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Geological setting and lithostratigraphy of the Lesser Himalaya in the Mugling-Banspani area, central Nepal

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ABSTRACT

The Lesser Himalaya in central Nepal is a fold-and-thrust belt with a complex stratigraphy and structure. In the present study, detailed geological mapping was carried out in the Mugling-Banspani area based on stratigraphic units proposed by Stöcklin and Bhattarai (1977) to reveal the geological setting and lithostratigraphy of the area. The study shows that the area is occupied by the low-grade metasedimentary rocks of the Lower Nawakot Group. However, there are several discrepancies in classification of the rocks of the Lower Nawakot Group and their classification does not correspond with the field realities. The Anpu Quartzite thought to be the oldest unit of the Nawakot Complex laterally joins to the Fagfog Quartzite. Similarly, the Banspani Quartzite and Labdi Phyllite laterally join to the Purebensi Quartzite and Dandagaon Phyllite, respectively. Similarly, the Nourpul Formation is clearly divisible into three members with distinct lithological characteristics. Based on the above facts, a revised stratigraphic classification has been proposed for the rocks of the Lower Nawakot Group in the Mugling-Banspani area. The Lower Nawakot Group can be divided into the oldest Kunchha Formation followed up section by the Fagfog Quartzite (~Anpu Quartzite), Dandagaon Phyllite (~Labdi Phyllite), Nourpul Formation and Dhading Dolomite. The Nourpul Formation comprises three members namely the Purebensi Quartzite, the Amdanda Phyllite and the Labdi Khola Carbonate. The Jalbire Syncline, Mugling Anticline, Aklang Syncline and the Anpu Anticline are the major geological structures of the study area.

Keywords: Lithostratigraphy, Nawakot Complex, Lesser Himalaya, central Nepal

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INTRODUCTION

Nepal Himalaya is located in the central part of the 2400 km long Himalayan arc and covers the one third of its length. It is divided longitudinally into four tectonic zones, known as the Siwaliks, the Lesser Himalaya, the 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). 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 on a large scale (Valdiya 1980). Tectonically, the LH is made up of the autochthonous-paraautochthonous units, with various nappes, klippe and tectonic windows.

Central Nepal Himalaya is also a complex tectonic zone with several faults and folds. The area includes Mahabharat Synclinorium (Stöcklin and Bhattarai 1977, Stöcklin 1980) in the east; Gorkha-Kunchha Anticlinorium in the north (Arita et al. 1973, Pêcher 1977); Kanhu Syncline (Jnawali and Tuladhar 1996) in the north west; Tansen Synclinorium (Sakai 1985) in the south east 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 metasedimentary rocks of the Lesser Himalayan autochthonous zone in central Nepal are known as the Nawakot Complex (Stöcklin and Bhattarai 1977, Stöcklin 1980). The Nawakot Complex is sub-divided into the Lower and Upper Nawakot groups, separated by an erosional unconformity. Several researchers have carried out geological investigations in the central Nepal Lesser Himalaya and have contributed on stratigraphy of the area (Stöcklin and Bhattarai 1977; Stöcklin 1980; Sakai 1985; Hirayama et al. 1988; Dhital 1995; Jnawali and Tuladhar 1996; Paudel and Arita 2000, Dhital et al. 2002). However, there are still several problems and discrepancies on the stratigraphic classification of the Nawakot Complex. Many

parts of the Lesser Himalaya still lack detailed geological maps. Different authors have proposed different stratigraphic classifications even in a same section. This has created great problem not only for accurate correlation of the sequences in contiguous region but also for structural interpretation and tectonic evolution of the Lesser Himalaya as a whole. This problem points to the needs of reassessment of the stratigraphy of the Lesser Himalaya and prepare a unified and widely acceptable stratigraphic classification.

One of the main objectives of the present study is to fulfill the gap of detailed geological map in the Lesser Himalaya in central Nepal. In central Nepal, the eastern part is mapped in detail by Stöcklin and Bhattarai (1977), Stöcklin (1980); the northern part mapped by Dhital (1995); and western part mapped by Sakai (1985), Hirayama et al. (1988) and Dhital et al. (2002). The intervening area in Tanahu District, west of Mugling is still unmapped. Therefore, the Mugling-Banspani area was selected for detailed geological mapping in the present study and a geological map of the area was prepared in 1:25000 scale (Fig. 1). At the same time, stratigraphic classifications of the previous researchers in central Nepal were evaluated in the field. Wherever possible, attempts were made to adopt the stratigraphic units proposed by Stöcklin and Bhattarai (1977), Stöcklin (1980). The study shows that the classification of Stöcklin and Bhattarai (1977), Stöcklin (1980) for the Lower Nawakot Group does not correlate with the field realities and modification of their classification is necessary. A revised stratigraphic classification for Lower Nawakot Complex in the Mugling-Labdi area is purposed in this study.

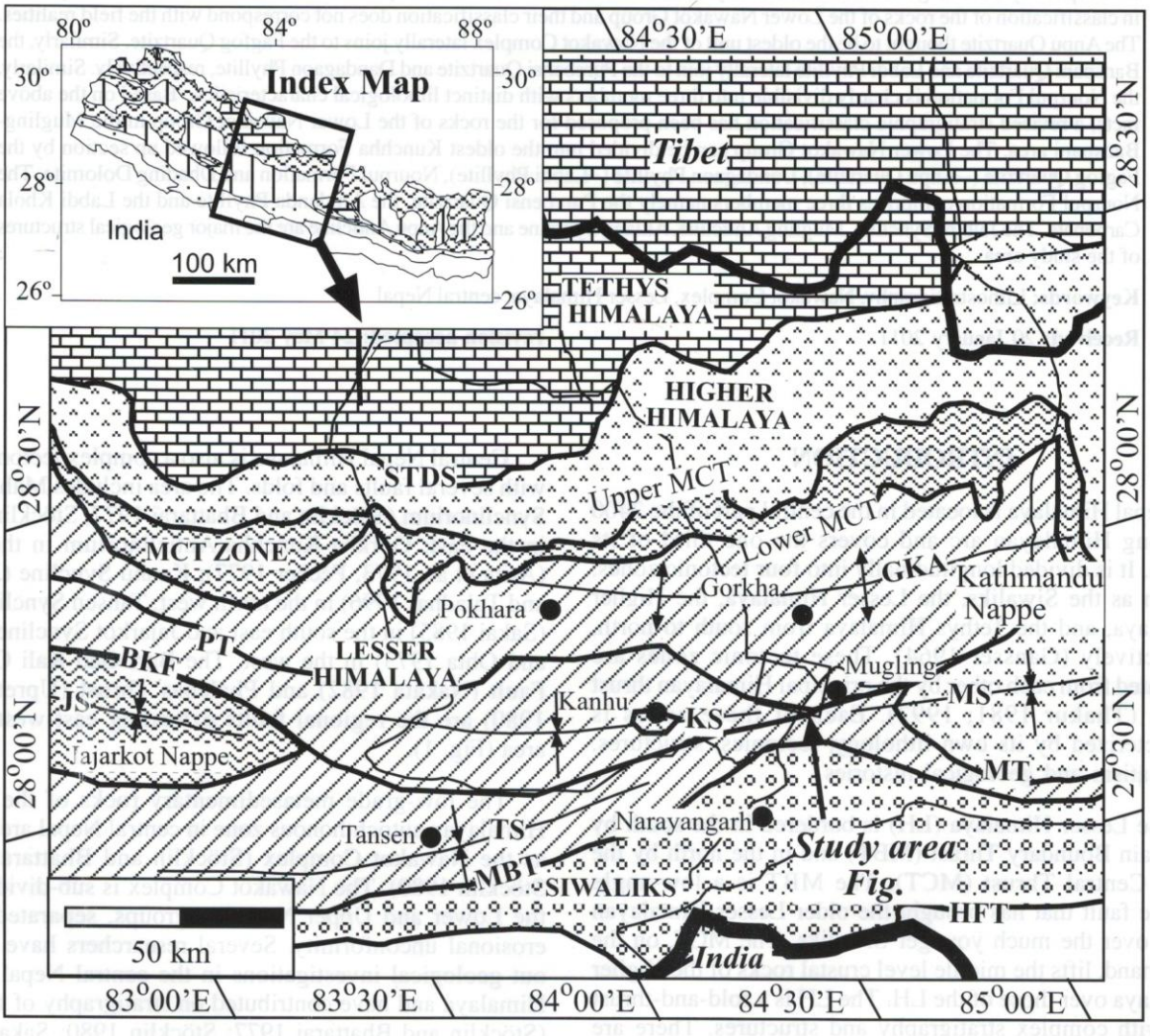

Fig. 1: Regional tectonic map of central Nepal Lesser Himalaya showing the location of the study area (modified after Paudel and Arita 2000). STDS: South Tibetan Detachment System, MCT: Main Central Thrust, MBT: Main Boundary Thrust, HFT: Himalayan Frontal Thrust, MT: Mahabharat Thrust, BKF: Bari Gad-Kali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

PREVIOUS WORKS

Many authors have included this area in their regional geological investigation of central Nepal (Auden 1934; Bordet et al. 1964; Hagen 1969; Arita et al. 1973; Colchen et al. 1980). However, very few researchers have shown stratigraphic details of the present study area. Stöcklin and Bhattarai (1977) and Stöcklin (1980) prepared a detailed geological map of the Mugling-Anbu Khaireni-Labdi area (Fig. 2). The area comprises the Kunchha Formation, Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation, Dhading Dolomite and Benighat Slate from bottom to top (Fig. 3). The Kunchha Formation comprises three members, oldest Anpu Quartzite followed by the Banspani Quartzite and the Labdi Phyllite, respectively. The Nourpul Formation contains a prominent quartzite member at the base (Purebensi Quartzite). The units have been repeated several times in the area by faults and folds. The western closure of the Mahabharat Synclinorium (Jalbire Syncline) is observed at Jalbire, southwest of Mugling.

