

## **Stratigraphy of the western Nepal Lesser Himalaya: A synthesis**

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### **ABSTRACT**

The western Nepal Lesser Himalaya, lying between the Marsyangdi and Bheri Rivers, is generally free from crystalline nappes and exposes the sedimentary and metasedimentary rock sequences in a wide zone between the MBT and the MCT. Geologically, the area is complicated by the presence of a number of folds, thrusts and imbricate zones. Despite the complicated geology, excellent studies have been carried out in recent years on the stratigraphy of this region. However, individual work has been confined in areas separated by wide intervening parts that are not as well studied. Many researchers have proposed different stratigraphic nomenclatures in their respective study areas, and their stratigraphic subdivisions do not always correspond well with each other. Therefore, confusion and uncertainties have remained in the stratigraphic interpretation of the western Nepal Lesser Himalaya. An attempt has been made here to appraise and synthesize the work done so far to bring out a clearer picture of the problems and prospects in the stratigraphic investigations in western Nepal.

For convenience, the stratigraphy of the Lesser Himalayan metasediments, the younger group of fossiliferous sedimentary rocks and the Jajarkot Nappe are treated separately. An attempt has been made to extend the stratigraphic nomenclature of the Nawakot Complex of central Nepal established by Stocklin and Bhattarai (1977) and Stocklin (1980) to western Nepal. In spite of the type sections of these rocks in central Nepal and the rocks of western Nepal being separated by a large intervening area, there is a fair consistency in the stratigraphic sequence and rock assemblages in the two areas. The uniformity in the use of nomenclature of rock units will greatly help to build up a more systematic and reliable stratigraphy of Nepal Lesser Himalaya in the future.

The low grade metamorphic and the sedimentary rocks of the Lesser Himalaya are divided into the older Nawakot Unit and the younger Tansen Unit. Only the Tansen Unit is fossiliferous. Whereas the Nawakot Unit is largely of Precambrian age, the Tansen Unit ranges in age from Permo-Carboniferous to Lower Tertiary. The Jajarkot Nappe, tectonically overlying the Lesser Himalayan metasediments, consists of medium grade metamorphic rocks such as garnet bearing schists, feldspathic schists and quartzites. These rocks are succeeded conformably by unmetamorphosed carbonate rocks of possibly Cambro-Ordovician age and stratigraphically and tectonically comparable to the Phulchauki Group of the Kathmandu Nappe of central Nepal.

### **INTRODUCTION**

The geology of the western Nepal Lesser Himalaya between the Marsyangdi River in the east and the Bheri River in the west (Fig. 1) was studied mainly by Bordet et al. (1964a,b), Boudenhausen et al. (1964), Nadgir and Nanda (1966), Fuchs (1967), Hagen (1969), Fuchs and Frank (1970), Talalov

(1972), Nanda (1973), Hashimoto et al. (1973), Sharma (1977), Upreti and Merh (1978), Upreti et al. (1980, 1984), Sakai (1983, 1985), Hayashi et al. (1984), Sharma et al. (1984), Arita et al. (1984), Bashyal (1986), Dhital and Kizaki (1987a,b), Hirayama et al. (1988) and Kansakar (1991, 1992). Work by the Department of Mines and Geology (DMG), Nepal, is summarised in a series of maps

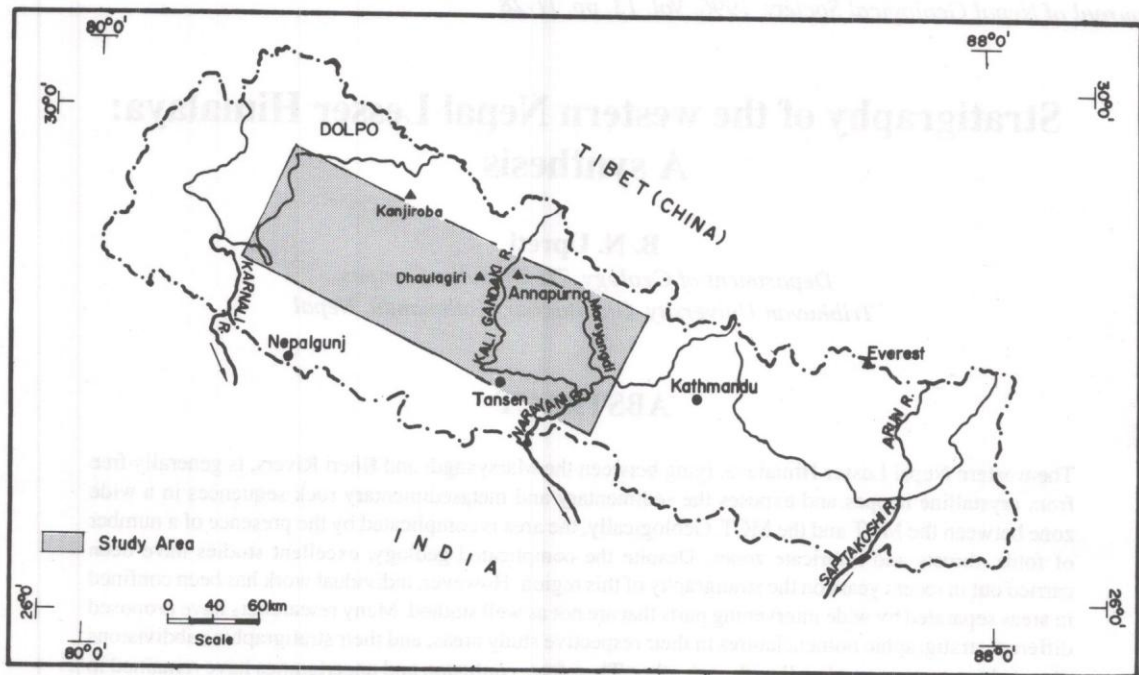


Fig. 1: Location map.

published by the department (Shrestha et al. 1986, 1987; Amatya and Jnawali, 1994; ESCAP/DMG, 1993; Jnawali and Tuladhar, 1996a,b).

The stratigraphy discussed in this paper is primarily based on the work of Fuchs and Frank (1970), Stocklin and Bhattarai (1977), Sakai (1983, 1985), Sharma et al. (1984), Dhital and Kizaki (1987b) and Kayastha (1992). In spite of the rarity of fossils in general, the rocks of the Tansen, Daban, Sallyan and Surkhet areas have yielded a great variety of fossils ranging in age from Paleozoic to Tertiary. In fact, these are amongst the few important fossil localities in the entire Lesser Himalayan belt.

Based on the previous works, a generalised geological map has been compiled showing the broad stratigraphic and tectonic units of the area under discussion (Fig. 2). In the western part of the area, there is a narrow elongate body of a crystalline nappe with a Cambro-Ordovician carbonate rock cover named the Jajarkot Nappe by Hagen (1969). No other crystalline nappes have been recognised in the Lesser Himalaya between the Bheri and Marsyangdi Rivers. In the Dang and Palpa areas, however, the older Lesser Himalayan sequences have also been found to thrust to the south over the younger sedimentary

