

Lithostratigraphy of Nepalese Siwaliks: an appraisal for standardisation

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ABSTRACT

The Siwalik succession of Nepal is well studied in different sections of the entire country. The lithological successions of individual sections are very similar and comparable to each other. An attempt has been made to work out a unified lithostratigraphic classification of the Siwaliks for the entire country. Based on the available material, nine basic lithostratigraphic units has been proposed in ascending order; Bhorlegaon, Bankas, Jangli Khola, Chor Khola, Surai Khola, Dobata, Dudhaura, Dhan Khola and Deorali.

Present study revealed the presence of a complete fossiliferous succession of the Nepalese Siwaliks along the Mahendra Highway from Surai Naka to Kalakate in western Nepal. Out of nine proposed units, eight are present in this section and hence, has been recommended as reference section for the study of the Siwalik sequence of Nepal.

INTRODUCTION

The Siwaliks are the late Tertiary continental molassic sediments deposited within the southern foredeep basin of the Himalaya. In Nepal, they constitute a narrow zone upto 30-40 km wide running through out the country from east to west and constitute the the Churia Range or Sub-Himalaya of Nepal. The Siwalik successions in general are 4-6 km thick and represent a coarsening up sequence with fining up cycles. The different sections are comparable to each other, are mainly composed of alternate beds of mudstone, sandstone and conglomerates and are of middle Miocene to early Pleistocene in age. The lithostratigraphy of the Siwaliks has been worked out from different sections by various researchers.

Earlier workers (Auden, 1935; Hagen, 1959; Ithara et al., 1972; Yoshida and Arita, 1982; Tokuoka and Yoshida, 1984) have classified the succession into three units as "Lower Siwaliks", "Middle Siwaliks" and "Upper Siwaliks". Similar but little different classification (pebble bearing sandstone as a separate Middle Siwalik unit-MS2) has been made by Kayastha (1978/79), Tater et al. (1983) and Shrestha et al. (1984; 1987 a,b).

In course of detailed geological mapping (1:50,000), Sah et al. (1992, 1994), Tokuoka et al. (1986, 1990), Corvinus (1988, 1993) and Dhital et al. (1995) have locally classified the Siwalik succession into 4 to 6 basic mappable units and provided different names for them.

Vertebrate fossils from the Siwaliks of Nepal, have been studied by West et al. (1978), West and Munthe (1981), Conroy et al. (1985), Munthe et al. (1983) and Corvinus and Nanda (1994). Most of the recorded fossils are float specimens. So, they have less stratigraphic importance but clearly indicate the presence of the Upper Miocene, Pliocene and Pleistocene successions within the Siwaliks of Nepal.

Seventeen species with some new forms belonging to 14 genera of gastropods and bivalves have been grouped into five biostratigraphic horizons in the Arung Khola area (Takayasu et al., 1992, 1995). Ostracods, Charaphytes, Spores and Pollens have been recognised from Amlekhganj, Surai Khola and Nepalganj but no attempt has been made to work out their biostratigraphic zonation based on these microfossils (CPIT, 1973; Khosla et al., 1994; Mathur, 1972).

Magnetostratigraphy of the Arung Khola, Surai Khola and Tinau Khola sections of Nepalese Siwaliks has been worked out and it provides an age interval of 14.0 to 0.5 Ma (Tokuoka et al., 1986; Appel et al., 199; Gautam and Appel, 1994).

LITHOSTRATIGRAPHY

The Siwalik succession of Nepal has been studied in more than fifteen sections from the different part of the country by the author. Lithological successions have been measured and also geological maps (Fig. 1) are prepared for several sections (Fig. 2 and 3). The rocks exposed in different sections are found comparable to each other. Based on the field study nine distinctly different basic lithostratigraphic units have been established for the entire country. These units are well recognisable in the field by their lithological composition, thickness of the individual beds, colour, grain size and sedimentary structures and are named as Bhorlegaon, Bankas, Jangli Khola, Chor Khola, Surai Khola, Dobata, Dudhaura, Dhan Khola and Deorali formations.

Bhorlegaon Formation

The Bhorlegaon Formation is the lowermost unit of the study area. It is well exposed near the Bhorlegaon, along the left bank of the Tawa Khola, about 2 km east of the Katari Bazar, eastern Nepal. A very well-marked angular unconformity separates this unit from the underlying bluish grey, massive dolomites containing columnar and dome shaped stromatolites possibly of Precambrian-early Cambrian. These dolomites resemble the Dhading Dolomite of the Nawakot Complex described from the central part of the Lesser Himalaya by Stöcklin (1980).

