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Stratigraphy and palaeontology of the Siwalik Group of Surai Khola and Rato Khola in Nepal

By

Gudrun Corvinus, Kathmandu, and **Avinash C. Nanda**, Dehra Dun

With 11 figures and 9 tables in the text

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Abstract: Stratigraphical and palaeontological investigations in the Siwalik molasse sediments in Nepal include lithological studies in several sequences, particularly at Surai Khola, which exposes a rather complete succession of deposits from the Lower to the Upper Siwaliks. Substantial fossil findings from Surai Khola and Rato Khola provided an Upper Siwalik fauna (including the Tatrot and the Pinjor faunal zones) for the upper sequence. Magnetostratigraphical studies have provided additional information for the dating of the sequence.

Zusammenfassung: Stratigraphische und paläontologische Untersuchungen in den Molasse-Sedimenten der Siwaliks in Nepal, vor allem in der fast vollständigen Siwalik-Sequenz des Surai Khola, haben erstmalige Ergebnisse für die lithologische Einstufung und eine relative Datierung an Hand der Fauna der Nepal-Siwaliks ergeben. Eine Ober-Siwalik-Fauna mit Tatrot- und Pinjor-Elementen wird für die obere Sequenz beschrieben. Magnetostratigraphische Untersuchungen haben zusätzliche Informationen zum Alter der Sequenz geliefert.

I. Introduction

Under the geo-archaeological project/Nepal from the University of Erlangen/Nürnberg in Germany, financed by the German Research Council, extensive geological fieldwork has been carried out by the first author during many fieldseasons between 1984 and 1990 in several areas in the Miocene to Pleistocene Siwalik and post-Siwalik sediments in Nepal. The Siwalik Hills, which are called locally the Churia Hills, are the continuation of the Siwalik Range from India.

The Siwalik Hills form the southernmost foothills of the Himalayas in Nepal and are the youngest mountain range involved in the folding and faulting of the last phase of the mountain building of the Himalayas. They form a belt of a length of 800 km of molasse sediments which were

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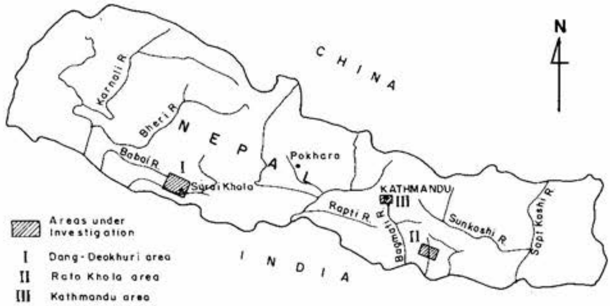

Fig. 1. Map of Nepal with investigated areas indicated.

deposited into the foredeep along the margin of the rising mountains during the Late Miocene to Early Pleistocene times.

The investigations were undertaken in 4 areas in the Siwalik Group in Nepal: (1) in the Surai Khola and Arjun Khola areas south of Dang valley in western Nepal, (2) in the Surkhet area, further west of Dang, (3) in the Rato Khola area, Eastern Nepal, and (4) in the Kathmandu valley (Fig. 1). But the major work concentrated in the Surai Khola area, where a continuous and uninterrupted Lower to Upper Siwalik sequence is exposed and in the Rato Khola area, where a rich Upper Siwalik fauna was found.

The sequence at Surai Khola consists of a variety of argillaceous and calcareous siltstones, sandstones and of pebble to boulder conglomerates. A few limestone beds have been reported from the upper part of the Middle Siwaliks from the Surai Khola area for the first time.

The deposits proved to be quite fossiliferous in vertebrate and invertebrate fauna and in plant fossils. Especially abundant is an Upper Siwalik fauna of Tatrot and Pinjor affinities and for this reason collaboration was started with the second author from the Wadia Institute of Himalayan Geology in Dehra Dun, who undertook the study of the vertebrate fauna.

Vertebrate fossils were first discovered in India in 1832 by P. T. CAUTLEY & FALCONER (1832) and since then excellent biostratigraphical work has been carried out both in India and in Pakistan. The Nepal Siwaliks had received very little attention and little biostratigraphical data has existed. It was therefore felt necessary to concentrate on these hithertoo neglected aspects of the Nepal Siwaliks.

The present research work consists of the investigation of the above mentioned fossiliferous Siwalik sequences as well as of the post-Siwalik deposits in the same areas.

One major aspect of the project is to fill the lacuna concerning the neglected litho- and biostratigraphy of the Nepal Siwaliks, their depositional pattern, their palaeoenvironmental nature and the development of fauna, flora and climate. This is a first attempt of a combined litho- and biostratigraphical analysis in several fossiliferous areas of the Siwaliks in Nepal.

Another aspect of the project was to undertake a survey of the post-Siwalik development in later Pleistocene and Holocene times in the intermontane Dun valleys[1] and in the river valleys in connection with a search for prehistoric occupation sites. Results of this aspect have been published elsewhere (CORVINUS 1985–1991).

II. Previous work and aim of the present work

Apart from a few scanty collections made by a number of previous workers (MATHUR 1972; SHARMA 1977), first accounts of vertebrate fossils from the Siwaliks in Nepal were reported by the American team, WEST et al. (1978, 1983, 1991) WEST (1984). MUNTHE et al. (1983) also recorded the magnetic stratigraphy of the Lower Siwalik beds near Butwal, where a molar of *Ramapithecus* was found.

Structural geological work has been carried out by various scholars. The first detailed account was given by HAGEN in his report (1969). Other reports include work by the Japanese team (ITIHARA et al. 1972, YOSHIDA & ARITA 1982, TOKUOKA & YOSHIDA 1984), and by the French team (MASCLE et al. 1982, HERAIL et al. 1986, BEDEN et al. 1984). A more detailed record of the geology, lithostratigraphy and magnetostratigraphy of the Siwaliks of the Arung Khola area in western central Nepal is reported in TOKUOKA et al. 1986 and 1988. References to the Siwaliks have also been made by SHARMA (1977) and by various geologists in their unpublished reports to the Department of Mines and Geology, Kathmandu.

A combined systematic stratigraphic and palaeontological survey of the Siwalik succession was, however, lacking in Nepal. In the present work, therefore, an attempt has been made to combine detailed data of the lithostratigraphy with that of the palaeontological findings.

For this purpose one particular area of the Siwalik Group in Nepal in Surai Khola has been studied where an uninterrupted, quite complete section of Siwalik sediments from the Lower to the Upper Siwaliks has been preserved. A detailed stratigraphical column has been prepared in the Surai Khola, showing the occurrence of vertebrate and invertebrate fossils as well as an abundance of plant fossils. Systematic collections have been made to determine the ages of the sediments and to interprete the environments (vegetation, climate and fauna) throughout the sequence, and relate them to the geological and depositional history.

It is found that the Surai Khola sequence ranges back in age from the Chinji Formation in the Lower Siwaliks to the Boulder Conglomerate in the Upper Siwaliks. In the Rato Khola area in Eastern Nepal only the arenaceous facies of thick, multistoried, micaceous sandstones which

[1] Dun: Tectonically initiated, longitudinal valleys, separating the Siwalik ranges from the Lesser Himalayas.

proved to be very fossiliferous was investigated. On the basis of the vertebrate fauna the arenaceous facies of the Rato Khola has been referred to the Tatrot and the Pinjor of the Upper Siwaliks.

A third area, in which the first author made a brief survey, was the Kathmandu valley, where some collections of vertebrate fossils were made in the Lokhundol Formation. The Surkhet area so far has yielded only abundant plant fossils but no fauna.

The present investigations are discussed now by area below.

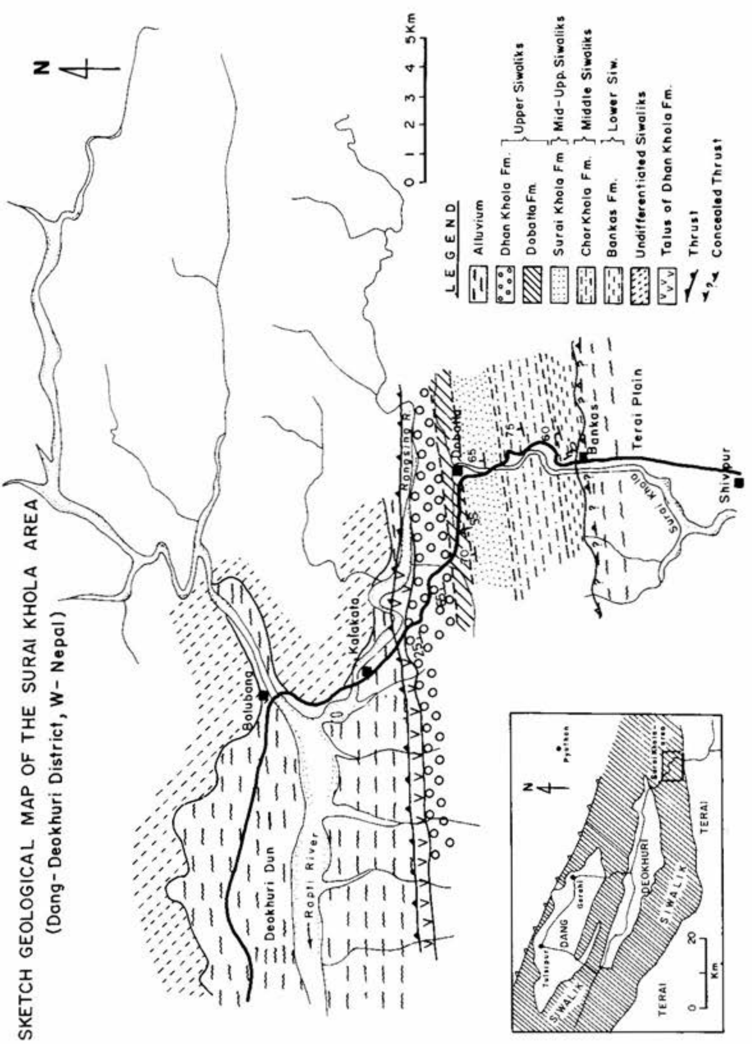

Fig. 2. Roadmap along which the Surai Khola Siwaliks are exposed.

III. The Siwalik succession at Surai Khola and Rato Khola

This part deals with the geology and stratigraphy of the two areas which promised to fulfil the above mentioned, combined approach.

1. Surai Khola

In the Surai Khola area a new road had been constructed in 1983–86, connecting the Terai Plains with the Dang-Deokhury valley. The road was cut through the southern range of the Siwalik sediments separating the Dang-Deokhuri valleys from the Terai. The blasting and cutting of the road displayed fresh rock faces and permitted the first author to undertake detailed measurements of the entire succession of freshly exposed sediments of about 5500 m. A road map was prepared (Fig. 2) and mapping of the surrounding area is to be done soon.

A comprehensive chronostratigraphical column with all collected and recorded in situ data from the Surai Khola Siwaliks has been prepared in a 1 : 200 scale of which only a reduced column in a simplified sketch of a scale of 1 : 20 000 is given here, showing the three major facies of argillaceous, arenaceous and conglomeratic deposits (Fig. 3). A recently carried out compass traverse helps to check thickness and extent of the individual units of the measured litho-column.

The column shows a gradual coarsening-up of the sediments from a predominantly argillaceous facies in the lower units to a predominantly sandy facies in the middle units, while the uppermost part consists mainly of coarse conglomeratic debris, as the last depositional phase of the Siwaliks.

The Surai Khola sequence is having all the three subgroups of the Siwaliks exposed: Lower Siwalik (base unexposed), Middle Siwalik and Upper Siwalik. These have been further subdivided into five formations: Bankas (corresponding to the Chinji), Chor Khola, Surai Khola, Dobatta (belonging to the Middle and Upper Siwaliks) and Dhan Khola (corresponding to the Boulder Conglomerate) (Fig. 3). Claystone/sandstone/conglomerate ratios of these five formations are given in Table 1.

Table 1. Percentage of the major facies within the five units of the Surai Khola sequence.