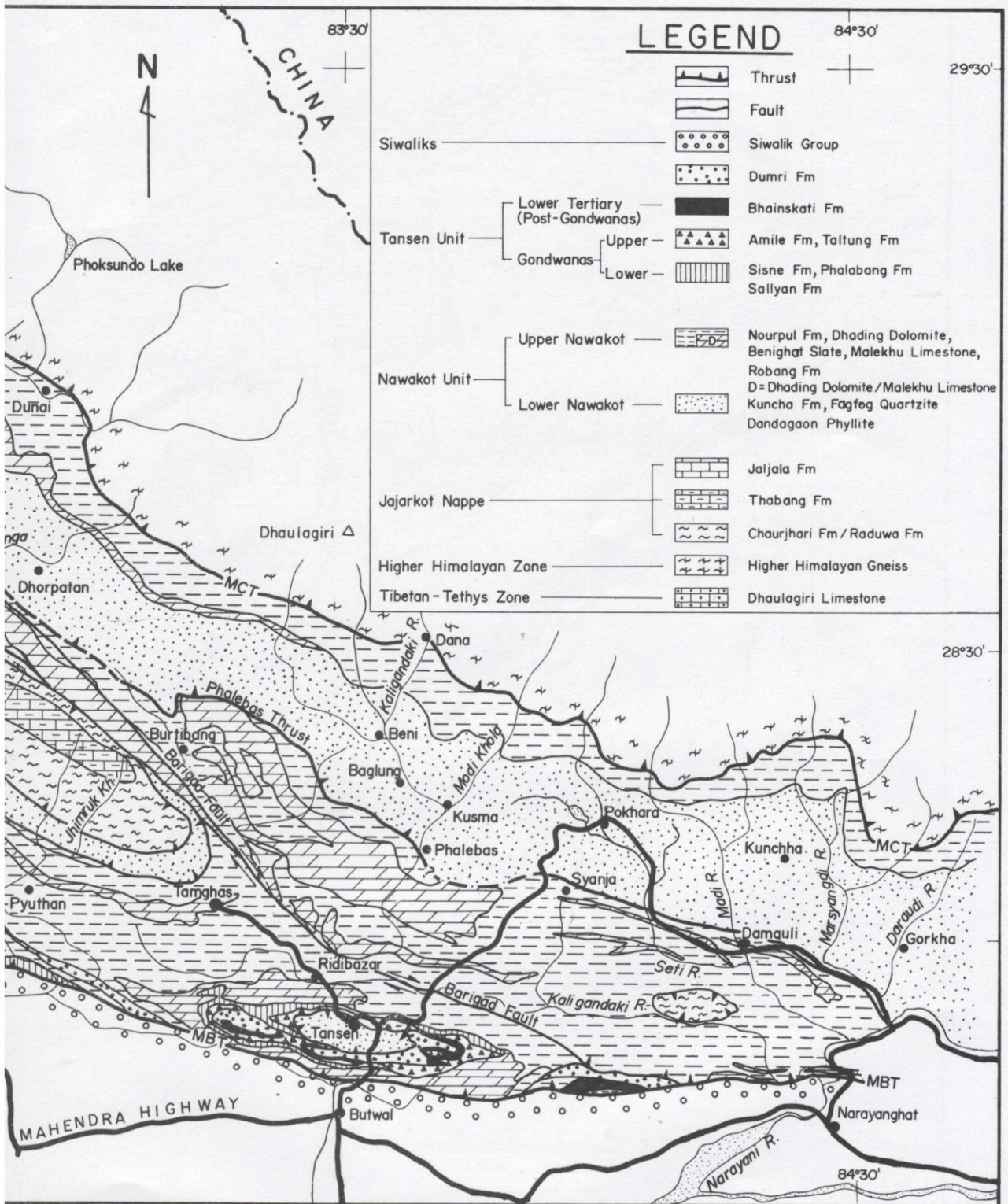
units, and now preserved in the form of small klippen (Sakai, 1983; Sharma, 1984; Dhital and Kizaki, 1987ab). West of the Bheri River the Jajarkot Nappe is thrust over by another higher crystalline thrust sheet, the Karnali Nappe. The Karnali Nappe covers a wide area in the Karnali River region. The rocks of the Karnali Nappe are kyanite-sillimanite bearing high grade gneisses and schists similar to the rocks found above the MCT (Tibetan Slab). Carbonate rocks comparable to the Tibetan-Tethys Zone (Dhaulagiri Limestone of Fuchs and Frank, 1970) conformably overlies the kyanite-garnet-mica gneiss of the Karnali Nappe (Hayashi et al., 1984). Except the narrow arm of the Jajarkot Nappe, the entire area between the Bheri and Marsyangdi Rivers, is underlain by the Nawakot Unit and the unconformably overlying younger rocks of the Tansen Unit. It is the Tansen Unit that contains a fairly widespread occurrence of determinable fossils of faunas and floras. All along the northern vicinity of the MBT, the rocks show imbricate structures, recumbent folds, schuppen structure tectonics (Sakai, 1985, 1986) and duplex structures (Dhital, 1987a) indicating intense compression along the frontal part of the Lesser Himalayan Zone.







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i, 1983,1985; Sharma et al.,  
 3; Kansakar, 1991; ESCAP/



## STRATIGRAPHY

The stratigraphy of the central Nepal Lesser Himalaya is fairly well established, and has been mapped continually for about 250 km along the strike from the Dudh Kosi River in the east to the Marsyangdi River in the west (Stocklin and Bhattarai, 1977; Stocklin, 1980; UN/UNDP, 1981). Therefore, as far as possible, it is desirable to extend the use of the stratigraphic nomenclature of this area to farther in the west. The area between the Marsyangdi River and the Tansen area has been investigated in detail only recently (Jnawali and Tuladhar, 1996a, b). This lack of data of the intervening area in the past has created some uncertainties in the correlation of the formations. However, it is still worth attempting to synthesise the work done so far in different parts of the area to enable a coherent picture of the stratigraphy of western Nepal to emerge.

The stratigraphy of the western Nepal Lesser Himalaya may be described separately under the headings: (1) Nawakot Unit, (2) Tansen Unit, and (3) Jajarkot Nappe. Except the crystalline rocks of the Jajarkot Nappe, the entire terrain of western Nepal between the MBT and the MCT is covered by the rocks of the Nawakot Unit and the Tansen Unit. The stratigraphy of the area is summarised in Table 1. The section south and southwest of Pokhara around Tansen has been investigated in detail by Sakai (1983, 1985), whereas most of the western part up to the Bheri River has been investigated by Fuchs and Frank (1970), Sharma et al. (1984) and Dhital and Kizaki (1987a,b). Further west in the Surkhet area, the stratigraphy of the Lower Tertiary rocks has been described by Kayastha (1992).

### STRATIGRAPHY OF THE NAWAKOT UNIT

In central Nepal Stocklin and Bhattarai (1977) and Stocklin (1980) have used the term *Nawakot Complex* to include all the formations of the Lesser Himalayan rocks whereas the *Kathmandu Complex* incorporates all the rock formations lying within the Kathmandu Nappe, including the crystallines below and the overlying fossiliferous sedimentary rocks. Sakai (1983) has used the term *Nawakot Group* instead of *Nawakot Complex* for a similar Lesser

Himalayan rocks in western Nepal. Here in this paper, the term *Nawakot Unit* has been used informally to denote a tectono-sedimentary unit belonging to the older suite of rocks of the Lesser Himalaya lying unconformably below the younger group of rocks such as the Gondawanas or post-Gondawanas.

### Kuncha Formation

This is the oldest formation of the Lesser Himalaya of Nepal, whose base has not been recognised anywhere. It covers an extensive area in the Gorkha-Kuncha-Pokhara area. The N-S aerial distance covered by this formation alone is 20-30 km, and reaches a maximum width of about 40 km in the Burhi Gandaki section. The wide exposure of this formation is due to the existence of the broad E-W trending anticlinorium whose axis extends for nearly 150 km passing through the Gorkha-Kuncha-Pokhara area in the east to the Myagdi Khola in the west. This formation continues westward through Baglung-Dhorpatan and ends near the Thulo Bheri River area (Fig. 2). It is interesting to note that from Kathmandu westward, the Kuncha Formation extends uninterrupted for over 300 km with an average width of 20 km. Surprisingly, no other Lesser Himalayan formation extends continually for such a long distance maintaining such a consistent lithology.