At the base of the Bhorlegaon succession, about 2 m thick basal conglomerate bed is well developed. The clasts of the basal bed are rounded to subrounded and composed of dolomites, slates and quartzites. The succession is dominantly consisting of thick beds of medium to fine grained, grey, brown sandstone with thin beds of grey mudstone. The red, purple mudstone beds are rare. The succession is more than 150 m in thickness.

The rock succession similar to Bhorlegaon is also well exposed in Taraghari, south of the Katari Bazar, eastern Nepal. The sequence is more than 200 m in thickness. A very similar type of succession is developed above the Frontal Churia Thrust (FCT) in the Surai Khola section, western Nepal. The lithological succession similar to Bhorlegaon is well developed in the Godawari section of far western Nepal. The succession is widely distributed around the Godawari Bazar and has been mapped as the Lower Member of the Godawari Formation.

In each section, the Bhorlegaon type of lithologic sequence lies stratigraphically below the typically red-purple mudstone dominated succession of the Bankas Formation.

Bankas Formation

Typical section of this formation is exposed along the Mahendra Highway from Surai Naka to Paira Khola in the Surai Khola section of western Nepal (Corvinus, 1988). The lithological succession is represented by a rapid alternation of variegated mudstone and fine grained sandstone, dominated by mudstone. The mudstone beds are chiefly red, purple, brown and yellow in colour. The thickness of mudstone beds varies from a fraction of a meter to several (5-6) metres whereas the sandstones are thinly bedded, mottled, highly indurated, calcareous and mainly quartz arenitic in composition. The thickness of the individual bed of sandstone varies from a fraction of a meter to few (2-3) metres. This unit is about 750 m thick in the Surai Khola section.

Based on lithological dominance the present unit is comparable with the Katari Formation of eastern Nepal, the lower part of the Rapti Formation of Amlekhganj-Hetauda area of central Nepal (Sah et al., 1994) and with the Lower Member of the Arung-Tinau Khola of western Nepal (Tokuoka et al., 1986, 1990). Based on palaeomagnetic works, an age of 15-12 Ma (early-middle Miocene) have been assigned to the unit.

Corvinus and Nanda (1994) have recorded *Gomphotherium* sp., carapace of turtle and plant fossils from the Bankas Formation of the Surai Khola section. A complete and continuous succession of this formation is developed in the Surai section, and has been recommended as the type area.