Department of Mines and Geology has compiled the geological maps of the central Nepal Lesser Himalaya in 1:50,000 scale (DMG 1987). According to their map (Fig. 4), the oldest unit is Ranimatta Formation (Rm), an equivalent to the Kunchha Formation. Then Naudanda Formation (Nd), Ghanapokhara Formation (Gp), Galyang Formation (Gl) with Baitadi beds (Ba), Sangram Formation (Sg), Syangja Formation (Sy), and Lakharpata Formation, from stratigraphically bottom to the top, respectively. However, it is very difficult to correlate their units with that of Stöcklin and Bhattarai (1977).

Dhital (1995) carried out geological mapping in the Gorkha-Ampipal area, north of the present study area. The area from Anpu Khaireni to Gorkha is covered by the Kunchha Formation.

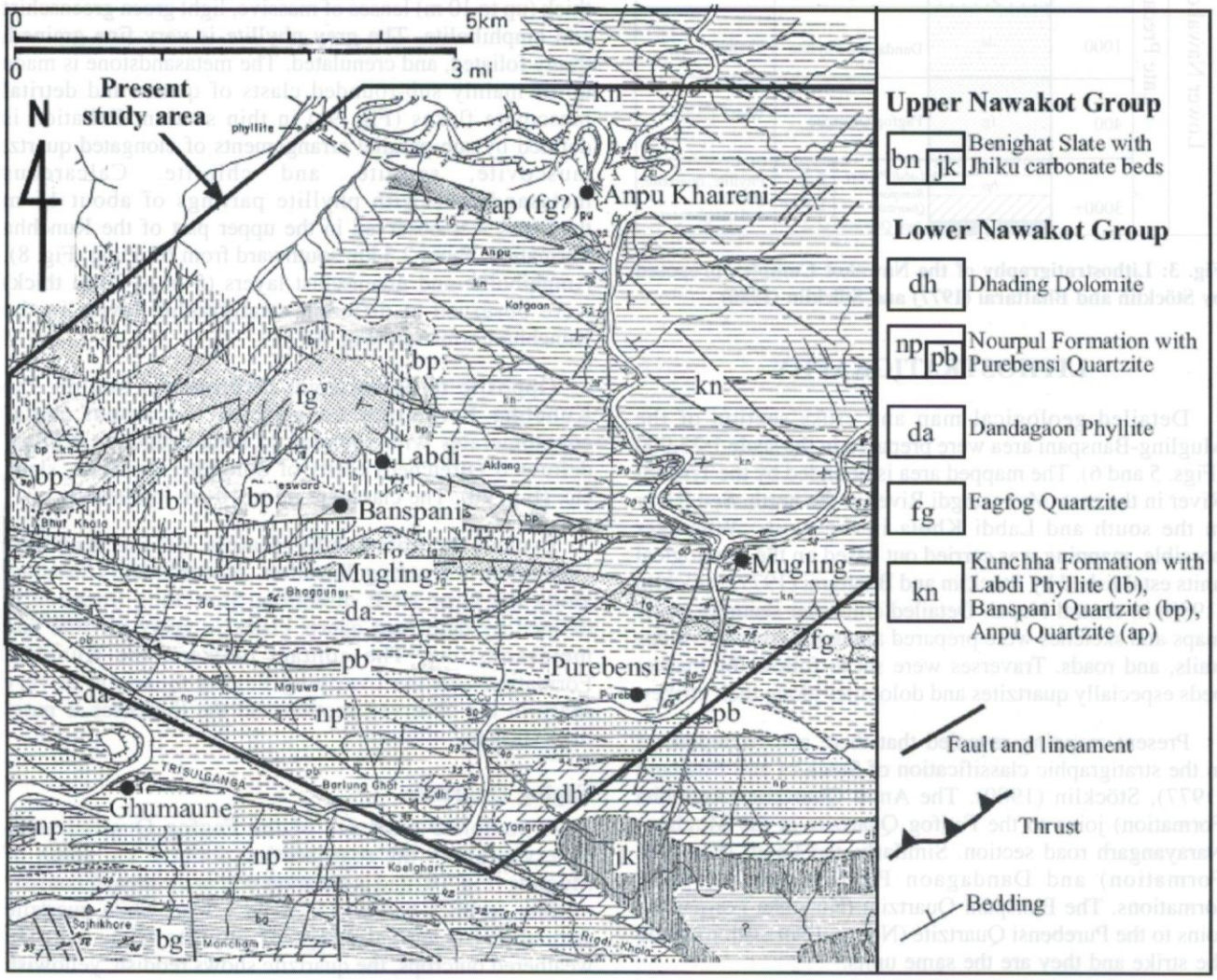

Fig. 2: Geological map of Mugling-Banspani-Anbu Khaireni area of the central Nepal Lesser Himalaya after Stöcklin and Bhattarai (1977). The present study area is marked.

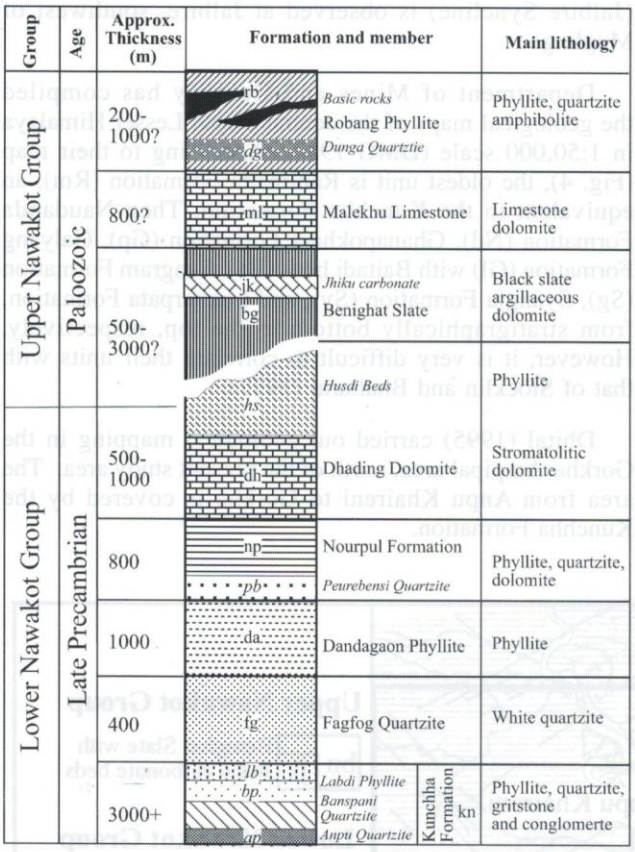

Fig. 3: Lithostratigraphy of the Nawakot Complex proposed by Stöcklin and Bhattarai (1977) and Stöcklin (1980)

LITHOSTRATIGRAPHY

Detailed geological map and cross section of the Mugling-Banspani area were prepared in the scale 1:25,000 (Figs. 5 and 6). The mapped area is bounded by the Trishuli River in the east, Marsyangdi River in the north, Seti River in the south and Labdi Khola in the west. Wherever possible, mapping was carried out based on the lithological units established by Stöcklin and Bhattarai (1977), Stöcklin (1980) in central Nepal. Detailed columnar sections, route maps and sketches were prepared along the rivers, rivulets, trails, and roads. Traverses were set to follow the marker beds especially quartzites and dolomites along their strikes.

Present mapping revealed that there are discrepancies in the stratigraphic classification of Stöcklin and Bhattarai (1977), Stöcklin (1980). The Anpu Quartzite (Kunchha Formation) joins to the Fagfog Quartzite at the Mugling-Narayangarh road section. Similarly, the Labdi (Kunchha Formation) and Dandagaon Phyllite are the same formations. The Banspani Quartzite (Kunchha Formation) joins to the Purebensi Quartzite (Nourpul Formation) along the strike and they are the same units.

Based on the above findings, a revised stratigraphic classification for the Lower Nawakot Group is proposed (Fig. 7). Characteristics of each unit are described below.Fig. 7

Kunchha Formation

The Kunchha Formation is well distributed in and around the Mugling-Manakamna-Anbu Khaireni area (Fig. 5). It forms comparatively smooth ridges with rather gentle spurs and valley slopes. In the study area, only the upper part of the Kunchha Formation is exposed along the motor road and river section. A detailed columnar section of the upper part of the Kunchha Formation exposed along the Mugling-Narayangarh road is given in Fig. 8. The formation consists of green-grey, medium- to coarse-grained metasandstone, blue-green to grey phyllite, grey to yellowish-grey, fine- to medium-grained quartzite and green-grey to light grey gritty phyllite. The metasandstones are medium- to thick-bedded (50 cm to 2 m) with faint laminations.

The Kunchha Formation also comprises a sporadic interbanding of coarse-grained metaconglomerates and thick (up to 10 m) lenses of massive, light green greenschist and amphibolite. The grey phyllite is very fine grained, thinly foliated, and crenulated. The metasandstone is made up of mainly sub-rounded clasts of quartz and detrital muscovite flakes (Fig. 9a) in thin section. Foliation is defined by sub-parallel arrangements of elongated quartz, muscovite, sericite, and chlorite. Calcareous metasandstone with phyllite partings of about 15 m thickness was observed in the upper part of the Kunchha Formation, about 2.5 km southward from Mugling (Fig. 8). Amphibolite and greenschist layers (5 m to 20 m thick) were observed at different stratigraphic levels in the Kunchha Formation (Fig. 8).

Opposite to Marsyangdi Hydropower station, the Kunchha Formation consists of calcareous meta-conglomerates with rounded to semi-rounded, strongly deformed (stretched) clasts of dolomite, quartzite, slate, etc. (Fig. 9b). The clasts are up to 10 cm in diameter.

Especially noteworthy feature of the Kunchha Formation is a strong lineation, predominantly oriented along the N or NNE direction. Stretching lineation is defined by deformed quartz clasts in gritty phyllite and metasandstone. The contact between the Kunchha Formation and the overlying Fagfog Quartzite is very sharp in the observed section and the thickness is more than 1000 m.