The lower part of this formation consists of a monotonous sequence of flysch-like alternation of phyllites, phyllitic quartzites and phyllitic gritstones. Strikingly, carbonate rocks are altogether missing except as cementing material in some sandstones (Banspani Quartzite Member of Stocklin and Bhattarai, 1977). The phyllites have a silky luster and are yellowish, bluish-grey and greenish-grey in colour. The phyllitic gritstones contain opal-like milky-grey or bluish quartz, giving a diagnostic feature to these rocks (Hashimoto et al., 1973). These quartz grains are considered to be the primary elements of the Indian Peninsular gneiss.

The Kuncha Formation is broadly equivalent to the Lower Arenaceous subgroup exposed in the Nawakot metasediment zone of Hashimoto et al. (1973). A satisfactory subdivision of this formation has not been developed so far, although, Hashimoto et al. (1973) have shown that metasandstones

Table - 1: Stratigraphic correlation of the Lesser Himalaya of western Nepal.

Stratigraphic subdivisions adopted in this work		Tansen Area (Sakai, 1983, 1985)	Pluthan-Sallyan-Jairkot Area (Sharma et al., 1984)	Northern Dang (Pluthan-Sallyan Area) (Dhital and Kizaki, 1987)	Surkhet Area (Kayastha, 1992)	Geologic Age	
Tansen Unit	Lower Tertiary Group	Dumri Formation	Dumri Formation	Dubring Formation	Suntar Formation	Oligocene- Early Miocene	
			Bhainskati Formation	Bhainskati Formation	Sharda Gr (Klippe)		Swat Formation
Gondwanas	Upper Gondwanas	Amile Formation	Amile Formation	Satim Formation	Melpani Formation	Lower-Middle Eocene	
			Taltung Formation with Aulis Volcanics	Goyalham Formation	Phalabang Fm		
Gondwanas	Lower Gondwanas	Sisne Formation	Sisne Formation	Phalabang Fm		Late Cretaceous- Paleocene	
			Unconformity	Kochhap Formation	Sallyan Fm		
Nawakot Unit	Lower Nawakot Unit	Dabang Group	Kerabari Formation	Sallyan Fm		Late Jurassic- Early Cretaceous	
			Ramdighat Formation	Unconformity	Ranibas Formation		
			Saidi Khola Formation		Sirchaur Formation		
			Khoraidi Formation				
			Chappani Formation				
			Virkot Formation				
			Heklang Formation				
			Naudanda Formation				
			Kuncha Formation				
			Kuncha Formation				
Nawakot Unit	Upper Nawakot Unit	Kali Gandaki Supergroup	Surtibang Dolomite			Early paleozoic ?	
			Variegated Formation				
			Harchaur Formation				
			Hatia Formation				
Nawakot Unit	Lower Nawakot Unit	Kuncha Group	Kuncha Formation			Late Precambrian	



predominate in the lower section and phyllites increase their proportion in the upper section. The dominant siliceous and argillaceous phyllites of the Kali Gandaki area gradually give way to quartzites and siliceous phyllites in the western part of the formation. As in the eastern sections, metabasics form an important association within the phyllites and quartzites. The Ulleri augen gneisses and nepheline syenites are also intercalated within this formation.

### **Fagfog Quartzite**

This formation is well exposed around Syangja and extends to the west to Kusma and Phalebas and possibly further west in the Sallyan area. The stratigraphic position of these thick quartzite horizons is sometimes doubtful, as there are a number of white quartzite horizons within the Kuncha Formation too. This formation is characteristically discontinuous and pinches after a few kilometers, as observed in the Naudanda, Kusma and Phalebas areas, making it difficult to trace continually for a long distance.

In the Naudanda area, this formation consists of fine to coarse-grained, white meta-quartz arenite with several intercalations of phyllites, conglomerates and metabasics. The quartzites are strongly rippled and commonly cross bedded. In the Sallyan area, Dhital and Kizaki (1987b) have described a 950 m thick quartzite horizon (their Balle Quartzite of Sharda Group forming a klippe) constituted of thick to very thick bedded, coarse to very coarse-grained and sometimes pebbly quartz arenites and arkosic arenites. The quartzites alternate with dark green to grey phyllites and chlorite schists. It transitionally overlies laminated grey slates and phyllites alternating with light green fine-grained quartzites and thick bedded white quartzites. Sharma et al. (1984) have included the above rocks in the Kuncha Formation (their Kuncha Group).

### **Dandagaon Phyllite**

This greenish to greyish coloured predominantly phyllitic formation with metagraywacke intercalations is difficult to recognize away from its type locality. A lack of diagnostic characteristics and the absence of fossils have led many authors to put

the rocks of the same formation into different stratigraphic horizons. In the Dang area, for example, the formation exposed just north of the MBT has been considered to be the Kochhap Formation (Gondwana) by Sharma et al. (1984), whereas the same formation is considered to be the Ranagaon Formation comparable to the much older Dandagaon Phyllite by Dhital and Kizaki (1987b). Sharma et al. (1984) consider their Harichaur Formation to be equivalent to the Dandagaon Phyllite. In general, all these formations are composed of grey, green and bluish green pelitic to silty laminated slates alternating with thin lithic sandstones.

Sakai (1983, 1985) has correlated his Heklang Formation with the Dandagaon Phyllite. As there is no detailed work in the intervening area between Tansen and the type locality of the Dandagaon Phyllite in the east, there is always an element of uncertainty in such correlations. The Heklang Formation is mainly exposed to the north and northeast of Tansen in a narrow belt along the Barigad Fault. It is mainly composed of dark-green phyllites with brown and grey weathering tints. The phyllites are frequently intercalated with layers of limestones, calcareous sandstone, marls and dolomites.

### **Nourpul Formation**

This Formation is well exposed in the Tansen and Piuthan areas. Sharma et al. (1984) have also mapped this formation in a narrow belt along the northern side of the Jajarkot Nappe and near the MCT. In the Tansen area, this formation (Virkot Formation of Sakai, 1985) is composed of white to pink quartzites and reddish-purple phyllitic slates. Interlayering of these white and reddish-purple rocks gives a characteristic colour banding. Sakai (1985) has divided this formation into two members. The lower member is represented by the monotonous reddish-purple coloured slaty phyllites with fine calcareous laminae. The upper member (Virkot Quartzite Member) is predominantly composed of white to pinkish quartzites. The quartzites of this member are believed to have been formed as sand dunes.

West of Kali Gandaki, the Variegated Formation of Sharma et al. (1984) is comparable to the Nourpul



Formation of the type locality. Here the formation is represented by variegated slates, sandstones and limestones intercalated with each other and showing a typical banded nature. The slates are purple, pink, maroon, green, dark-grey and brick-red in colour. Sharma et al. (1984) have divided this formation into three members. The lower member is characterised by arenaceous rocks, the middle member is dominantly argillaceous, whereas the upper member is more calcareous in nature, containing variegated slates interbedded with limestones.

To the north of Dang Valley, Dhital and Kizaki (1987b) have described the Khamari Formation, which is comparable to the Nourpul Formation. The formation is composed of interbedded pale orange, yellow and pink orthoquartzites, calcareous sandstones, and red, purple and green slates with some argillaceous limestone. The lower part of this formation is mainly arenaceous with load casts, wavy and lenticular beddings whereas the upper part is an impure dolomite sequence containing stromatolites.