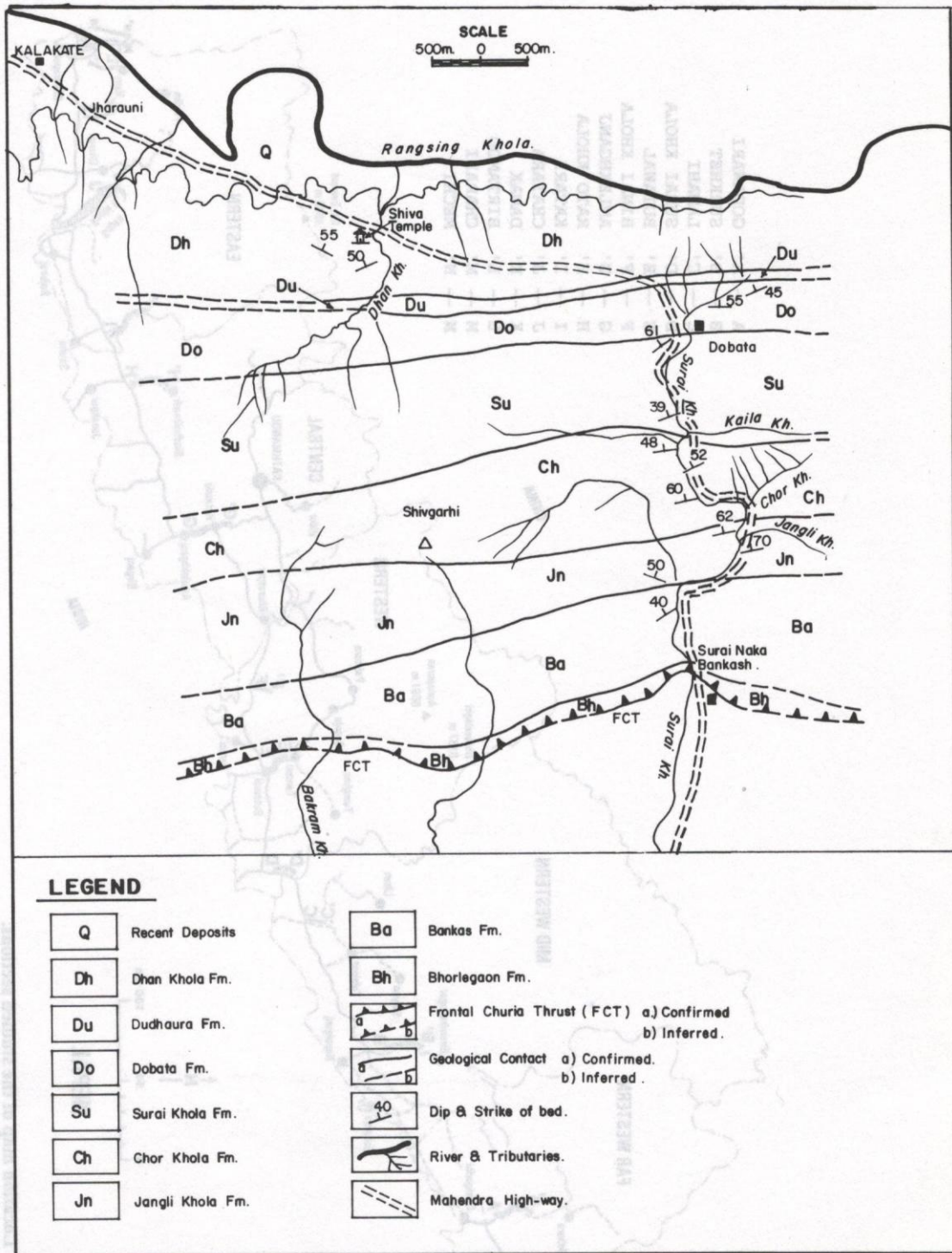


Fig. 1: Geological map of the Surai Khola area.

