER NAWAKOT GROUP			
Robang Phyllites with Dunga Quartzites	Phyll.,Quartz.	200-1000	? Palaeozoic
Malekhu Limestone	Limest.,Dolom.	800 ?	? Palaeozoic
Benighat Slate with Jhiku calc. beds.	Slate,argill; dolom.	500 ? -3000	? Palaeozoic
- - - - - - - - - - - ? Unconformity - - - - - - - - - - -			
LOWER NAWAKOT GROUP			
Dhading Dolomite	Stromatolitic dolom.	500-1000	Late Precambrian
Nourpul Formation	Phyll.,quartz., dolom.	800	" "
Dandagaon Phyllites	Phyllite	1000	" "
Fagfog Quartzite	White Quartzite	400	" "
Kuncha Formation with:	Phyllite,Quartz. grit stones,	3000 +	" "
Labdi phyllite	conglom.		
Banepani Quartzite			
- - - - - - - - - Main Boundary Thrust - - - - - - - - -			

The rocks of the study area are comparable to those of Lower Nawakot Group of these authors.