### **Dhading Dolomite**

These ridge forming dolomites are widely exposed in western Nepal and have been traced almost continuously from the Marsyangdi to Bheri River sections. However, there is no general agreement among authors about the stratigraphic position of these dolomites. Two different horizons of dolomites have been generally identified in central Nepal (Stocklin and Bhattarai, 1977) and the Tansen area (Sakai, 1983, 1985): the older Dhading Dolomite (Chappani-Khoraidi and parts of the Saidi Khola formations of Sakai) and the younger Malekhu Limestone (Kerabari Formation of Sakai). The Benighat Slate with variable thickness, is the intervening formation between the two. Sharma et al. (1984) correlate their Surtibang Dolomite with the Dhading Dolomite of Stocklin and Bhattarai (1977) and the same is also correlated with the Kerabari Dolomite of Sakai (1985). On the other hand, they also correlate their Hatiya Formation (their oldest formation of the Nawakot Group) with the Benighat Slate and partly with the Malekhu Limestone. They also identify a still younger Goyaltham Formation of Permo-Triassic age and correlate it with the Krol of Kumaon. The dolomites of small thickness belonging to the upper part of the

Benighat Slate (Jhiku Carbonate Bed of Stocklin and Bhattarai, 1977) is also sometimes mixed together. West of the Kali Gandaki River, as in central Nepal and Tansen area, there are probably only two carbonate horizons, representing the older Dhading Dolomite and the younger Malekhu Limestone (Kerabari Formation). Sharma et al. (1984) have put the same dolomite unit into different stratigraphic levels. North of Dang Valley, the Dhorbang Khola Formation and perhaps the upper part of the Hapurkot Formation of Dhital and Kizaki (1987b) belong to the Dhading Dolomite. The Krol of Fuchs and Frank (1970) includes both the Dhading Dolomite and the Malekhu Limestone (Kerabari Formation of Sakai, 1983). In the area south of Phalebas along the Kali Gandaki Valley, Upreti and Merh (1978) and Upreti et al. (1980) have described the stromatolitic dolomite belonging to this formation.

In the Tansen area and to the north along the Kali Gandaki River, the Dhading Dolomite is well developed. In the Tansen area, this formation is described by Sakai (1983, 1985) as the Chappani and Khoraidi formations. Here, the lower part of the Dhading Dolomite (Chappani Formation) is composed of grey slates, stromatolitic limestones, thinly laminated light-purple and green clay slates and quartzites. The upper part (the Khoraidi Formation), is made up of more than 80% stromatolitic dolomite, and the remaining part comprises oolitic dolomites, quartzose sandstones, sandstone and intraformational pebble conglomerates. Pseudomorphs of gypsum crystals are found at many levels. The upper most member of the Dhading Dolomite described as the Husdi Bed in the type locality in central Nepal is represented here by the Saidi Khola Formation of Sakai (1985). This rock unit consists chiefly of coarsely interlayered sandstones and shales with some bioturbated rhythmities.

In the west along the Barigad, Rukumkot and Thulo Bheri sections north of the Jajarkot Nappe, this formation is widely developed. Here the formation is described as Surtibang Dolomite by Sharma et al. (1984). The formation is composed of thick bedded, massive bluish grey to dark grey fine crystalline to dense limestones and dolomites. Oolitic beds and intra-clastic dolomites are also reported.



Widespread stromatolitic structures are found in these dolomites. Sharma et al. (1984) have considered the carbonate rocks of the Daban area south of the klippe as the Krol Formation of Permo-Triassic age, younger than the Surtibang Formation (Dhading Dolomite). In the light of the recent work in Kumaon Himalaya, the Krol Formation is upper Precambrian in age and therefore, these rocks of western Nepal described by Sharma et al. (1984) essentially belong to the Dhading dolomite and the Malekhu Limestone. Dhital and Kizaki (1987b) consider them to be partly the Dhading Dolomite (their stromatolitic Dhorbang Khola Formation) and partly the Malekhu Limestone (their Ranibas Formation). Here the rocks are light grey, greenish grey, medium to thick bedded and thin bedded dolomites together with green slates.

Though stromatolites are widely developed in the dolomites and limestones of the Lesser Himalaya of Nepal, only a few systematic studies of these organosedimentary structures have been carried out. In the Kali Gandaki Valley, Upreti et al. (1980) have identified two broad groups of these structures: *collenia* and *conophyton*, and compared them with the well-known forms of other parts of the Himalaya and Peninsular India. Some of the identified forms are *collenia columnaris*, *collenia symmetrica*, *conophyton cylindricus* Maslov, *collenia compacta*. They have assigned a late Precambrian age to these structures. The structures indicate a supratidal, intertidal and subtidal depositional environment of these dolomites.

### Benighat Slate

This formation has also been recognised from the Marsyangdi to the Bheri Rivers. However, mapping this formation is difficult as its colour and lithofacies vary laterally. In the Tansen area, Sakai (1985) has described the Ramdighat Formation and the lower part of the Kerabari Formation (Riri Limestone Member) as being equivalent to the Benighat Slate. This formation consists of calcareous argillites and a minor amount of limestones. Coarse clastic rocks are rare. The lower member of this formation consists of mainly black slate passing upward into green slates. The middle member is characterised by marked colour banding of reddish-purple, pink and green calcareous slate and white

limestones. The upper member is composed largely of calcareous and argillaceous grey slates. The Riri Limestone Member of the Kerabari Formation, consisting of black, platy-bedded, argillaceous limestones and slates, has been included in the upper part of the Benighat Slate.

West of Kali Gandaki, Sharma et al. (1984) have included this formation in the lower part of their Hatiya Formation and the upper part is compared with the Malekhu Limestone. The rocks of the lower part of the Hatiya Formation consist of dark grey to greenish grey argillaceous and silty slates, and graded bedding, current bedding, load casts and flute casts are occasionally present. However, as mentioned earlier, Sharma et al. (1984) consider the Hatiya Formation as the oldest formation of their Nawakot Group. Therefore, the stratigraphic position of the Hatiya Formation and its correlation seems to be doubtful.

North of Dang, Dhital and Kizaki (1987b) compare their Sirchaur Formation with the Benighat Slate because of its stratigraphic position with respect to the stromatolite bearing dolomites of the Dhading type (Dhorbang Khola Formation). The rocks are dark green calcareous argillites passing upward into laminated purple-red and dark green calcareous claystones alternating with white-pink and light-green limestones. Perhaps the upper part of the Dhorbang Khola Formation, represented by black slates, may also be a part of the Benighat Slate.

### Malekhu Limestone

The Malekhu Limestone represents the youngest formation of the Nawakot Unit in western Nepal and is widely exposed in the southern part of the Lesser Himalaya near the MBT. Sakai (1985) correlates his Kerabari Dolomite (upper part of the Kerabari Formation) with Malekhu Limestone. This formation begins with thin bedded grey dolomites and thinly laminated shales with some algal structures. It passes upward to thick bedded dolomites with ripple marks and parallel laminae, and the upper part is characterised by many intraformational pebble conglomerates and platy and wedge-bedded dolomite. Chert beds and nodules are quite common in the middle and upper part of the formation in contrast to the Dhading Dolomite. Also, stromatolites



are poorly developed, and are represented by small dome-shaped to sheet form type. Here, this formation is overlain by the conglomerate of the Sisne Formation (Lower Gondwanas) with a distinct disconformity. In the west, Sharma et al. (1984) consider the upper part of their Hatiya Formation to be equivalent to the Malekhu Limestone. The Hatiya Formation consists of thick bedded light bluish grey to dark grey limestones, dolomites and sandstones. The limestones are sometimes stromatolitic, containing long columnar stromatolites. The Goyaltham Formation of Sharma et al. (1984) also possibly belongs to the Malekhu Limestone.

The Ranibas Formation of Dhital and Kizaki (1987b) has been compared to the Malekhu Limestone. The Ranibas Formation is mainly composed of light grey to dark grey limestones and a minor amount of black slates. The lower part is characterised by dark-grey calcareous argillites interbedded with lenticular grey limestones. In the upper member, the rocks are laminated grey dolomitic limestones, slightly siliceous in the upper part. Small, laterally linked columnar stromatolites are noted in the upper member.