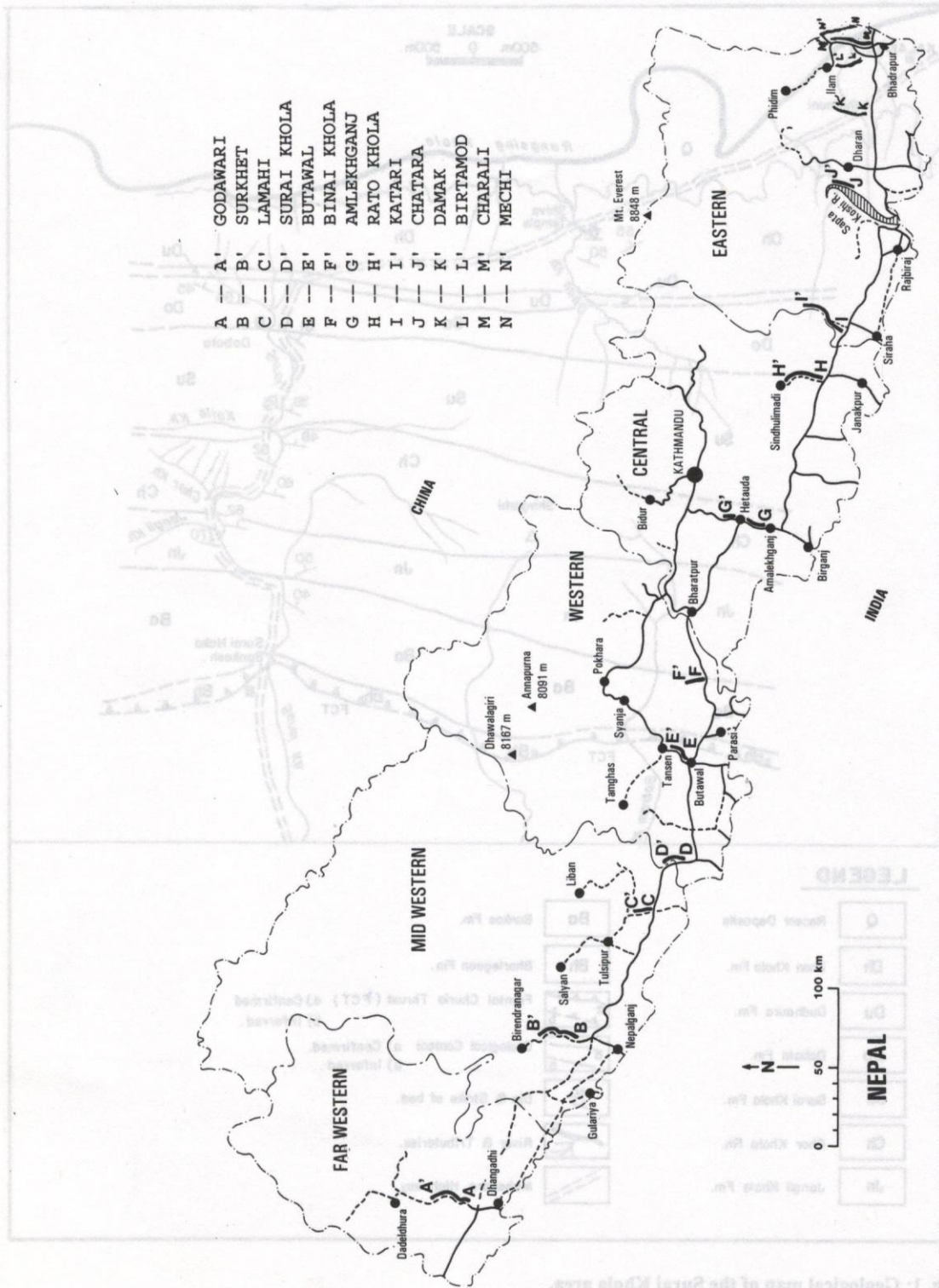


Fig. 2: Location map of the studied sections.

Jangli Khola Formation

This formation is well-exposed along the Mahendra Highway from the Paira Khola to the Jangali Khola in the Surai Khola section of western Nepal (Dhital et al., 1995). The succession is about 500 m thick and is composed of alternating beds of variegated mudstone and sandstone. The proportion of sandstone gradually increases towards the top of the succession. The sandstone beds are massive, thick bedded (5-6 m thick), often contain ripple marks and cross-beddings. They are generally fine-grained but sometimes very thick beds of medium-grained sandstone also occur. The mudstone beds of red and purple colours occur frequently. Comparatively less indurated, greenish grey beds are found frequently near the top of the formation.

Lithologically, this unit is comparable to the Kakaru Khola Formation of the Katari area, the Upper Member of the Arung Khola Formation (Tokuoka et al., 1986, 1990), and the upper part of the Rapti Formation described from Hetauda-Amlekhganj area (Sah et al., 1994). Corvinus (1988) had considered this as "Waterspring Beds" but in a later publication (Corvinus, 1993), it was considered as the Lower Member of the Chor Khola Formation. Dhital et al. (1995) have recognised it as a separate mappable unit and named it as the "Jangli Khola Member".

In Butwal, near the top of this unit (Upper Member of the Arung Khola Formation), Munthe et al. (1983) have recorded an upper molar of *Sivapithecus punjabicus*. It has been found in situ, on the right bank of the Tinau Khola. They have also recorded a suid- *Conohyus sindiensis* and a rhizomyid-rodent. The palaeomagnetic dating and vertebrate fossil records as mentioned above indicate an age interval of 12-8.5 Ma (late-middle Miocene-early-late Miocene) for this formation.

Chor Khola Formation

A complete and typical succession of this unit is well exposed in the Surai Khola section. It starts from near the Jangli Khola, passes over to the Chor Khola and ends at the Kaila Khola. Corvinus (1988) described this unit as the Chor Khola Beds. The lithological succession of this formation is entirely

composed of greenish grey mudstone and fine- to medium grained thick bedded sandstone. The sequence frequently contains "Pepper-Salt" textured sandstone beds. Some layers of marl beds have been recorded from the upper part of the succession. This formation measures about 1000 m in the Surai Khola section.

Stratigraphic position and lithological characteristics of this Chor Khola unit is very similar to the Ghurmi Formation described from Katari area, eastern Nepal, lower part of Amlekhganj Formation described from Central Nepal (Sah et al., 1994), Lower Member of the Binai Khola Formation of the Arung-Binai and Butwal sections of western Nepal and the lower part of the Middle Siwalik (MS-1) mapped by Tater et al. (1983) and Shrestha et al. (1984, 1987 a,b) from different parts of the Sub-Himalaya of Nepal.

Corvinus and Nanda (1994) have recorded *Crocodylus* sp., remains of turtle and microvertebrates from this unit in the Surai Khola section. A crocodile tooth and some leaf imprints have been recorded from the top part of this unit from the Katari area in eastern Nepal. The magnetostratigraphic study conducted in Surai Khola, Arung Khola and Tinau Khola sections have indicated an age of 9-7 Ma (late Miocene) for this formation.