Formation	Thickness	Clayst/Mudst.	Sandst.	Conglom.
Dhan Khola	1530 m	19%	26%	55%
Dobatta	550 m	48%	51%	1%
Surai Khola	1180 m	10%	90%	–
Upper Chor Khola	850 m	38%	62%	–
Lower Chor Khola	930 m	49%	51%	–
Bankas	610 m	71%	29%	–
	5650 m			

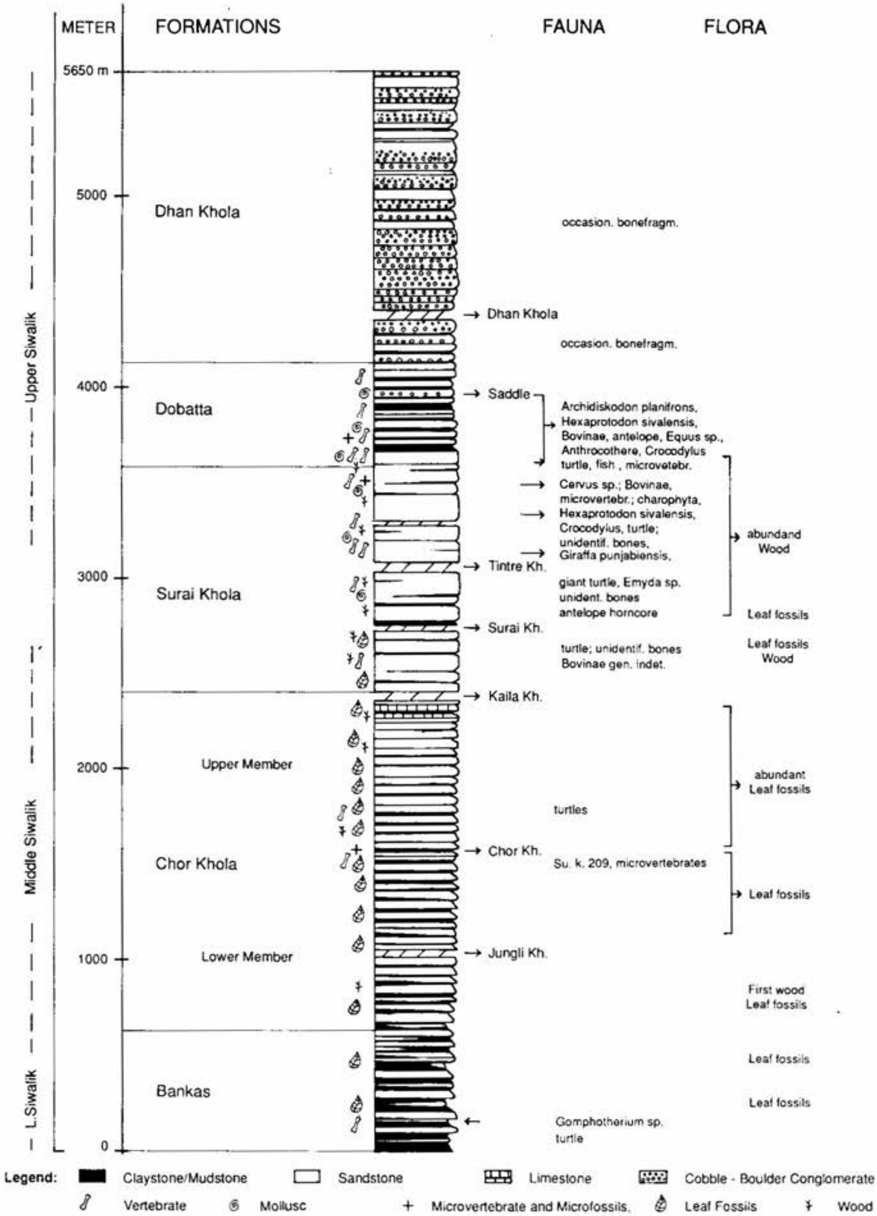

Fig. 3. Surai Khola profile with the 5 lithological units and the fauna indicated, scale 1:20 000.

Table 1 shows the percentages of the three major facies at the Surai Khola profile. It shows the rapid decrease of finer clasts in favour of increasing sandstone constituents from the Bankas to the Surai Khola Formations. An intercalating unit with again increasing clay amounts is recorded in the Dobatta Formation before the final deposition of conglomerates and coarse sands of the Dhan Khola Formation.

The Surai Khola sequence forms a homoclinal range of hills of a width of about 7.5 km, exposed along a road of 16 km length, between Surai Naka (Bankas) in the south at the border to the Terai plain and Kalakata in the north on the Rangsing River. The deposits have a general dip of 60° to 75° to the NNW, striking more or less in WSW–ENE direction (Fig. 2).

In the south, near Bankas, the beds dip much more gently and with varying strike directions, and a thrust is supposed to be present where the oldest deposits of the Surai Khola sequence override the alluvial sediments of the Gangetic Plains in the Terai.

Along its northern border a thrust is running along the Rangsing Khola, seperating the youngest member of the sequence, the Dhan Khola boulder conglomerates, from older Siwalik rocks to the north. Gentle folding with occasional overturning of the beds and minor faulting is present in the homocline.

The lowermost **Bankas Formation**, of a thickness of 600 m consists predominantly of argillaceous deposits, of claystones, shales and siltstones and only of a subordinate amount of intercalated beds of calcareous sandstones.

The claystones and mudstones are mottled and are conspicuously coloured bright purple to red-brown and yellow-brown, but rarely grey. Mud cracks and bioturbated surfaces are very common on the contacts to overlying sandstones. Fining-up cycles are rare. Shales are not common but increase towards the upper part.

The sandstones of the Bankas Formation are well-bedded and usually single storied, with often pronounced bedding planes exposed, and range in thickness from thin beds of only 0.20 m to beds of 3 m, but are generally between 0.5 to 1 m in thickness. They are usually very fine grained and calcareous, but occasional massive, medium grained micaceous sandstones occur.

The Bankas deposits have so far not yielded many fossils apart from plant fossils.

The floristic record is quite abundant in the form of leaf impressions and pollen, but carbonaceous wood, which becomes very abundant in the younger deposits, is absent.

The faunal record is poor. Life of small, mud living invertebrate animals on the shore of ponds and quiet watercourses, however, was thriving, as bioturbation on the bedding planes of the mudstones and fine sandstones is

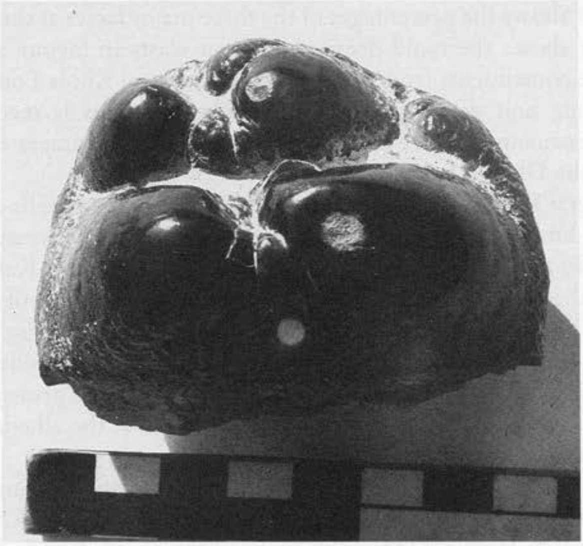

Fig. 4. Fragmentary molar of *Gomphotherium* sp. from Bankas.

very conspicuous and horizons full of trace fossils are abundant. Mollusc remains, however, which become later-on quite abundant, are almost absent.

Vertebrate fossils are rare and include fragmentary mammalian bones and fragments of turtle carapace in the lower part of the Bankas Formation. The find of a partial, but well preserved tooth of a Gomphotheroid from a clay bed in the lower part of the section however was important and was identified as *Gomphotherium* sp. (Fig. 4) by Dehm and Heissig (pers. comm.) after comparison with material they had collected from the Chinji Formation of Pakistan. This find conclusively places the Bankas deposits into the time span of the Chinji Formation of the Lower Siwaliks. It seems that only the upper part of the Lower Siwaliks is represented at the Suraị Khola sequence.

The boundary to the overlying Chor Khola Formation is based on purely lithological grounds but the boundary between the Lower and the Middle Siwaliks could be established by the magnetostratigraphy (Appel et al. 1991).

The overlying **Chor Khola Formation**, of a thickness of about 1800 m, comprises alternations of mottled claystones, siltstones and shales with hard beds of grey and greenish to buff fine grained sandstones and calcareous sandstones with increasing proportions of the sandstones towards the upper levels. They have been referred to the Middle Siwaliks though, so far, no identifiable vertebrate fossils have been found in these beds.

The lower member of the Chor Khola deposits (formerly the Waterspring Beds of CORVINUS 1988) still shows a predominance of mottled claystones and siltstones, which are intercalated with smaller proportions of hard, fine grained sandstones, while the upper Chor Khola deposits have increasing proportions of sandstones. These are hard, calcareous and fine grained in the lower part, but become increasingly coarse grained in the upper levels. Fining-upward cycles are very common and increase in size from the lower to the upper member of the Chor Khola Formation. Load casts, ripple mark surfaces and mudcrack fillings are common, as well as bioturbated surfaces with trace fossils. Pedogenetic processes have changed the finer clastic sediments and claystones and siltstones are predominantly mottled. Conspicuous in the upper levels of the Chor Khola are first appearances of beds of softer, micaceous sandstones of "salt and pepper" appearance, which is the typical facies of the overlying Surai Khola Formation.

The uppermost 100 m of the Chor Khola deposits expose a series of very calcareous siltstones and limestones which form conspicuous, well-preserved bedding planes and serve as marker beds in the area.

The Chor Khola Formation is very fossiliferous in mega plant fossils of monocot and dicot leaves, and abundant horizons of thin coal seams and lignites are present, usually at the top of fining-upward cycles.

Vertebrate fossils in the upper Chor Khola Formation are still rare after the almost sterile lower Chor Khola deposits. They consist only of a few fragments of crocodile and of turtle carapace. One thin bed of a calcareous intraformational conglomerate (a calcareous sandstone with mud pebbles)

Fig. 5. Hoofprints of small artiodactyle animals from a mudstone horizon in the upper Chor Khola Formation.

in the middle part of the formation is fossiliferous with small bone fragments and microvertebrates. Such intraformational mud-pebble conglomerates become increasingly common within the sandstone bodies of the upper Chor Khola Formation and are very conspicuous in the Surai Khola sandstone facies where they are usually fossiliferous.

A particularly interesting find in the uppermost levels of the Chor Khola Formation, above the limestone beds, was a mudstone bedding plane, now unfortunately destroyed by further blasting of the rocks during the road construction, which carried abundant hoofprints of small artiodactyls (Fig. 5).

In the overlying **Surai Khola Formation** (with a thickness of about 1200 m) the facies changes drastically to one of massive, light-grey, soft, medium to coarse grained, very micaceous, "salt and pepper" sandstones with a percentage of 90 % over only 10 % of fine clastic sediments of dark grey clays. The sandstones are massive and multistoried, exceeding 50 m in thickness. They form high cuesta-type ridges and actually constitute the highest hillrange in the Surai Khola area. Cross bedding of all types of small and large scale as well as convolute bedding is common. Hard concretionary ledges and boulders of calcareous sandstone are prominent in the otherwise rather soft, easily weathering sandstones. Alignments of pebbles and cobbles of clay within the sandstones are very common and together with lenses of intraformational mud-pebble conglomerates, so-called "puddingstones", indicate erosional surfaces in the multistoried sandstones. These are usually the best source for fossil findings and generally contributed the greatest amount of the fossil discoveries, not only of larger bones but chiefly of smaller vertebrate bones.

The intercalated grey to dark grey clays within the sandstones are often abundant with shells of gastropods and lamellibranchs on their upper contacts with overlying sandstones and contain also microvertebrates, remains of fish and charophytes. The microvertebrates are currently under study by KOTLIA, but results are to be awaited.

The palaeontological record of the Surai Khola Formation is of great variety, much more so than in the older deposits. There is still abundant evidence of plant life, though leaf-bearing horizons become less frequent than in the older deposits.

The faunal record of the Surai Khola Formation and the overlying Dobatta Formation is the richest record of vertebrate fossils in the Surai Khola area. Most of the larger vertebrate fossils are derived from these micaceous, massive sandstone beds and their interbedded "puddingstone" lenses. Such massive, salt and pepper sandstones, wherever they have been exposed and investigated (such as at Tapt Kund and at Rato Khola) have invariably yielded large vertebrate fossils of Upper Siwalik age.

Amongst the mammalian fossils particularly abundant are large fossil bones of Elephantidae and Hippopotamidae besides Bovinae, Cervidae, Suidae. Particularly abundant are remains of reptilian fossils of *Crocodylus, Gavialis* and turtles, amongst which the giant land turtle is very prominent (Schleich, pers. comm.). The reptile fauna will be studied separately (Corvinus & Schleich, in press).

The fauna so far identified, indicates an age comparable to the Tatrot and Pinjor period of India. There does not seem to be any doubt that the major part of the massive micaceous sandstone facies of the Surai Khola succession (as well as that of the Rato Khola area) is of Upper Siwalik age.

The Tatrot fauna at Surai Khola is recognised only by the occurrence of *Giraffa punjabiensis* in the lower part of the micaceous sandstone facies, while the Pinjor fauna is encountered in the upper part of the Surai Khola Formation and the Dobatta Formation.

