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The Siwalik Group of Sediments at Surai Khola in Western Nepal and its Palaeontological Record.

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Abstract

The Siwalik Group is a sequence of molasse sediments consisting of claystones, siltstones, sandstones and conglomerates deposited in the foredeep in the front of the Himalaya from later Miocene to Pleistocene times. An almost complete sequence of Siwalik Group of rocks having a thickness of about 5,500 m have been recorded in the Surai Khola area in the Western Nepal. This group of rocks have been divided into five lithological units, which show a gradual coarsening of the deposits upwards. The lithostratigraphy and biostratigraphy of the Siwalik Group of sediments occurring in the Surai Khola area have been established. Their detailed investigation yielded abundant palaeontological and environmental records which have provided much insight into the understanding of the geologic evolution and the palaeoenvironment during the deposition of the Siwalik Group.

Introduction

The Siwaliks are a sequence of molasse sediments of claystones, siltstones, sandstones and conglomerates, which were deposited into the foredeep in front of the Himalaya from later Miocene to Pleistocene times. They reflect the varying fluvial depositions of erosional debris from the rising Himalayas, carried down into the foredeep basin by the rivers, quite similar to the way the recent rivers deposit their erosional load today into the Terai plain.

The last 13 million years are the crucial period of time when the evolution of the human species began to evolve from their non- human ancestry. We do not know yet, the exact time when this change took place. It was, in fact, a very gradual evolution. But we do know that the changing climate and environment worldwide, from Miocene times onwards into the Pleistocene, which has changed the face of our earth everywhere, had a great influence on this evolutionary process.

Did the palaeoenvironment in this area change to the same degree as in Africa, from where we have most of the evidences of this evolutionary process? Could this area have been favourable for human evolution? We know that an early hominoid ancestor, *Ramapithecus* and *Sivapithecus*, has lived in the tropical forests some 12 to 7 m.y.ago in this area, but he was still a forest dweller.

It is exactly these last 13 million years which is so fully documented in the Siwaliks, embedding in their sediments not only the remains of rare and elusive *Sivapithecus* but also a great variety of the animals which lived with him and after him. They also give profound information about the changing environment and climate and vegetation through an extremely rich floristic record of plant mega fossils and pollen, which to that extent has never been recorded from the same period in Africa.

We know much about Africa. But there we do not have so complete sequences. We have mosaic fragments and we have to piece them together. But here we have no gap, everything is present geologically.

The geological record

Preview

The Siwaliks in Nepal have only recently drawn the attention of palaeontologists like West and his group (West et al.,1983,1991; West,1984; Munthe et al.,1983), who had worked previously in the Siwaliks in Pakistan, and of geologists who studied the geology and structure of the Siwaliks (Hagen,1969; Itihara et al., 1972; Yoshida & Arita,1982; Mascle et al.,1982; Herail et al.,1986; Delcailau et al.,1987). Detailed records of the geology and magnetostratigraphy of the Siwaliks is reported from Arung Khola in western central Nepal (Tokuoka et al.,1986,1988).

In this paper attention is drawn not only to the lithostratigraphy of the Siwaliks but also to the biostratigraphy and the palaeoenvironment of fauna, flora and climate during the Siwalik period.

Primarily a lithostratigraphical framework had to be built up to accommodate any fossil findings in their exact stratigraphical positions. When in 1983-86 a new road from the Terai into Dang was constructed, a rather complete and uninterrupted sequence of Siwalik sediments was freshly exposed at Surai Khola, which was used for the search of fossils and for the measurement and study of the stratigraphy (Fig. 1 and 2).

Abundant fossils were found embedded in them, not only of vertebrate and invertebrate animals but also of plants and of pollen which were extremely abundant and which now have made us understand the climate and the vegetational pattern of the whole period. These floristic records were of the utmost importance for the understanding of the environment of the Siwalik period.

Therefore much stress was laid on the collection and study of the plant fossils and the pollen, which is carried out in collaboration with colleagues (Drs.Awasthi, Prasad and Sarkar) from the Birbal Sahni Inst. of Palaeobotany in Lucknow. First results have been published (Awasthi & Prasad,1991; Sarkar,1991), but work is continuing.

A second area, in Mahottari District at Rato Khola, eastern Nepal, which proved to be very fossiliferous, was studied simultaneously. At Rato Khola only the arenaceous facies of thick, multi-storied sandstones with a rich vertebrate fauna which could be identified as being of Tatrot and Pinjor (Upper Siwalik) age was investigated (Fig.1).

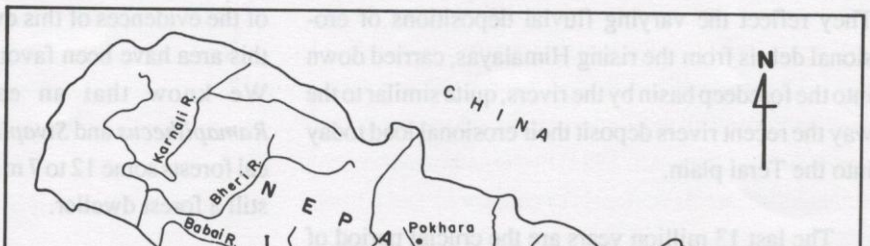

Fig. 1. Location map of the study area.