Surai Khola Formation

This unit is well developed around the Surai Khola bridge in western Nepal (Corvinus, 1988). The succession is characterised by the dominance of multi-storied, very thick bedded (upto 30-40 m) pebbly, medium- to coarse-grained, "Pepper and Salt" like arkosic sandstones with frequent large cross and parallel laminations, convolute beddings, cut and fill structures. The sequence is often characterised by intercalation of grey to dark grey mudstones and abundant occurrences of coalified tree trunks. The top part of the succession contains several horizons of calcareous sand balls or lenses and ferruginous and calcareous concretions. Similar successions are well developed in Katari, Amlekhganj, Binai Khola and Butwal sections. The unit is about 800 m thick in the Surai Khola section.

On lithological grounds and stratigraphic position, this unit is comparable with the Belsoth Formation of the Katari area, upper part of the Middle Siwaliks (MS2) by Shrestha et al., (1984, 1987 a,b) and Tater et al., (1983), Middle Member of the Binai Khola Formation described by Tokuoka et al., (1986, 1990) from the Arung-Tinau Khola area and the upper part of the Amlekhganj Formation of Hetauda-Amlekhganj area.

Corvinus and Nanda (1994) have described a very rich assemblage of vertebrate fossils from similar in the unit of Rato Khola and Surai Khola. The fossils include: *Stegodon insignis*, *Archidiskodon planifrons*, *Hexaprotodon sivalensis*, *Cervus* sp., *Hippomythus tatroti*, *Crocodylus* sp., *Gavialis* sp., *Trionyx* sp., *Giraffa punjabiensis*, *Bovinae indet.* Based on the paleomagnetic studies and recorded vertebrate fossils, this formation has an age of 7-4 Ma (late Miocene-early Pliocene).

Dobatta Formation

This formation is well-exposed from Dobata to near the Dhan Khola village along the Mahendra Highway in the Surai Khola section, western Nepal (Corvinus, 1988). The succession is about 500 m in thickness. It is composed of an alternation of loose, medium to fine grained, grey sandstone and dark grey highly fossiliferous mudstone. The succession is dominated by mudstones. The fossiliferous horizons are very rich in molluscan remains. Ferruginous concretionary horizons, calcareous sandballs and trace fossils are found frequently in the horizon. About one meter thick bed of grey, brown mudstone is entirely composed of molluscan shells at the Saddle point. Corvinus (1993) had recorded the fossil remains of *Cervus*, *Equus* and *Archidiskodon planifrons* from this unit.

A similar succession with nearly an equal proportion of mudstone and sandstone occurs north of Butwal, around the Dobhan village, western Nepal. The mudstone beds are of various colour (yellow, brown, green and grey) and the sandstones are often medium to coarse grained and frequently contain pebbly horizons. This unit has been mapped by Tokuoka et al. (1990) as the Upper Member of the Binai Khola Formation. In the Arung Khola, the lithological successions in the Hetauda-Amlekhganj

and Katari sections, possibly correspond to this stratigraphic level are little different and contain pebbly conglomerate beds in this section. Considering vertebrate fossils and magnetostratigraphic data, the formation have been given an age of 2.5-4.0 Ma (early Pliocene).

Dudhaura Formation

This formation is well exposed along the Churia Khola, the upper stream of the Dudhaura Khola in the Amlekhganj-Hetauda area of central Nepal. The unit is about 800 m thick and consists of predominantly clast supported pebbly conglomerate beds. The clasts mainly consist of quartzite and subordinate shale, limestone, granite and sandstone pebbles embedded in sandy matrix. The pebbly conglomerate beds are alternated with sandstone and mudstone beds of pale yellow to reddish brown color. A very thick (50 m) highly indurated and calcareous conglomerate bed constitute the upper limit of this unit. Sah et al. (1994) had recorded some vertebrate fossils (ribs, vertebrae and limb bones) from the Hetauda-Amlekhganj area of this unit and named it as the "Churia Khola Formation."

A similar succession consisting of alternating beds of pebbly conglomerate, sandstone and mudstone is well developed along the Kamala River and around the Garas village in the Katari area, eastern Nepal. It has been mapped as the Garas Formation. Lithologically the Dudhaura Formation is comparable with the lower part of the Chitwan Formation described from the Arung-Tinau Kohl area (Tokuoka et al., 1986, 1990) and the lowermost part of the Dhan Khola Formation. This unit can be considered as a separate lithostratigraphic unit and named as the Shiv Mandir Member.