## STRATIGRAPHY OF THE TANSEN UNIT

Here, the term *Tansen Unit* has been used informally to denote a group of rocks occurring in a specific tectono-stratigraphic setting. Sakai (1983), however, uses the term Tansen Group, when formally describing the stratigraphy.

The geology of Tansen Unit is important from the view point that at a number of places fossiliferous sequences ranging in age from Permo-Carboniferous to Lower Miocene (Gondwana and Post-Gondwana) rocks have been mapped. These younger group of rocks of this unit unconformably overlies the older Precambrian to Lower Paleozoic (?) metasediments. Apart from this, the core of the syncline of the Jajarkot Nappe at Jaljala Dhuri and at Baregaon of the Karnali Nappe (Jumla area), the Cambro-Ordovician limestones (Dhaulagiri Limestone of Fuchs and Frank, 1970) lying over the crystallines represent the Tethyan element in the Lesser Himalaya of western Nepal. The Kathmandu, Jaljala Dhuri and Baregaon areas are the only localities in Nepal where

the Tethyan rocks are thrust to the south along with the crystallines, and preserved at the cores of these Lesser Himalayan crystalline nappes. Unlike western Nepal, in eastern Nepal (east of Kathmandu) crystalline rocks cover a larger area, and fossiliferous rocks are restricted to a very narrow zone near the MBT. Here, along the southern slopes of the Mahabharat Range, a narrow strip of mainly Gondwana rocks in the form of tectonic slices bounded by the MBT in the south and a thrust in the north have been mapped more or less continually up to the eastern border of Nepal (Bashyal, 1984; Shrestha and Shrestha, 1984). However, no Gondwana or post-Gondwana rocks are reported further towards north including the tectonic windows.

The rocks of the Tansen Unit with a total thickness of over 2 km, rest over the Nawakot Unit with a marked unconformity. This fossiliferous group of rocks is developed in the Tansen, Piuthan, Tosh, Sallyan, Jajarkot, Rukum and Bari Kot areas (Fuchs, 1967; Fuchs and Frank, 1970; Sakai, 1983; Sharma et al. 1984; Dhital and Kizaki, 1987b). The Tansen Unit includes the Gondwanas and the Lower Tertiary (Paleogene-early Neogene) sequences (Table 1). From the Surkhet area, Kayastha (1992) has described the Lower Tertiary rocks, where the Gondwanas are largely missing.

### The Gondwanas

The Gondwana sequence, unconformably overlying the older metasedimentary formations, is largely a non-marine sequence though some formations of marine origin have been identified. Gondwana rocks in western Nepal may be divided into the Lower and Upper Gondwanas depending upon their fossil assemblages and other characters.

#### *Lower Gondwanas*

The Lower Gondwanas are well developed in western Nepal in Tansen, Phalabang and Sallyan areas. In the Tansen area, this formation has been described as the Sisne Formation by Sakai (1983, 1985). The Sisne Formation of Sakai (1983) represents the oldest rocks of the Tansen Group and is well exposed in the Tansen synclinorium. This formation rests disconformably over the Kerabari



Formation of the Kali Gandaki Supergroup (Sakai, 1985) with a basal conglomerate derived from the underlying Kerabari Formation. However, in the western area, west of Tansen, Fuchs and Frank (1970) have found angular unconformity between their Lower Tal (Gondwanas) and the older formations. The Sisne Formation is mainly composed of diamictite and claystones or mudstones (converted into slates) with some beds of sandstones and conglomerates. Diamictites show wide variations in the proportion of clasts and matrix. They are unstratified and consist of scattered clasts of various sizes and shapes embedded in the structureless clayey to silty matrix. The clasts vary in size from pebble-cobble to sand, but sometimes exceed 2 m in diameter. Claystones form a major constituent of the Sisne Formation. They are dark grey to black and of massive nature. Thin lenticular beds of diamictites are also intercalated within them. Strong bioturbation is noted in these rocks due to burrowing organisms. Several reworked mudfloats containing *Fenestella* are found within the upper part of the mudstones of the formation.

The abundant large clasts of pinkish and reddish brown porphyritic granites and gneisses contained in the diamictites indicate their source to the Malani granites of Rajasthan of western Peninsular India (Sakai, 1983). Similarly, the clasts of limestone, dolomite and quartz arenite may point the source to lie in the Vindhyan System of the northern Peninsular India. The Sisne diamictite is believed to be of glacial origin. However, the associated sandstones, shale and finer diamictites might have originated in a glacio-fluvial environment.

The upper part of the Sisne Formation contain abundant *fenestellan* bryozoa. The bryozoa belongs to the genera *Fenestella*, *Polypora* and *Acanthocladia* with *Pamirella nepalensis*, n. sp., *Fenestella* sp. indet. and *Polypora* sp. indet. species (Sakai, 1983, Sakagami and Sakai, 1991). They suggest a middle Early Permian age to the Sisne Formation. The Sisne Formation has been correlated with the Talchir Boulder Bed of Peninsular India, the Agglomeratic Slate of Punjab and the Blaini Boulder Bed of Kumaon.

To the west in the Sallyan area, near the Phalabang village, Fuchs and Frank (1970) have described slightly metamorphosed argillo-

arenaceous rocks overlying their Chail Formation. The black slates yielded reticulate and pitted tracheids (araucaroidal type) and relatively well-preserved spores of the genus *Vittatina*. These fossils are believed to be the remains of land living plants belonging to the Permo-Carboniferous Gondwana flora.

Sharma et al. (1984) also did stratigraphic studies in the Sallyan Phalabang area and have divided these rock sequences into two formations, the lower Sallyan Formation and the overlying Phalabang Formation both belonging to their Gondwana Group. The Sallyan Formation, resting over the Kuncha Formation, is a conglomeratic phyllite consisting of pebbles and cobbles of pink dolomite and bluish grey dolomite and some quartzite and shale dispersed in the argillaceous matrix. This formation resembles the Sisne Formation of the Tansen area. Sharma et al. (1984) also correlated these rocks with the Talchir Boulder Beds of Peninsular India. The Phalabang Formation rests conformably over the conglomeratic Sallyan Formation. It is dominantly a black shale formation with a basal argillaceous sandstone bed.

Around Daban Village, Sharma et al. (1984) have separated the Daban Group, a predominantly marine sequence of Gondwana age, from the terrestrial Gondwana deposits (Sallyan and Phalabang formations). However, such a distinction has confused the stratigraphy of the area. The rocks show lateral changes from marine to terrestrial environments as shown by Dhital and Kizaki (1987b) for their Sattim Formation. Also, a depositional environment from marine to non-marine occurs in the same formation as it passes into upward or downward sequences. The Kochhap Formation (Daban Group) of Sharma et al. (1984), consisting of yellowish, brown, grey-green shales inter-bedded with white grey sandstones and limestones with diamictite layers, is comparable to the diamictites of the Tansen area belonging to Permo-Carboniferous age. The Goyaltham Formation of Sharma et al. (1984), shown overlying the Kochhap Formation, seems more likely to belong to the Malekhu Limestone (Kerabari Formation of Sakai, 1985) and does not belong to the Gondwanas or the Permo-Carboniferous carbonates (their Krols). This implies that the Goyaltham Formation is older than the Kochhap Formation.



