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# Depositional environment of the Lesser Himalayan rocks in the Muglin-Bandipur area, central Nepal

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## ABSTRACT

The Muglin-Bandipur area of central Nepal, Lesser Himalaya comprises non-fossiliferous, low-grade meta-sedimentary rocks of the Midland Group. Study of the depositional sedimentary environment of the rocks exposed in the area was carried out in the present work. Lithological characteristics, bedding thickness and continuity, sedimentary structures, available fossils and petrographic study were the basis of assessing the depositional sedimentary environment of the area. The Midland sediments of the study area were deposited in the marine environment. The Kunchha Formation, the oldest unit of the Midland Group and of the whole Lesser Himalaya is considered to be deposited in the deep and calm oceanic condition.The sediments of Fagfog Quartzite are found to be deposited under the fluvial dominated delta environment.The argillaceous materials of Dandagaon Phyllite are considered as deposits of the transitional environment between deep and shallow marine.The depositional environment of the Nourpul Formation fluctuates fluvial dominated pro-delta condition to shallow marine condition with short term aerial exposure as well.The Dhading Dolomite is also inferred as the shallow marine deposits. Deposition of suspended materials of the Benighat Slates is considered relatively on deep and calm reducing environment.

**Key words**: Midland Group, sedimentary structures, depositional environment, central Nepal, Lesser Himalaya.

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## INTRODUCTION

Nepal Himalaya is located in the central part of the 2400 km long Himalayan arc and covers one third of its length. It is divided longitudinally into four tectonic zones, known as the Sub-Himalaya, Lesser Himalaya, Higher Himalaya, and the Tethys Himalaya from south to north, respectively (Gansser 1964). These tectonic zones are separated from each other by the principal Himalayan thrust faults (Thakur 1981; 1992). Each of these zones is characterized by its own lithology, tectonics, structures, magmatism and geological histories.

The Lesser Himalaya (LH) is bordered in the south by the Main Boundary Thrust (MBT) and in the north by the Main Central Thrust (MCT) (Fig.1). The MBT is a low-angle reverse fault that has brought the older Lesser Himalayan rocks over the much younger Siwaliks. The MCT, on the other hand, lifts the middle level crustal rocks of the Higher Himalaya over those of the LH. The LH is a fold-and-thrust belt with complex stratigraphy and structures. There are several thrust sheets, stacked one over the other and folded and faulted non-clarified rock successions on a large scale (Valdiya 1980). Tectonically, the LH is made up of the autochthonous-parautochthonous rock units, with various nappes, klippe and tectonic windows.

Central part of theNepal Lesser Himalaya is also a complex tectonic zone with several faults and folds. The area includes Mahabharat Synclinorium (Stöcklin 1980) in the east, Gorkha-Kunchha Anticlinorium in the north (Pêcher 1977), Kanhu Syncline (Jnawali and Tuladhar 1996) in the north west, Tansen Synclinorium (Sakai 1985) in the southeast and Jajarkot Syncline (Ando and Ohta 1973) in the west. The Bari Gad-Kali Gandaki Fault (Nakata 1982) and Phalebas Thrust (Upreti et. al. 1980) are the regional faults extending east-west in the area (Fig. 1).

The low-grade meta-sedimentary rocks of the Lesser Himalayan autochthonous zone in central Nepal are known as the Midland Group (Arita et. al. 1984; Shrestha et. al. 1983; 1987) and Nawakot Complex (Stöcklin and Bhattarai 1977; Stöcklin 1980). Several researchers have carried out geological investigation in the central Nepal Lesser Himalaya and have contributed on stratigraphy of the area (Stöcklin and Bhattarai 1977; Stöcklin 1980; Sakai 1985; DMG 1987; Hirayama et. al. 1988; Dhital 1995; Jnawali and Tuladhar 1996; Sah 1999 and 2007; Paudel and Arita 2000; Dhital et. al. 2002). However, there was a gap of geological