Fagfog Quartzite

A complete sequence of the Fagfog Quartzite was observed along the road section about 2 km south of Mugling (Fig. 10) and is a marker unit in the area. It consists of thin- to thick-bedded (5 cm to 1.5 m) white quartzite with thin (~1 cm) partings of phyllite (Fig. 11a). In weathered outcrops, the quartzite shows reddish, yellowish or pale orange colour. The beds are usually parallel and continuous to several meters. Graded beddings, parallel- and cross-laminae (Fig. 11b) and ripple marks are the

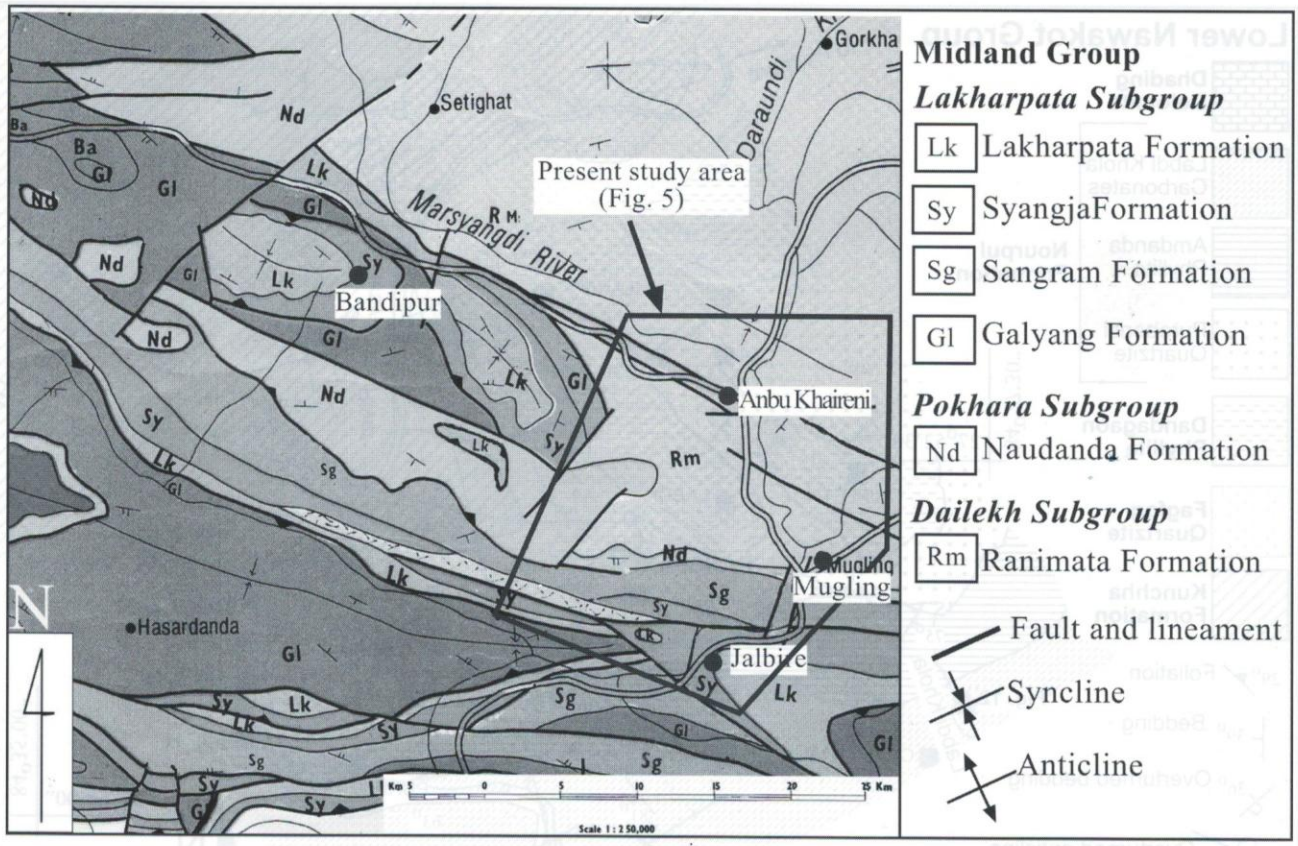

Fig. 4: Geological map of the Mugling-Bandipur area of central Nepal Lesser Himalaya after DMG (1987). The present study area is marked.

prominent sedimentary structures observed in the lower and middle parts of the unit. Coatings of malachite and azurite are observed on the outcrops of white quartzite near the Marsyangdi Hydropower station and south of Anpu Khaireni indicating possible cupper mineralization in this formation. The phyllite alternating with quartzite shows silky luster and soapy weathering surface due to the presence of chlorite and sericite.

The Fagfog Quartzite uninterruptedly extends westwards from Mugling to Loprang, Marsyangdi Hydropower station and Anpu Khaireni. It forms a broad anticline in between Mugling and Anbu Khaireni and an overturned syncline exposed to north of the Hydropower station (Fig. 5). The Fagfog Quartzite is followed up section by the Dandagaon Phyllite with very sharp contact. The thickness of the unit is about 400 m.

Dandagaon Phyllite

The Dandagaon Phyllite is extensively distributed to south and south-west of Mugling along the Mugling-Narayangarh road section and around the villages of Loprang, Labdi, and Aklang (Fig. 5). The lower part of the Dandagaon Phyllite comprises black phyllite, gritty phyllite, calcareous phyllite and dirty grey quartzite. This is followed by a thick sequence (100 m) of non-calcareous grey, bluish grey and dark grey laminated soapy phyllite with some intercalations of sandy phyllite. The upper part of the Dandagaon Phyllite consists of alternating bands of finely foliated black phyllite and grey gritty phyllite (Fig. 12). The beds are usually very thin to thin (1 cm to 10 cm). Dolomite bands with thickness less than 5 cm are also found intercalated with phyllite and dirty quartzite.

The Labdi area is extensively covered by light grey laminated phyllite with cleavage developed oblique to the laminations. Stöcklin and Bhattarai (1977), Stöcklin (1980) mapped this phyllite as a member of Kunchha Formation (Labdi Phyllite member). However, present mapping shows that the Labdi Phyllite is a direct continuation of the Dandagaon Phyllite observed in the Mugling-Narayangarh road section (Fig. 5). The Dandagaon Phyllite is exposed as an inlier at Chipleti.

The Dandagaon Phyllite is followed up section by the Purebensi Quartzite (Nourpul Formation) with a sharp and conformable contact. The thickness of the Dandagaon Phyllite is about 200 m.

Nourpul Formation

The Nourpul Formation is exposed extensively in the study area. Based on lithological characteristics, the

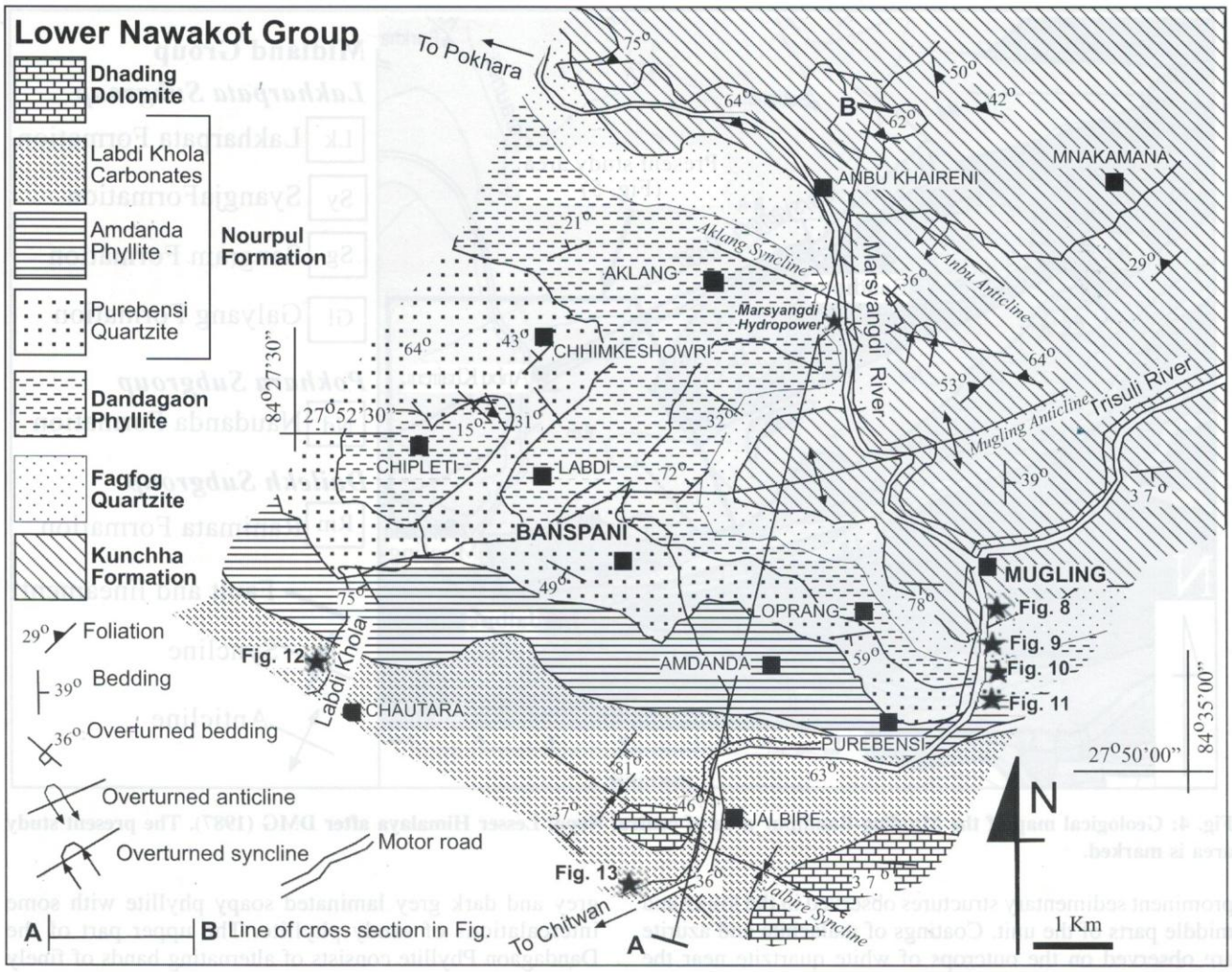

Fig. 5: Geological map of the Mugling-Banspani area of the central Nepal Lesser Himalaya prepared in the present study. A-B: Line of cross-section in Fig. 6. Locations of detailed columnar sections in Figs. 8-13 are shown in the map.