Dhital and Kizaki (1987b) have mapped the Gondwana rocks to the north of Dang Valley. They have recognised Gondwanas within and outside the Klippe. The well-known Gondwana localities of the Phalabang and Sallyan areas are found within the Klippe of their Sharda Group. The Gondwanas of the Gwar Khola and Tosh are included into their Tosh Group. In the same manner, Sharma et al. (1984) also divide the Gondwanas (the upper part of the Sharda Group within the Klippe) into the Sallyan and Phalabang formations. According to them, the Sallyan formation (500 m thick) mainly consists of poorly sorted conglomeratic phyllite with clasts of dolomites, quartzites and granites. Apart from the conglomerates, the formation also includes some beds of very coarse grained quartzite, grey-green phyllites, and in the lower part, black phyllitic diamictite with well-developed foliation. The overlying Phalabang Formation (450 m thick), occupying the core of the large E-W trending syncline, comprises predominantly black carbonaceous slates with a basal sandstone sequence (Lower Gondwana of Fuchs and Frank, 1970).

Outside the klippe, the Gondwana type rocks have been described as the Sattim Formation (Dhital and Kizaki, 1987). This formation is almost continually exposed for more than 30 km of the mapped area. This brown weathered rock sequence is a thick bedded white, pale orange, brown and black quartzose sandstone and graywackes often alternating with dark green and brown black shales. Thin coal seams are also intercalated at various levels. This formation has a distinct disconformable contact with the underlying older formations. The disconformity is marked by basal conglomerate. The rocks show fining upward sequence in sandstones with channel-fill and channel-lag deposits and lenses of coal seams indicating the fluvial origin of the Sattim Formation. In the Tosh section also, interbeds of coal seams are present but here, it is a dominantly marine sequence. The uppermost part of the Sattim Formation is represented by mottled argillaceous limestones grading upward to calcareous argillites with some *Nummulite* and *Assilina* fossils. The interbedded shales include bivalve and gastropod fossils. The topmost part again contains scattered foraminifera. The Sattim Formation thus might represent the Lower (?) to Upper Gondwana.

### *Upper Gondwanas*

In western Nepal, the Upper Gondwanas appear to cover a larger area than the Lower Gondwanas. This sequence has been well studied in the Tansen area by Sakai (1983). Sharma et al. (1984) have also described these rocks from the western area. In the Tansen area Sakai has divided this sequence into two formations: the Taltung Formation and the overlying the Amile Formation.

### *Taltung Formation*

This formation rests disconformably on the eroded surface of the Sisne Formation (Table 1). Some basaltic lava flows are intercalated near the base of the formation. According to Sakai (1983), the formation begins with a conglomerate bed about 20 m thick (the Charchare Conglomerate) and forms a conspicuous horizon. It is mainly composed of conglomerates with subordinate sandstone beds. The conglomerate consists of densely packed, well sorted pebbles and cobbles. Wood fragments are common in the sandstones. The conglomerates are mainly made up of quartzites and volcanic rocks. Sometimes, the volcanic rocks constitute over 85% of the total volume.

The typical sequence of the Taltung Formation begins over the conglomerates or the Aulis Volcanics. The lower part is characterised by a fining upward sequence, each beginning with conglomerate, followed by sandstone, and ending with silty shale, indicating the fluvial nature of the sequence. Plant fossils are abundantly reported. The upper part of the formation is represented by upward-fining rhythmic sequences, represented by alternating beds of sandstone and shales.

The basic volcanic unit (Aulis Volcanics) makes a distinct member of the Taltung Formation. At one place, it lies directly over the Charchare Conglomerate and two other layers occur at higher levels. As the overlying conglomerates contain a lot of volcanic rock, it is quite probable that these volcanic rocks were extruded simultaneously or prior to the deposition of the conglomerate. The thickness of the volcanic bodies vary from 30 to 200 m, and extend for nearly 13 km in the Aulis area of Tansen. These rocks are dark-green to dark-grey and massive.



Pillow-lava structures along the margins have been reported and amygdaloidal and vesicular structures are commonly noticed. Sakai (1983) correlates the Aulis Volcanics with the Rajmahal Traps of northeastern Peninsular India.

The plant fossils found in this formation are mainly Bennettitales and Ficales. Four genera belong to *Ptilophyllum* sp., *Pterophyllum* sp. The assemblage comprising *Cladophrebia indica* (OLDHAM & MORRIS) SAHNI & RAO, ? *Sphenopteris* sp., *Pachypteris* sp., *Pterophyllum* sp. A, *Pterophyllum* sp. B., ? *Taeniopteris* sp./ *Pterophyllum* sp., *Ptilophyllum* cf. p. *cutchense* MORRIS, *Weltrichina* sp. and *Elatocladus tenerrimus* (FEISTMANTEL) SAHNI have been identified (Sakai, 1983, Kimura et al. 1985). They are well comparable to the Upper Gondwana plant fossils of the Upper Jurassic-Lower Cretaceous found in Rajmahal and Jabalpur series in Indian Himalaya.

It is important to note that at about 5 km NW of Daban along the Swargdwari-Sallyan trail, Fuchs and Frank (1970) have reported an outcrop of an acid extrusive rock within the shales of their Tal Formation. The rock is light grey, fine-grained and fractured. Quartz grains are identifiable by unaided eyes. Phenocrysts of fractured quartz are embedded in a vitreous matrix intensively stained with iron hydroxide. The stratigraphic position of this volcanic rock is doubtful but might represent the Upper Gondwana volcanics.

North of Dang, the Sattim Formation (Dhital and Kizaki, 1987) represents the undifferentiated Gondwanas, part of which may also include the Upper Gondwanas. Further west in the Sallyan area also the Lower and Upper Gondwanas have not been differentiated.

#### *Amile Formation*

Sakai (1983) has described this formation in the Tansen area. It unconformably overlies the Taltung Formation. The formation is mainly composed of sandstone with a subordinate alternating sequence of sandstones, shales and limestones. Except the middle part, this is a non-marine sequence. The formation begins with a 10 m thick conglomeratic

quartz arenites resting over the irregular eroded surface of the Taltung Formation. It is followed by thick bedded white sandstone mottled by ferruginous material. The middle member is characterised by the presence of fossiliferous siltstones and limestones. The argillaceous limestone contain marine bivalves, gastropods, echinoids, corals and larger foraminifera. The beds are strongly bioturbated. The middle member is also conspicuous in having rhodocrosite bearing beds. The upper member consists of quartzose sandstones with alternations of carbonaceous sandstones and shales containing coalified wood fragments. Sakai (1983) has placed this formation in the Upper Gondwanas. On the basis of scleractinian coral, shark teeth, vertebrate bone fragments, gastropods, pelecypods and echinoids, this formation has been assigned to the late-Cretaceous to Paleocene (?) age.

Sharma et al. (1984) have mapped the Amile Formation both in the south as well as north of the Jajarkot Nappe. However, stratigraphically they place the Amile Formation over the Gondwanas. As the Amile Formation of the Tansen area contains coalified wood fragments and a lot of ferruginous and carbonaceous beds, it shows strong affinity to the Gondwana rocks. The Gondwanas, with interstratified marine beds, are widely developed in peninsular India also (Umia Series of Kutch, Godavari district of Madras etc.). Probably towards the end of Upper Gondwana, the largely terrestrial environment slowly gave way to the marine environment. Subsequently, during the Eocene time, the marine environment was more widespread.

In northern Dang and the Rolpa area, Sharma et al. (1984) have found only the lower part of the Amile Formation. Here, the formation overlies the carbonates with a well defined angular unconformity. Occasionally, calcareous horizons are encountered, in which pelecypod and gastropod fossils have been reported. The Tal Formation; (Fuchs and Frank, 1970) which has been shown to occur as far as the Jajarkot and Barikot areas along the Bheri River, might partly represent the Upper Gondwanas. In the Tansen area north of Masem, Fuchs and Frank (1970) have reported gastropods (*Promathildia*) and pelecypods (*Modiola*, *Pleuromya*, *Homomya*) in these rocks and assigned them the Jurassic-Cretaceous age. Badly preserved ostracods (*Cypridae*)



or *Cytheridae*) reported by them indicate a post-Triassic, Mesozoic age. The fossiliferous limestones occurring in the upper part of the Sattim Formation of Dhital and Kizaki (1987b) may be equivalent to the middle part of the Amile Formation of Sakai (1983).