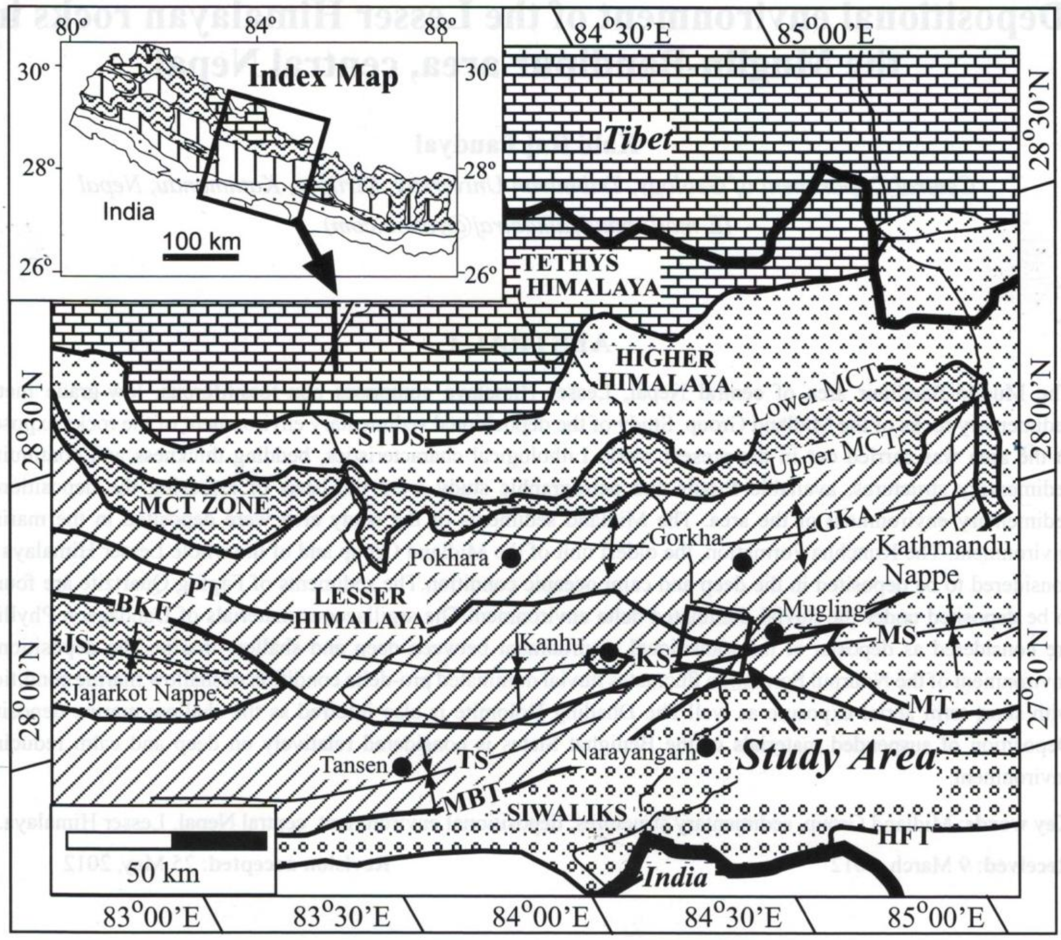


**Fig. 1: Regional tectonic map of central Nepal Lesser Himalaya showing the location of the study area (modified after Paudel and Arita 2000). STDS: South Tibetan Detachment System, MCT: Main Central Thrust, MBT: Main Boundary Thrust, HFT: Himalayan Frontal Thrust, MT: Mahabharat Thrust, BKF: Bari Gad-Kali Gandaki Fault, PT: Phalebas Thrust, MS: Mahabharat Synclinorium, GKA: Gorkha-Kunchha Anticlinorium, TS: Tansen Synclinorium, KS: Kanhu Syncline, JS: Jalbire Syncline.**

map in between the Muglin and Damauli area. To fulfill the gap, mapping was started from the Muglin to Banspani area first (Paudyal and Paudel, 2011) and it was extended to Bandipur area (Paudyal et. al. 2012) (Fig.2). After detailed geological mapping in 1:25,000; some of the discrepancies on stratigraphy and structures are made clear.In the same time an effort is made on the study of the depositional sedimentary environments of the rocks of the region as it is less described in the previous works.

## LITHOSTRATIGRAPHY

Geological map and its cross-section of the Muglin-Bandipur area of the Tanahu District in central Nepal are given in Fig. 2a and 2b, respectively. The area is occupied by the rocks of the Midland Group. Generalized stratigraphic column of the study area is given in Fig.3.

In the study area, the rocks of the autochthon comprise the Kunchha Formation, Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation, Dhading Dolomite and the Benighat Slates successively from bottom to top.The detail description of lithostratigraphy and geological structures of the area are presented in Paudyal and Paudel (2011) and Paudyal et. al. (2012). In brief, the lithological summary is given in a generalized columnar section.

## DEPOSITIONAL ENVIRONMENTS

Most of the units in the Midland Group are unfossiliferous and sedimentary structures are rare. Deep weathering and soil formation have posed further difficulties to see the syn-sedimentary evidences for environmental studies. However, the presence of algal mats, columnar stromatolites, and various sedimentary structures like cross-beddings, parallel-

