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ON THE SIWALIKS OBSERVED ALONG SOME ROUTES IN CENTRAL NEPAL

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The Siwaliks of central Nepal were surveyed along six routes. The large part of the Siwaliks in the present area except for the Upper Siwaliks in the eastern part seems likely to correspond to the Lower to Middle Siwaliks on the basis of their lithology. The western part can be regarded as an upheaved area bounded by Chitawan Dun on the east and by the Rapti and Dang Duns on the west.

INTRODUCTION

A vast pile of late Cenozoic sediments designated as the Siwalik Group is widely distributed in the southern front of the Himalayas, and constitutes a narrow belt, with a width of 20 to 100 km, of the Sub-Himalayas ranging from Baluchistan in the west to Burma in the east.

The Siwalik Group has been the object for detailed investigations from the view point of the stratigraphy as well as the biostratigraphy because of the discoveries of many kinds of vertebrate fauna including *Primates* in the Potwar Basin in eastern Pakistan and the Siwalik Hills in northwestern India (Wadia, 1975). In recent years in addition to the sedimentological studies (Tandon, 1976; Tandon and Narayan, 1981; etc.) the chronostratigraphical studies by paleomagnetism and isotope dating (Opdyke *et al.*, 1979 ; Johnson *et al.*, 1979) have been in progress.

On the Siwalik Group distributed in the Nepalese Sub-Himalayas, however, little information is obtained so far because of the paucity of leading fossils and considerable lateral change of lithology.

On the other hand the Siwalik Group is known as the Molassic sediments of the Himalayan orogeny (Wadia, 1975 ; Gansser, 1964). Gill (1952) proposed the Siwalik phase of Himalayan orogenesis in the early Pleistocene and pointed out the relationship between the sedimentation of the Siwaliks and the upheaval of the Mahabharat range. Powell and Conaghan (1973) discussed the Siwaliks in connection with tectonic movements resulted from the collision of Indian to Eurasian continents.

The studies on the Siwaliks are expected to visualize the process of the upheaval of the Himalayan mountains. For the purpose the field survey was performed in central Nepal for 25 days in total from October in 1980 to January in 1981. The present paper outlines the lithostratigraphy and structure of the Siwaliks in the area. The paleomagnetic stratigraphy and chronostratigraphy of the area will be dealt with separately.

PREVIOUS STRATIGRAPHICAL STUDIES ON THE SIWALIKS

The Siwalik Group, named after the Siwalik Hills, is freshwater sediments reaching up to several thousands meters in total thickness and ranging in age from Miocene to Early Pleistocene. On the

Table 1. General three-fold division of the Siwalik Group (Wadia 1975).

Upper Siwaliks *700 m*	Mainly cosist of sands and gravels and intercalate silt and mud in places. The grain size of gravels ranges from pebble to boulder, and cobble gravels are common.
Middle Siwaliks *1200 m*	Mainly composed of arkose sands, silt and mud, and sands are the most predominant constituent. These are generally semiconsolidated.
Lower Siwaliks *2000 m*	Mainly made up of freshwater arkose sandstone, mudstone and shale and scarcely intercalate very thin coal layers.

paleontological grounds the Siwaliks are divided into three Subgroups as shown in Table 1 (Wadia, 1975).

According to Hagen (1969) the general tripartite classification into Lower, Middle and Upper Siwaliks is also available in Nepal and the Middle Siwaliks is most predominant in Nepalese Sub-Himalayas. Itihara *et al.* (1972) made the photogeological and hydrogeological survey in southeastern Nepal. They subdivided the Siwaliks in southeastern Nepal into the Lower, Middle and Upper parts, though their correlation with the three-fold division mentioned above is not certain (Table 2). West *et al.* (1978) and West *et al.* (1981) collected two assemblages of fossil vertebrates along the southern part of the Dang Dun Valley in western Nepal. According to them, the older and younger assemblages are equivalent to the Chinji fauna of the Lower Siwaliks in Pakistan and the Indian Pinjor fauna of the Upper Siwaliks, respectively.