It is not possible to demarcate the boundary between the two faunal zones at the Surai Khola on the basis of the lithology nor on the basis of the fauna. Fossils of Tatrot and Pinjor age seem to overlap each other at Surai Khola and it is possible that an undetected hyatus in sedimentation is present in the multistoried sandstones in the upper part of the Surai Khola Formation. With the recent discovery in March 1991 of a probable ash bed within the lower part of the Surai Khola sandstone Formation it is hoped that a radiometric date could be obtained from this horizon to clarify the faunal boundaries.

Overlying the fossiliferous Surai Khola sandstones in the Surai Khola sequence are the equally fossiliferous beds of the **Dobatta Formation** with a thickness of 550 m. The facies becomes again more clayey. These beds are exposed to the west of the Dobatta teashops where the road turns to the west towards the Dhan Khola bridge and the new Dhan Khola temple. The road here goes more or less along the strike of the deposits and the previous measurement of 750 m for this formation by one of us (Corvinus 1988 a, b) exceeds the true thickness of the sequence. The recently carried out compass traverse along the road has given a thickness of 550 m.

The clays are not indurated as those of the lower formations. They are rather colourful and are of a light-grey to dark grey or yellow to buff colour or are yellow-brown, but never purple or mottled like in the Bankas or the lower Chor Khola Formation. They are often rich with molluscan remains, and several clay horizons show an abundance of microvertebrates and fish.

The clays are intercalated with soft, micaceous, fossiliferous sandstones, some upto 17 m thick, yet not as thick as those in the Surai Khola Formation. They are similar in composition to those of the Surai Khola Formation, and also contain numerous lenses of "puddingstones", which are invariably rich in small bones and bone fragments.

Lenses of pebble and cobble conglomerates in sandstones make their first appearance in the upper part of the Dobatta succession and are still intercalated with rather thick clays and silts.

The faunal record is extremely rich and varied in the Dobatta Formation. Vertebrate fossils are abundant. Particularly abundant are the remains of crocodiles and turtles, and mammalian fossils are frequent as well. One sandstone bed of 24 m thickness in particular is very rich in vertebrate fossils, which are contained mainly in several "puddingstone" lenses within this sandstone.

The youngest formation at Surai Khola is the **Dhan Khola Formation** with a thickness of approximately 1500 m. The deposits consist mainly of massive cobble-boulder conglomerates. The lower part of the conglomerates are highly indurated and form steep ridges. The conglomerates in the upper part are less indurated and are intercalated with yellow, coarse sandstones and gravels as well as with yellow silts and clays.

The fossil content is low. Only a few unidentifiable bones were found. Molluscs are derived from three horizons of clays. A few carbonaceous layers are recorded in the uppermost part.

Fig. 3 shows the lithocolumn of Surai Khola with the recorded fauna, and Table 9 shows the lithological characteristics of the Surai Khola sequence and the distribution of the fauna.

2. Rato Khola

A large vertebrate collection of an Upper Siwalik fauna, was made in 1985 and 1986 in the Rato Khola area in Eastern Nepal from a massive, salt and pepper sandstone succession, lithologically of the same facies as that of the Surai Khola Formation.

From this area the richest vertebrate fossil collection of an Upper Siwalik fauna has been made and again, like at Surai Khola, the Tatrot element is present only in the lower part of the arenaceous succession.

A skull of the suid *Hippohyus tatroti* and a recently found horn core of *Proamphibos* or *Hemibos* was recovered from the lower part of the massive sandstone succession. More collections include a skull of *Hexaprotodon sivalensis* and abundant cranial and post cranial bones of mainly *Hexaprotodon* and elephants.

In the upper part of the sandstone succession the first author excavated a skull of *Archidiskodon planifrons* with mandibles and with partial tusks from a sandstone cliff of the salt and pepper sandstone succession. The skull is now housed at the Natural History Museum at Kathmandu and is under reconstruction and will be described separately together with another skull of a *Stegodon* from the same sandstones nearby.

These findings are important. They indicate that wherever such massive, micaceous sandstones similar to those of the Surai Khola Formation are

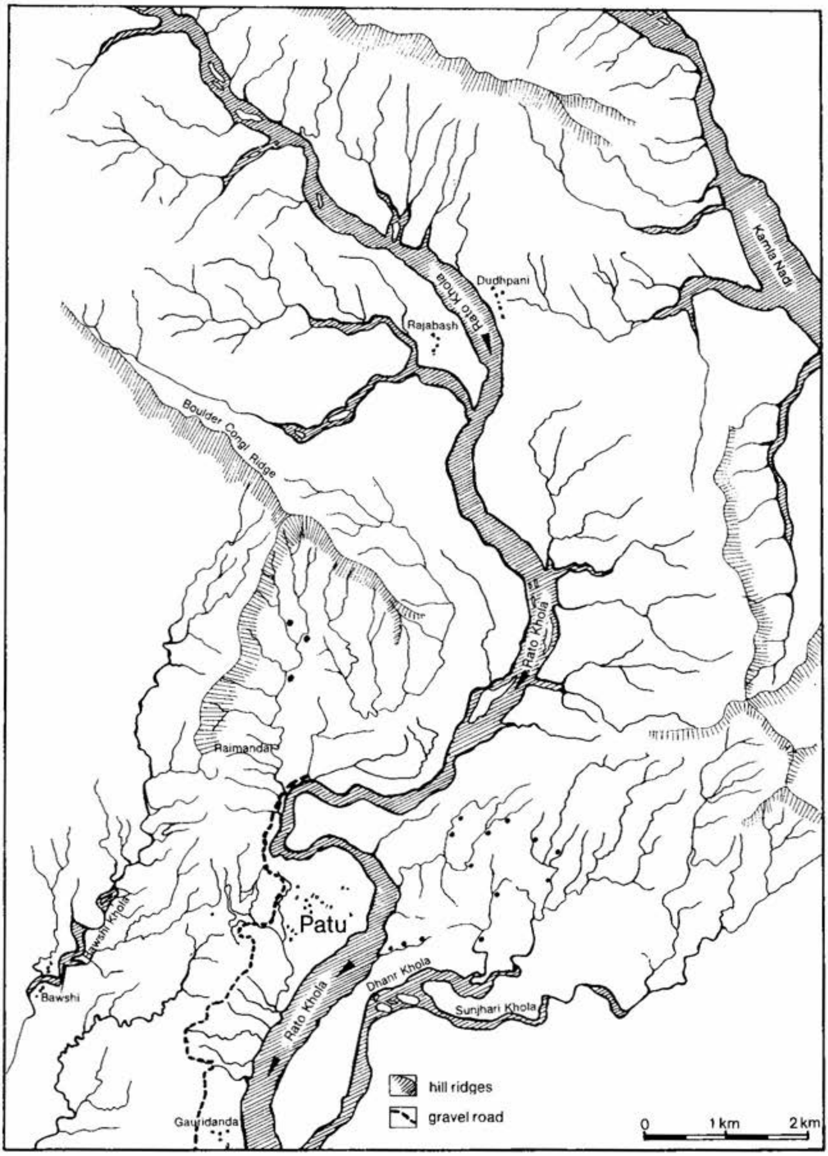

Fig. 6. Map of Rato Khola and its tributaries with fossil sites indicated.

encountered in the investigated areas, they are for the main part of Upper Siwalik age. This is significant, too, for the reason that until now similar sandstones have been placed in Nepal in the Middle Siwaliks by earlier workers on purely lithological grounds.

IV. Recent fossil findings in the Lokhundol Formation in Kathmandu valley

Another section that has been studied (though only partly) is the Lokhundol Formation in the southern part of the Kathmandu valley. It consists of lacustrine and fluviatile sediments with intercalations of lignites. Fossils had been found here, previously (SHARMA 1977, FORT & GUPTA 1981). DANGOL (1985) has made a more extensive collection in the Lokhundol Formation. The fossils found by him suggest an age equivalent to the Pinjor. He collected antlers of cervidae, tusk fragments and a molar of *Archidiskodon* cf. *planifrons*, postcranial bovid bones and a suid tooth. Recently YOSHIDA & IGARASHI (1984) and YOSHIDA & GAUTAM (1988) have carried out magnetostratigraphic and palynological analyses of the lacustrine and fluviatile beds of the Lokhundol Formation.

Some additional fossils were found to ascertain the position of the Lokhundol Beds of the Kathmandu valley, which are now considered indeed to be contemporaneous with the Pinjor deposits of the Siwaliks. The proximal part of a horncore of *Cervus* sp. (Fig. 8, i) was found near Pharsidol, which places the Lokhundol Beds conclusively into the Pinjor. A molar of a suid could be identified as the second lower molar of *Potamochoerus* cf. *P. theobaldi*, (Fig. 8, a) which too is known from the Pinjor (from the Kangra valley in the Indian Siwaliks). This species is not found yet in the Siwaliks of Surai Khola and Rato Khola.

V. Palaeoenvironmental interpretation

The Surai Khola profile, with its newly established five formational units, is a rather exceptionally complete sequence of Siwalik sediments, and is unique in the sense that it exposes a seemingly uninterrupted molasse sequence from the upper part of the Lower Siwaliks to the uppermost Siwaliks and, at the same time, has a rich and varied palaeontological record, particularly of floral remains, which reflects the changing environments during the entire time of the sequence. The wealth of plant fossils and of palynofossils has prompted a systematic collection in chronological order throughout the sequence in collaboration with the Birbal Sahni Institute of Palaeobotany in Lucknow, India. This has provided additional data on the environmental changes as seen in the changes of the vegetational pattern and the climatic conditions (AWASTHI & PRASAD 1991, SARKAR 1991, CORVINUS 1991).

A gradual coarsening-up of the deposits can be observed from the lower to the upper strata at Surai Khola, which reflects the changing sedimentological pattern in relation to the rising Himalaya.

During the time of the Bankas Formation the environment was dominated by swamps and swampy lowland situations with aquatic plants and algae which is reflected in the pollen record (SARKAR 1991), and with a tropical evergreen vegetation as evidenced by the rich mega plant fossils (AWASTHI & PRASAD 1991).

In Middle Siwalik times during the Chor Khola Formation the environment must have gradually changed from quiet pools and swamps to a more active river regime. The Himalayas began to rise more prominantly and rivers discharged increasingly coarser sandy material into the foredeep. The vegetational pattern, too, began slowly to change from tropical evergreen forests towards moist deciduous vegetations in the Chor Khola Formation and continued to change towards a dry deciduous vegetation in the lower Surai Khola Formation (AWASTHI & PRASAD 1991).

During the Surai Khola Formation increasing sedimentation of medium to coarse sandstones took place in wide, braiding river channels, reflecting increased uplift of the mountains and an increased discharge of sediments from them. The fauna encountered during this time seems to have been particularly abundant in large mammalian animals, especially in Elephantidea and Hippopotamidea, as well as in large reptiles (Crocodilidae and turtle). The floristic record as seen by the pollen (SARKAR 1991) indicates a change towards drier climatic conditions with the appearance of Cycadaceae and pollen of pinus-like affinity.

The fauna during the short return to a quieter river activity in the Dobatta Formation indicates a rich aquatic life as seen by the particular abundance of a reptilian fauna and of fish and by the presence of many molluscan horizons. The mammalian remains are abundant as well, more so than in any of the other Formations at Surai Khola. An interesting feature is shown by the pollen record with the reemergence of algal elements (SARKAR 1991), which had been absent since the lower Chor Khola Formation and which points to local swampy conditions during this time, corresponding well with the lithological evidences.

The deposition of cobble-boulder conglomerates in the uppermost part of Surai Khola marks not only a maximum of uplift of the mountains, but also the closeness of the depositional area to the mountain foot. Unfortunately the vertebrate fauna is scarce, though a number of rolled bones of large animals, encased in a pebbly matrix, has been found in the upper Surai Khola river bed. Interestingly enough, pollen are still present in the finer sediments intercalated in the conglomerates, and they establish much drier climatic conditions with the appearance and predominance of graminaceous pollen and acacia, indicating the presence of grasslands and open woodlands.

The fossiliferous sandstones of the Rato Khola area which correspond lithologically and faunally with those of the Surai Khola Formation and contain an Upper Siwalik fauna, reflect a similar environmental pattern as that displayed in the Surai Khola Formation at Surai Khola.

VI. Systematic palaeontology

A large number of vertebrate fossils are collected from the Upper Siwalik Subgroup of Surai Khola and Rato Khola in which the Class Mammalia dominates. The Middle Siwalik Subgroup of the Surai Khola has not yet yielded any identifiable vertebrate fossils. Only one *Gomphotherium* (Order Probscidea) tooth has been identified from the Lower Siwalik Subgroup. Mammalian fossils of the Upper Siwalik Subgroup are described here. Reptilian fossils are fragmentary and they are commented only briefly. The fossils described below are at present in the personal collection of the first author (C. G. and will be given to the Department of Geology, Tribhuvan Univrsity, Kathmandu. Part of them are exhibited in the Museum of Natural History in Kathmandu, Nepal.