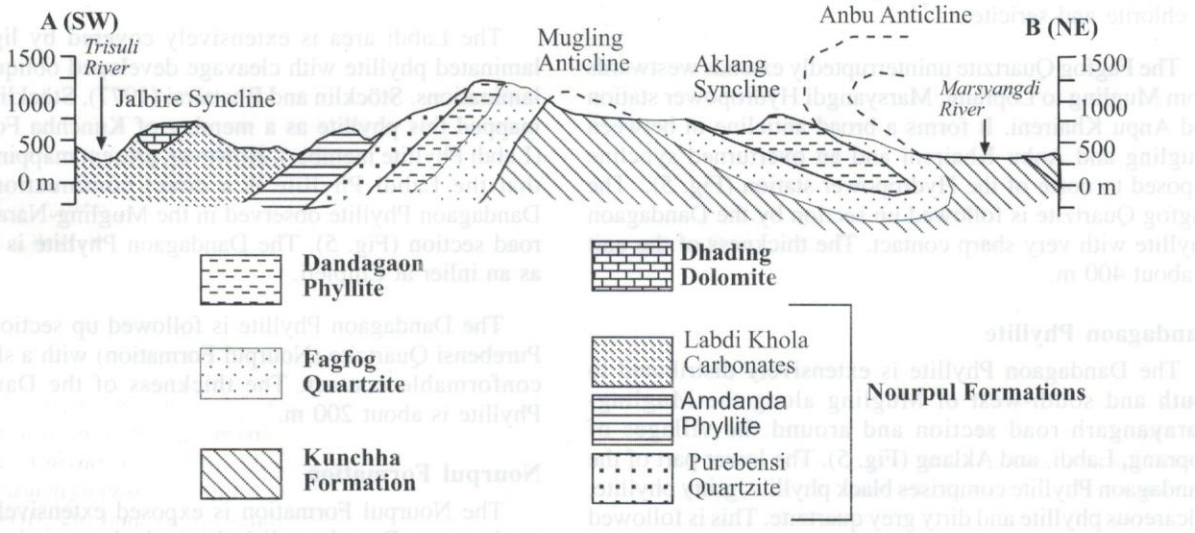

Fig. 6: Geological cross-section of the present study area along A-B in Fig. 5

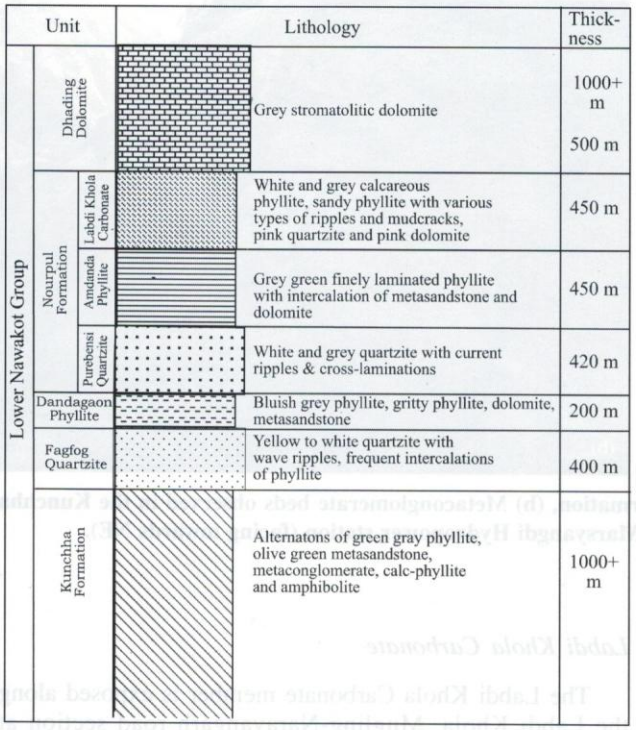

Fig. 7: Revised lithostratigrphy of the Lower Nawakot Group in the present study area. See the stratigraphic classification of Stöcklin and Bhattarai (1977) in Figs. 3 and 16 for comparison.

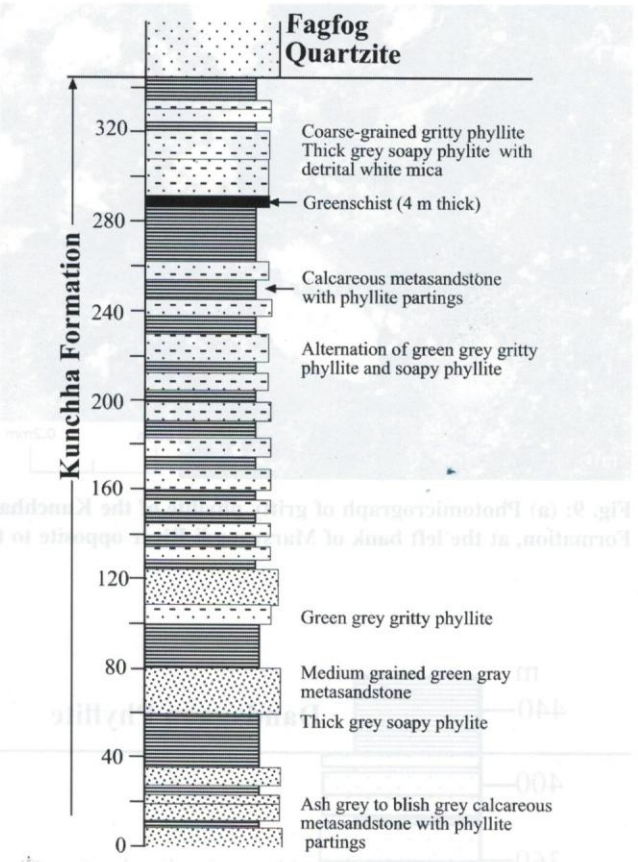

Fig. 8: Columnar section of the upper part of Kunchha Formation along the Mugling-Narayangarh road. See Fig. 5 for location of the column.

Nourpul Formation is divided into three members from bottom to top as the Purebensi Quartzite, Amdanda Phyllite, and Labdi Khola Carbonate, respectively. They have unique lithology and the boundaries between them are clearly discernible in the field.

Purebensi Quartzite

The Dandagaon Phyllite is sharply followed up section by the Purebensi Quartzite (Fig. 13). It is observed along the road section and continues westward to Banspani (Fig. 14a), Chipleti and Chhimkeshowri. In the road section, it is very steep topography (about 70-80° inclination) and covers only a narrow section. But in the Banspani-Chhimkeshowri area the dip becomes gentle and quartzite covers an extensive area. This unit is dominated by green-grey to light grey, parallel- and cross-laminated quartzite (90 %). The Purebensi Quartzite is coarse-grained, medium- to thick-bedded (3.0 cm-1.3 m) with abundant wave and current ripples. A faint weathering on quartzite shows brown, yellow and rusting coloration. In the Chhimkeshowri area, the quartzite is light-grey, thick-bedded (>1 m) with abundant wave ripple marks (Fig. 14b) and parallel- and cross-laminae. The quartzite is intercalated with frequent bands of grey phyllite up to 10 m thickness.

Massive, deep green amphibolite and greenschist bodies are found within the Purebensi Quartzite at different places. Along the road section from Mugling to Narayangarh it is about 5 m and near to Loprang it is up to 45 m. Laterally, some bands are continuous and some bands pinch out at places. The total thickness of Purebensi Quartzite is about 440 m in road section (Fig. 13). It is sharply followed up section by a monotonous phyllite sequence of the Amdanda Phyllite.

Amdanda Phyllite

The Amdanda Phyllite represents the middle part of the Nourpul Formation and is well-exposed in the Amdanda village about 9 km southwest of Mugling (Fig. 5). The Amdanda Phyllite extends westwards to the Labdi Khola. It consists of finely laminated (2 mm to 1 cm), grey, psamatic phyllite. In many exposures, phyllite alternates with greenish grey, laminated, thin- to medium-bedded (5 to 50 cm) metasandstone. The color of phyllite is bluish green in places with vivid yellow, pink, purple and violet variations in weathered condition. Quartz veins are frequent and show the cross-cutting relation with laminae. Total thickness of this unit is about 450 m and it passes transitionally into Labdi Khola Carbonate.

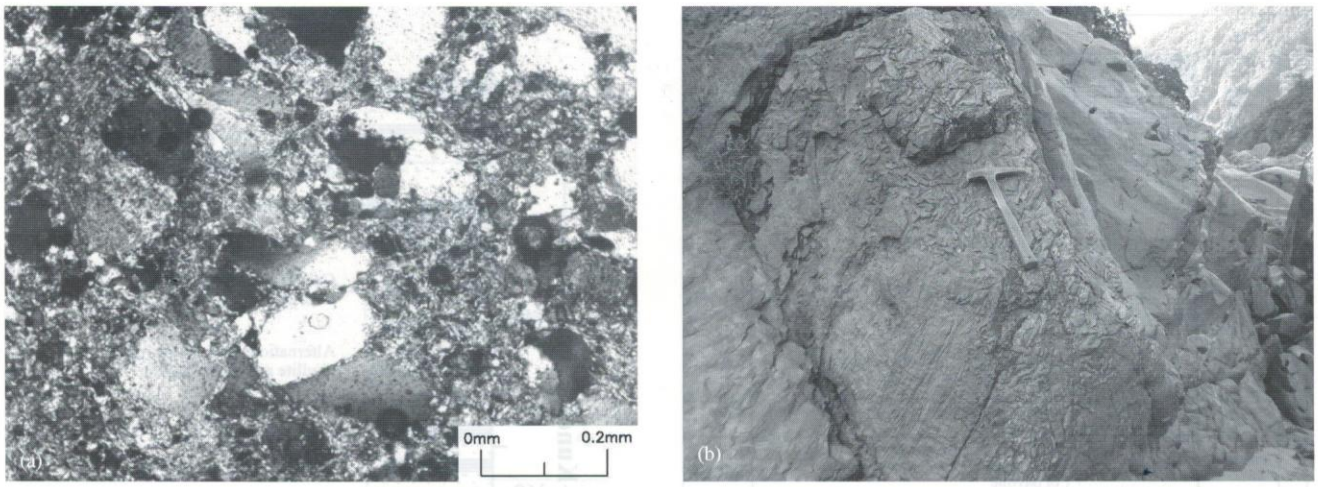

Fig. 9: (a) Photomicrograph of gritty phyllite of the Kunchha Formation, (b) Metaconglomerate beds observed in the Kunchha Formation, at the left bank of Marsyangdi River opposite to the Marsyangdi Hydropower station (facing towards NE).