From Surkhet area, Kayastha (1992) has described the Melpani Formation, a light to dark grey ferruginous well-bedded massive orthoquartzite and sandstone sequence intercalated with grey to black carbonaceous shales. The basal part also shows intercalation of limestone and conglomerate. The black shales contains coalified wood fragments. The formation rests unconformably over the much older rocks of the Nawakot Group (Lakharpata Formation of Shrestha et al., 1987). Although no fossils are found in this formation, the Melpani Formation has been correlated with the Amile Formation of the Tansen area on the basis of the lithology and the stratigraphic position with respect to the overlying well dated fossiliferous rocks.

### Lower Tertiary Group

Restricted occurrences of these post Gondwana rocks (Paleogene-early Neogene) are well documented all along the Himalaya. In Nepal, the Eocene rocks were known to occur in the Tansen, northern Dang and Surkhet areas from the early days of geological investigations (Hagen, 1969; Fuchs, 1967; Sharma, 1977). Recent mapping (Bashyal, 1986; Kayastha, 1992) has shown that these rocks also extend westward across Karnali up to the Seti River in far western Nepal. In fact, one of the best exposures of these Lower Tertiary rocks occurs in the Karnali section just to the north of the MBT (Amatya and Jnawali, 1994, ESCAP/DMG, 1993).

In the Tansen area, Sakai (1983) has mapped these rocks and divided them into two formations: the lower Bhainskati Formation and the upper Dumri Formation. Westward, Sharma et al. (1984) and Dhital and Kizaki (1987b) have also mapped these rocks in the south and east of Phalabang, Daban, and north of Dang.

#### *Bhainskati Formation*

This *Nummulite* bearing rock formation was the first well known Eocene locality in the Lesser

Himalaya of western Nepal (Sharma, 1977). The formation is exposed in the Tansen synclinorium. In this area, the formation conformably overlies the Amile Formation with an abrupt change of lithofacies. The boundary between the Eocene rocks and the pre-Eocene Gondwanas lies within the *Nummulite* bearing limestones of Amile and the Bhainskati formations. The precise boundary is difficult to fix, especially when the two formations occur independently. Therefore, a more work on the systematics of the poorly studied *Nummulites* and other fossils has to be carried out in order to better understand the stratigraphic positions of these fossiliferous rocks.

The Bhainskati Formation is a marine sequence made up of black shales with many thin fossiliferous dark muddy limestones. Bioturbation is conspicuous in the shales. The upper part of this formation mostly consists of green and reddish-purple shales with subordinate hematite beds and hematite ooids. The lower middle part of this formation consists of a large number of fossils of bivalves, gastropods and larger foraminifera. Some fragmentary vertebrate bones, along with marine fishes, are occasionally found. Small coalified tree branches are also reported. Sakai (1983) and Matsumaru and Sakai (1989) have identified *Nummulites beaumonti* d'Archaic and Haime and *Assillina papillata* Nuttall of Middle Eocene (Lutetian) age, and *Asteracantus* sp. Among the vertebrates teleostei (vertebra, spine, skull), chelonia (carapace) and Trionichidae (carapace) are identified. The Bhainskati Formation ranges in age from middle to late Eocene. Sakai (1983) has correlated these rocks with the Subathu of Garhwal and Kumaon Lesser Himalaya.

North of Dang, Dhital and Kizaki (1987b) have described foraminiferal beds grouped as the Dubring Formation overlying their Sattim Formation with possibly a transitional contact. Here the Dubring Formation is represented by a cyclic alternation of red-purple mudstones and green sandstones with a minor amount of green, brown and black shales. At several horizons, the wavy lenticular beds of pink, red and purple limestones interbedded with calcareous argillites contain *Nummulites* and *Assillina* fossils and compact lenses of bivalvia. Sharma et al. (1984) have also mapped similar rocks in the west around the Daban area. Fuchs and Frank (1970) have



described these rocks from the Barikot area as Subathus, belonging to Paleocene to Lower Eocene age, and consisting of nummulitic limestones and shales. They have reported *Assilina Placentula* DESHAYES from this area.

In the Surkhet area, the Swat Formation (named after the Swat Khola in Surkhet) conformably overlies the Melpani Formation (Kayastha, 1992). The Swat Formation is 50 to 150 m thick and is composed of grey to dark grey limestones and dark shales. Lenses of fossiliferous limestones are found within them. The Chinese Petroleum Investigation Team (CPIT, 1973) has identified a number of foraminifera, bivalvia and gastropoda species from this formation in the Surkhet area and assigned a Lower to Middle Eocene age.

**Dumri Formation**

Sakai (1983) described this formation from the Tansen area and found it to disconformably overlie the eroded surface of the Bhainskati Formation. This formation comprises a thick series of medium grained, bluish grey to greenish grey quartzose sandstones interbedded with red, purple and green shales. The sandstones are quartzose wacke in composition. They are massive and occasionally with wedge-shaped cross-beddings. Several

intraformational shale-pebble conglomerates are also noted. Strong bioturbation is common in shales and can be easily recognised by their mottled structures. The presence of scour channels, rhythmic sequence of sandstone and shale, and coalified wood fragments including trunks suggest that the Dumri Formation is comprised of rapidly deposited fluvial flood-plain deposits. Vertebrate bone fragments, carbonised plant remains including leaves, trunks and branches are also reported. However, no fossils for age determination have been found. Sharma et al. (1984) have also reported these rocks in the west in the Dang, Rolpa and Salyan districts. As this formation unconformably lies over the late Eocene Bhainskati Formation, it can be correlated with the Dagshai of Simla and the Murrees of the Sub-Himalayas of Punjab. The age assigned to these rocks is Oligocene to early Miocene.

In the Surkhet area, the Swat Formation unconformably overlies the Suntar Formation. The Suntar Formation comprises of an alternating sequence of sandstones and shales with marl beds. The sandstones are fine to medium grained and hard, and mainly composed of detrital quartz with some argillaceous matrix. The formation is devoid of fossils. However, bioturbation in shales is commonly observed. The maximum thickness of the formation is 775 m, and its upper limit is always truncated by

**Table 2: Stratigraphy of the Jajarkot Nappe**

Stratigraphy (Sharma et al., 1984)	Tentative Correlation		Age	
	Central Nepal (Stocklin and Bhattarai, 1977)	Far western Nepal (Hayashi et al., 1984)		
Jajjala Formation	Kathmandu Complex	Phulchauki Group (Chandragiri Limestone)	Baregaon Formation	Cambro- Ordovician
Thabang Formation		Unconformity		
Chaurjhari Formation		Bhainsedobhan Marble		
	Raduwa Formation	Gneisses		



a thrust (Ranimatta Thrust). The Swat Formation is correlated with the Dumri Formation of the Tansen area (Kayastha, 1992).

## **STRATIGRAPHY OF THE JAJARKOT NAPPE**

The Jajarkot Nappe was first described by Hagen (1969). The nappe forms a long narrow arm and joins with the Karnali Nappe in the west (Arita et al., 1984b). It is 10-20 km wide and more than 100 km long, and occupies the core of an east-west trending synclinorium (Fig. 2). This unit partly belongs to the lower crystalline nappe of Fuchs and Frank (1970) and tectonically rests over the less metamorphosed Nawakot Group of rocks. The stratigraphy and correlations of the rocks belonging to the nappe are given in Table 2.