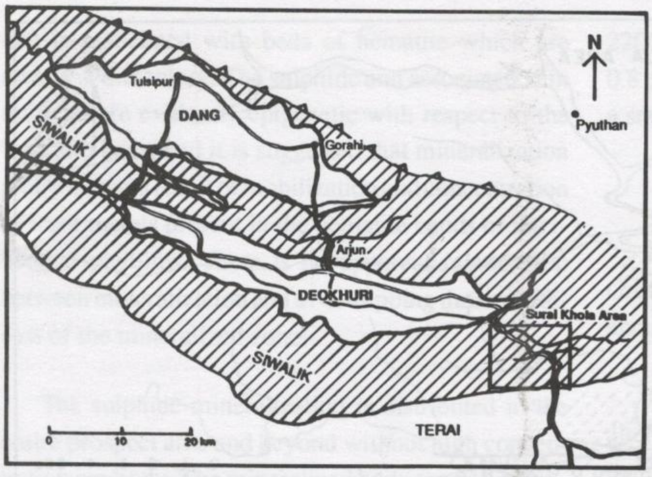

Fig. 2. Map showing the study area.

The vertebrate fossils from Surai and Rato Khola have been identified in collaboration with A.Nanda, Wadia Institute of Himalayan Geology, Dehra Dun, India (Nanda & Corvinus, in press; Corvinus & Nanda, in press). The fossils are housed at the Dept. of Geology, Tribhuvan University and part of them are permanently exhibited at the Natural History Museum at Kathmandu.

Lately, magnetostratigraphical studies too, have been carried out, especially at Surai Khola (Appel et al., 1989,1991; Roesler,1990; Roesler Ph.D.thesis in preparation), and also at Arjun Khola (Metzler, M.Sc.thesis in preparation) and Balubang South and at Rato Khola in Eastern Nepal.

The stratigraphy at Surai Khola

The range of foothills of the Himalayas in Nepal, commonly called the Churia Hills, are made up of the molasse sediments of the Siwalik Group.

At the Surai Khola we have an almost complete sequence of ca. 5500 m of sediments with a time range between 13 to 1 m.y., with abundant palaeontological and environmental information (Fig.3).

The Surai Khola sequence is part of the southern belt of the Siwalik Group of sediments. The Siwaliks here form a hill range of an average height of 900 to 1200 m and a width of 40 to 45 km between the Terai of Kapilvastu District in Lumbini Zone and the Main Boundary Thrust (MBT) in Dang-Deokhuri District in western Nepal.

The southern belt at Surai Khola has a general width of 7 to 7.5 km between Surai Naka (Bankas) at the Terai and Rangsing Khola, a tributary of Rapti River in Deokhuri valley. It has a steeply inclined homoclinal structure, with general dips of 60° to 75°to the NNW, striking more or less in WSW-ENE direction. In the south the beds dip much more gently and with varying strike directions, and a frontal thrust, generally called the HFT (Himalayan Frontal Thrust) is present, separating the oldest deposits of the sequence from the thick alluvial sediments of the Gangetic plains in the Terai. Along the northern border of the Surai Khola sequence a thrust is running along the Rangsing Khola, separating the youngest member of the Surai Khola sequence of the southern belt from older Siwalik rocks of the northern Siwalik belt (Fig.2).

Gentle folding with occasional overturning of the beds and minor faulting is present in the homoclinal Surai Khola range.

The deposits at Surai Khola have been divided into 5 local lithological units which show a gradual coarsening-up of the deposits. These are in ascending order: the Bankas, Chor Khola, Surai Khola, Dobatta and Dhan Khola Formations (Table 1), ranging in time from between 13 m.y.to 1.m.y. (Fig. 4).

The earliest deposits are made up of predominantly argillaceous sediments of variegated and mottled clay- and siltstones with intercalated calcareous, well-bedded fine-grained sandstones in the **Bankas Formation**, which is of Lower Siwalik age. The occurrence of *Gomphotherium* sp. assigns them to the Chinji period, between about 10 to 13 m.y. They are bordering the