Abbreviations: Dha-Dhan Khola area, Ra-Rato Khola area, Su.K. – Surai Khola area.

Order Proboscidea Illiger, 1811

Family Elephantidae Gray, 1821

Subfamily Elephantinae Gill, 1872

Genus *Archidiskodon* Pohlig, 1888

Type species *Elephas meridionalis* Nesti, 1825

Archidiskodon planifrons (Falconer & Cautley), 1845

Fig. 7, a–c

Additional material

Ra 4/6. A left mandibular ramus which is part of a complete skull with partial tusks which is now exhibited at the Natural History Museum at Kathmandu. It was excavated in a tributary of Rato Khola from the micaceous multistoried sandstones of the Upper Siwalik Subgroup, about 2 km NE of Patu Village.

Su.K. 98. Partial left last upper molar, collected from the Dobatta Formation near the Dobatta Camp.

Su.K. 99. Two small enamel figures; surface, near Dobatta Camp, derived from the Dobatta Formation.

Dha 1/5b. Fragment of lamella. Collection from the lower part of the sandstone succession of Rato Khola, from Dhanr Khola tributary (gully 1).

Description

Specimen Ra 4/6 (Fig. 7, a–b). Described here is the left mandibular ramus of the large excavated skull from the Rato Khola tributary, in which M/2 and M/3 are preserved. M/2 is only partially preserved and only two and a half plates can be seen; the posterior-most is represented by half a plate, but the posterior enamel of one more plate is seen at the anterior-most extremity. The buccal enamel of the plates is broken. Both the plates are

Table 2. Measurements in millimeters of *Archidiskodon planifrons* (FALCONER & CAUTLEY).

Tooth	Ra 4/6	Su.K. 98	Su.K.E. 99
Second Molar			
Lamellar frequency	4.35		
Enamel thickness	4.0		4.0
Last Molar			
Length	33.7	182 +	
Breadth	97	92	
Lamellar frequency	3.2	3.4	–
Enamel thickness	3.9	4.3	

confluent in the median portion. The posterior-most half plate is not confluent with the plate just anterior to it. The valleys in between the plates are filled with cement. The median portion also shows antero-posterior expansion which is characteristic of *Archidiskodon planifrons.*

The last molar M/3 is represented by ridge formula 1/2-11-1/2, only the first five ridge plates were in use. The sixth and seventh ridges are not erupted and the rest of the ridges are still inside the jaw and can be seen, as the jaw is broken on its posterior extremity, and their respective position can be demarcated. The anterior-most half plate is worn and shows posterior expansion. This half plate does not extend upto the lingual margin.

The first ridge plate from the anterior is represented by two enamel figures. The figure on the buccal side is showing expansion in the central part of the occlusal surface of the tooth. The second plate is having two enamel figures and the buccal figure shows a marked anterior and posterior expansion. The valley between the first and second plates on the lingual side is unusually wide and deep but the posterior expansion of the first plate and anterior expansion of the second plate blocks the valley, and the valley on the buccal side is filled with cement and is not deep.

The third ridge or plate is represented by five worn enamel figures. The second figure from buccal is slightly posterior to all the other three figures, and it also shows a slight anterior expansion. The fourth ridge is represented by five conelets, the second from the buccal is slightly posterior to all the other conelets. Dentine is exposed in all the conelets except the lingual-most. Only four conelets can be seen in the fifth ridge and dentine is not exposed in any of these conelets. The rest of the ridges are in cement, but the respective positions can be seen.

The valleys between the various ridges or plates are at least partially blocked due to posterior expansion of the ridges in the median part. The cement is abundant in the valleys. Enamel is smooth and moderately thick, average thickness 3.9 mm. The lamellar frequency of M/3 is 3.3.

Su.K. 98 (Fig. 7, c) was found not in situ but in the Surai Khola channel in its upper part, where it cuts through the Dobatta Formation, above the micaceous sandstone facies of the Surai Khola sequence. It is a last left upper molar and is broken on the anterior side. Its ridge formula can be given as M/3 7-1/2. The first and second ridges or plates from anterior are confluent and the valley is completely closed whereas the valleys in between the second and third and fourth plates are closed in the respective median portion. All the valleys between the rest of the plates are open and partially filled with cement. The third, fourth and fifth ridges show median expansion on both sides, the anterior expansion is comparatively more on the anterior side than on the posterior. The sixth plate is represented by three figures, the lingual one is broken at its occlusal surface. The seventh ridge plate is represented by four conelets in which dentine is exposed. The enamel is smooth, and coarsely folded. The average thickness is 4.3 mm and lamellar frequency is 3.4.

Su. K. 99 shows just two small enamel figures. The enamel thickness is about 4 mm. No other character is visible.

Dha 1/15 b. Fragment of lamella of elephant tooth (with an erupted cone). Lamellar thickness is about 4 mm.

Remarks

Both the well preserved teeth belong to *Archidiskodon planifrons.* Only one species of *Archidiskodon*, i. e. *A. planifrons*, is known from the Upper Siwalik Subgroup of the Indian sub-continent. It differs from *Elephas hysudricus* as the present specimen has thicker enamel and is more coarsely plicated and that the lamellar frequency is also less in comparison to *E. hysudricus.* On the basis of enamel thickness another specimen, Su. K. 99, is also provisionally referred to this species. The measurements are tabulated in Table 2.

Subfamily Stegodontinae Osborn, 1918

Genus *Stegodon* Falconer & Cautley, 1847

Type species *Elephas insignis – ganesa* Falconer & Cautley, 1845

Stegodon sp.

Fig. 7, d

Additional material

Ra 1/22. Fragment of Upper molar, collected from the lowermost part of the micaceous sandstone facies at Rato Khola, from a small gully, Ra 1.

Ra 10/6. Fragment of lower molar, collected from the upper part of the micaceous sandstone facies of Rato Khola, in the upper, western part of a gully, Ra 10.

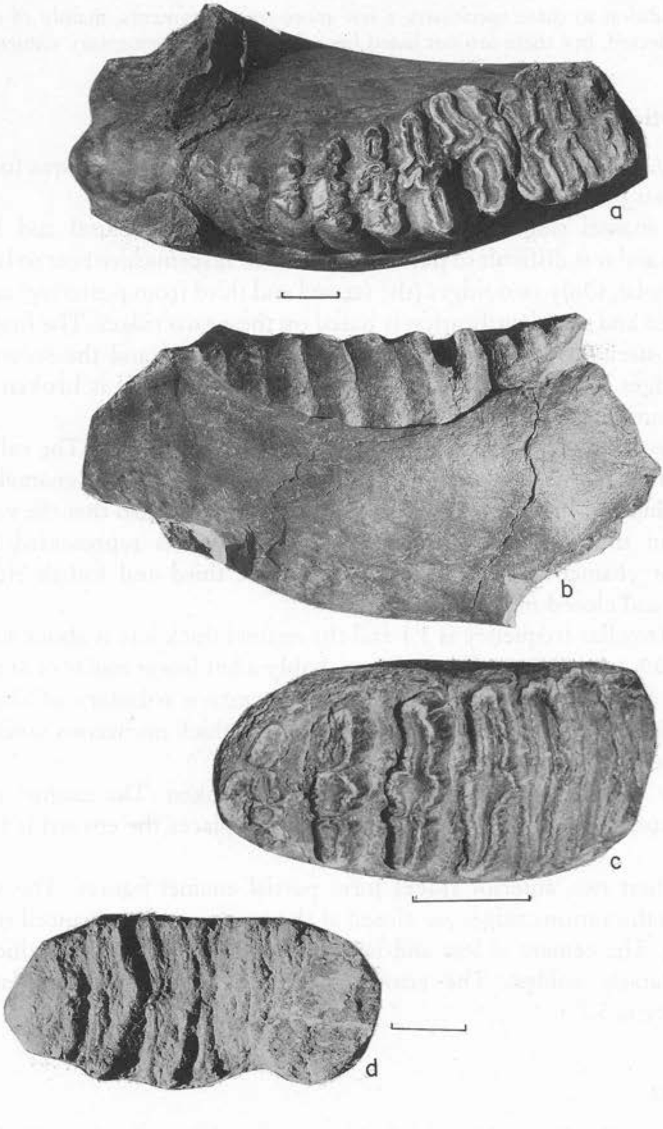

Fig. 7
a: *Archidiskodon planifrons* (FALCONER & CAUTLEY).
Left mandibular ramus (Ra 4/6), occlusal view.
b: Lingual view of above.
c: *Archidiskodon planifrons* (FALCONER & CAUTLEY), partial left last upper molar (Su.K. 98), occlusal view.
d: *Stegodon* sp., fragment of upper probably left molar (Ra 1/22), occlusal view.
Each corresponding scale represents 5 cm.

In addition to these specimens, a few more teeth fragments, mainly of enamel, were collected, but these are not listed here due to their fragmentary nature.

Description

Ra 1/22 (Fig. 7, d) is a fragmentary molar of *Stegodon* and was found in the lowest part of the micaceous sandstones at Rato Khola.

The enamel ridges are broken partially on the occlusal and lingual surfaces and it is difficult to place it in position. It seems however to be a left upper molar. Only two ridges (the second and third from posterior) are well preserved and the identification is based on these two ridges. The first ridge from posterior is represented by its anterior enamel and the second and third ridges form full enamel figures, though the enamel is broken on its lingual surface.

The enamel of both the ridges is thick and slightly folded. The valleys in between these are filled with cement. Dentine is exposed. The enamel of the second and third ridges from posterior is just touching, so that the valley is closed in the median portion. The fourth ridge is represented by its posterior enamel and the valley between the third and fourth ridges is narrow and closed in the median part.

The lamellar frequency is 3.1 and the enamel thickness is about 4.8 mm.

Ra 10/6 is a broken tooth and is probably a left lower molar of *Stegodon insignis* and was found in the first small, western tributary of the Rato Khola, Ra 10, where only the upper part of the thick micaceous sandstones is exposed.

Only four ridges are present, the rest is broken. The enamel on the lingual surface is missing, and at various other places the enamel is broken too.

The first two anterior ridges form partial enamel figures. The valleys between the various ridges are closed as the tooth is in an advanced stage of wearing. The cement is less and is probably eroded. Enamel is thick and very coarsely folded. The enamel thickness is 5.5 mm and lamellar frequency is 3.7.

Remarks

Osborn (1942) considered only four species of *Stegodon* from the Indian Siwaliks. These are *S. bombifrons, S. elephantoides, S. insignis* and *S. pinjorensis.* He considered *S. clifti* and *S. ganesa* as synonyms of *S. elephantoides* and *S. insignis* respectively.

Both the above teeth are referred to *Stegodon insignis* on the basis of their general form. In *S. bombifrons* cement is abundant, but at least in one of the present specimens, No. Ra 1/22, it is abundant. Both the specimens are broken in their anterior and posterior margins, so that it is difficult to have the exact number of ridges in each specimen, but it seems to have a higher ridge formula as compared to *S. elephantoides* and *S. bombifrons.*

S. pinjorensis is reported from the Siwalik Hills of India and is not a common form like *S. insignis. S. pinjorensis* is differentiated from *S. insignis* by its superior size, larger number of ridges and higher hypsodonty. Therefore the described specimens are referred to *S. insignis.*

Specimen No. Dha 1/15, which is only a fragmentary enamel, may also be referred to this species, as the enamel thickness is 5.5 mm.

The burnt *Stegodon insignis* from the Kathmandu Valley

This fossil has an interesting history. It is probably one of the oldest or even the oldest collected fossil from the Kathmandu valley and its provenance is unknown. It was given to the first author by Mr. J. L. SHARMA, then Director General of the Department of Archaeology in Kathmandu. It had been in the possession of the department for many years, but was burnt in the great fire of the Singha Durba, in 1973, where the department was housed previously. It survived the fire, but was quite heavily damaged and records concerning the provenance etc. were lost. Its horizon is in the Lokhundol Formation of the southern Kathmandu valley, which is contemporary with the Pinjor Formation.

The burnt specimen is a right mandibular jaw in which the occlusal surface is very badly damaged and the ridges are completely destroyed, but the damaged enamel figures of a few posterior ridges can be seen. These are exposed, because the occlusal surface is broken, otherwise they would not have been exposed. The posterior part of the alveolus of the anterior tooth can be seen, but no details are visible. It is estimated that there were eleven ridges and it is probably the second molar. The enamel of eight ridges can be seen. Probably the three anterior-most were worn as the enamel between the first and second and the second and third seems to be confluent. Enamel is thick, about 6.0 mm, and coarsely folded. The lamellar frequency is about 5.3. Dentine is exposed in between the enamel, and is of dark brown colour.