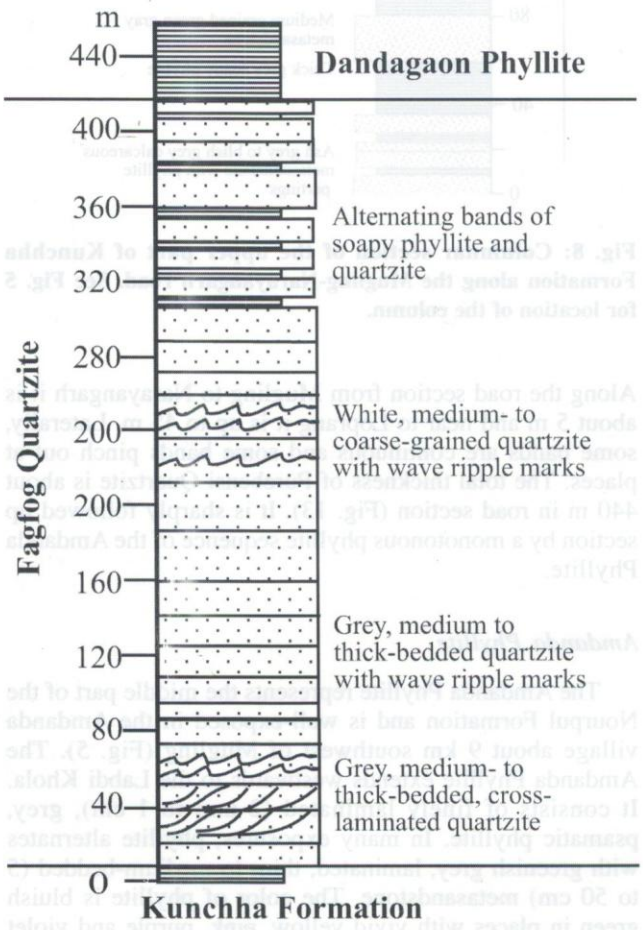

Fig. 10: Columnar section of the Fagfog Quartzite along the Mugling-Narayangarh road. See Fig. 5 for location of the column.

Labdi Khola Carbonate

The Labdi Khola Carbonate member is exposed along the Labdi Khola, Mugling-Narayangarh road section at Jalbire and along the Trishuli River at 9 km southwards from Mugling (Fig. 5). Detailed lithlology of the Labdi Khola Carbonate member is shown in Fig. 15 (along the Labdi Khola) and Fig. 16 (at 9 km west from Mugling). This member is a mixed lithology of dominantly carbonates (dolomite, limestone, and calc-quartzite) with sub-ordinate amount of variegated gritty phyllite and metasandstone (Fig. 17a). Some bands of greenschist (17 m thick) and hematite (1 cm - 4 m thick) are found at the lower part of the Labdi Khola Carbonate member. Dolomite is light grey to pink and medium- to thick-bedded (50 cm - 2 m) without any algal structures. The phyllite in this unit comprises polygonal and deformed mud-cracks showing right-side-up stratigraphic position (Fig. 17b). The gritty phyllite contains sinuous and linguid ripple marks. The uppermost part of this sequence is composed of alternation of thin- to medium-bedded (10-50 cm) pink siliceous dolomite and pink quartzite. Then the sequence sharply passes into the Dhading Dolomite at the southeastern part of the study area (at Jalbire). The thickness of the Labdi Khola Carbonate is about 450 m.

Dhading Dolomite

Dhading Dolomite is exposed approximately 4 km south east of Jalbire. It forms a small outlier in the ridge, west of Jalbire. It is a ridge-forming unit of the terrain and consists of grey, medium- to thick-bedded, massive dolomite with frequent partings of grey chloritic phyllite (Fig. 17c). Algal mats are distinctly observed mostly in siliceous dolomite. The laminae are from 1 mm to 1 cm thick, continuous, parallel to sub-parallel, grey to dark grey in colour. They are distinct in slightly weathered surfaces. There are also calcite veins of various generations. Dolomite beds

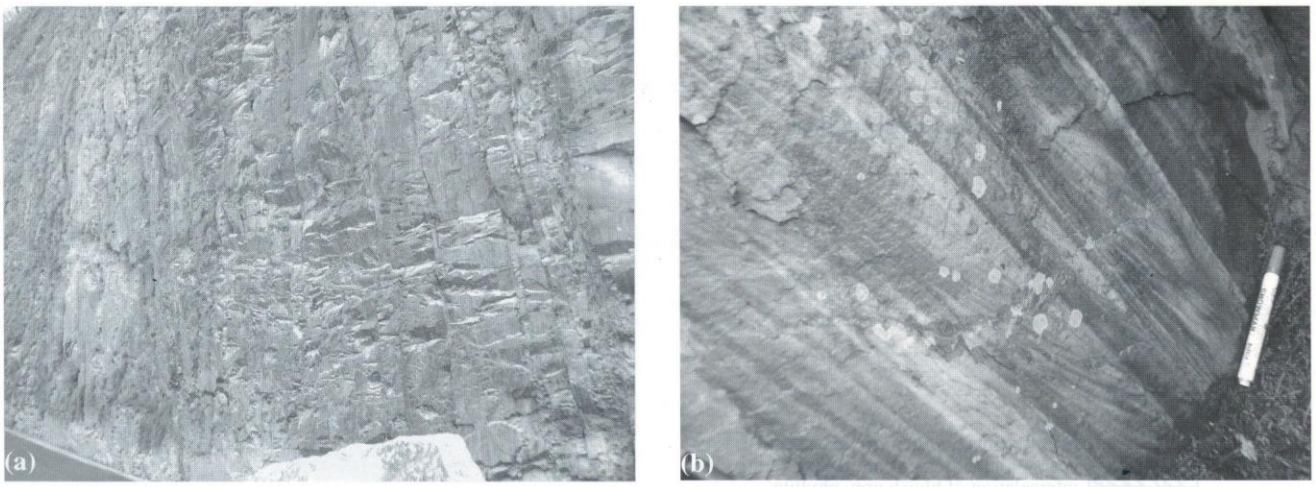

Fig. 11: (a) Outcrop view of the Fagfog Quartzite along the Mugling-Narayangarh road approximately 3 km west of Mugling (facing towards E), (b) Cross-laminations in the Fagfog Quartzite approximately 3 km south of Mugling (facing towards E)

occasionally contain columnar type of stromatolites pointing right-side up. Several leaching features, crustifications on outcrops, and stalactites and stalagmites are observed in well-developed caves, west of Jalbire.

STRUCTURES

There are four E-W trending major folds in the area (Figs. 5 and 6). The axial trace of the Jalbire Syncline (western closure of the Mahabharat Synclinorium) passes about 1 km south of Jalbire. The core of the syncline is occupied by the Dhading Dolomite. The fold plunges 7^0 to the ESE with trend of 98^0. The Nourpul Formation is repeated along the road by this fold. The axis of the Mugling Anticline passes from about 4 km north of Mugling. The anticline plunges to the 6° with trend of 260° (WSW). The Aklang Syncline is an overturned fold with both of its limbs dipping towards north. The axis of the fold passes from just north of the Marsyangdi Hydropower station. The axis of the fold is trending WNW-ESE. The Anbu anticline passes from north of Anbu Khaireni. This is also an overturned syncline both of its limbs dipping to the north.

DISCUSSIONS ON STRARTIGRAPHIC DIVISION OF THE LOWER NAWAKOT GROUP

One of the problems of stratigraphic correlation in the Lesser Himalaya is that the stratigraphic units have been defined on the basis of lithology only. Most of the units are unfossiliferous, and radiometric data are rare. Lithological characteristics extensively vary laterally. Deep weathering also adds confusion on identification of rocks (e. g., slates appearing charcoal black in the river cut section and appear to be light ash-grey coloured in the ridges). Other rock types such as quartzite, dolomite and metasandstone also show similar kind of complications. Stöcklin and Bhattarai (1977) also realized these facts and suggested

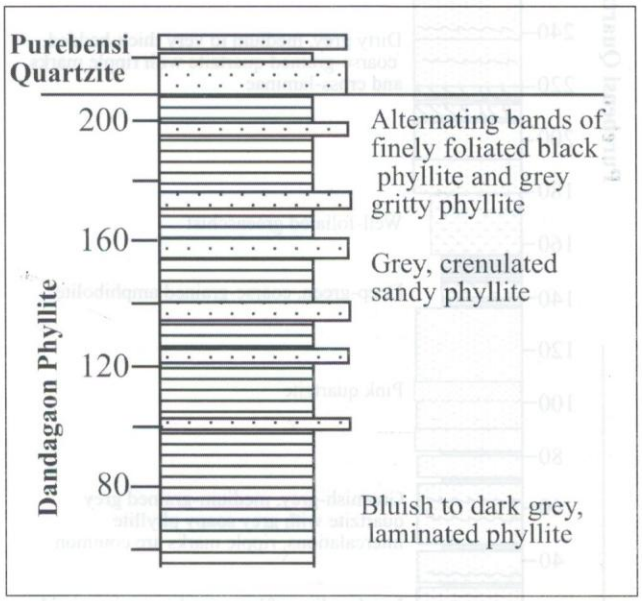

Fig. 12: Columnar section of the Dandagaon Phyllite along the Mugling-Narayangarh road. See Fig. 5 for location of the column

that "the identity of a rock unit is fully ascertained only if the exposure is linked through uninterrupted outcrop with the type section. The criterion of similarity is subjective in correlation of the Lesser Himalayan Formations". Therefore, in the present mapping we made an attempt to follow the units of Stöcklin and Bhattarai (1977) westward along strike from Mugling and link them to the type localities.