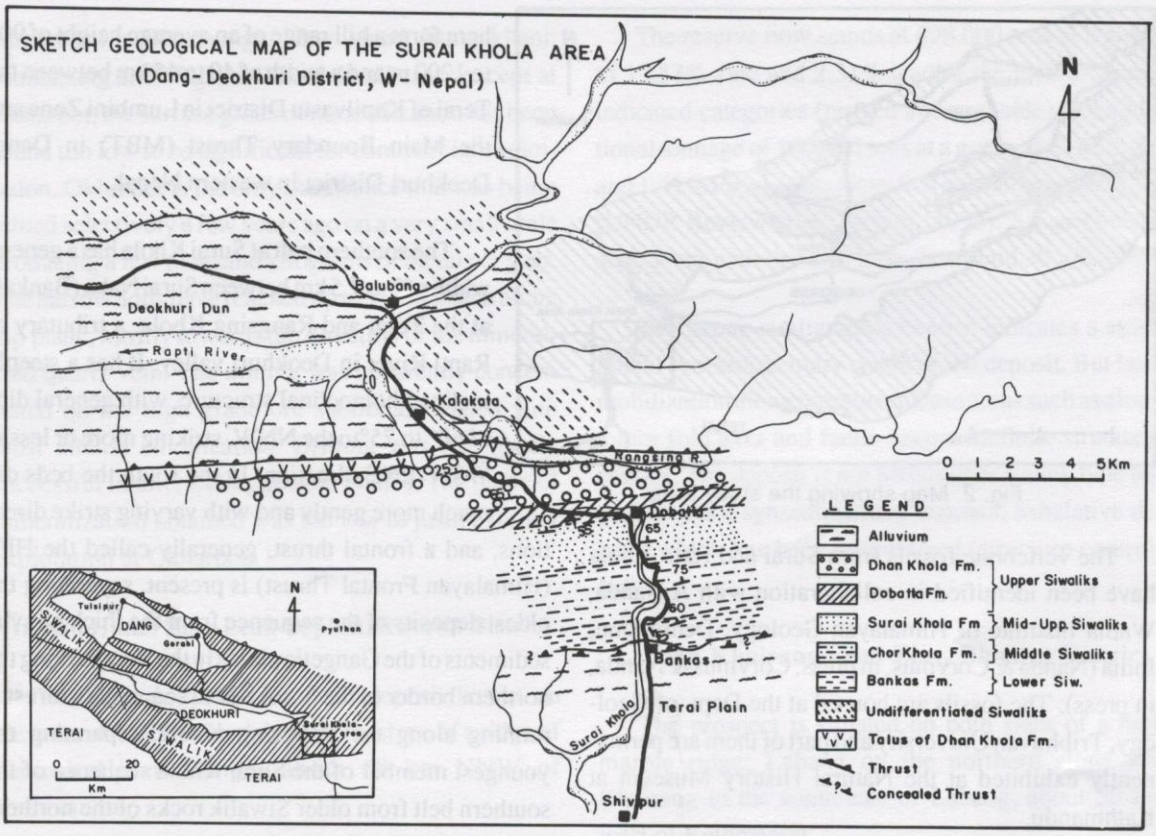

Fig. 3. Geological map of the Surai Khola area, Dang-Deukhuri District, Western Nepal.

Terai plains and the southern-most deposits are affected by young tectonic movements along the Himalayan front. The gentler dip amounts and the more varying dip directions of the lower Bankas deposits point to the existence of a Frontal Thrust Zone. Boving (1992) has recognised the HFT north-west of Surai Naka, where he measured 30° to 40° NW dipping Bankas deposits thrust over by Quaternary fluvial gravels. The HFT runs in a south-eastern direction towards Surai Naka and can not be recognised east of Surai Naka.

The sandstone intercalations increase in the following **Chor Khola Formation** which consists of alternations of mottled clay-and siltstones with well bedded, calcareous sandstones in its lower member, which is of Nagri age. The alternations show well developed sedimentary fining-up cycles of lateral (channel) accretions of sandstones and vertical accretions of overbank mudstones. According to the magnetostratigraphy (Appel et al.,1991) it corresponds to chron 5 of the polarity scale of Harland et al. (1982).

In the upper Chor Khola Formation the sandstone percentage increases slowly, but they still form alternations of well bedded sandstone cycles which are fining up into silt and claystones. Though only rare faunal remains are found embedded in them, which consist mainly of reptilian fossils and are not datable, the beds are assigned to the Dhok Pathan period by the magnetic polarity stratigraphy (Fig. 4). They begin to incorporate medium grained thicker sandstone bodies of multi-storied character in the upper part and are terminated by a series of limestone beds which are well marked in the countryside.