Order Artiodactyla OWEN, 1848

Family Suidae GRAY, 1821

Subfamily Suinae ZITTEL, 1893

Genus *Potamochoerus* GRAY, 1854

Type species *Sus koiropotamus* DESMOULINS

Potamochoerus cf. *P. theobaldi* PILGRIM

Fig. 8, a–b

Additional material

Ba 4/16. Isolated lower molar, collected from the Lower Lokhundol Formation, Kathmandu valley.

Description

Ba 4/16. This specimen derives from a lignitic horizon in the lower part of the Lokhundol Formation in the southern Kathmandu valley and was given to the senior author by a farmer, who was digging there for coal. From the same locality G. DANGOL collected other fossils (DANGOL 1985).

This specimen is a right second lower molar. The four cusps are well developed. In addition to these cusps two posterior elements are also developed at the posterior extremity of the tooth, of which the element at the postero-lingual angle is larger. One median conule lies in the valley between the anterior and posterior cusps, thus this valley is closed in the central part but open on the buccal and lingual margins. On the base of the valley, one small tubercle is present on each side of the valley. At the anterior extremity the cingulum, in the form of a raised conelet, is present. The buccal cusps, i. e. the protoconid and the hypoconid are stouter than their corresponding cusps on the lingual side, and also placed more anteriorly to their corresponding cusp on the lingual side.

Remarks

In measurements and in general form, Ba 4/16 resembles the right second lower molar of *Potamochoerus theobaldi* figured by PILGRIM (1926: pl. 10, fig. 3), but the present specimen is having an additional tubercle on the base of the buccal side of the valley between the anterior and posterior cusps. In addition, one more prominent conelet in the form of a cingulum is present on the anterior extremity. Therefore the present specimen is referred to *Potamochoerus* and compared with *P. theobaldi*. *P. theobaldi* is known from the Upper Siwalik Subgroup of the Indian Sub-continent only by a single mandibular ramus which was reported from the Pinjor Formation of Kangra, Himachal Pradesh.

Comparative measurements are given in Table 3.

Genus *Hippohyus* FALCONER & CAUTLEY, 1840–45
Type species *Hippohyus sivalensis* FALCONER & CAUTLEY, 1840–45
Hippohyus tatroti PILGRIM, 1926

Fig. 8, c

Additional material

Ra 1/20. Partial skull with maxilla, collected from the lower micaceous sandstone facies at Rato Khola, from the Ra 1 gully.

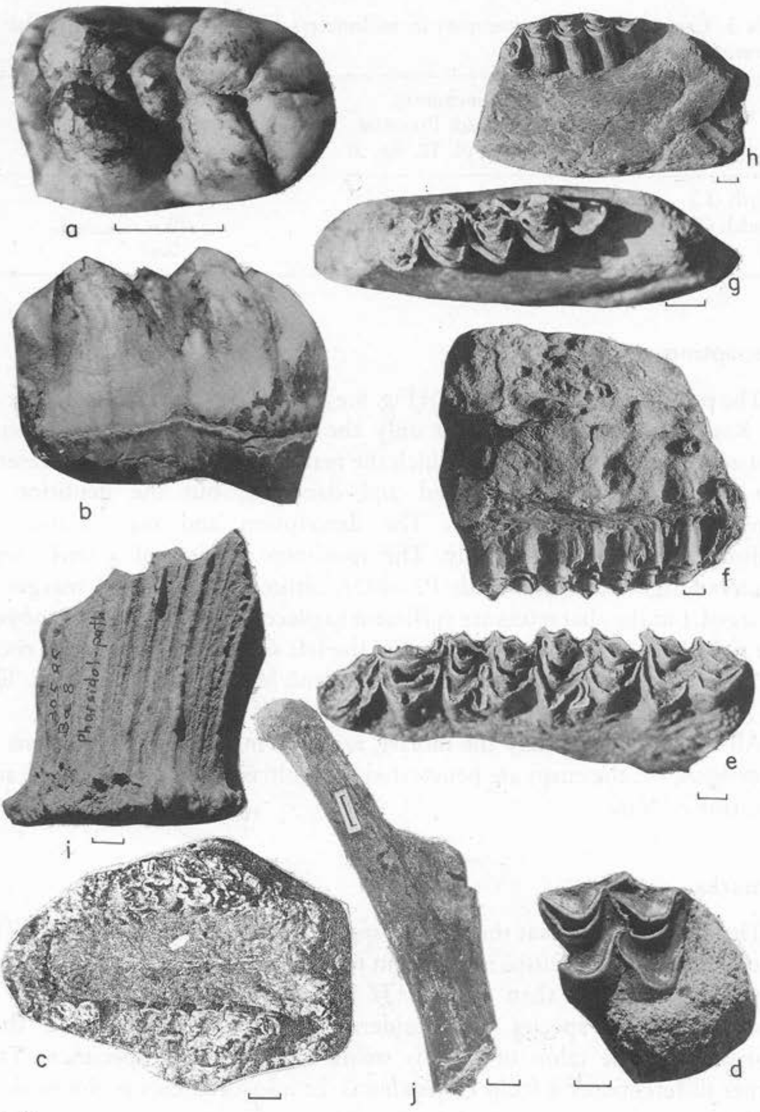

Fig. 8
a: *Potamochoerus* cf. *P. theobaldi* (PILGRIM), right second lower molar (Ba 4/16), occlusal view.
b: Lingual view of above.
c: *Hippohyus tatroti* (PILGRIM), maxilla with broken dentition (Ra 1/20), ventral view.
d: *Giraffa punjabiensis* (PILGRIM), right upper second molar (Su K.5), occlusal view.
e: Left upper jaw of bovinae, (Dha 371), occlusal view.
f: Lingual view of the above.
g: Left partial mandibular ramus of bovinae, (Ra 4b/1), occlusal view.
h: Buccal view of the above.
i: Part of *Cervus* antler with base (Ba 8/8).
j: Fragment of antler of *Cervus* (Su.K. 12), lateral view.
Each corresponding scale represents 1 cm.

Table 3. Comparative measurements in millimeters for the second lower molar of *Potamochoerus* cf. *theobaldi.*

	Potamochoerus theobaldi PILGRIM (1926: pl. 10, fig. 3)	*Potamochoerus* cf. *theobaldi* (present specimen Ba 4/16)
Length (L)	28	29
Breadth (B)	21	20
B/L	0.75	0.69

Description

The present specimen, Ra 1/20 (Fig. 8, c) comes from a small tributary of the Rato Khola, which exposes only the lowest part of the micaceous sandstone facies. It is a skull in which the maxilla and the nasals are present. The specimen is slightly rolled and damaged, but the dentition is comparatively well preserved. The description and identification is confined to the dentition only. The specimen consists of a fairly well preserved right dentition with P2/–M3/, although the buccal margin is damaged, but the characters are sufficient to place it in the genus *Hippohyus.* The right M1/ is completely worn. On the left side of the maxilla the roots of P3/–M1/ and the occlusal surface of M2/ and M3/ can also been seen. The left M3/, too, is badly damaged on its buccal surface.

All the teeth, especially the molars, are showing the typical patterns of *Hippohyus*, i. e. the cusps are penetrated by a fold each on their anterior and posterior margins.

Remarks

There is no doubt that the present specimen belongs to *Hippohyus.* The general pattern of the cusps is sufficient to place it in this genus. The present dentition is smaller than that of *H. grandis* but bigger than that of *H. deterrai.* The species is considered to be more primitive than *H. sivalensis.* The talon of M3/ is small in the present specimen. This further differentiates it from *H. sivalensis.* In measurements is comes close to *H. tatroti.*

The present dentition resembles in morphology and measurements very closely the specimen figured by PILGRIM (1926: pl. 17, fig. 3). It is therefore referred to *H. tatroti.* The comparative measurements are tabulated in Table 4.

Hippophyus tatroti is widely known from the Tatrot beds of Potwar, Pakistan. NANDA (1982) reported this species from the Siwalik Hills of India. The presence of *H. tatroti* in Nepal shows a wider geographical distribution for this species and is also indicative of the presence of beds

Table 4. Comparative measurements of *Hippohyus tatroti.*

		PILGRIM 1926: pl. 17, fig. 3	Present specimen Ra 1/20
P3/			
	Length (L)	12	11
	Breadth (B)	10	9 (e)
	B/L	.83	.82
P4/			
	Length (L)	11	10
	Breadth (B)	14	12.5
	B/L	1.27	1.25
M1/			
	Length (L)	12	12
	Breadth (B)	15	14.5
	B/L	1.25	1.21
M2/			
	Length (L)	20	18
	Breadth (B)	17	18
	B/L	.85	1.00
M3			
	Length (L)	30	32
	Breadth (B)	20	19.5+
	B/L	.67	.61

(e) – estimated

equivalent in age to the Tatrot Formation in this area. That means, that the lower part of the massive micaceous sandstone facies of the Surai Khola and Rato Khola area belongs to the Tatrot Formation.

Family Hippopotamidae GRAY, 1821

Genus *Hexaprotodon* FALCONER & CAUTLEY, 1836

Type species *Hexaprotodon sivalensis* FALCONER & CAUTLEY, 1836

Hexaprotodon sivalensis FALCONER & CAUTLEY, 1836

Fig. 9, a–d

Additional material

A large number of cranial and post-cranial specimens of *Hexaprotodon sivalensis* were collected during the recent work in the Siwaliks of Nepal. They all are derived from the massive micaceous, medium to coarse sandstones which were formerly called Middle Siwalik, but which in fact belong, at least partly, to the Upper Siwalik Subgroup, after the identification of their vertebrate fossil content described in this article.

The identifiable specimens are listed below:

Ra 5/12. A rather well preserved skull from the middle part of the micaceous sandstone facies in tributary Ra 5 of Rato Khola (Fig. 9, a and b).

Ra 1/21. Rolled anterior part of a skull with roots of premolars, from the lower part of the thick micaceous sandstone facies of Rato Khola in tributary Ra 1.

Ra 9/5. Rolled maxillary portion of a skull from the middle part of the micaceous sandstones in tributary Ra 9 of Rato Khola.

Ra 4/7. Fragment of the dorsal part of a skull, from the middle part of the micaceous sandstones of tributary Ra 4 of Rato Khola.

Ra 5/7. Symphysis portion with roots of various incisors and premolars. Collected from the middle part of the micaceous sandstones in tributary Ra 5 of Rato Khola (Fig. 9, c).

Ra 10/5. Right mandibular jaw with broken M1/–M3/, from the upper part of the micaceous sandstones facies in tributary Ra 10 of Rato Khola (Fig. 9, d).

Dha 1/22. Part of right mandible with root of a canine, from the micaceous sandstone facies of Dhanr Khola, the southern-most left tributary of Rato Khola.

Dha 1/11. Broken right canine, represented by its root only, and with broken symphysis. Collected from the lower part of the thick micaceous sandstone facies in the Dhanr Khola, the southern-most tributary of Rato Khola.

Su.K/11. An isolated incisor, from the lower micaceous sandstones of the Surai Khola Formation at Surai Khola.

A few of these, Ra 5/12, Ma 5/7 and Ra 10/5 are described below:

Ra 5/12 (Fig. 9, a–b). The dentition of this skull is well preserved. The right jaw is better preserved and is represented by P3/–M3/, whereas the left jaw is damaged and P4/ and M1/ are broken at the occlusal surface and the alveolii of P2/ and P3/ can be seen. The skull is just broken anterior to it. The basi-occipital of the skull can be seen but the occipital condyles are missing. The zygomatic arch is missing as well except for the right anterior portion. The skull in dorsal view is deformed due to small cracks, and no suture is visible. The dentition is best preserved and is discussed here.

P3/ In the right P3/, the enamel of the lingual side is broken. The metacone is at a higher level. The cingulum is well developed on the anterior and postero-buccal angles.

P4/ Two cusps, the paracone and protocone, of the right side are better preserved. The cingulum at the posterior margin is developed and higher than the cingulum on the anterior side. A weak cingulum is seen on the lingual surface. The tooth is slightly used.

M1/ The teeth of both sides are very much worn and the cusps are completely confluent. The cingulum is present only at the postero-lingual angle and is weak.

M2/ The teeth of both sides show very well trefoil pattern of *Hexaprotodon.* The paracone and protocone are confluent with each other. Each cusp is having one anterior and one posterior vertical groove which gives a trefoil pattern. The posterior lobe of the paracone is lingual to the anterior lobe of the metacone. The metacone and metaconule are pressed together, so that there is no longitudinal valley left between these cusps. The cingulum at the lingual margin is more prominent than the cingulum on the buccal margin.