The study shows some discrepancies in the stratigraphic classification of Stöcklin and Bhattarai (1977) and Stöcklin (1980). They are:

(1) The Anpu Quartzite of the Kunchha Formation with suspicious stratigraphic position is in reality the westward

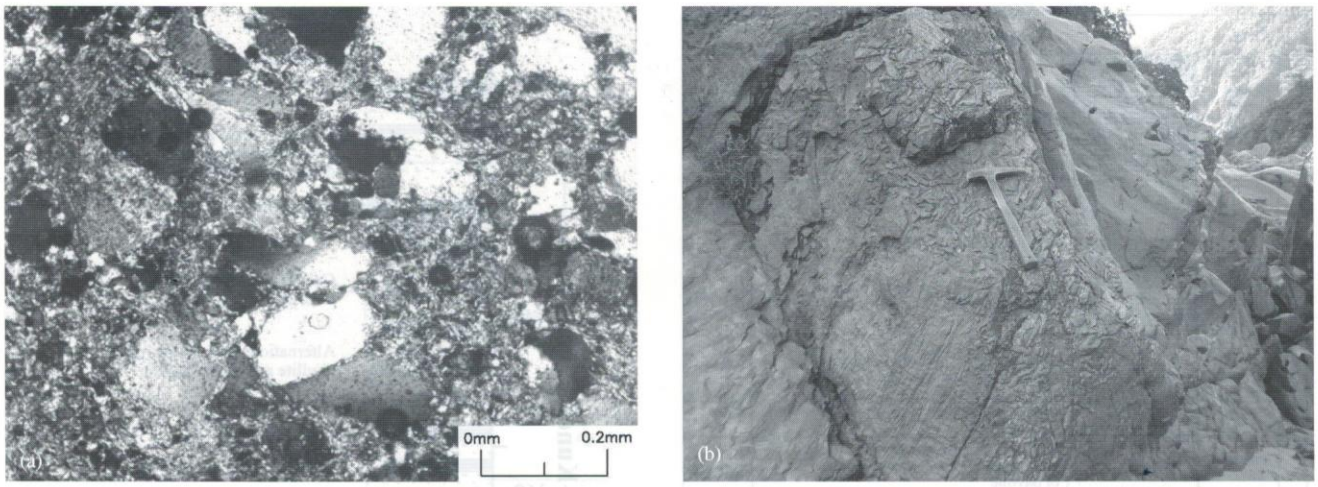

Fig. 9: (a) Photomicrograph of gritty phyllite of the Kunchha Formation, (b) Metaconglomerate beds observed in the Kunchha Formation, at the left bank of Marsyangdi River opposite to the Marsyangdi Hydropower station (facing towards NE).

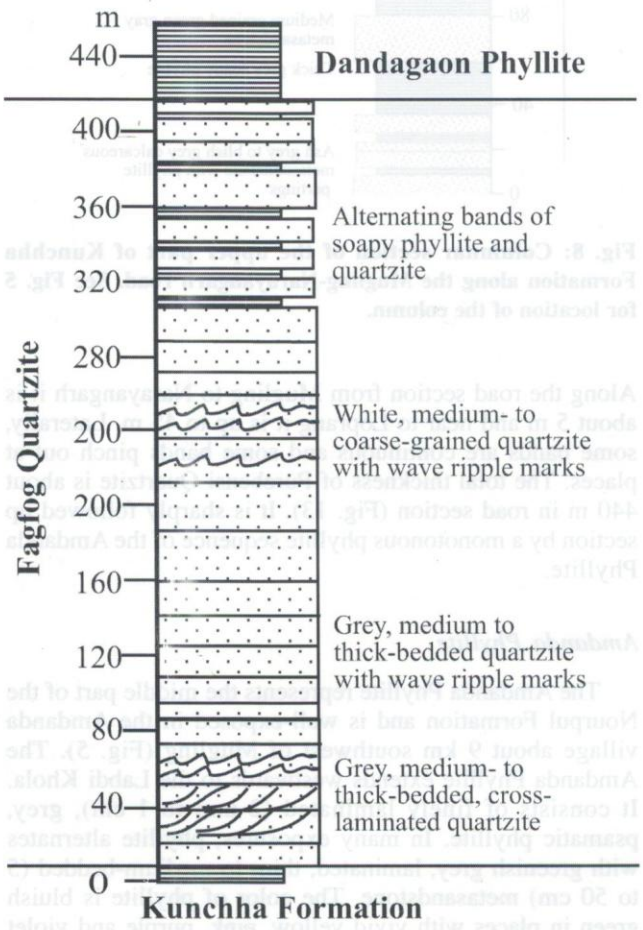

Fig. 10: Columnar section of the Fagfog Quartzite along the Mugling-Narayangarh road. See Fig. 5 for location of the column.

Labdi Khola Carbonate

The Labdi Khola Carbonate member is exposed along the Labdi Khola, Mugling-Narayangarh road section at Jalbire and along the Trishuli River at 9 km southwards from Mugling (Fig. 5). Detailed lithlology of the Labdi Khola Carbonate member is shown in Fig. 15 (along the Labdi Khola) and Fig. 16 (at 9 km west from Mugling). This member is a mixed lithology of dominantly carbonates (dolomite, limestone, and calc-quartzite) with sub-ordinate amount of variegated gritty phyllite and metasandstone (Fig. 17a). Some bands of greenschist (17 m thick) and hematite (1 cm - 4 m thick) are found at the lower part of the Labdi Khola Carbonate member. Dolomite is light grey to pink and medium- to thick-bedded (50 cm - 2 m) without any algal structures. The phyllite in this unit comprises polygonal and deformed mud-cracks showing right-side-up stratigraphic position (Fig. 17b). The gritty phyllite contains sinuous and linguid ripple marks. The uppermost part of this sequence is composed of alternation of thin- to medium-bedded (10-50 cm) pink siliceous dolomite and pink quartzite. Then the sequence sharply passes into the Dhading Dolomite at the southeastern part of the study area (at Jalbire). The thickness of the Labdi Khola Carbonate is about 450 m.

Dhading Dolomite

Dhading Dolomite is exposed approximately 4 km south east of Jalbire. It forms a small outlier in the ridge, west of Jalbire. It is a ridge-forming unit of the terrain and consists of grey, medium- to thick-bedded, massive dolomite with frequent partings of grey chloritic phyllite (Fig. 17c). Algal mats are distinctly observed mostly in siliceous dolomite. The laminae are from 1 mm to 1 cm thick, continuous, parallel to sub-parallel, grey to dark grey in colour. They are distinct in slightly weathered surfaces. There are also calcite veins of various generations. Dolomite beds

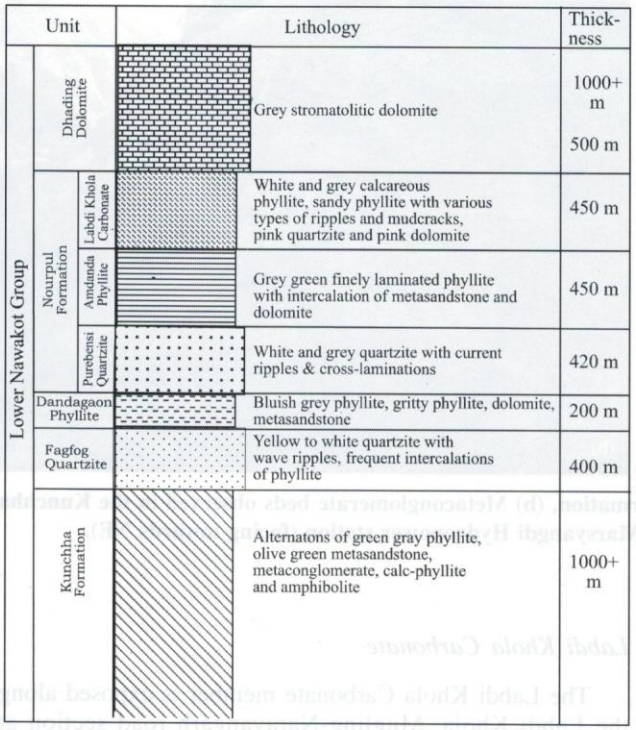

Fig. 7: Revised lithostratigrphy of the Lower Nawakot Group in the present study area. See the stratigraphic classification of Stöcklin and Bhattarai (1977) in Figs. 3 and 16 for comparison.

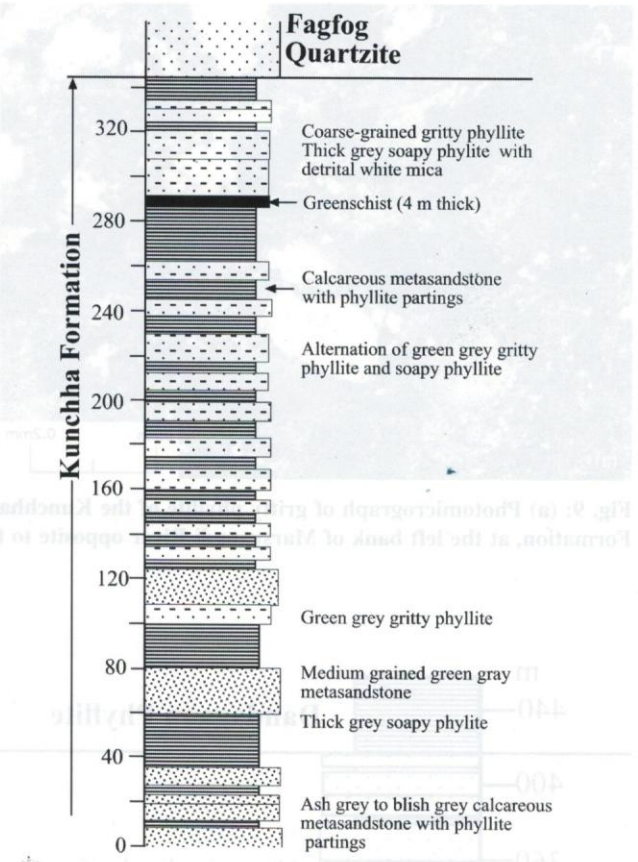

Fig. 8: Columnar section of the upper part of Kunchha Formation along the Mugling-Narayangarh road. See Fig. 5 for location of the column.