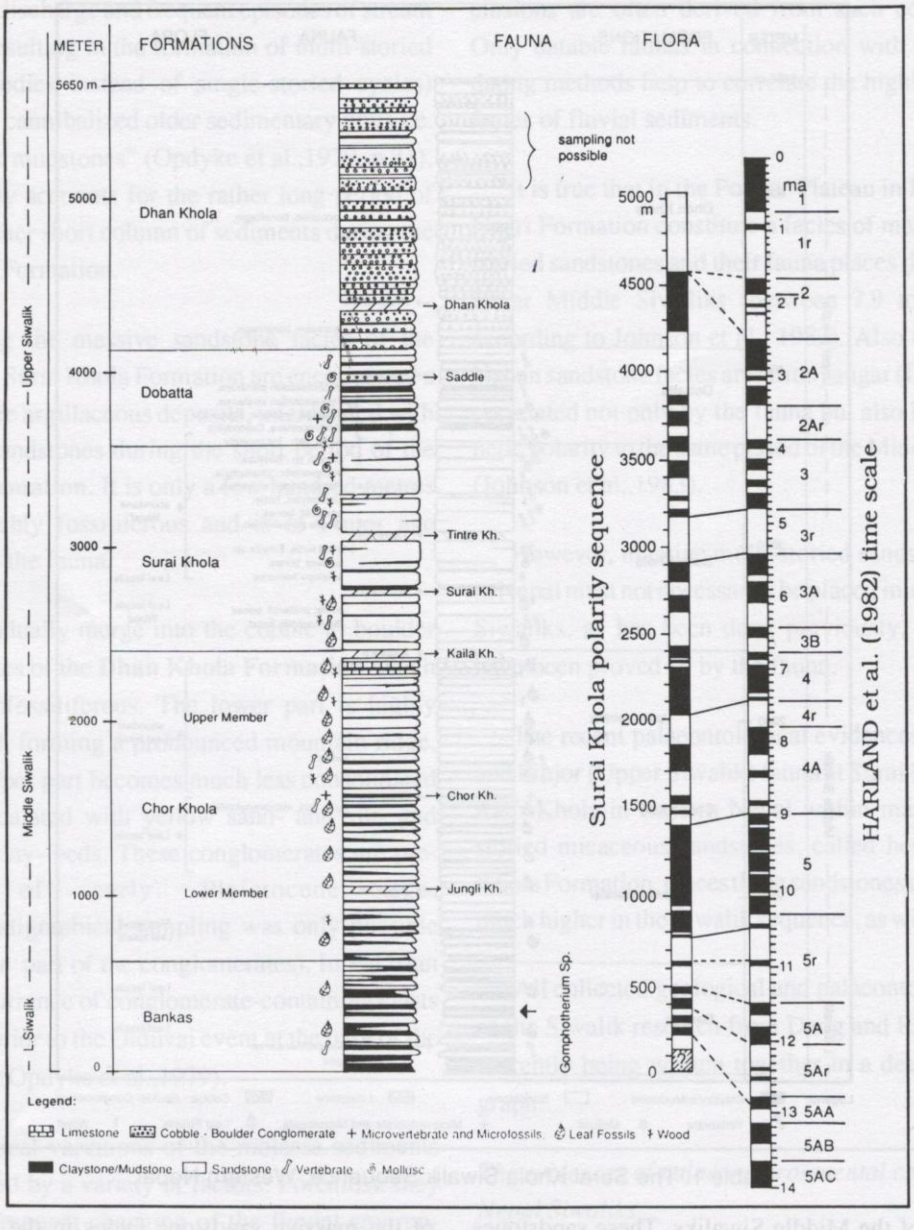

Fig. 4. The Surai Khola Siwalik Sequence, Dang-Dekhuri District, Western Nepal.

Then follows the **Surai Khola Formation** which marks a change of sedimentation towards massive, multi-storied, medium to coarse- grained micaceous, "salt-and-pepper" sandstones. They are often interspersed with lenses and layers of intraformational mudpebble conglomerates which usually are a good source for fossil findings. The sandstone beds often exceed 70 m in thickness and begin to contain pebble alignments and pebble beds.

These sandstones are quite fossiliferous, especially in the upper part and contain a Tatrot and Pinjor fauna, thus assigning them for the main part to the Upper Siwaliks. The lower part still belongs to the

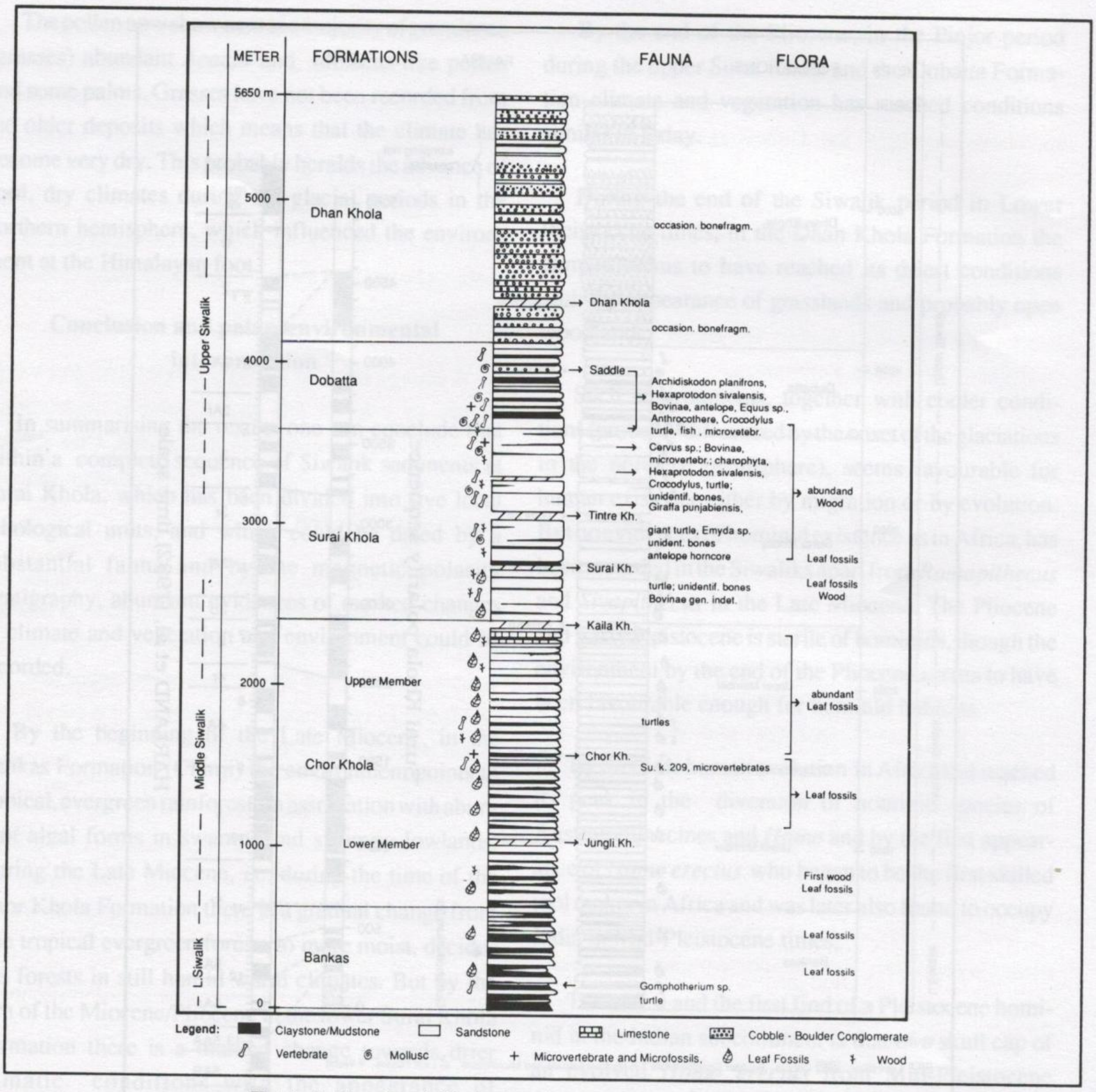

Table 1. The Surai Khola Siwalik Sequence, Western Nepal.

upper part of the Middle Siwaliks. These sandstones form high cuesta-type ridges.