M3/ The right last molar is well preserved. All the four cusps are slightly worn and the longitudinal valley between the cusps is not yet

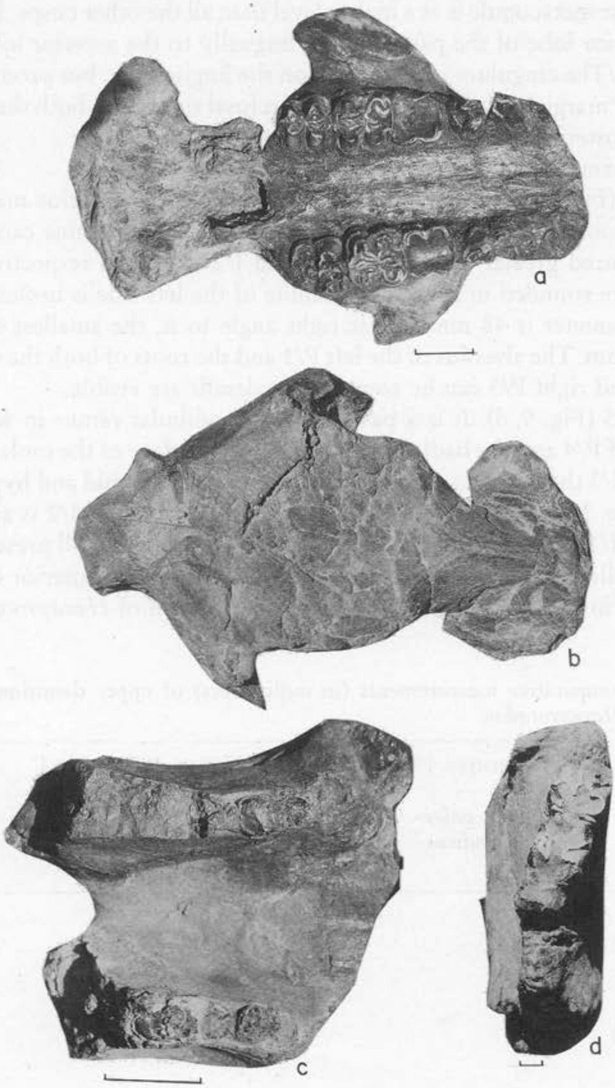

Fig. 9
a, b: *Hexaprotodon sivalensis* (Falconer & Cautley). Partial skull (Ra 5/12),
a: dorsal view, b: ventral view.
c: Symphysis, broken at anterior margin (Ra 5/7), occlusal view.
d: Partial right mandibular ramus (Ra 10/5), occlusal view.
Each corresponding scale represents 5 cm.

closed. The metaconule is at a higher level than all the other cusps. Like M2/ the posterior lobe of the paracone lies lingually to the anterior lobe of the metacone. The cingulum is very weak on the lingual side, but prominent on the buccal margin and rises towards the occlusal surface on both the anterior and the posterior margins of the tooth.

The enamel is slightly rugose in all the teeth.

Ra5/7 (Fig. 9, c). This symphysis is broken on the anterior margin and only the roots of I/1 to I/2 of both side and of the left canine can be seen. The measured greater diameter of I/1 and I/2 is 22 mm respectively. The incisors are rounded in shape. The canine of the left side is broken and its greater diameter is 48 mm and at right angle to it, the smallest diameter, being 25 mm. The alveolus of the left P/1 and the roots of both the right and left P/2 and right P/3 can be seen, but no details are visible.

Ra 10/5 (Fig. 9, d). It is a partial right mandibular ramus in which the alveolus of P/4 and the badly damaged occlusal surface of the molars can be seen. In M/3 the talonid and the posterior cusps (entoconid and hypoconid) are broken. M/1 is worn and all the cusps are confluent. M/2 is also worn and like M/1 all the cusps are confluent, but the enamel is still present in the median valleys of the lingual and buccal sides. Only two anterior cusps are preserved in M/3 and these show the typical pattern of *Hexaprotodon.*

Table 5. Comparative measurements (in millimeters) of upper dentition of some species of *Hexaprotodon.*

	Hooijer 1950: table 2					Nanda 1978: table 1 *H. sivalenis*			Present specimen
	H. iravat.	*H. palaeindicus*		*H. sivalensis*					*H. sivalensis* Ra 5/12
Length (L)									34
Breadth (B)									27
B/L									0.79
Length (L)									25
Breadth (B)									30
B/L									1.20
Length (L)	28	40	41	35	31	32			35
Bredth (B)	29	39	36	41	40	39			40
B/L	1.04	0.98	0.88	1.17	1.29	1.22			1.14
Length (L)	36	54	54	48	39	44+	42	46	43
Breadth (B)	34	47	44	51	47	44	38	46	43
B/L	0.94	0.87	0.81	1.06	1.21	1.00	0.90	1.00	1.00
Length (L)	39	51	54	50	40	45	47	45	38
Breadth (B)	37	46	–	52	44	43	46	43	42
B/L	0.95	0.90	–	1.04	1.10	0.96	0.98	0.96	1.11

Table 6. Comparative measurements (in millimeters) of lower teeth of some species of *Hexaprotodon.*

Tooth	HOOIJER 1950: table 3 *H. iravaticus*		*H. palaeindicus*		*H. namadicus*		*H. sivalensis*		NANDA 1978 table 1 *H. sivalensis*		Present specimen *H. sivalensis* Ra 5/7	Ra 10/5
Greater Diameter of C	38		54	57	47	54	61				48	
Greater Diameter of I1	21	26	40	37	32	33	30	22			22	
Greater Diameter of I2	18	23	16	18	23	23	22	20			18	
Greater Diameter of I3	18	25	40	42	36	38	28	20				
P1:												
Length (L)											14 (e)	
Breadth (B)											16	
B/L											1.14	
P2:												
Length (L)											34	
Breadth (B)											17	
B/L											0.50	
P3:												
Length (L)											41 (e)	
Breadth (B)											18 (e)	
B/L											0.44	
P4:												
Length (L)									33			
Breadth (B)									22			
B/L									0.67			
M1:												
Length (L)									34	39		37
Breadth (B)								31	32	36		29
B/L									0.94	0.92		0.78
M2:												
Length (L)		47					51	52	52	50		41
Breadth (B)		31					39	36	37	38		33
B/L		0.66					0.76	0.69	0.71	0.76		0.80
M3:												
Length (L)			68				72	63	46 +	71		59
Breadth (B)			43				42	39	39	39		34
B/L			0.63				0.58	0.62	0.85	0.55		0.58

Samples Nos. Ra 1/21, Ra 4/7, Su.K./11 and the Dha 1/11 are not described here as these are quite fragmentary or rolled, but the general shape or pattern of the worn dentition or roots etc. leave no doubt that these belong to *Hexaprotodon.*

Remarks

Only two species of *Hexaprotodon*, *H. sivalensis* from the Siwaliks of India and Pakistan, and *H. iravaticus* from the Irrawaddy beds of Burma, are known from the vicinity of Nepal. West & Munthe (1983) reported *H. sivalensis* from Nepal. It differs from *H. iravaticus* by its larger size (Colbert 1935: 280). Hooijer (1950) has described fossil Hippopotomidae from Asia and recognised *H. palaeindicus* and *H. namadicus* from the Narbada beds of central India. According to Hooijer (1950: 79) in *H. sivalensis* the posterior lobe of the paracone lies lingually to the anterior lobe of the metacone and this differentiates it from *H. palaeindicus.* The present material (specimen No. Ra 5/12) demonstrates this character. On the basis of the general pattern and measurements the material is referred to *H. sivalensis. H. namadicus* is known so far by its lower jaw. Since in the present material a good symphysis is lacking; it is not feasible to give a detailed comparison with *H. namadicus*; and as only one species of *Hexaprotodon*, i.e. *H. sivalensis*, is known from the Siwaliks, it is much safer to refer it to this species. Comparative measurements of the upper dentitions (specimen No. Ra 5/12) and lower dentitions (specimen No. Ra 5/7 and Ra 10/5) are tabulated in Tables 5 and 6 respectively.

Family Cervidae Gray, 1821

Subfamily Cervinae Baird, 1857

Genus *Cervus* Linnaeus, 1758

Cervus sp.

Fig. 8, i j

Additional material

Ba. 8 (Fig. 8, i). Fragment of antler with base, collected from the path from Pharsidol village to Bagmati river, probably derived from the upper part of the Lokhundol Formation at the level of contour line 1320 m in the Kathmandu basin.

SU.K. 12 (Fig. 8, j). Fragment of antler, collected in situ from the uppermost part of the micaceous sandstone facies of the Surai Khola Formation of the Surai Khola profile, some 170 m below the top of the formation, at a distance of 200 m south of the Dobatta teashop.

Description

Ba 8. It is a broken antler with its base (i.e. burr). It is very heavily built and is of round cross section. The burr is prominent. The beam is covered with longitudinal grooves and ridges. The antero-posterior diameter of the beam above the burr is 61 mm.

Su.K. 12. It is a fragment of an antler without its lower part as the burr is missing. The main stem of the antler or beam is bifurcated. The brow line or the bifurcated part of the beam is missing, but the junction place is clearly seen. The fragment is convex on one side and concave on the other side. The concave surface is marked with a prominent longitudinal depression. The surface of the antler is smooth and shows fine striations.

Remarks

Both the specimens from the Lokhundol Formation and from the Surai Khola Formation are fragmentary and it is not possible to identify them to species level. The presence of longitudinal grooves and ridges with the burr in Ba 8 confirms its inclusion in the family Cervidae; their characters and general forms are sufficient to refer them to *Cervus*, as Cervidae are represented in the Siwalik Group only by one genus i.e. *Cervus* (COLBERT 1935: 314–322).

Family Giraffidae GRAY, 1821
Subfamily Giraffinae ZITTEL, 1897

Genus *Giraffa* BRISSON, 1762
Type species *Girafffa giraffa* BRISSON, 1762
Giraffa punjabiensis PILGRIM, 1910
Fig. 8, d

Additional material

Su.K. 5. Isolated upper tooth, collected in situ from the middle part of the micaceous sandstone sequence of the Surai Khola Formation, 400 m below the top of the Formation and 170 m north of the Tintre Khola bridge.

Description

Su.K. 5 (Fig. 8, d) is an isolated, probably right upper second molar. The tooth is broken on its posterior and buccal margins and enamel is completely missing except the enamel of the mesostyle. The mesostyle seems to be prominent. The anterior fossette touches the buccal margin and both the fossettes show selenodont pattern. The tooth is quadrate and moderately hypsodont, and the enamel is rugose.

Remarks

The tooth is quite broken and it is difficult to identify it up to species level with certainty. It has been compared with the described and figured dentitions of Siwalik Giraffidae (PILGRIM 1911; COLBERT 1935). It is found that it differs from *Giraffokeryx punjabiensis* by its bigger size, but it is smaller in size to the known Siwalik species of *Sivatherium, Bramatherium* and *Hydaspitherium.* In size, the present tooth closely resembles *Giraffa punjabiensis* drawn by Colbert (1935: figs. 194–196), but it differs from these specimens as the median valley between the lingual cusps is wide in the present specimen and is having no tubercle in the valley like the figured specimens of Colbert (1935: figs. 194–195). But a tubercle is present in one of the other figured present specimens (Colbert 1935: fig. 192). According to Colbert (1935, p. 367) a tubercle is seldom present so that the presence or absence of tubercles does not differentiate the species. The mesostyle, present in the specimen, seems to be slightly more prominent than in the figured specimens of Colbert (1935). Keeping in mind the broken nature and the lack of additional material it is referred here provisionally to *G. punjabiensis* to which it tallies in size also.

The measurements are tabulated in Table 7.

Table 7. Comparative measurements (in millimeters) of the upper molars of *Giraffa punjabiensis.*

		Colbert 1935:		Present specimen
		p. 368, fig. 192	fig. 194	Su.K./5
M1/				
	Length (L)	23.5	30	
	Breadth (B)	23.5	30	
	B/L	1.00	1.00	
M2/				
	Length (L)		33	34
	Breadth (B)		34	34
	B/L		1.03	1.00
M3/				
	Length (L)		32	
	Breadth		32	
	B/L		1.00	

Family Bovidae Gray, 1821
Subfamily Bovinae Gill, 1872

Fig. 8, e–h

Material

The remains of this subfamily are quite plentiful. Apart from post-cranial remains, which are not considered here, three partial upper jaws (Su.K. 106, Su.K. 107 and Dha 3/1) and one upper molar Ra 9/4) and a left mandibular ramus with M/2–M/3 (Ra 4b/1) were collected from the Upper Siwalik beds at Surai Khola and Rato Khola. Su.K. 106 and 107 were collected in the same locality in the Khola channel of the upper Surai Khola where it cuts through the Dobatta Beds and the Dhan Khola conglomerates. The matrix of both fossils is pebbly sandstone and it is probable that they derived from a pebbly sandstone horizon within the Dhan Khola conglomerate. Su.K. 107 is a rolled partial upper skull, with the left maxilla preserved, but the dentition is quite damaged. Therefore it is not described here. It is possible that both fossils belong to the same individual.