Nourpul Formation is divided into three members from bottom to top as the Purebensi Quartzite, Amdanda Phyllite, and Labdi Khola Carbonate, respectively. They have unique lithology and the boundaries between them are clearly discernible in the field.

Purebensi Quartzite

The Dandagaon Phyllite is sharply followed up section by the Purebensi Quartzite (Fig. 13). It is observed along the road section and continues westward to Banspani (Fig. 14a), Chipleti and Chhimkeshowri. In the road section, it is very steep topography (about 70-80° inclination) and covers only a narrow section. But in the Banspani-Chhimkeshowri area the dip becomes gentle and quartzite covers an extensive area. This unit is dominated by green-grey to light grey, parallel- and cross-laminated quartzite (90 %). The Purebensi Quartzite is coarse-grained, medium- to thick-bedded (3.0 cm-1.3 m) with abundant wave and current ripples. A faint weathering on quartzite shows brown, yellow and rusting coloration. In the Chhimkeshowri area, the quartzite is light-grey, thick-bedded (>1 m) with abundant wave ripple marks (Fig. 14b) and parallel- and cross-laminae. The quartzite is intercalated with frequent bands of grey phyllite up to 10 m thickness.

Massive, deep green amphibolite and greenschist bodies are found within the Purebensi Quartzite at different places. Along the road section from Mugling to Narayangarh it is about 5 m and near to Loprang it is up to 45 m. Laterally, some bands are continuous and some bands pinch out at places. The total thickness of Purebensi Quartzite is about 440 m in road section (Fig. 13). It is sharply followed up section by a monotonous phyllite sequence of the Amdanda Phyllite.

Amdanda Phyllite

The Amdanda Phyllite represents the middle part of the Nourpul Formation and is well-exposed in the Amdanda village about 9 km southwest of Mugling (Fig. 5). The Amdanda Phyllite extends westwards to the Labdi Khola. It consists of finely laminated (2 mm to 1 cm), grey, psamatic phyllite. In many exposures, phyllite alternates with greenish grey, laminated, thin- to medium-bedded (5 to 50 cm) metasandstone. The color of phyllite is bluish green in places with vivid yellow, pink, purple and violet variations in weathered condition. Quartz veins are frequent and show the cross-cutting relation with laminae. Total thickness of this unit is about 450 m and it passes transitionally into Labdi Khola Carbonate.

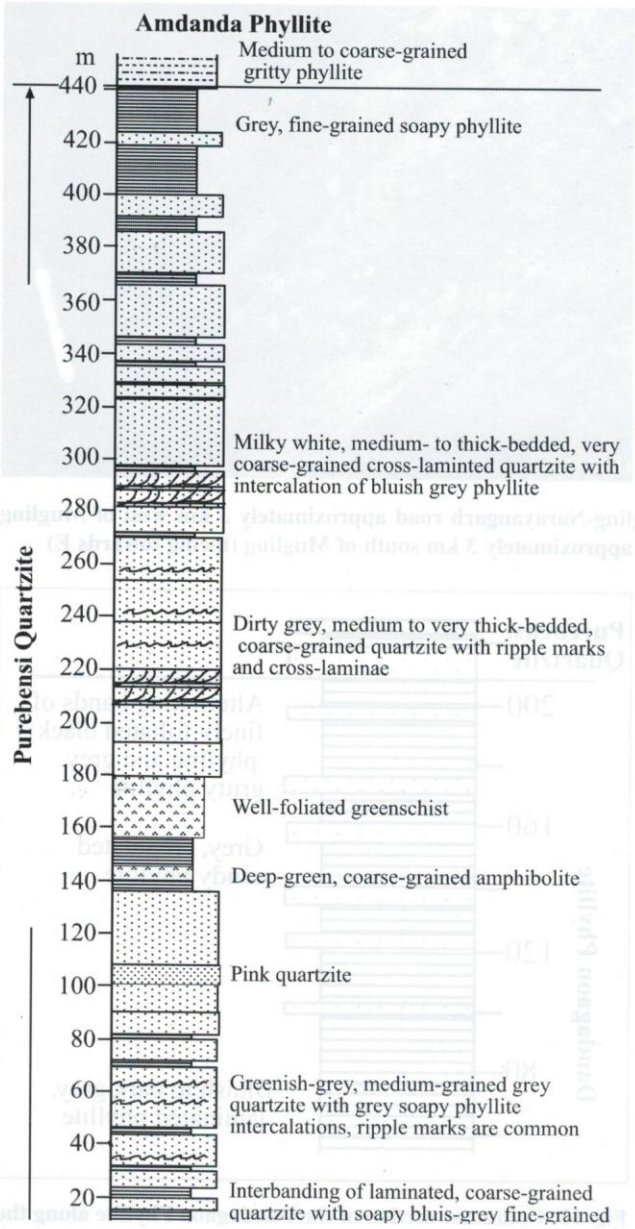

Fig.13: Columnar section of the Purebensi Quartzite observed along the Mugling-Narayangarh road. See Fig. 5 for location of the column.

extension of Fagfog Quartzite. This is confirmed by the fact that they have similar lithology, occupy the same stratigraphic position and laterally join to each other as shown in the geological map.

(2) Banspani Quartzite is not the oldest unit of the Kunchha Formation. This is the westward extension of the Purebensi Quartzite which is conformed by mapping the quartzite unit along its strike. It occupies the position above the Dandagaon Phyllite and has lithology, similar to the Purebensi Quartzite.

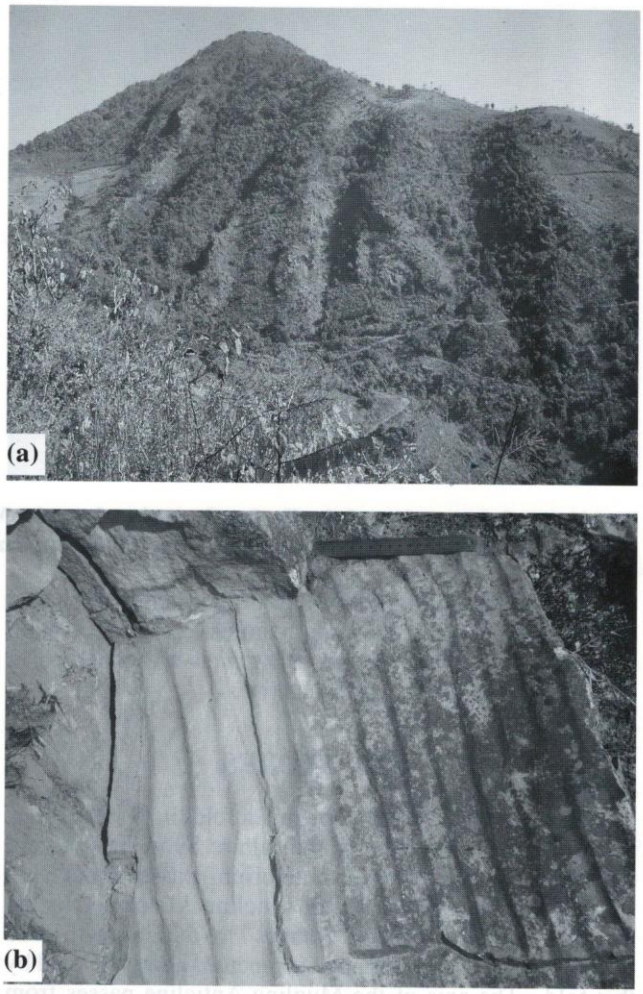

Fig.14: (a) Outcrop view of Purebensi Quartzite at Banspani (view towards east from Chipleti), and (b) wave ripples in Purebensi Quartzite observed at Chhimkeshowri (facing towards E).

(3) Stöcklin (1980) has shown the Labdi Phyllite at the upper part of the Kunchha Formation. However, it is above the Fagfog Quartzite and has lithology, similar to the Dandagaon Phyllite. Continuous mapping of the Dandagaon Phyllite from Mugling to Labdi also shows that they are the same units.

(4) Kunchha Formation is not entirely non-calcareous as noted by Stöcklin (1980). It comprises calcareous phyllite, measandstone, metaconglomerate, and grey phyllite.

(5) The Nourpul Formation is clearly divisible into three units: lower quartzite member (Purebensi Quartzite), middle phyllite member (Amdanda Phyllite) and upper carbonate member (Labdi Khola Carbonate).

Therefore, stratigraphic classification by Stöcklin and Bhattarai (1977), Stöcklin (1980) for the Lower Nawakot Group in the study area has been revised (Fig. 7) to address

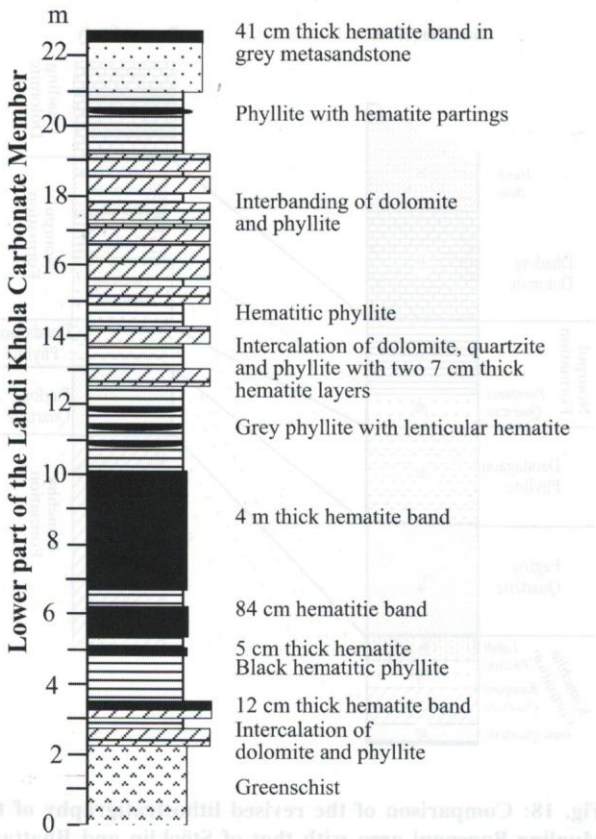

Fig. 15: Columnar section of the lower part of the Labdi Khola Carbonate exposed along the Labdi Khola approximately 200 m upstream from the junction of the Labdi Khola and the Seti River. See Fig. 5 for location of the column.