The boundary between the Middle and Upper Siwaliks which coincides with the Miocene-Pliocene boundary and which has been placed at 5.1 m.y. (Johnson et al.,1982) or 5.3 m. y. (Barry et al.,1982) could be established at Surai Khola by the palaeomagnetic dating and has been placed in the lower part of the massive sandstone facies in the Surai Khola Formation above (just north of) the Surai Khola bridge (Fig. 4).

The rate of deposition of such lateral accretion (channel) deposits during the Surai Khola Formation must have certainly increased on the whole, but at the same time an increase in the rate of erosion must have taken place during the cut- and fill events in this period of high river discharge and frequent episodes of stream migration (resulting in the formation of multi-storied sandstone bodies instead of single-storied cycles) "which have cannibalized older sedimentary units i.e. the overbank mudstones" (Opdyke et al.,1979, p.31). This probably accounts for the rather long period of time for a rather short column of sediments during the Surai Khola Formation.

Following the massive sandstone facies of the fossiliferous Surai Khola Formation are encountered a return to more argillaceous deposits, intercalated with micaceous sandstones during the short period of the **Dobatta Formation**. It is only a few hundred metres thick but richly fossiliferous and is of Pinjor age according to the fauna.

They gradually merge into the cobble to boulder conglomerates of the **Dhan Khola Formation** which are quite unfossiliferous. The lower part is highly consolidated, forming a pronounced mountain ridge, while the upper part becomes much less consolidated and is intercalated with yellow sand- and silt- and occasional clay- beds. These conglomerates are presumably of early Pleistocene age, (magnetostratigraphical sampling was only possible for the lower part of the conglomerates). In Pakistan the first occurrence of conglomerate-containing clasts occurs just prior to the Olduvai event at the base of the Pleistocene (Opdyke et al.,1979).

Lithological variations of the molasse sediments are controlled by a variety of factors. Foremost: they reflect the frequent changing of the fluvial environment in response to the extensive lateral movement and migrations of the rivers (Johnson et al.,1979,p.164). They are also controlled by the rock types in their source areas and by their distances to the foot of the mountains.

It is therefore not advisable to correlate fluvial facies by their lithological similarities. Erroneous conclusions are often derived from such comparisons. Only datable faunas in connection with other exact dating methods help to correlate the highly changing facies of fluvial sediments.

It is true that in the Potwar Plateau in Pakistan the Nagri Formation constitute a facies of massive multi-storied sandstones and their fauna places them into the lower Middle Siwaliks (between 7.9 to 10.1 m.y. according to Johnson et al., 1982). Also the massive Nahan sandstone facies at Haritalyangar (India) can be correlated not only by the fauna but also by the magnetic polarity to the same period of the Middle Siwaliks (Johnson et al.,1983).

However, massive multi-storied sandstone bodies in Nepal must not necessarily be placed into the Middle Siwaliks, as has been done previously, unless they have been proved so by the fauna.

The recent palaeontological evidences of a Tatrot and Pinjor (Upper Siwalik) fauna at Surai Khola and at Rato Khola in Eastern Nepal within massive multi-storied micaceous sandstones, called here the Surai Khola Formation, places these sandstones conclusively much higher in the Siwalik sequence, as will be shown.

All collected geological and palaeontological data of the Siwalik research from Dang and Rato Khola is currently being written together in a detailed monograph.

The evidences of palaeoenvironmental changes in the Nepal Siwaliks

The earliest deposits at Surai Khola, the **Bankas** deposits, which are bordering the Terai, belong to the Chinji faunal zone, recognised by the occurrence of *Gomphotherium* sp. (Dehm and Heissig, pers.comm.) (Plate 1,1). The Chinji ranges in time from about 13 to 10 m.y. in Pakistan (Johnson et al.,1982) and the recent magnetostratigraphy by Roesler (Appel et al.,1991) has also given that time range.

The deposits show a quiet water regime with a predominantly argillaceous facies. The Himalayas had not risen to that extent, not yet forming the great mountain barrier as it is today.

The plant fossils and the pollenstratigraphy indicate a tropical, moist climate with evergreen forests as they are found now a days only in the tropical rain forests of South East Asia (with evergreen species like *Dipterocarpus, Cynometra, Polyalthia*). The pollen on the other hand indicate a very swampy and swampy lowland environment with algal forms (like *Botryococcus, Pediastrum, Zygnema*) and fungal spores (like *Phragmothyrites*) of fresh water habitat (Sarkar,1991).

The lower **Chor Khola** time which belongs according to the magnetostratigraphy to the Nagri period of the lower Middle Siwaliks, still indicates similar environments. The few fauna found there belongs to turtle and crocodile. The vegetation is still tropical evergreen. But a slow change of climate and vegetation is realised in the upper Chor Khola Formation, which seems to correspond to the Dhok Pathan.