TOPOGRAPHY AND GENERAL GEOLOGY

The present area surveyed is situated in the southern part of central Nepal (Fig. 1). The area is geologically as well as topographically divided into the Mahabharat zone, the Sub-Himalayan zone and the Indo-Gangetic Plain in the WNW-ESE trend from north to south. The Mahabharat zone constitutes the Mahabharat Lekh* generally ranging in altitude from 1,500 to 3,000 meters, and is occupied by the pre-Tertiary rocks. The Sub-Himalayan zone, which is separated from the Mahabharat zone by the Main Boundary Fault, is a hilly belt named the Churia Range or Siwalik Range with a maximum elevation of 2,000 meters. The zone in the eastern part of the present area is topographically subdivided into two zones: the inner Siwalik zone in the north and the outer Siwalik zone in the south, and these zone are separated by the intermediate low land called the Dun** between them. In the Dun the terrace gravel (Dun gravel) of middle Pleistocene to Holocene in age is widely distributed and covers unconformably the Siwaliks (Itihara *et al.*, 1972). On the south of the Siwalik zone the Indo-Gangetic Plain named the Terai in Nepal with an elevation lower than 200 meters is distributed. The Terai is composed of gravels, sands and mud of late Pleistocene to Holocene in age.

* Lekh means a range in Nepalese.

** Dun means a wide basin in the Churia Range such as the Chitawan, Rapti, Dang Duns in Nepalese.

Table 2 Division of the Siwaliks in southeastern Nepal (Itihara *et al.*, 1972).

Upper Siwalik *1800~2750m*	Boulder Conglomerate zone. *Elephas namadicus, Equus, Camelus, Buffelus palaeo-indicus*	Coarse boulder-conglomerates, thick earthy clays, sands and pebbly grit.
	Pinjor zone. *Elephas planifrons, Hemibos, Stegodon*	
	Tatrot zone. *Hippobyus, Leptbos*	
Middle Siwalik *1800~2500m*	Dhok Pathan zone. *Stegodon, Mastodon, large Giraffoids, Sus, Merycopotamus*	Grey and white sandstones and sand-rock with shales and clays of pale and drab colours. Pebbly at top.
	Nagri zone. *Mastodon, Hipparion, Prostegodon*	Massive thick grey sandstones with fewer shales and clays, mostly red coloured.
Lower Siwalik *1200~1500m*	Chinji stage. *Listriodon, Amphicyon, Giraffokeryx, Tetrabelodon*	Bright red noduler shales and clays with fewer grey sandstones anb pseudo-conglomerates.
	Kamlial stage. *Aceratherium, Telmastodon, Tetrabelodon, Anthropoids, Hyoboops*	Dark, hard sandstones and red and purple shales and pseudo-conglomerates.

DESCRIPTION OF LITHOLOGY AND GEOLOGICAL STRUCTURE

Hitaura Section (Figs. 1-B- I and 2-13,14)

This route is along the motor road connecting Kathmandu to Birganji via Hitaura. The inner Siwalik zone is underlain by well-consolidated pale grey to light brown arkosic sandstone with homoclinal structure dipping north to northeast. The sandstone shows a normal stratigraphic polarity judging from the cross bedding and parallel lamination develops in places. Thin layers of shale and conglomerate are often intercalated. The conglomerate is rather predominant in the northern part of the inner Siwalik zone. The pebbles are composed of quartzite and a subordinate amount of granite. The inner Siwalik zone is in fault contact with the pre-Tertiary phyllitic shale on the north (Main Boundary Fault) about 2 km north of Hitaura. On the south the inner Siwalik zone, as Itihara *et al.* (1972) inferred, is considered to be bounded to the outer Siwalik zone by a thrust fault (Hitaura fault) dipping north, although its precise position is uncertain because of the covering of the Dun gravel.

The outer Siwalik zone, being low hilly belt south of Hitaura, is almost occupied by the northern flank of a gentle anticline that trends northwest to west-northwest. Its homoclinal structure dipping north to nornteast is also indicated by a cuesta-like topography. The northern and southernmost parts of the outer Siwalik zone consist of the half-consolidated conglomerate with pebbles and cobbles of quartzite, sandstone and granite. These sediments are poorly stratified and rarely intercalate thin layers of sandstone and shale. Furthermore these are heavily weathered and accompanied with reddish soil on

the surface. On the other hand the southern part of the outer Siwalik zone, occupying core of an anticline, is composed of characteristic light grey to pale white, coarse-grained sandstone containing fossil leaves of plant in places. The sandstone shows distinct graded bedding in many places and is half-consolidated.

Narayani River Section (Fig.2-10,11,12)

The area along the Narayani River is widely covered by the terrace gravels and fan deposits so that complete lithostratigraphic columnar section could not be obtained.