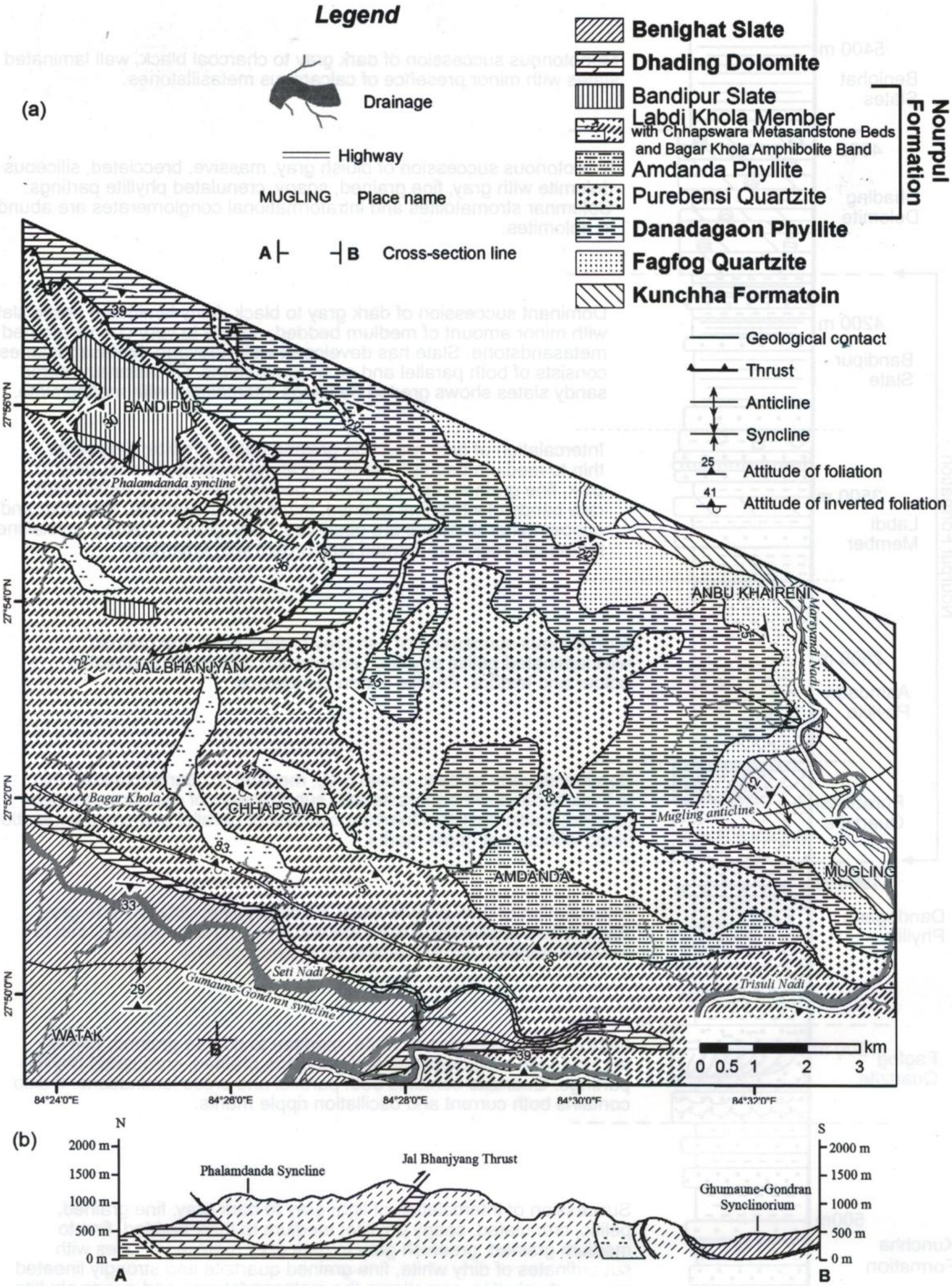


**Fig. 2: (a) Geological map of Muglin-Bandipur area of central Nepal, Lesser Himalaya. (b) Geological cross-section along A-B. (after Paudyal and Paudel 2011 and Paudyal et. al. 2012).**