The Chor Khola Formation is extremely rich in plant fossils. 35 horizons with plant fossils have been recorded, of which 12 are much rich in leaf fossils. The flora includes evergreen species like *Myristica, Calophyllum, Dipterocarpus* and moist deciduous species of *Bambusa, Millettia* and *Entada*. The pollen include pteridophytic spores of marshy, shady places (like *Striatriletes*) and of wet, shady habitats like *Lycopodium, Polypodium, Lygodium* (a climber) and *Crassoretitriletes*, which are all of tropical to subtropical climate (Awasthi & Prasad,1991).

The environment in Middle Siwalik times was one of meandering rivers through deeply forested lowlands of evergreen to semi- evergreen forest vegetation, slowly changing towards a more deciduous, but still moist subtropical forest vegetation.

A marked change of environment took place in the following **Surai Khola Formation** with its massive, soft, micaceous sandstones. It is obvious that by this time the water regime had become high, with much water- and sediment discharge from the then more rapidly rising Himálayas. The mountain front is nearer and the rivers are highly braiding with constantly shifting channels, after having suddenly reached the base level in the plains. Much cut- and fill episodes must have occurred and heavy floods, too, are indicated by the abundance of intraformational conglomerates. Concretional sandstone balls with calcareous cementation are very prominent in the otherwise easily weathering sandstones.

The few intercalated clay beds are of pool and pond environment in abandoned loops and oxbow niches which favoured the deposition of clayey back-swamp material which formed clay plugs. The pools must have experienced a teaming life of fish and molluscs and small vertebrates, judging by the rich remains of them in these clay plugs.

The flora changes within the lower part of this sandstone facies which marks the turn from the Miocene to the Pliocene. Seven leaf horizons were found in the lower part of the sandstone succession. These leaf fossils indicate a change towards moist to dry deciduous forests. According to Awasthi and Prasad (1991) moist deciduous forms like *Clinogyne, Millettia, Diaspyros, Breynia* and *Entada* and *Terminalia* are dominant, though evergreen forms like *Caryota, Mangifera* and *Gluta* are still present. First dry deciduous forms like *Flacourtia* and *Bauhinia* make their appearance, and point to a gradual change of the forest pattern at the transition from the Middle to the Upper Siwaliks at the Miocene/Pliocene boundary.

The pollen, too, show an interesting change with the appearance of first gymnospermous pollen of Cycadaceae and of pollen with pinus affinity, which together with *Acacia* is definitely a sign of the onset of somewhat drier climatic conditions. But they are still associated with pteridophytic spores of *Polypodium, Dictyophyllidites* (warm,humid) and *Lycopodium* which prefer moist and shady places (Sarkar,1991).

Interesting is the large amount of carbonaceous wood recovered from 26 horizons in these sandstones, pointing too, to forested environments. But the cellular structure of the wood, after making thin sections, is almost destroyed by the process of carbonization,making it not possible to identify them (Awasthi, pers.comm.).

The vertebrate faunal remains, which have been so scarce in the older deposits, becomes abundant here. Remarkable are the remains of large, forest-living animals, like hippo and elephant as well as many reptiles like crocodile, gavialis and turtle.

The fauna, so far identified by Nanda (Corvinus & Nanda, in press, and Nanda & Corvinus, in press) indicates an age comparable with the Tatrot and Pinjor period of India. The major part of the multi-storied, "salt-and-pepper" sandstone facies at Surai Khola as well as at Rato Khola and Tapt Kund, is thus of Upper Siwalik age.

A Tatrot fauna could be recorded with *Giraffa punjabiensis* (Plate 1,3) from the middle part of the Surai Khola Formation at Surai Khola. A Tatrot fauna with *Hippohyus tatroti* (Plate 1,2), which is an index fossil of the Tatrot period (Colbert,1935,p.155; Nanda,1982), and *Hemibos* cf.*lachrymans* (Plate 2,1), (Nanda, pers. comm.) is recorded also from the lower part of the massive "salt-and-pepper" sandstone facies at Rato Khola, in association with the hippo *Hexaprotodon sivalensis* (Plate 2,2), which makes its first appearance at 5.3 m.y. according to Barry et al. (1982). The change from the Tatrot to the Pinjor fauna occurs at about 2.47.m.y. (the Gauss/Matuyama boundary) and is based on the first occurrences of cervids with antlers (Plate 4,1) and of *Equus* and *Bos* (Opdyke et al.,1979).

A Pinjor fauna with *Cervus* sp. (Plate 4,1) and *Archidiskodon planifrons* (Plate 2,3 and Plate 3),(both species have also been found in the Lokundol Formation in Kathmandu valley by Dangol [1985]) is found in the upper part of the massive "salt-and-pepper" sandstone facies at Surai Khola and at Rato Khola, where it is in association with *Stegodon* (Plate 4,2), *Hexaprotodon sivalensis* and bovinae. The excavated skull of *Archidiskodon planifrons* with mandible and partial tusks is a unique fossil find as such complete skulls of this species, especially with tusks are not recorded from other Siwalik areas. It is now housed at the Natural History Museum in Kathmandu, together with many of the other fossils from Surai and Rato Khola.

Archidiskodon planifrons appears at 2.9 m.y. (Barry et al.,1982) and cervidae with bifurcated antlers as well as *Equus* and *Bos* make their first appearance at about 2.5.m.y.(Opdyke et al.,1979). Thus the occurrence of fossils of these animals in the massive micaceous sandstone facies at Surai and Rato Khola assigns the upper part of the "salt-and-pepper" sandstones of the Surai Khola Formation to the Pinjor.