The rocks in the inner Siwalik zone of the area consist mainly of purple to pale grey, well stratified hard sandstone with subordinate amounts of thin layers of shale and conglomerate. The sandstone shows generally a homoclinal structure dipping northwest, although an anticline exists in the southern margin.

The outer Siwalik zone represents a gentle anticlinal structure, the axis of which plunges northwest. The upper horizon composed of conglomerate is exposed along the river bed of the Narayani near Narayan Garh. The conglomerate consists of rounded pebble, cobble to boulder of quartzite, sandstone and granite. The Hills north of Makar village are underlain by light grey to pale white, well stratified, coarse-grained sandstone of the lower sequence. The sandstone may be correlative lithologically with the sandstone in the southern margin of the Hitaura section.

Between the Hitaura and Narayan Garh sections the Chitawan Dun valley widens up about to 20 km from north to south and separates the Siwalik Range into two as mentioned above. The inner Siwalik Range runs continuously forming an arc convex northwards, while the lower outer Siwalik Range stretches intermittently almost parallel to the general structural trend of the Siwaliks.

Butwal Section (Figs. 1-B-Ⅱ and 2-8,9)

The peculiar Dun valley topography does not exist between the Chitawan Dun in the east and the Rapti Dun in the west. Accordingly the division into the inner and outer Siwalik zones is not possible here. The section, however, is divided into the northern and southern zones by a thrust fault traceable along the Dobhan Khola and the Jhumsa Khola (Dobhan fault). Both the zones show a homoclinal structure dipping north to north-northeast steeply in the northern zone and gently in the southern zone.

The northern zone consists of purplish to pale grey hard sandstone with subordinate amount of shale in the lower horizon. This sandstone is generally medium to coarse in size, and formed of lithic fragment, quartz, feldspar, mica and other mafic mineral grains. The sandstone represents a clear stratification in a normal bedding. In the upper horizon thin beds of pebbly sandstone and conglomerate composed mostly of rounded pebbles of quartzite and subordinate amount of shale and sandstone are rarely interbedded in the hard sandstone. These rocks, 1.3 km south of Kerabari village, contact to the pre-Tertiary limestone (Kerabari Formation) with the Main Boundary Fault (Arita and Yoshida, 1982), which is running along the Tinau Khola.

The lower part of the southern zone is almost made up of alternating beds of variegated sandstone and siltstone to mudstone, graded bedding of which indicates a normal stratigraphic polarity. These rocks alternate in a rhythmic manner. Most of the cycles of 2 to 20 meters thick start with massive coarse-grained variegated sandstone, which is followed by well stratified medium-grained sandstone and then by reddish purple to greenish grey shale that is often sheared in its upper horizon. The alternation contains in places trace fossils such as sand-pipe and fragments of plant fossil.