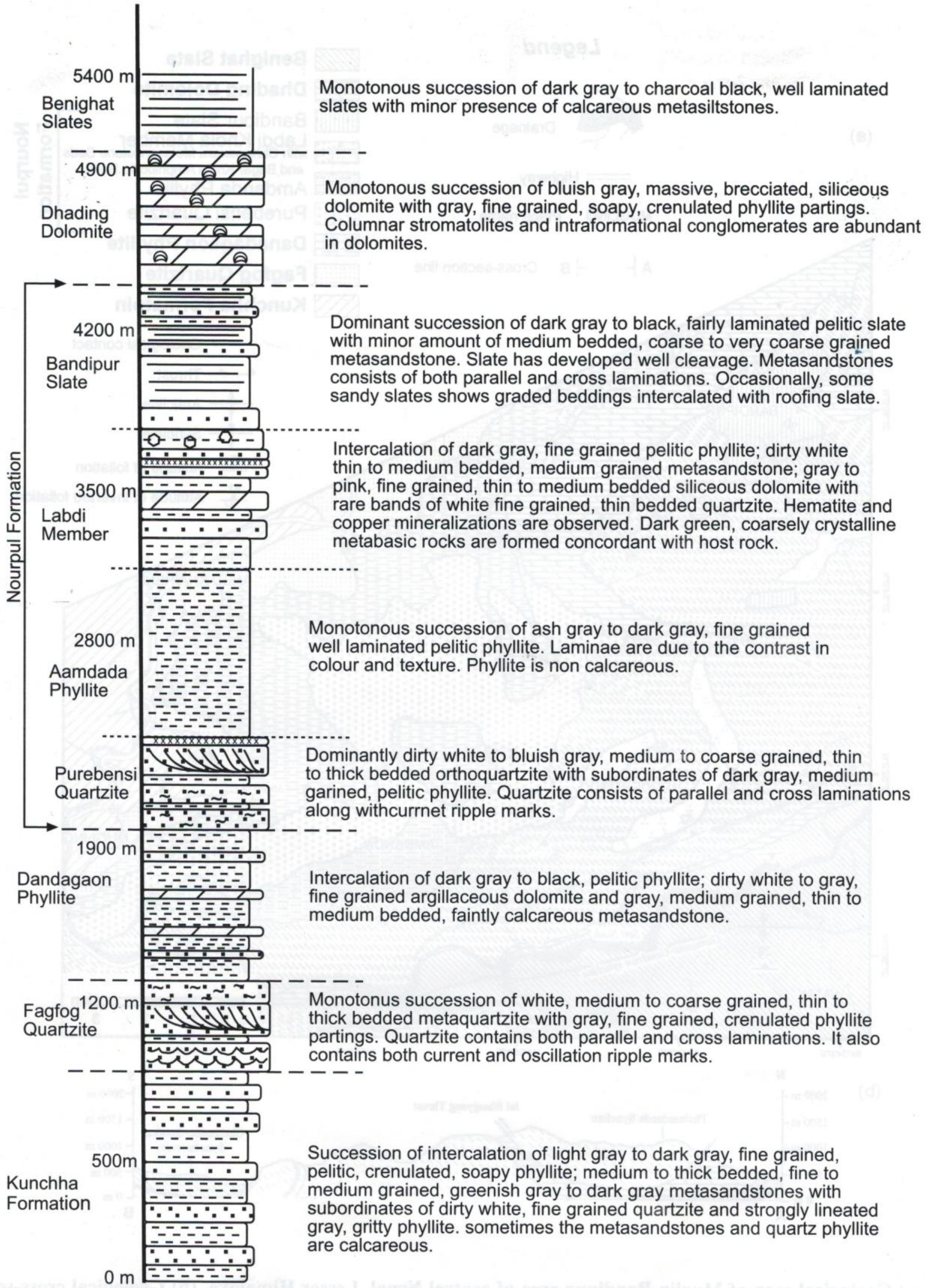


**Fig. 3: Generalized columnar section of the rocks of the Midland Group exposed in the Muglin-Bandipur area.**

laminations, graded-beddings, mud-cracks, ripple marks and characteristics of beddings provide evidences for the interpretation of depositional environment. The depositional environment for different formations has been discussed as follows.

### Kunchha Formation

In the studied section, only the upper part of the Kunchha Formation is exposed in the Muglin area. Thick succession of alternation of pelitic phyllite and gritty phyllite of this formation represents calm and uniformly deposited marine environment. The thick and continuous beds of meta-sandstones with parallel laminations also represent the deltaic deposits of relatively shallow marine environment. The intercalation of calcareous metasandstone (Fig. 4a) with gritty phyllite indicates a transitional environment between the off-shore and the shore-face.At the upper part of the Kunchha Formation, about 5m thick conglomerate bed is found in the Muglin-Anbu Khaireni section, at the right bank of the Marshyangdi river which represents the high flow fluvial environment while growing the submarine delta (Fig. 4b). The phyllite shows significant amount of quartz with minor feldspar in thin sections. Some rock fragments, opaque and detrital micas are also found (Fig. 4c). It shows some episodic high flow river influx within the basin carrying some angular fragments of quartz and rock fragments. The rocks of the Kunchha Formation do not preserve any fossils in this area. No more sedimentary structures are also found except the laminations in phyllite and metasandstones and ortho-quartzites. On the basis of these observations it can be suggested that the majority of the Kunchha Formation was probably deposited in deeper basin environment. Presence of graded-bedding in greywacke represents the locally controlled turbidite deposition. In this way, a thick succession of the Kunchha Formation was the product of diagenesis and metamorphism of mixed type of clastic deposition under transitional to deeper part of the sea basin.

### Fagfog Quartzite

The Fagfog Quartzite follows the Kunchha Formation upward with sharp and conformable contact (Fig. 5a). It is a monotonous succession of thin- to thick-bedded, coarse-grained quartzite with fine-grained pelitic phyllite partings. Both parallel- and cross-laminations (Fig. 5b) are found in the quartzites. In addition, both current and osccilation ripple marks (Fig. 5c) are also observed abundantly. Under petrographic microscope, the rocks of this formation consists >90% quartz (Fig. 6). Based on these evidences, it can be said that the Fagfog Quartzite was deposited in shallow sea or near the flood-delta with active current environment.

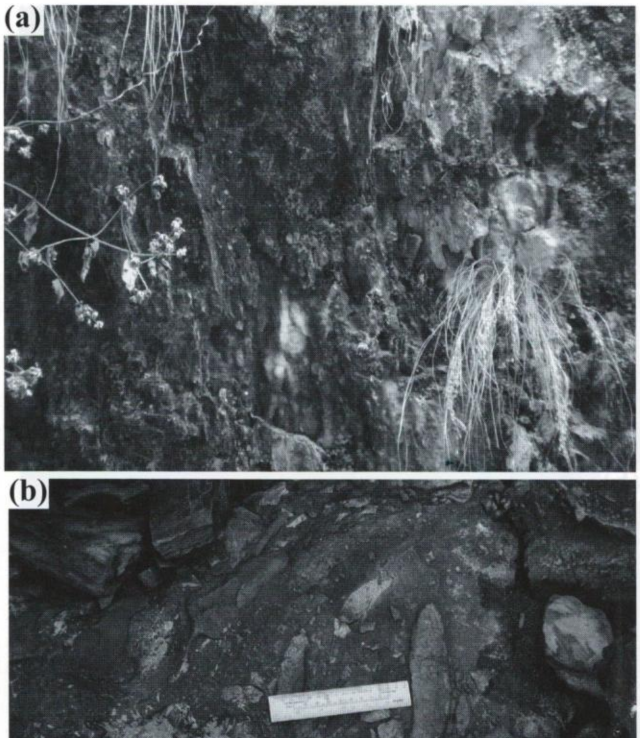


**Fig. 4: (a) Photograph of calcareous crust on outcrop of the Kunchha Formation exposed about 2km south of Muglin Bazzar along Muglin-Narayangarh road. (b) Outcrop view of metaconglomerate observed at the top part of the Kunchha Formation at the right bank of the Marshyangdi river in between Muglin and Anpu Khaireni. (c) Photomicrograph of the gritty phyllite of Kunchha Formation taken from the Muglin area, under cross nicols.**