The recent magnetostratigraphy from the Surai Khola (Appel et al.,1991) is well understood from the Bankas Formation upto the boundary of the Middle/ Upper Siwaliks at 5.1 m.y. according to Johnson et al. (1979) or 5.3 m.y. (Barry et al.,1982). This boundary is found at Surai Khola just above the Surai Khola bridge in the lower part of the massive sandstones.

But for the upper part of the Surai Khola sequence the magnetostratigraphic column is still rather controversial and does not tally with the recorded Upper Siwalik (Pinjor) fauna from the Surai and Rato Khola. The column shows older ages as compared to the ages given by the fauna and the data is currently being reevaluated. But an increase in erosional activity dur-

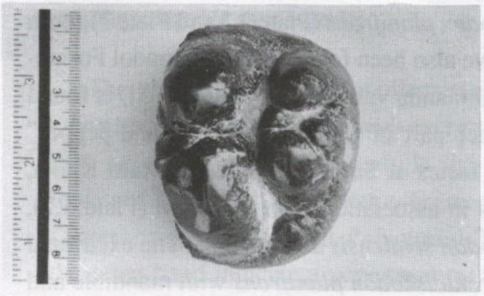

Plate 1.1

Plate 1.2

Plate 1.3

Plate 2.1

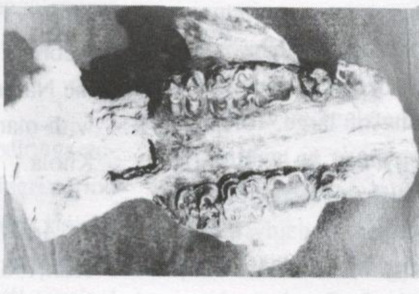

Plate 2.2

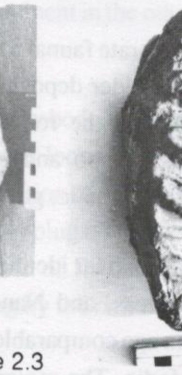

Plate 2.3

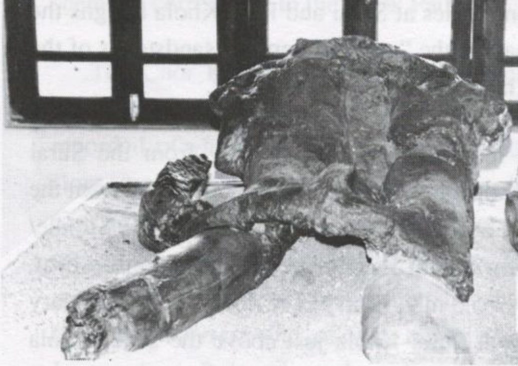

Plate 3.1

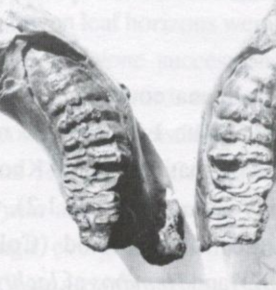

Plate 3.2

Plate 4.1

Plate 4.2

ing a fluvial environment of higher discharge and floods in a braiding, frequently migrating river system is highly probable and may account for missing polarity reversals within the Gilbert reversed magnetic epoch.

Before the deposition of the thick screes of conglomerates as the last member of the Siwalik succession at Surai Khola is a short interval of a return to quieter environments during the more argillaceous facies of the **Dobatta Formation**.

The clays are sometimes very fossiliferous with abundant molluscs of gastropods and lamellibranchs and with fish and rodents and other small vertebrate bones as well as microfossils of charophyta and ostracodes.

Equally fossiliferous are the intercalated sandstones which are similar but less massive than the Surai Khola Formation sandstones. The fauna is of Pinjor age with *Cervus* and *Equus*, bovinae and *Archidiskodon planifrons*. The Dobatta Formation is a local facies and is not encountered at Rato Khola where the massive, "salt-and-pepper" sandstones pass gradually into the conglomerates.

Leaf fossils are absent except fragmentary leaves in some clay horizons. But the pollenstratigraphy continues and Sarkar (1991) records mainly angiospermous pollen of palms and compositae and Malvaceae and Mimosaceae, and only few pteridophytes. But a high percentage of more than 30% of bisaccate gymnospermous pollen of pinus affinity and Cycadaceae is present which prefer dry places. In the clayey pool deposits which are so characteristic of the Dobatta Formation there are again abundant evidences of aquatic (freshwater) algae.

A change from an evergreen/semi-evergreen vegetation to a moist and dry deciduous vegetational pattern is clearly marked in this period. Climate and vegetation have become, at the Plio/Pleistocene boundary, more or less as it is today.

The **Dhan Khola Formation**, constituting the last member at Surai Khola, consisting of pebble to boulder conglomerates with alternations of soft, yellow sandstones, silts and some clays in the upper part, has yielded only rare fossils. A footbone of a cervid was found besides fragmentary bones.

The pollen evidences show that during this period of tremendous deposition of erosional debris during a time of maximal last uplift of the Himalayas, the climate has become quite dry, probably even drier than today.

Plate 1: 1. Left, lower, second molar of *Gomphotherium* sp. (Su. K., 134);
2. Skull of *Hippophyus Tatroti*, (Ra1/20);
3. Second upper molar of *Giraffa punjabiensis* (Su.K.5), at Nat.Hist.Museum.

Plate 2: 1. Horncore of *Hemibos* cf. *lachrymans*, (Ra 2/2);
2. Skull of *Hexaprotodon sivalensis* (Ra 5/12);
3. Left upper molar of *Archidiskodon planifrons* (Su.K.98), at Nat.Hist.Museum.