Description

Su.K. 106 is a right partial upper jaw, and M1/–M3/ are preserved. The teeth are hypsodont with well developed cement and smooth enamel. The basal pillar is confluent with the main part of each tooth. Three enamel islets are present in the last molar, one between the two fossettes, and two slightly lingual. At least one enamel islet is preserved in between the fossettes of the second molar. M1/ is broken at the antero-buccal angle and no enamel islet is seen due to the poor preservation. Median ribs are very prominent on the buccal surface.

Dha 3/1 (Fig. 8, e–f) was found in sandstones in a tributary nallah of the Dhan Khola, the southern-most, left tributary of Rato Khola, where the gully cuts through the middle part of the micaceous thick sandstone facies of Rato Khola. It is a partial left upper jaw with P4/–M3/, and a fragment of P3/ can also been seen. The dentition is hypsodont with selenodont pattern. Enamel is smooth. Median ribs are strongly developed. In P4/ one tubercle is seen at the base of the postero-lingual angle. The basal pillar is confluent with the main part of the tooth in M1/ and M2/. A small enamel islet is present between the fossettes of M1/. The basal pillar is not visible in M3/, probably it is covered with cement. Cement is amply developed, and on the buccal surface of all the molars median ribs are also well developed.

Ra 9/4 was found in a larger, right tributary of Rato Khola, which cuts through the upper part of the thick micaceous sandstone facies. This isolated tooth, a left upper molar, is broken at the occlusal surface. The basal pillar is separate and median ribs are moderately developed.

Ra 4b/1 (Fig. 8, g–h) was found in a small, left tributary of the Rato Khola in the middle part of the massive micaceous sandstone succession. It is a left partial mandibular ramus, with M2/–M3/ in which the anterior cusp of M2/ is broken. On the buccal-occlusal margin the enamel is missing partially. Enamel is smooth on the lingual surface but very weakly rugose on the buccal surface. No pillar is seen in M3/, but M2/ is having a pillar which is separate. The anterior and posterior lobes of M2/–M3/ are convex.

Remarks

It is very difficult to distinguish the dentition of Bovidae to generic or specific level as the dentitions of various forms resemble each other very closely. The dentitions described here have been referred to the subfamily Bovinae on the basis of general characters as discussed by Pilgrim (1939: 154, 249). These dentitions may be mistaken with the one belonging to the subfamily Boselaphinae, but the present collection differs from Boselaphinae by the presence of strong folds and ribs on the buccal surface of the upper molars and by the convexity of the internal surface of each lobe in the lower molars. Moreover in Boselaphinae the upper molar is quadrate which is not the case with the present specimens or with Bovinae. The enamels of the present specimens are smooth and not rugose as in the Boselaphinae.

Pilgrim (1939: 155) has tabulated the measurements of the last upper molar of Boselaphinae and Bovinae, and in measurements (i. e. the quadrate nature of Boselaphinae) the present dentitions are more in agreement with Bovinae. The present collection, therefore, is referred to Bovinae and the measurements of the dentition are given below in Table 8.

Table 8. Measurements (in millimeters) of upper dentition (I) and of lower dentition (II) of Bovinae.

		I Dha 3/1	I Su.K. 106	I Su.K. 107	I Ra 9/4	II Ra 4b/1
P3						
	Length	–	–	17 (e)	–	
	Breadth	–	–	17 (e)	–	
P4						
	Length	20	–	16 (e)	–	
	Breadth	23	–	18 (e)		
M1						
	Length	25	24 (e)	24	–	
	Breadth	23	25	25 (e)	–	
M2						
	Length	29	27	27 (e)	–	31
	Breadth	23	23	24 (e)	–	19
M3						
	Length	30	27	27 (e)	29 (e)	39
	Breadth	24	22	22 (e)	27	18

(e) estimated

Comments on the reptilian fossils

The collection includes a great amount of reptilian fossil remains, in fact they have a higher percentage than any other group of the vertebrate fossils. Numerous pieces of carapaces and of plastrons of chelonians as well as teeth of crocodile are collected. Only a few of the reptile fossils will be described here. Most of them are derived from the Upper Siwalik micaceous sandstone beds. The described fossils include the partial anterior part of a skull (Dha 1/8) of an unidentified reptile (probably *Crocodylus*), two partial jaws of *Gavialis* (Dha 1/19, Ra 1/7) and fragments of skulls of *Crocodylus* (Dha 1/12, Ra 1/12, Su.K. 64), broken pieces and plates of carapace (Ra 1/8,

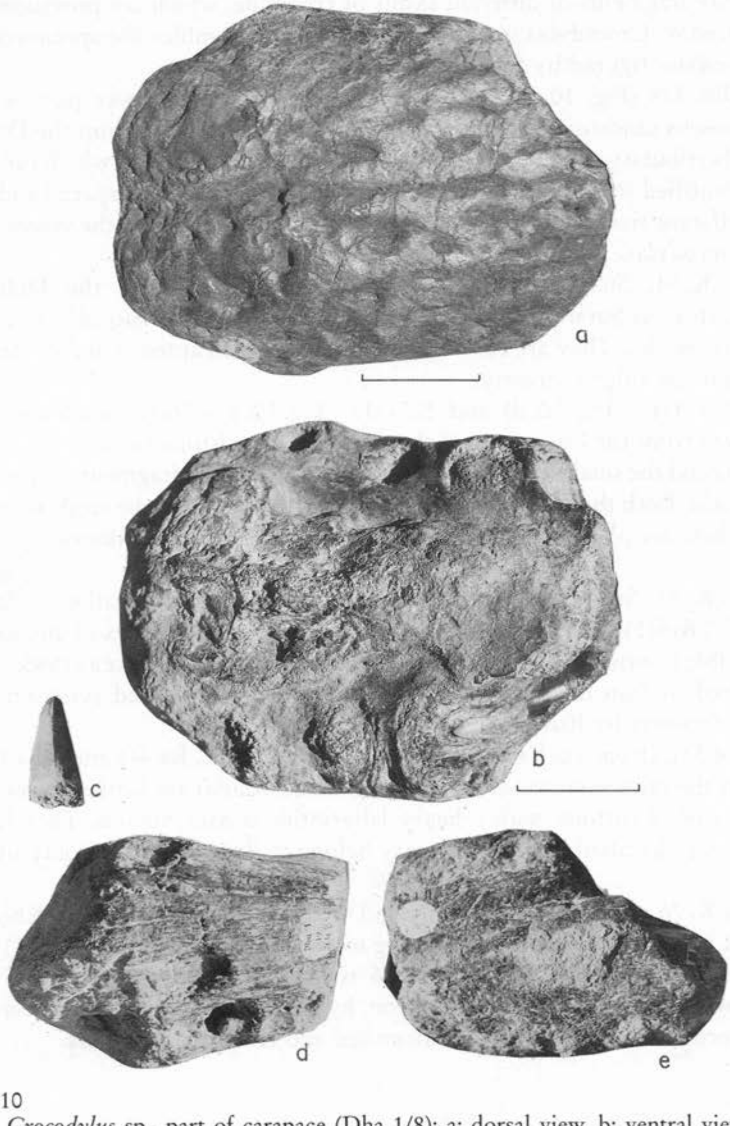

Fig. 10
a, b: *Crocodylus* sp., part of carapace (Dha 1/8); a: dorsal view, b: ventral view. c: *Crocodylus* sp., isolated tooth (Su.K. 118). d, e: fragment of jaw of *Gavialis* sp., ventral views, d: Dha 1/19; e: Ra 1/17.

Tui 33y, Ra 4/3, Ra 5/10, Dha 1/16, Dha 1/20, Su.K. 92, Su.K. 86, Koi/11 etc.), and plastrons (Su.K. 119 and Su.K. 76) as well as isolated crocodilian teeth (Su.K. 91, Su.K. 118 and more). Only a few specimen have been commented on.

Dha 1/12, Su.K. 64, Su.K. 10. All are from the micaceous sandstone facies of the Surai Khola Formation from Rato Khola and Surai Khola areas, and are fragments of different skulls of crocodile, which are provisionally referred to *Crocodylus* sp. The ornamentation resembles the specimens of *Crocodylus* figured by LYDEKKER (1886: 28).

Dha 1/8 (Fig. 10, a–b). This specimen is from the lower part of the micaceous sandstone beds of the Upper Siwalik Subgroup from the Dhanr Khola tributary of Rato Khola. It is the anterior part of a jaw which can not be identified so far. Sockets of the teeth are visible, these are spaced and are of different sizes. It may be representing the anterior part of the symphysis of *Crocodylus.*

Su.K. 91, Su.K. 118 (Fig. 10, c). Both teeth are from the Dobatta Formation at Surai Khola. These isolated teeth are provisionally referred to *Crocodylus.* They are curved inward and on each anterior and posterior margin one ridge is present.

Dha 1/19 (Fig. 10, d) and Ra 1/17 (Fig. 10, e). These specimens are derived from the lower part of the micaceous sandstone facies from Dhan Khola and the small Ra 1 gully at Rato Khola. They are fragments of jaws of *Gavialis.* Both the jaws are narrow anteriorly. Sockets of the teeth are seen and these are placed slightly away from each other, but are almost equal in size.

Su.K. 87, Su.K. 121, Su.K. 127 (from the Dobatta Formation at Surai Khola) Koi/11 (from Koilabas area). These broken fragments of carapaces resemble in ornamentation the specimens figured by LYDEKKER (1885:. 26), referred by him to genus *Emyda.* This genus is considered synonymous with *Lissemys* by ROMER (1968: 53).

Tui 33y, (from Tui Valley, Dang), Ra 1/8, Dha 1/20, Ra 4/3 and Dha 1/16 (from the micaceous sandstone facies at Rato Khola) are broken pieces of carapaces of tortoise with a heavy labyrinthic ornamentation. They have not been identified though they may belong to *Trionyx* and are only listed here.

Su.K. 76 and Su.K. 119 (from the Dobatta Formation at Surai Khola). These two plastrons probably belong to two different species. Su.K. 119 is more or less complete, but Su.K. 76 is broken. The bony plates of the plastron viz. epiplastron, entoplastron, hypoplastron, and xiphiplastron are not recognizable. They are not identified and are only listed here.

Table 9. Lithology and fauna of the Siwalik group of Surai Khola and Rato Khola in Nepal. In Rato Khola only the Surai Khola Formation is represented.

Local Formation	Lithology	Characteristic fauna
Dhan Khola (1500 m)	Consolidated to unconsolidated cobble to boulder conglomerates, subordinate yellow, soft sandstones and siltstones	Occasional unidentifiable bone fragments
Dobatta (550 m)	Alternations of yellow-brown and grey clays + mudstones with soft micaceous, medium to coarse-grained sandstones	*Archidiskodon planifrons*, *Equus* sp. Cervidae, *Hexaprotodon sivalensis*, Bovinae, *Crocodylus* sp., tortoise, fish etc.
Surai Khola (1150 m)	Massive, grey to beige, micaceous, medium to coarse-grained sandstones with few intercalations of dark grey clays	*Stegodon insignis*, *Archidiskodon planifrons*, *Hexaprotodon sivalensis*, *Cervus* sp. *Hippyhyus tatroti*, *Giraffa punjabiensis*, Bovinae, *Crocodylus* sp., *Gavialis* sp., *Trionyx* sp., giant turtle, fish and microvertebrates, plant fossils
Upper member (850 m)	Alternations of calc. grey-greenish to buff fine to medium-grained sandstone with mottled siltstones and claystones. Sandstone percentage increases in	*Crocodylus* sp., tortoise, and microvertebrates, plant fossils dominate
Chor Khola	younger beds. First appearance of salt and pepper sandstone. Limestone beds in uppermost part	
Lower member (950 m)	Alternations of grey to greenish, calc., fine-grained sandstones with mottled, variegated mudstone/claystones	
Bankas (600 m)	Variegated, mottled claystones and mudstones with subordinate grey, calc. fine-grained sandstones	*Gomphotherium* sp. tortoise carapace, plant fossils

VII. Interpretation of the Upper Siwalik faunas

A rich collection of Upper Siwalik vertebrate fossils has been recovered from the Surai Khola and the Rato Khola sections, whereas in the Lokhundol Formation of the Kathmandu valley additional fossil findings have corroborated the earlier records.