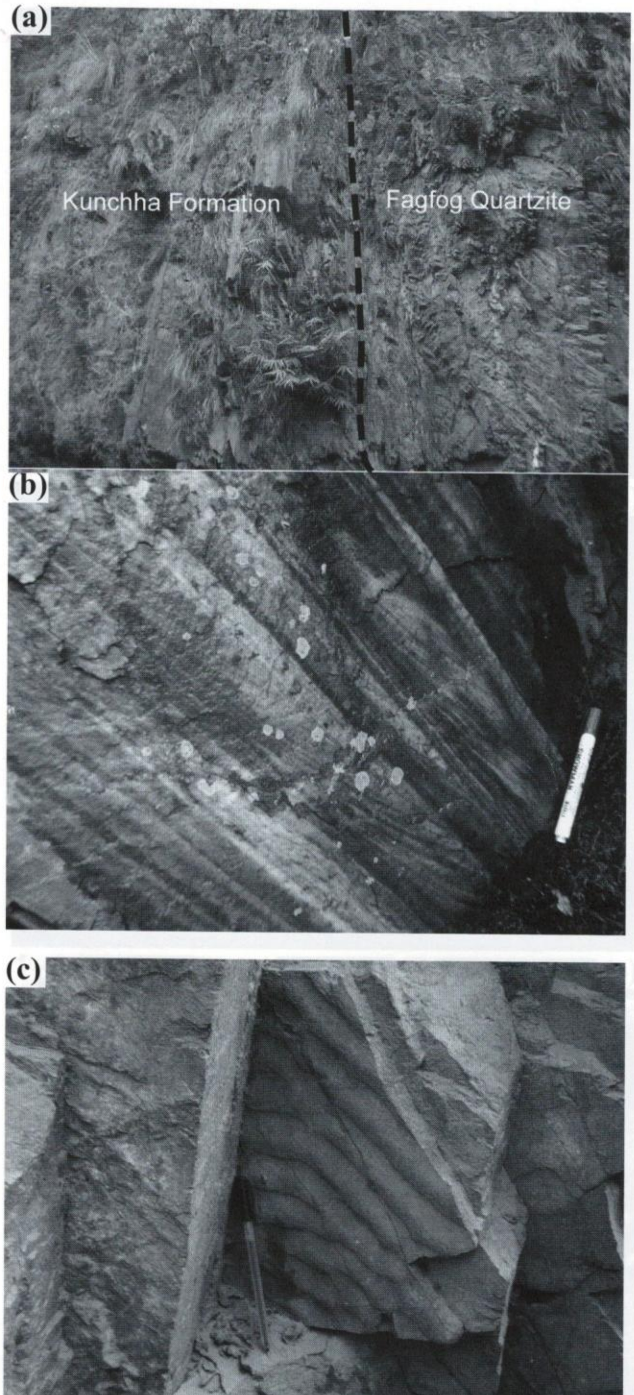


**Fig. 5: (a) Contact of the Kunchha Formation (left) and the Fagfog Quartzite (right) exposed about 3 km south of Muglin along the Muglin-Narayangarh road. (b) Cross-laminations in the Fagfog Quartzite approximately 3 km south of Muglin (facing towards E). (c) Current ripples in the Fagfog Quartzite observed at Muglin-Narayangarh road, about 3.5 km south from Muglin (facing towards E).**

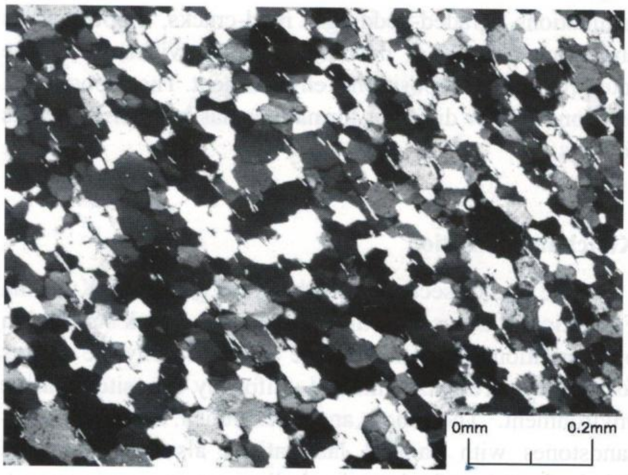


**Fig. 6: Photomicrograph of Fagfog Quartzite showing >96% deformed quartz grains.**

Continuous and parallel beds of quartzite succession reflect its deposition in high turbidity shallow sea. The presence of small ripple marks in some beds also shows continental shelf with high turbidity. Presence of rhythmic phyllite partings indicates periodic short term calm condition.The relatively thicker beds (>2m) with long persistency, larger grain size with >90% pure quartz grains is only possible in shallow marine environment with high current activity.