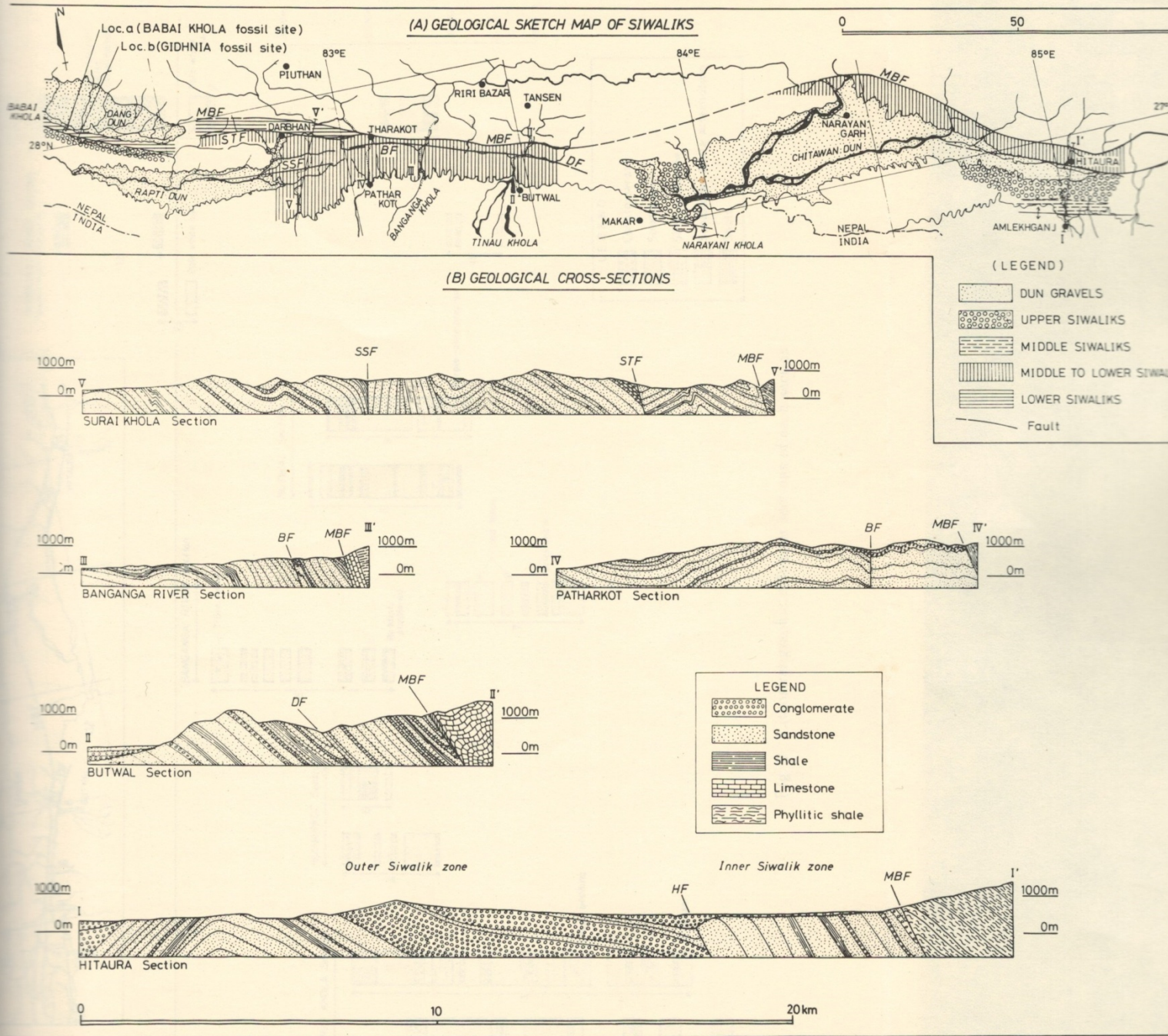

Fig. 1 Geological sketch map of the Siwaliks in central Nepal(A) and geological cross-sections (B). Loc. a and b represent vertebrate fossil sites which have been assigned to the Lower and Upper Siwaliks, respectively (West *et al.*, 1981). Dotted lines represent the mapped routes.
MBF: Main Boundary Fault, DF : Dobhan fault, BF : Banganga fault, SSF : Sisne fault, STF : Sit fault.