The base of the Upper Siwaliks, i.e. the boundary between the Dhok Pathan and the Tatrot, is dated 5.1 m.y. in the Potwar Plateau, Pakistan

(Johnson et al. 1982: 41). Magnetostratigraphic studies of the Surai Khola section are available now (Appel et al. 1991) and the base of the Upper Siwaliks is marked in the middle part of the Surai Khola Formation (Fig. 11). The older Siwalik deposits of the Surai Khola area, such as the Bankas and the Chor Khola Formation, have not yielded any significant faunas except for the occurrence of a *Gomphotherium* tooth within the Bankas beds. On the basis of this the Bankas Formation is suggested to have an age equivalent to the Chinji (Corvinus 1988b).

It is appropriate to place the beds occuring above 5.1 m.y. of Appel et al. (1991) in the Upper Siwaliks. They comprise the upper part of the Surai Khola Formation, the Dobatta and the Dhan Khola Formations. *Giraffa punjabiensis* occurs just above the bed marking 5.1 m.y. age. The upper limit of *Giraffa punjabiensis* was earlier considered to be upto the Dhok Pathan Formation (Colbert 1935: 367). However, now it is recorded at a level younger than 5.1 m.y. and thus extends into the basal part of the Upper Siwaliks.

Giraffa punjabiensis is thus definitely an indicator of a pre-Pinjor fauna. Another significant marker for the Tatrot fauna is from the Rato Khola section. From here a partial skull of *Hippohyus tatroti* is recognised. *Hippohyus tatroti* is considered restricted to the Tatrot Formation in the Potwar Plateau (Pilgrim 1926: 52; Colbert 1935: 255). Nanda (1982: 19) reported the species from the Siwalik Hills of Chandigarh, India. Now, this species is being reported also from Rato Khola in eastern Nepal. This shows not only the presence of the Tatrot fauna at Rato Khola but also the wider biogeographical distribution of the species.

Thus the occurrence of *Hyppohyus tatroti* and *Giraffa punjabiensis* indicates the presence of a pre-Pinjor fauna from Nepal. The Pinjor fauna has been reported by previous workers also from Nepal (West 1983), but the presence of the Tatrot fauna is being recorded for the first time (Nanda & Corvinus, in press).

About 220 m above the occurrence of *Giraffa punjabiensis* at Surai Khola we have recorded the first appearance of *Cervus.* Cervidae with antlers are taken as characteristic for the Pinjor fauna (Opdyke et al. 1979: 29). Thus the presence of antlers marks the beginning of the Pinjor fauna in the Surai Khola sequence. With this cervid, and above it, *Hexaprotodon sivalensis* fossils are recorded. Teeth of *Archidiskodon planifrons, Hexaprotodon sivalensis* and a limb bone of Equidae (referred to *Equus* provisionally) are recorded from the basal Dobatta Formation.

The studied Siwalik succession at Rato Khola is arenaceous and consists predominantly of soft, micaceous, multistoried sandstones which are lithologically similar to the sandstone facies of the Surai Khola Formation at Surai Khola, though the magnetostratigraphic controls are not yet available. However, the lower part of this succession has yielded *Stegodon*

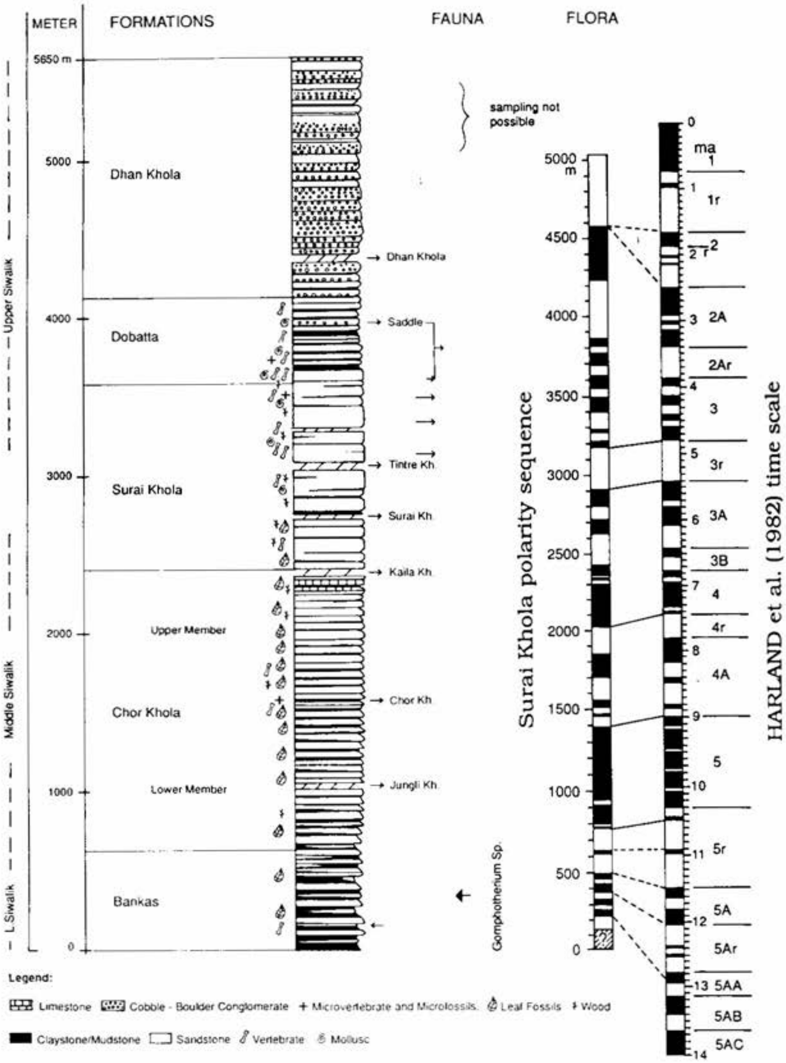

Fig. 11. Palaeomagnetic timescale of Surai Khola, (after APPEL et al. 1991) compared with the lithological column.

and *Hippohyus tatroti* and on the basis of the latter appearance the lower part of the arenaceous facies of Rato Khola has been referred to the Tatrot.

The upper part of the arenaceous facies at Rato Khola yielded a large number of vertebrate fossils which include *Archidiskodon planifrons*, *Stegodon* sp., *Hexaprotodon sivalensis* and unidentified teeth of bovinae. It has therefore been referred to the Pinjor fauna, although no typical marker for the Pinjor fauna is yet recorded here.

From the Lokhundol Formation of the Kathmandu valley, antlers of *Cervus* and molars of *Potamochoerus* cf. *P. theobaldi* were collected. All workers (PILGRIM 1926: 27–28; COLBERT 1935: 243–244) considered the genus *Potamochoerus* restricted to the Pinjor. However, NANDA (1982: 17) has recorded this genus also from the pre-Pinjor beds of the Siwalik Hills, Chandigarh, India. As discussed above, *Cervus* (Cervidae with antlers) is considered as characteristic for the Pinjor. Thus the presence of *Cervus* along with *Potamochoerus* establishes that the fauna of the Lokhundol Formation is equivalent with the Pinjor fauna of the Siwaliks.

The distribution of the various genera and species is tabulated in Table 9.

VIII. Discussion on the faunal ages and the time scale of the Surai Khola sequence

Magneto-stratigraphic sampling has been carried out recently in winter 1989 and winter 1991 at Surai Khola as well as in the neighbouring areas north of Surai Khola (Balubang South, and Arjun Khola) and preliminary results have been published (APPEL et al. 1989, 1991; RÖSLER 1990)).

The long, normal polarity anomaly 5 of the standard polarity time scale of HARLAND et al. (1982) can be recognised in the lower Chor Khola Formation (formerly the Waterspring beds of CORVINUS 1988, APPEL et al. 1991) (Fig. 11). It indicates an age of 9 to 10.3 million years for the lower member of the Chor Khola Formation, attributing it to the lower part of the Middle Siwalik (Nagri Formation of Pakistan). This tallies well with the occurrence of *Gomphotherium* below the anomaly 5, in the lower Bankas Formation.

The 5.1 m.y. boundary of the Middle to the Upper Siwaliks seems to lie, according to the polarity scale of the Surai Khola (Fig. 11), in the middle of the Surai Khola Formation, thus suggesting a Middle Siwalik age to the lower part of the massive sandstone facies at Surai Khola, while the upper part of it belongs into the Upper Siwaliks.

The upper part of the Surai Khola polarity sequence however is still controversial, as the magnetostratigraphical results do not correspond to the ages indicated by the discovered fauna and seem to give a greater antiquity to the beds of the Dobatta Formation which provided a Pinjor fauna at Surai Khola.

Giraffa punjabiensis and *Hexaprotodon sivalensis* is found in situ in the middle part of the Surai Khola sandstone facies, just above the 5.1 m.y. age indicated by the magnetostratigraphy. A horncore with bifurcation, identified as belonging to *Cervus* sp. has been found in situ 220 m above the *Giraffa punjabiensis*, in the sandstone facies of the upper Surai Khola Formation together with teeth of bovinae and *Hexaprotodon sivalensis.* Cervidae with antlers, however, make their first appearance not before 2.5

m.y. (OPDYKE et al. 1979), thus attributing an age of 2.5 m.y. and younger to the upper Surai Khola Formation.

The Dobatta Formation seems to be clearly belonging to the Pinjor, by the occurrence of *Equus* (though only present in the form of a second phalange) and *Cervus*, in association with *Archidiskodon planifrons.*

The magnetostratigraphic results, however, indicate ages of roughly 3.5 to 2 m.y. for the Dobatta Formation which seems to be improbable in the view of the recovered fauna.

Moreover, the fauna recovered at Rato Khola tallies in age with the fauna of the upper Surai Khola Formation at Surai Khola, and lithologically, too, the sandstone facies at Rato Khola corresponds with that of the Surai Khola Formation.

The fauna from the Rato Khola sandstone succession indicates a Tatrot age for its lower part (with *Hippohyus tatroti* in association with *Hexaprotodon sivalensis* and *Proamphibos/Hemibos*).

The upper part of the sandstone facies at Rato Khola is characterised by many remains of *Hexaprotodon sivalensis* and by the excavated skull with tusks of *Archidiskodon planifrons* and by *Stegodon* and clearly indicates an upper Siwalik probably Pinjor age.

The discrepencies of the ages indicated by the fauna and by the magnetostratigraphy has to be understood and analysed by further surveys.

The Rato Khola area has only recently (in November 1991) been sampled by ROESLER for magnetostratigraphic analysis, and the results are being awaited.

IX. Conclusions

1. An uninterrupted sequence of the Siwaliks from the Lower to the Upper Siwalik subgroups is exposed in the Surai Khola area in western Nepal, and five local formations have been recognised: Bankas (upper part of Lower Siwaliks), Chor Khola (Middle Siwaliks), Surai Khola (Middle and Upper Siwaliks), Dobatta and Dhan Khola (Upper Siwaliks).

2. The complete Siwalik succession at Surai Khola shows a coarsening-up of the sediments from the older to the younger deposits, i. e. from Bankas to Dhan Khola, reflecting the changing sedimentological pattern during the rise of the Himalayas.

3. The Bankas Formation has yielded a *Gomphotherium* tooth, on the basis of which the Bankas Formation at Surai Khola is referred to the Chinji. The rest of the collected fauna at Surai Khola is confined to the Upper Siwaliks.

4. The arenaceous Rato Khola facies is referred to the Upper Siwaliks on the basis of the fauna.

5. The vertebrate fauna includes both the Tatrot and the Pinjor faunas. The Tatrot fauna is characterized by *Hippohyus tatroti* at Rato Khola and by *Giraffa punjabiensis* at Surai Khola, while the Pinjor fauna is characterized by Cervidae, by *Equus* and by *Archidiskodon planifrons.*

6. The Tatrot/Pinjor faunal boundary lies in the upper part of the Surai Khola Formation.

7. The magnetostratigraphic results indicate a time range of about 13 m.y. for the Surai Khola sequence, from about 13 m.y. at the base to about 1–2 m.y. at the top.

8. The Lokhundol Formation of the Kathmandu valley has yielded cervids with antlers and *Potamochoerus*, which are representative of the Pinjor fauna.

9. The combined floristic record of mega plannts and pollen at Surai Khola indicate that the environment has changed from tropical, evergreen vegetations with swampy environments in the Bankas and lower Chor Khola Formation to moist and dry deciduous patterns in the middle part and finally to drier climates with grasslands in the uppermost part of the sequence.

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Anschriften der Verfasser:

Dr. Gudrun Corvinus, Nepal Research Centre, Box 180, Kathmandu, Nepal, und Inst. für Urgeschichte der Universität, Kochstr. 4, 91054 Erlangen, Germany.

Dr. Avinash C. Nanda, Wadia Institute of Himalayan Geology, Dehra Dun, Indien.