**Dandagaon Phyllite**

It is a succession of dominantly dark grey, pelitic, fine-grained slates/phyllites with subordinates of thin quartzite, meta-sandstone and dolomite beds. The phyllite is mostly darker in color and do not contain gritty fragments as in the Khuchha Formation. It suggests the deposition of protolith in deep and calm environment probably in zone below active current. The phyllite was derived from clay and lime-mud deposited in open marine neritic zone. The thickly laminated dark colored phyllite inter-bedded with quartzite and meta-sandstone shows frequent change from deep to relatively shallow environment.

**Nourpul Formation**

Based on lithology and their distribution, the Nourpul Formation has been further divided into four members. They are the Purebensi Quartzite at the base, the Amdanda Phyllite at the lower middle part followed stratigraphically upwards by the Labdi Khola Member with the Chhapswara Meta-sandstone bed and the Bagar Khola Amphibolite and the Bandipur Slate.

*Purebensi Quartzite*

It is a succession of dirty white quartzite with subordinates of grey, fine-grained phyllite intercalations. Quartzite is medium- to thick-bedded with distinctly preserved ripple marks (Fig. 7a) and cross-laminations. Both current as well as oscillation ripple marks are found in the quartzite beds. Beds are continuous, regular and parallel to each other. These sedimentary structures and lithological characteristics support that the basal part was deposited in the submarine deltaic environment. Presence of some lenticular phyllite intercalations indicate braided condition within submarine delta. Sedimentation of most of the thick sandy cycles of the middle and upper part can be explained by the progradation of the costal sand bodies with the rising sea levels. Thus the cross-laminated and rippled quartzose sand was probably deposited in the back-shore, foreshore or shoreface regions where as the inter-bedded unit of sand and silty clay were deposited near the lagoonal beach.Major part of the clay unit was formed either in the lagoonal pond or in the flood plain.

*Amdanda Phyllite*

The Amdada Phyllite comprises finely laminated fine-grained, light grey phyllite. It was probably deposited in the deeper condition below the wave action and calm environment. Well-developed fine laminations on these phyllites (Fig. 7b) indicate the uniform and slow supply of sediments under constant discharge from suspension load of water body.

*Labdi Khola Member*

It is quite diversified in lithology. The lower part of this member consists of intercalation of dark grey, pelitic, fine-grained phyllite, dirty white dolomite, grey, medium-grained meta-sandstone and dirty white, fine-grained quartzite.In the Labdi Khola and Bhut Khola sections, iron (hematite and magnetite) and copper mineralizations are observed. The genesis of hematite is found sedimentary as it is micaceous and has abundant phyllite partings.However, the genesis of copper is assumed from the magmatic origin as there are amphibolites in contact with copper mineralization. Phyllite with iron body indicates the deeper and calm environment with active bacterial activity where as the lenticular beds of meta-sandstones and pink strongly calcareous meta-sandstones indicate fluvial dominated submarine environment. In some places thick succession of meta-sandstone beds (Chhapswara Meta-sandstone) within this member is probably the deltaic deposit of open shallow marine environment. In some places at the topmost part a rhythmic deposit of dark pelitic phyllite, pink dolomite, white to pink quartzite and grey metasandstone are found. This is the indication of transgression of marine basin. Linguid ripples and mudcracks are found in the sandy shale occasionally (Fig. 7c). This indicates the sudden change in the water depth and sub-aerial exposure of muds and silts.

*Bandipur Slate*

The topmost member of the Nourpul Formation is mapped as the Bandipur Slate. It is a succession of dominantly laminated dark grey slates with subordinates of grey, meta-sandstones.The graphitic carbonaceous slate of Nourpul Formation indicate deeper marine environment with fluctuation in discharge of sediment as supported by the presence of graded bedding in psammitic slates of Bandipur Slate while the presence of cross laminated meta-sandstone (Fig. 7d) with slate intercalation indicate fluvial dominated deltaic deposits of open, shallow marine environment fluctuating from deeper to shallow littoral sea environment.

**Dhading Dolomite**

The Dhading Dolomite follows upwards the Nourpul Formation with sharp and conformable contacts. It consists of monotonous succession of bluish grey, massive and brecciaed dolomite with rarely preserved algal mats and columnar stromatolites (Fig. 8a). Occasionally, the phyllite partings are also observed within the dolomites. Dolomite is siliceous in nature. Intraformational conglomerates of dolomite fragments (Fig. 8b) and presence of columnar stromatolites are the indicative of deposition on very shallow-depth beach lagoons, bays or tidal flats environments. Probably, the intra-formational fragments of the dolomite within the dolomite beds were deposited in the supra-tidal and intertidal flats associated with the coastal lagoons.