### **Chaurjhari Formation**

This formation is well developed south of Jajarkot around Chaurjhari. The formation is mainly a schistose sequence consisting of grey to light greenish grey muscovite-biotite schists and garnetiferous mica-schists with minor intercalations of dark and light coloured quartzites, quartzitic schists with garnet and feldspathic schists (Sharma et al., 1984). In addition, biotite, chlorite and long crystals of hornblende have also been noticed. The metamorphism of the rocks belongs to albite-epidote almandine sub-facies of the greenschist facies (Fuchs and Frank, 1970). The formation may be broadly compared with the Raduwa Formation of the Bhimphedi Group of central Nepal.

### **Thabang Formation**

This formation overlies the Chaurjhari Formation with a gradational contact, and is represented by the alternating sequence of coarse crystalline impure marbles interbedded with mica schists. The marble contains calcite as its chief mineral, and quartz, muscovite, biotite, amphibole and garnet also occur in small proportions. The metamorphic grade decreases in the higher levels and finally dies out in the overlying Jaljala Formation. Considering the lithology of the crystalline marbles and the

interbedded schists, the formation is comparable to the Bhainsedobhan Marble of the Kathmandu Complex. However, it is quite possible that the upper part of this formation belongs to the basal part of the Dhaulagiri Limestone of Fuchs and Frank (1970), since much of the Thabang Formation mapped by Sharma et al. (1984) is shown as the Dhaulagiri Limestone by Fuchs and Frank (1970) in their geological map. Also, the Baregaon Formation of the Jumla area, which is supposed to be the Tethyan rocks belonging to the Dhaulagiri Limestone, shows similar lithology to that of the Thabang Formation (Hayashi et al., 1984). There is a gradational contact between the underlying crystallines and the Dhaulagiri Limestone of Cambro-Ordovician age.

### **Jaljala Formation**

This formation is best exposed at Jaljala Dhuri and is the youngest formation of the Jajarkot Nappe. It occupies the core of the Jaljala synclinorium. As mentioned above, there is some confusion among researchers in identifying the limit of the underlying crystallines and the carbonates of the Tethyan affinity. At Jaljala Dhuri, this formation consists of fine to medium grained calcareous sandstones and siltstones with some intercalations of grey phyllites. The rock is highly susceptible to weathering, and weathers to characteristic yellowish brown, brown, reddish-brown to brick-red colours. The upper part of the formation is represented by silty-sandy limestones and bluish grey limestones with intercalated phyllitic slates.

The quartzites and calc-mica schists below the limestones (Dhaulagiri Limestone of Fuchs and Frank, 1970) are regarded by Fuchs and Frank as a basal part of the Dhaulagiri Limestone, whereas Sharma et al. (1984) put them into their Thabang Formation. There is no break in grade of metamorphism between these metasediments and the crystalline rocks. Fuchs and Frank (1970) have reported Crinoids from these limestones. Fuchs and Frank (1970) have also indicated a similarity of these rocks with the Garbyang Formation of Kumaon. Due to the lithological similarities and the occurrence of crinoids, these rocks show a closer affinity to the Cambro-Ordovician Chandragiri Limestone of the Phulchauki Group of central Nepal.



## CONCLUSIONS

The Lesser Himalaya of western Nepal between the Marsyangdi and Bheri Rivers exposes a wide zone of low grade metamorphic rocks ranging in age from Precambrian to Lower Miocene age. The younger sedimentary rocks, unconformably overlying these low grade rocks, are found to occur in isolated bodies at many places. It is interesting to note that the older group of rocks which are mostly Precambrian in age are overlain directly by the rocks of Gondwana and younger ages (Permo-Carboniferous to Lower Miocene). No rocks of intervening ages are reported. It indicates that a long period of non deposition existed between the Precambrian or Lower Paleozoic (?) and the early Permian in the Lesser Himalaya of Nepal.

Based on a poorly recorded disconformity, Stocklin and Bhattarai (1977) placed the boundary between the Lower and Upper Nawakot Groups above the Dhading Dolomite. It would be more practical to subdivide the older metasedimentary rocks into: (a) The Lower Nawakot Group including the Kuncha Formation, Fagfog Quartzite and the Dandagaon Phyllite, all essentially the carbonate free formations, and (b) The Upper Nawakot Group consisting of the Nourpul Formation, Dhading Dolomite, Benighat Slate and the Malekhu Limestone, all carbonate rich formations and usually containing pink and purple slates.

The stratigraphy of the older metasedimentary sequences show that the Kuncha Formation is a well defined formation and can be traced for a long distance without interruption. It is a very monotonous and thick formation with over 3 km thickness, and whose base has not been found to be exposed any where. At many places it thrusts to the south over the younger rocks. It sometimes forms klippe as observed in the Tansen area, north of the Dang Valley and Sallyan area. The quartzites form conspicuous horizons in the older sequences. Some quartzites are part of the Kuncha Formation and some are clearly overlying the Kuncha Formation (Fagfog Quartzite). These quartzites are usually discontinuous and pinch out after few kilometers along the strike. Therefore, in the previous studies the stratigraphic position of various quartzites seem to be mixed up.

Thin carbonate rocks appear first in the Nourpul Formation. It is succeeded upward by a thick dolomite formation (Dhading Dolomite) with the profuse development of stromatolites. This stromatolite bearing carbonate sequence can be used as a good marker horizon. However, the distinction between the Dhading Dolomite and the younger Malekhu Limestone has posed some problem. These two carbonate formations are separated by a black slate formation (Benighat Slate). But black slates of variable thickness are also found within these carbonate rocks, especially within the Dhading Dolomite. Both these formations are made up of dolomites and both contain stromatolitic structures. The Dhading Dolomite, however, is more conspicuous due to a profuse development of the columnar stromatolites. There are also carbonate rocks within the Benighat Slate (Jhiku Carbonate Member). All these different carbonate horizons are generally difficult to recognise especially when occur in isolation and without the accompanying underlying or overlying formations. This has made the stratigraphic investigation of the area even more difficult. On the contrary, the younger sequence containing fossils pose less problem.

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## INTRODUCTION

The study area, which is a part of a series of longitudinal ridges and valleys composed mainly of dark sediments of Middle Miocene to Lower Pleistocene marine sediments. As in other parts of the Himalayas, the Siwalik Group of Nepal is tectonically bounded by the Main Boundary Thrust (MBT) to the north and Main Frontal Thrust (MFT) to the south.

Stratigraphically, the three-fold sub-division of the Siwalik Group as in other parts of the Himalayas holds true for the present area also. They are Lower Siwalik (LS), Middle Siwalik (MS) and Upper Siwalik (US). However, based on lithology, the Middle Siwalik has been further subdivided into Lower Middle Siwalik (MS1) and Upper Middle Siwalik (MS2) (Table 1, Fig. 2). The Lower Siwalik is mainly composed of grey calcareous fine grained sandstones interbedded with purple and grey

shales, mudstones and siltstones. It is gradually overlain by the Lower Middle Siwalik. The Lower Middle Siwalik dominantly consists of grey massive bedded fine to medium sandstones with grey shales and siltstones. The upper part of the Lower Middle Siwalik exhibits salt and pepper like appearance in north-south direction. The Upper Middle Siwalik unconformably overlies the Lower Middle Siwalik dominantly consists of pebbly sandstones and medium to coarse sandstones with grey mudstones and siltstones. The Upper Siwalik is composed of single bedded with sub-parallel amount of yellow sandstones, claystones and siltstones with thin beds and lenses of medium to coarse sand. The Upper Siwalik overlies the Lower Middle Siwalik also with a gradual contact.

The Pre-Cambrian and younger metamorphic rocks of the Midland Group of Lesser Himalayas have been overlain by the Siwalik Group along the Main Boundary Thrust (MBT). All over the Himalayas the

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