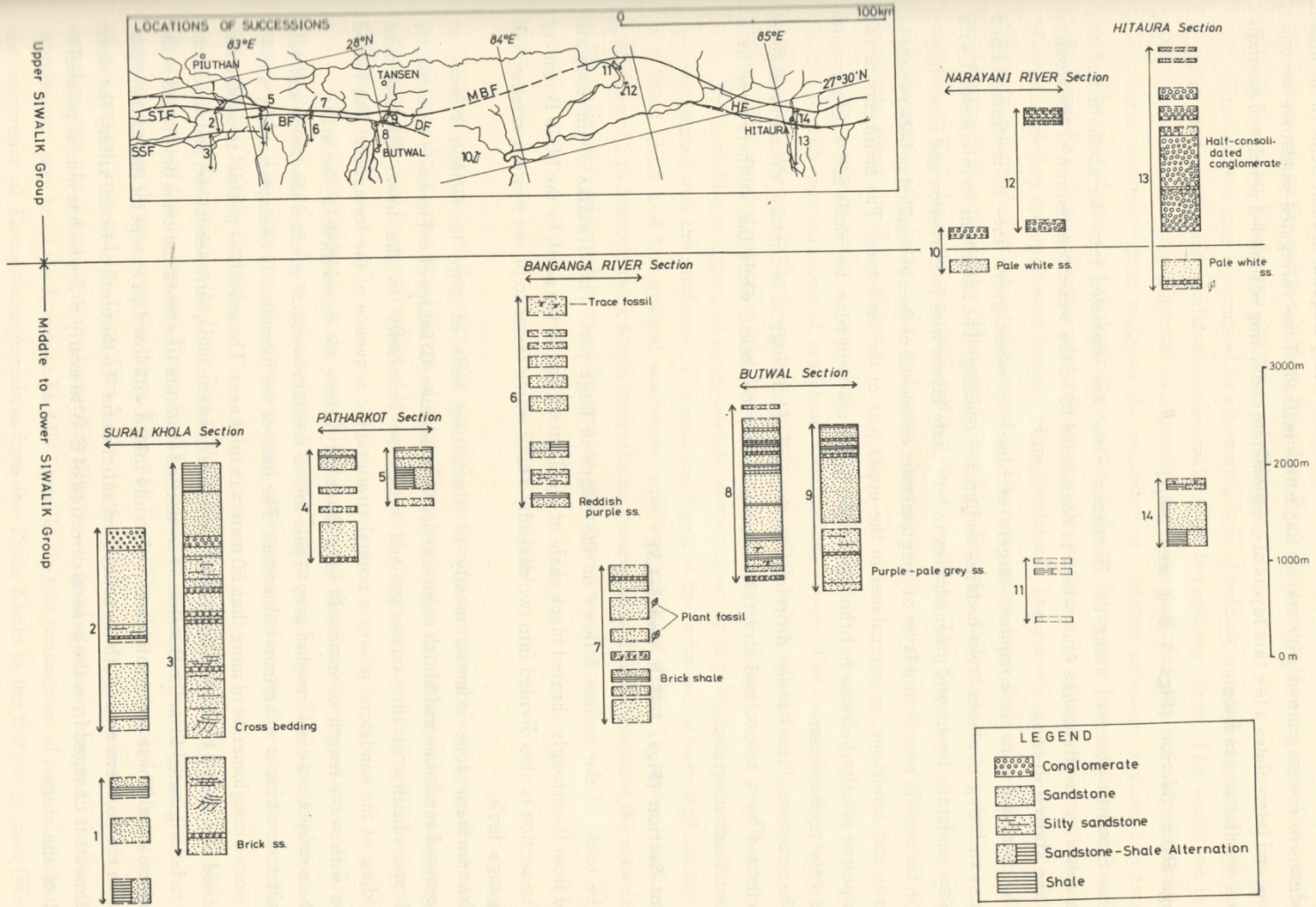

Fig. 2 Lithostratigraphic columnar sections of each section.

Sedimentary structures such as bioturbation and mud crack are very frequent in shale beds. In the upper part medium- to coarse-grained grey arkosic sandstone instead of the variegated sandstone becomes prevailing and intercalates a few thin layers of conglomerate consisting of rounded pebbles of quartzite, shale and hornfelsic sandstone.

Banganga River Section (Figs. 1-B-Ⅲ and 2-6,7)

The Siwaliks observed along the Banganga River are separated into the northern and the southern zones by the Banganga fault which is considered to be the western extention of the Dobhan fault in the Butwal section.

The northern zone is composed largely of bluish to white grey, fine- to medium-grained sandstone exhibiting in places cross-bedding and graded bedding. The sandstone is interbedded with thin pebbly sandstone layers and greenish grey to buff shale layers with bioturbation and fossil leaves of plant in the middle part. A thin layer of conglomerate, composed of the subrounded pebble to cobble of quartzite and sandstone, is intercalated in the upper part of the sandstone. The sediments in the southern part is mostly the same in lithology as that of the northern zone, but shale and silt layers are comparatively predominant.

The structure of these zones, differing from the case of lithology, is in contrast; the northern zone is characterized by a homoclinal structure dipping steeply northeast, while the southern zone by a gentle anticlinal structure.

Patharkot Section (Figs. 1-B-Ⅳ and 2-4,5)

The route of the section follows on the ridges in large part. The Siwaliks of the area are separated from the strongly sheared black shale of pre-Tertiary age on the north by the Main Boundary Fault. The section is also divided into two zones by a fault which seems to be the western extension of the Banganga fault.

The northern zone consists mostly of alternating beds of grey to reddish coarse- to medium-grained sandstone and bluish to brownish grey mudstone. Granules of red to white quartzite are scattered sporadically in the coarse-grained sandstone especially in the lower horizon. The cross-bedding of the sandstone proves a normal stratigraphic sequence of the formation. The folded structures with wave-length of hundreds to a thousand meters are developed in the area.