**Benighat Slates**

A monotonous succession of the Benighat Slates is found in the stratigraphic up position to the Dhading Dolomite with sharp and conformable contact (Fig. 9). Mostly, it consists of charcoal black, finely-laminated phyllite and slate with subordinates of carbonates. This type of dark-grey to black slates is inferred to be deposited by suspension load in deeper, tranquil and shallow and shelf environments below wave action. The thick succession of fine-grained black slate also reflects calm and deep marine reducing depositional environment. It is also justified by the presence of abundant pyrite crystals within the slates.

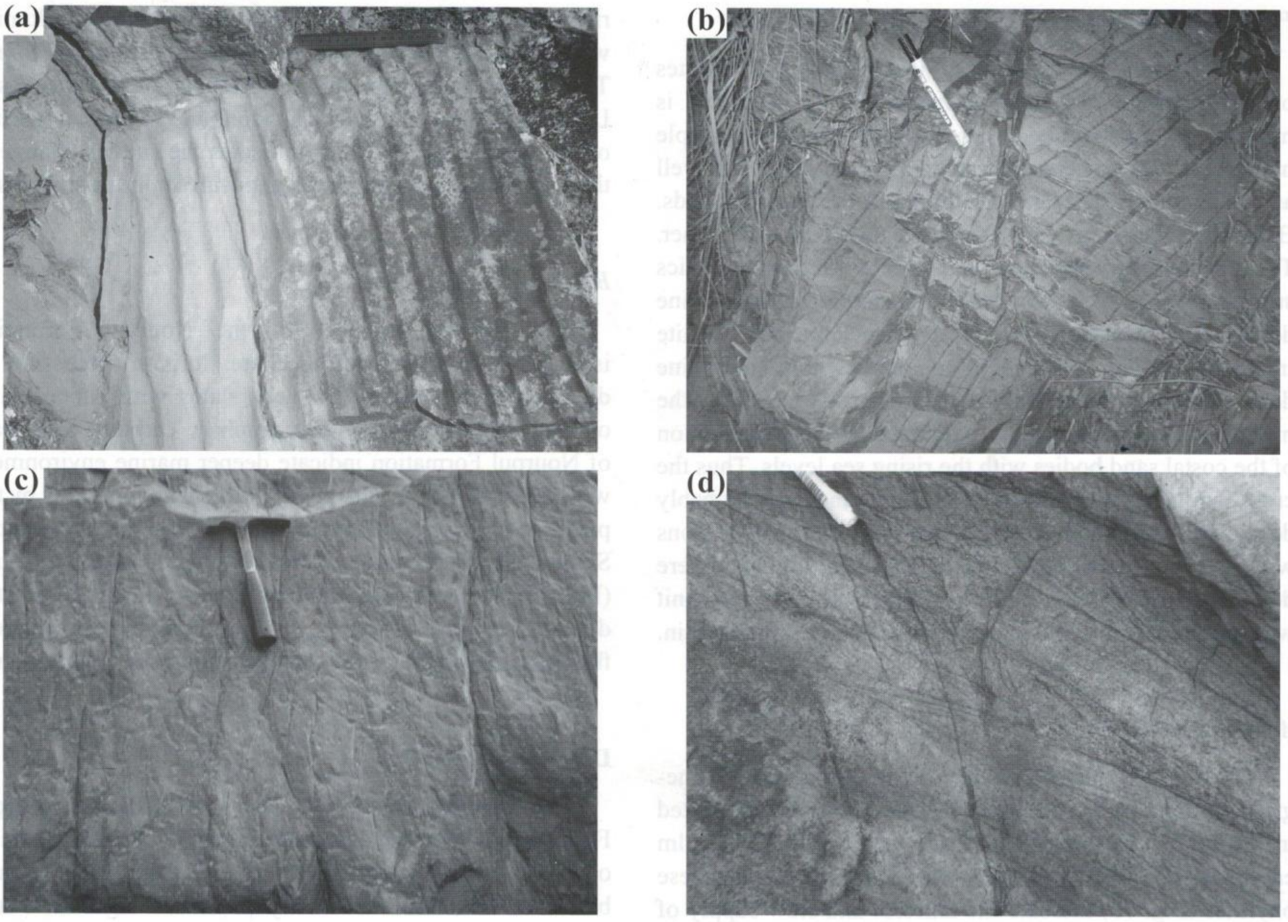


**Fig. 7: (a) Current ripples in the Purebensi Quartzite observed in Muglin-Narayangarh road section, about 4.5 km south from the Muglin. (b) Parallel laminations in the Amdanda Phyllite, observed in the type locality Amdanda (See Fig. 2a). (c) Mud cracks found in the upper most part of the Nourpul Formation in sandy shales, observed at Jalbire, about 7km south from Muglin. (d) Cross-laminations in the metasandstone beds of the Bandipur Slate observed in the lower reaches of the Bandipur Bazzar.**