Several molluscan horizons in dark grey mudstones occur within the lower part of this unit in the Surai section. Based on paleomagnetic data, an age of 2.5-1.5 Ma (late Pliocene) has been assigned to this formation.

Dhan Khola Formation

A complete and typical succession of this formation is developed along the Dhan Khola in the Surai Khola section, western Nepal (Corvinus,

1988). It is characterised by the occurrences of thick bedded, matrix supported cobble-pebble conglomerate with intercalation of sandstone and mudstone beds. At the base, a palaeosoil complex consisting of three palaeosoil layers is well developed. It measures about 1000 m in thickness.

On lithological grounds and stratigraphic position, this unit is comparable to the Tribeni Formation of the Katari area, Churia Mai Formation of the Amlekhganj-Hetauda area and upper part of the Chitwan Formation. Taking into account of the paleomagnetic investigations conducted in the Arung and Surai Khola sections and its stratigraphic position, the present unit could be of the early Pleistocene (1.5–1.0 Ma) in age.

Deorali Formation

This unit is well-exposed along the upper reaches of the Binai Khola and north of the Deorali village in central west Nepal. The succession of this unit has been studied and mapped by Tokuoka et al. (1986). The lithological succession is more than 450 m in thickness and consists of very thick, unsorted matrix supported boulder conglomerate beds often more than several tens of meters in thickness. Boulders are angular to sub-angular and are often larger than several metres in diameter and consist dominantly of the clasts of the Lower Siwalik rocks. Boulder beds are more resistant to weathering and form the water divides. The conglomerate beds are frequently intercalated with mudstone and sandstone. The unit has gradual contact with the underlying unit.

This formation has not been recorded from other parts of Nepalese Sub-Himalaya. But one can recognise the presence of similar beds (Boulder Conglomerate beds) within the Siwalik succession of the Surkhet area, mid-western Nepal and also from the Bhiman area of the Rato Khola section, eastern Nepal. The Deorali Formation is the youngest unit that developed within the Nepalese Siwaliks and possibly is of early Pleistocene in age. However, it is anticipated that the Deorali Formation represents the lateral variation of the Dhan Khola Formation of the area.

DISCUSSION AND CONCLUSIONS

The Siwalik succession of Nepal is well-studied from different sections of the entire country: Godawari, Surkhet, Lamahi, Surai Khola, Arung-Binai Khola, Tinau Khola, Amlekhganj, Rato Khola, Katari area, Chatara, Damak, Birtamor and Mechi. In each studied section, the lithological succession is divisible into three parts: Lower, Middle and Upper. Most of the earlier workers have described these three parts as "Lower Siwaliks", "Middle Siwaliks" and "Upper Siwaliks", respectively. According to the methodological principles of stratigraphic nomenclature (Heildberge, 1976; Salvador, 1994) the same name (as "Siwalik") should not be applied to different ranking units. Based on the above consideration, the author has divided Siwalik Group of present into the major subgroup, namely: "Arung", "Binai" and "Chitwan" subgroup following Tokuoka et al. (1986) methodology.

Considering the lithological composition, thickness, colour, grain size and sedimentary structures, the present study area is divided into nine different mappable units as formation for the Siwaliks of Nepal. Analysing available published material, these nine basic units could be named in ascending order as follows: Bhorlegaon, Bankas, Jangali, Chor Khola, Surai Khola, Dobata, Dudhaura, Dhan Khola and Deorali.

A complete succession of the Nepalese Siwalik Group is exposed within a very limited and structurally aera from the Surai Naka to Jharauni Khola (Kalakate) in western Nepal. Out of nine proposed lithostratigraphic units, eight are present in this section. So, the Surai Khola section of western Nepal can be recommended as the reference section for regional correlation for the Siwalik Group of Nepal.

In order to clarify the time-space relation between each recognised lithostratigraphic units of the different sections, a detailed integrated biostratigraphic, magnetostratigraphic and chronostratigraphic study is planned for future.

ACKNOWLEDGEMENTS

The author is grateful to Dr. H.H. Schleich, the Coordinator of a joint Volks-Wagen Project between

the University of Munich, Germany and Tribhuvan University, late Dr. C.K. Sharma, Chief of the National Stratigraphy Committee, Nepal and Dr. P.C. Adhikary, Head, Central Department of Geology, Tribhuvan University for their support and suggestions. He is also very thankful to Dr. V. Dangol, Department of Geology, Tri-Chandra Campus, Tribhuvan University for going through the manuscript.

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