The southern zone is formed of grey to pale brown medium-to coarse grained sandstone and pale brown mudstone which is sometimes calcareous. The base of the formation is characterized by a thick bed of ill-sorted conglomerate of more than 50 meters in thickness. The gravels of pebble- to cobble size are composed of rounded to subrounded reddish to white quartzite and quartz sandstone, and sandstone appeared to be originated from the Siwaliks. The mottled structure like bioturbation is developed at the top of the formation. These sediments are more broadly folded with low dips except for the northern part than those in the northern zone. Both the zones form anticlinoria. To the north of Kothe village the trend of the sediments is changed from the general direction of E-W to nearly N-S which is almost parallel to the trend of the ridge.

Surai Khola Section (Figs. 1-B-Ⅴ and 2-1,2,3)

The section is divided into the northern, central and southern zones by two faults; the Sit fault in

the north and the Sisne fault in the south. The northern zone is bordered by the variegated shales of pre-Tertiary age on the north; the Main Boundary Fault is traceable between them along the southern banks of the Mari Khola and the Bhimruk Khola.

The northern zone is occupied by alternating beds of reddish, purplish to greenish shale and pale brownish medium-grained sandstone occasionally with ferruginous seams. The sandstone is usually well-stratificated, showing a normal stratigraphic sequence excpt for near the Main Boundary Fault. The reverse sequence there suggests the existence of a closed anticline inclined southwards.

The central zone is lithologically similar to the northern zone, but stratificated, occasionally cross-bedded sandstone is rather predominant than the mudstone. In addition the conglomerate layers are interbedded in the uppermost horizon of the sandstone. The gravels of the ill-sorted conglomerate consist of subrounded to subangular sandstone, quartzite and reddish shale of pebble- to boulder-size. North of the Silling Khola the sediments dip north moderately, while these to the south are folded with moderate to high dips into anticlinal and synclinal structures. The Sisne fault, which is supposed to exist because of the vertical dip and some shearing feature of the rocks, is considered to extend westwards along the Rapti River.

The southern zone is composed of laminated and cross-bedded, fine- to medium-grained sandstone with intercalations of mudstone and siltstone layers. The cross-bedding shows a normal stratigraphic polarity. In the lower part reddish to purplish brown silt and mudstone are prominent in amount. The mottled structure like bioturbation is present in places in the middle part.

In the middle to upper part conglomerate layers consisting of pebbles of quartzite and sandstone are intercalated with the sandstone. The uppermost part of the sediments is formed of alternating beds of mottled shale and fine-grained sandstone, with sun crack, of 10 to 15 meters thick, and hard sandstone of 2 to 5 meters thick which forms the successive falls. The sediments of the zone dip mostly north moderately although a syncline and an anticline are recognized.

DISCUSSION

It is impossible to determine the age of the sediments mentioned above because of no discovery of fossils without some fossil leaves of palnt. Therefore, rough correlations of the sediments with the Upper, Middle and Lower Siwaliks of the conservative tripartite classification will be discussed on a lithologic basis.

The arkosic sandstone in the inner Siwalik zone and the conglomerate in the outer Siwalik zone of the Hitaura section have been assigned to the Lower and Upper Siwaliks (Itihara *et al.*, 1972), respectively. The characteristic coarse-grained sandstone overlain by the conglomerate may correspond to the Middle Siwaliks.

On the other hand in the Dang Dun to the west of the present area West *et al.* (1978, 1981) verified the existence of the Lower and Upper Siwaliks based on vertebrate fossils (Fig. 1-A). According to them the former thrust over the latter. Thus, the Upper Siwaliks are exposed only in the eastern part of the present area and the Dang Dun Vally. In the western part of the present area a thick pile of conglomerate characteristic of the Upper Siwaliks is not found. Probably almost all the Siwaliks in the western part may be of the Lower to Middle Siwaliks. In this connection, of particular significance is the occurrence of *Ramapithecus punjabicus* from the Tinau Khola in the Butwal section (West, 1981). This suggests that the Siwaliks of the section are correlative with the Lower to Middle Siwaliks.

In consequence it can be stated from the regional tectonic point of view that the western part of the present area is an upheaved area as compared with the eastern and westernmost parts where the

peculiar Dun Valleys, as well as the Upper Siwaliks, are widely distributed.

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