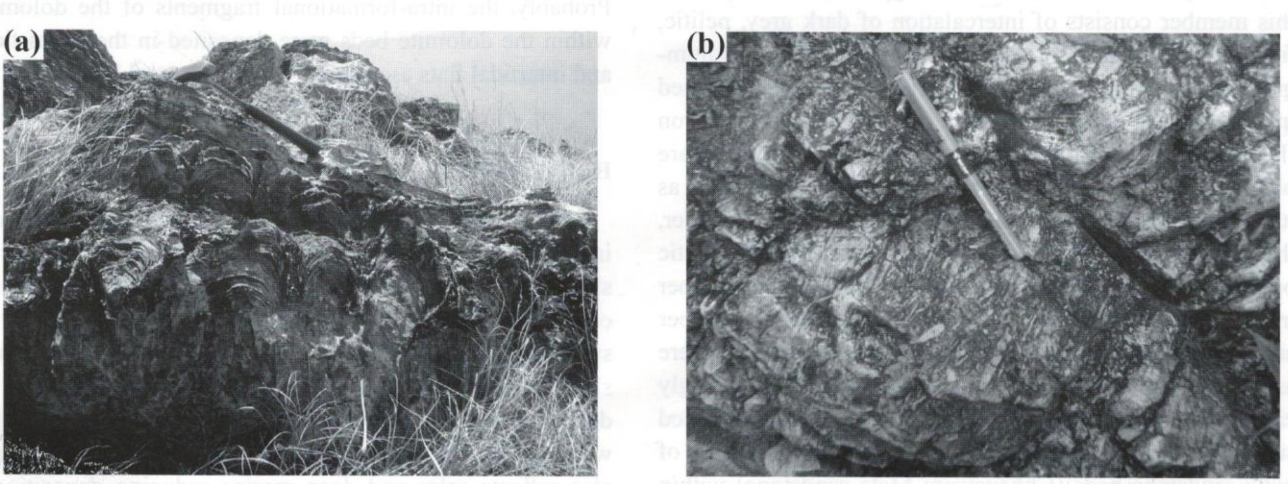


**Fig. 8: (a) Columnar stromatolites in the Dhading Dolomite, observed in the Dumre Bandipur road section. (b) Intra-formational conglomerates of dolomite in Dhading Dolomite observed in the Dumre-Bandipur road section.**

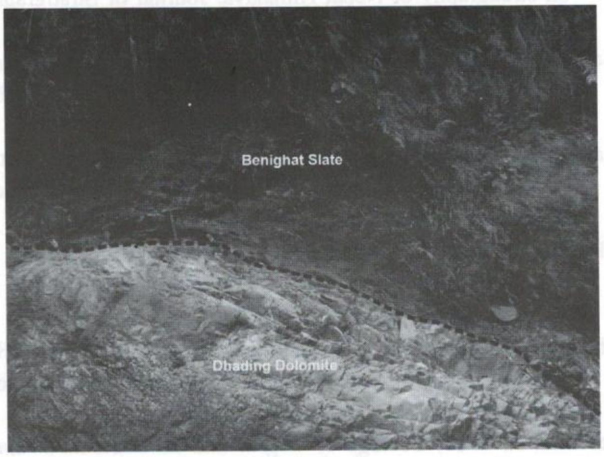


**Fig. 9: Photograph shows the sharp contact between the Dhading Dolomite (lower) and the Benighat Slates (upper), observed in the Labdi Khola section.**

## CONCLUSIONS

Based on the lithological characteristics, sedimentary structures, rock textures and petrographic studies, the following conclusions are drawn about the depositional environment of the Lesser Himalayan rocks of the Midland Group.

The thick succession of the Kunchha Formation represents the marine environment of deposition. Flysch type rocks show deeper and calm environment. However, the presence of calcareous meta-sandstones with psammitic phyllite indicates a transitional environment between the off-shore and the shore face.The Fagfog Quartzite is considered to be deposited on the fluvial dominated deltaic environment.The argillaceous sediments and lime-mud of the Dandagaon Formation is supposed to be deposited in deeper to neritic environment below the active current zone.The palaeo-environment of deposition of Nourpul Formation is not found uniform. The basal part (quartzite succession) could be deposited under fluvial dominated submarine deltaic environment which can be inferred by the presence of cross-beddings and current ripples. The middle part (Amdanda Phyllite) is considered to be deposited under some locally controlled deeper parts or lagoons. Similarly, the succession of Labdi Khola Member is considered to be deposited in intermediate depth to shallow depth and short term aerial exposure as well. Presence of rhythmic deposits on its topmost part clearly indicatesthe transgression stage of ocean which is also supported by the presence of mud-cracks in the sandy shale. However, locally distributed Bandipur Slate on the top of the Nourpul Formation might have been deposited on locally wave-controlled area within the deeper basin. Presence of columnar stromatolites in the Dhading Dolomite indicates its deposition on very shallow depths like beach lagoons, bays or tidal flats. Probably, the intra-formational fragment of the dolomite within the dolomite beds was deposited in the supra-tidal and intertidal flats associated with the coastal lagoons.The Benighat Slates can be considered as the deposition on the deeper oceanic environment below the active wavewith some episodic shallow environment as indicated by the presence of carbonates within the monotonous succession of finely laminated carbonaceous slates. The deposition of argillaceous material from the suspended load was probably in reducing environment as indicated by the black color of slates with pyrite crystals.

The overall succession seems to be deposited in a quite fluctuating depositional basin from deep and calm to fluvial dominated submarine deltaic to aerial exposures. It shows that in the past the depositional basin was unstable and there were the cycles of regression and transgression of the sea basin while depositing the Precambrian sediments of the Lesser Himalaya. Change in depositional basin is also indicated by tectonic environment as shown by the several basic intrusions concordant to the host rocks.

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