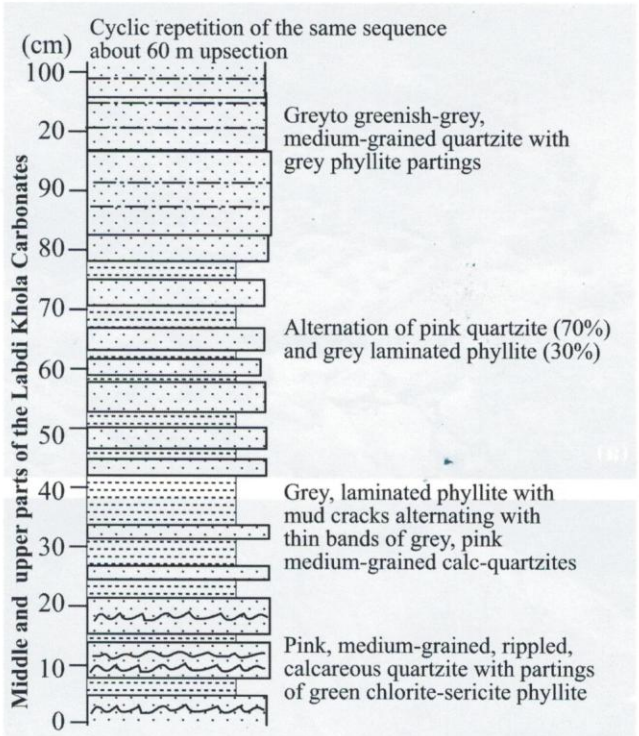

Fig.16: Detailed columnar section of the middle and upper part of the Labdi Khola Carbonate depicting cyclic repetition of the laminated phyllite, dolomite and calc-quartzite. See Fig. 5 for location of the column. See Fig. 15b for field photograph.

the present observations. Comparison of the revised stratigraphic classification with that of Stöcklin (1980) is shown in Fig. 18.

CONCLUSIONS

Detailed geological mapping was carried out in the Lesser Himalaya of Mugling-Banspani area, central Nepal. The area comprises low-grade metasedimentary rocks of the Lower Nawakot Group, Nawakot Complex. The mapping was carried out by extending the units of Stöcklin and Bhattarai (1977), westward along strike from Mugling and linking them with the type localities. It shows that revision of stratigraphic classification of the Lower Nawakot Group by Stöcklin and Bhattarai (1977) is necessary. Main discrepancies in his classification are that the Anpu Quartzite does not occupy the base of Nawakot Complex but this is an equivalent to the Fagfog Quartzite, the Banspani Quartzite is equivalent to the Purebensi Quartzite, and the Labdi Phyllite is equivalent to the Dandagaon Phyllite. Based on the above observations, a revised stratigraphic classification for the Lower Nawakot Complex has been proposed for the area.

The Kunchha Formation is the oldest unit comprising a monotonous sequence of phyllite, gritty phyllite, metasandstone, calcareous phyllite and metaconglomerate. The Fagfog Quartzite (~Anpu Quartzite, 400 m) is composed of white quartzite and uninterruptedly extends from Mugling to Anpu Khaireni. The Dandagaon Phyllite (~Labdi Phyllite, 200 m) is made up of alternations of laminated black phyllite, gritty phyllite, metasandstone, dolomite and quartzite. The Nourpul Formation can be divided into three members. The Purebensi Quartzite (~Banspani Quartzite, 420 m) is the lower member consisting of grey to white quartzite with phyllite and amphibolite/greenschist. The middle Amdanda Phyllite member comprises grey, finely laminated phyllite and metasandstone with sporadic layers of dolomite. The upper Labdi Khola Carbonate member is a mixed lithology of grey and pink dolomite, pink quartzite, phyllite, greenschist and amphibolite. This unit is also characterized by several hematite bands and copper mineralization. The youngest unit is the ridge-forming Dhading Dolomite. The Jalbire Syncline, Mugling Anticline, Aklang Syncline and the Anpu Anticline are the major geological structures of the study area.

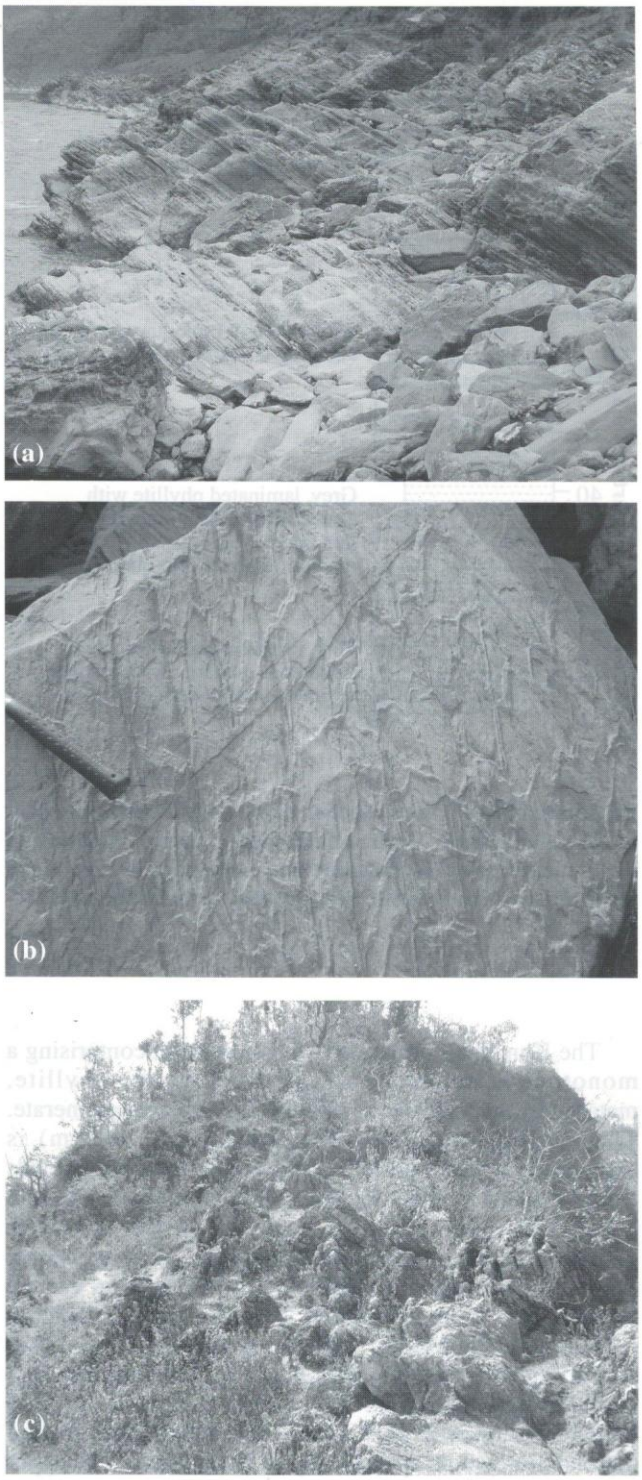

Fig.17: Field photographs. (a) Alternations of variegated phyllite and calc-quartzite of the lower part of the Labdi Khola Carbonate observed at 9 km from Mugling to Narayangarh (see column in Fig. 13) (facing towards SW), (b) Mud-cracks in grey phyllite of the upper part of the Labdi-Khola Carbonate, observed at the right bank of the Trisuli River at Jalbire, south of Mugling (facing towards south), and (c) Outcrop view of the Dhading Dolomite, NE of Jalbire

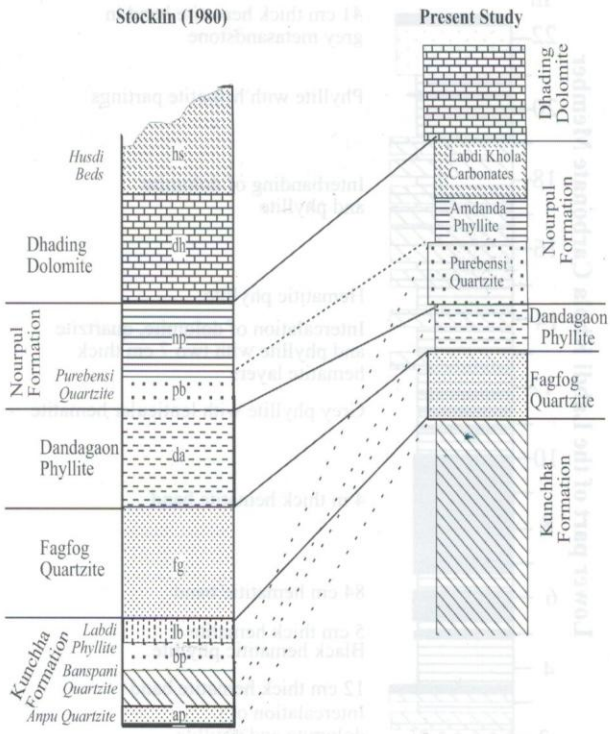

Fig. 18: Comparison of the revised lithostratigraphy of the Mugling-Banspani area with that of Stöcklin and Bhattarai (1977) and Stöcklin (1980)

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