Plate 3: 1 The skull with mandible and partial tusks of *Archidiskodon planifrons*, (Ra 4/6), at Nat.Hist.Museum.
2. The lower jaw of the same skull at Nat.Hist.Museum.

Plate 4: 1. Horncore of *Cervus* sp. (Su.K.12), at Nat.Hist.Museum.
2. Partial skull of *Stegodon insignis* with upper molars (Ra 5/13).

(The fossils which are not housed at the Natural History Museum at Kathmandu are housed at the Central Department of Geology, Tribhuvan University, Kirtipur).

The pollen now show next to a majority of gramineae (grasses) abundant *Acacia* and hibiscus-like pollen and some palms. Grasses have not been recorded from the older deposits which means that the climate has become very dry. This probably heralds the advance of cool, dry climates during the glacial periods in the northern hemisphere, which influenced the environment at the Himalayan foot.

Conclusion and palaeoenvironmental interpretation

In summarising the results one can conclude that within a complete sequence of Siwalik sediments at Surai Khola, which has been divided into five local lithological units, and which could be dated by a substantial fauna and by the magnetic polarity stratigraphy, abundant evidences of marked changes of climate and vegetation and environment could be recorded.

By the beginning of the Late Miocene, in the Bankas Formation (Chinji) the environment points to tropical, evergreen rainforests in association with abundant algal forms in swamps and swampy lowlands. During the Late Miocene, i.e. during the time of the Chor Khola Formation there is a gradual change from true tropical evergreen forests to more moist, deciduous forests in still humid warm climates. But by the turn of the Miocene/Pliocene in the lower Surai Khola Formation there is a marked change towards drier climatic conditions with the appearance of gymnospermous pollen and pinus-like pollen together with *Acacia*, and with dry deciduous mega plants like *Flacourtia*.

The floristic records are accompanied by a rich mega-vertebrate fauna of Tatrot and Pinjor age during the time of the Surai Khola and Dobatta Formation, placing the multi-storied sandstone bodies of the Surai Khola Formation conclusively into the Upper Siwalik period.

By the end of the Pliocene, in the Pinjor period during the upper Surai Khola and the Dobatta Formation climate and vegetation has reached conditions similar to today.

During the end of the Siwalik period in Lower Pleistocene times, in the Dhan Khola Formation the climate seems to have reached its driest conditions with the appearance of grasslands and probably open woodlands.

Such environments, together with cooler conditions (probably influenced by the onset of the glaciations in the northern hemisphere), seems favourable for human existence either by migration or by evolution. But no evidences of hominid existence as in Africa, has been recorded in the Siwaliks apart from *Ramapithecus* and *Sivapithecus* in the Late Miocene. The Pliocene and Early Pleistocene is sterile of hominids, though the environment by the end of the Pliocene seems to have been favourable enough for hominid habitats.

By this time human evolution in Africa had reached its peak in the diversion of hominid species of Australopithecines and *Homo* and by the first appearance of *Homo erectus* who began to be the first skilled tool maker in Africa and was later also found to occupy India in Mid-Pleistocene times.

The oldest and the first find of a Pleistocene hominid in the Indian subcontinent is that of a skull cap of an evolved *Homo erectus* from Mid-Pleistocene sediments in the Narmada Graben (de Lumley & Sonakia, 1985a,b), which also yielded early stone age artefacts and handaxe tools.

In Nepal, too, first discoveries by the author of early palaeolithic tools in the form of first handaxes ever found in Nepal, proved the existence of human prehistoric occupation in the Siwalik Hills in Pleistocene times. They were found in post- Siwalik fluvial sediments, in basal gravel deposits of the Dun valley alluviation above Siwalik bedrock, and are presum-

ably of Middle Pleistocene age (Corvinus,1988,1991), indicating that the filling of the Dun valleys must have started by Mid- Pleistocene.

Another interesting discovery was made in January 1992 during participation in the fieldwork of the Japanese geological team at the F.C.T.(Frontal Churia Thrust), as the Himalayan Frontal Thrust is called by the Japanese, near the Rapti River mouth at Beni Ghat dam. Here a few early palaeolithic handaxe tools and a tooth of a bovid, probably of the middle Pleistocene *Bos namadicus*, was found in a post-Siwalik fluvial sandstone which was affected and faulted by the tectonic events at the Himalayan frontal thrust.

This is an important finding, as it is not only the first evidence of human tools found to be involved in the Himalayan tectonic movements, but it also establishes the fact that these tectonic movements must have been as late as the late Middle Pleistocene or even later. A definite age can not be given, but the production of early palaeolithic handaxes is supposed to have ended about 100 000 years ago in Africa and probably also in India. Such datum line gives an indication of the age of the oldest definite occupation of prehistoric man in Nepal in the early post-Siwalik phase of Dun sedimentation of Dang.

Besides these findings of a handaxe assemblage the present research in the late Quaternary and Holocene Dun valley sedimentation of Dang-Deokhuri has provided an unexpected wealth of prehistoric sites of *in situ* palaeolithic, mesolithic and neolithic stone age assemblages.

Thus the human occupation in Nepal can be dated back at least to the later Mid-Pleistocene. But what had happened before, during the Siwalik periods, between *Sivapithecus* in the Late Miocene and handaxe-producing man in the later Middle Pleistocene in Nepal is not known. However it can be stated that by the end of the Pliocene the environment at the Himalayan foot was favourable for human occupation.

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