

STRATIGRAPHY AND VERTEBRATE FAUNA OF THE SIWALIK GROUP, MANSAR-UTTARBAINI SECTION, JAMMU DISTRICT, J&K

S.S. GUPTA¹ AND B.C. VERMA²

1. 435, JULLAKHA MOHULLA, JAMMU - 180 001.

2. V. & P.O. CHETRU, KANGRA (H.P.) - 176 209.

ABSTRACT

The southern limb of the Suruin-Mastgarh Anticline exposes a complete sequence (7000 m) of the Siwalik Group in Mansar-Uttarbaini area, Jammu district, J&K. This enormous pile of molassic deposits, on the bases of gross lithologies and physical characters of the sediments, is divisible into five formations, namely the Mansar, Dewal, Mohargarh, Uttarbaini and Dughor collectively ranging in age from Upper Miocene to Lower Pleistocene. The new formational names are suggested in view of the difficulties encountered in correlating these sediments with the distantly placed type sections most of which either fall in Pakistan or are very far from here. Moreover the earlier names in vogue, for the Siwaliks of this area, are not in accordance with the code of stratigraphic nomenclature.

Fossil remains of numerous larger vertebrate forms like fishes, chelonia, crocodiles, hippopotamids, suids, proboscideans, equids, giraffids, bovids etc. have been collected from about 85 localities located in the various stratigraphic units. These are likely to be helpful in biostratigraphic zonations and further correlation with other sections of the Siwalik Hills.

Many workers have felt the necessity of selecting a reference section for the Siwalik Group in the Indian part of this subcontinent. The authors suggest the Mansar-Uttarbaini section as an ideal one for this purpose in view of its rich fossil record, continuous depositional history and easy accessibility. It is required to be standardised by further detailed work.

INTRODUCTION

The Siwalik strata of northwest India are known to the palaeontologists for their vertebrate fossils for more than 150 years. Classic fossiliferous localities are those of Potwar Plateau (Pakistan), Lower Siwalik of Ramnagar (J.&K.), Middle Siwalik of Haritalyangar (H.P.), Upper Siwalik of north and east of Chandigarh (U.T.) and Markanda Valley (H.P.) and Middle and Upper Siwalik of Hardwar (U.P.). Vast stretches of the intervening Siwalik hill tract of the northwest India still remain unexplored, though occasional reports of fossil occurrences from a number of localities have been made by many workers from time to time.

The Siwalik belt in Jammu and Kashmir was first mapped by Medlicott (1876) and later by Wadia (1928), Hazra (1936-38), Bhatt (1961-63) and a number of other workers covering localised areas. Karunakaran and Ranga Rao (1976) have recently published a small scale map of the entire Siwalik belt which expresses views of the ONGC.

During the years 1981-86, one of us (Gupta) happened to remap the entire Siwalik belt of J&K. The survey revealed that the southern limb of Suruin-Mastgarh Anticline (Karunakaran and Ranga Rao, 1976) exhibits the best development of the entire Siwalik Group in the Mansar-Uttarbaini section,

Jammu district, J&K. and is ideal for detailed future studies and designating it as the reference section for the Siwalik Group in the Indian part of this subcontinent. The authors have proposed new formational names, namely, the Mansar, Dewal, Mohargarh, Uttarbaini and Dughor to the different lithological units decipherable in this succession from their lithological and physical characters. The new designations are intended to avoid difficulties of correlating these sediments with the distantly placed type localities of the different formations of the Siwalik Group which are either in Pakistan now or quite far from this area. The earlier formational/member names in use in this area are not in accordance with the Code of Stratigraphic Nomenclature as well.

The investigation also resulted in the collection of numerous vertebrate fossils from the proposed different stratigraphic units, which mostly contains cranial and postcranial parts of megavertebrate groups like fishes, chelonian, crocodiles, hippopotamids, suids, proboscideans, equids, camels, giraffids, felids and bovids. There are about 500 specimens in the present collection systematically collected from about 85 sites in the area investigated (Fig. 1). Among these sites, eighteen fall in the Mansar, six in the Dewal, fifteen in the Mohargarh and 28 in the Uttarbaini Formation.

Earlier reports of fossil collections from this part are by Wadia (1925), Verma and Verma (1968-69) and in Pascoe (1973). Two recent reports are by Ganjoo (1985) and Ranga Rao *et al.* (1988).

Detailed descriptions of the present collection are under preparation and will be published separately. The various taxa listed here, though carefully studied, are still provisional identifications.

Many workers (personal discussions) have been feeling the necessity of selecting a reference section for the Siwalik Group in the Indian part of this sub-continent. Keeping in view the requirements laid down in the Code of Stratigraphic Nomenclature of India, we suggest the Mansar-Uttarbaini section (Fig.1) as the ideal one for this purpose in view of its being richly fossiliferous, continuous and easily accessible. It falls in the intervening area between the Potwar (about 100 km to the west) and the famous fossiliferous locality of Ramnagar (25 km to the northeast). Brief descriptions of the various lithological units occurring in this sequence and the fossil vertebrate forms present in them form the subject matter of this paper.

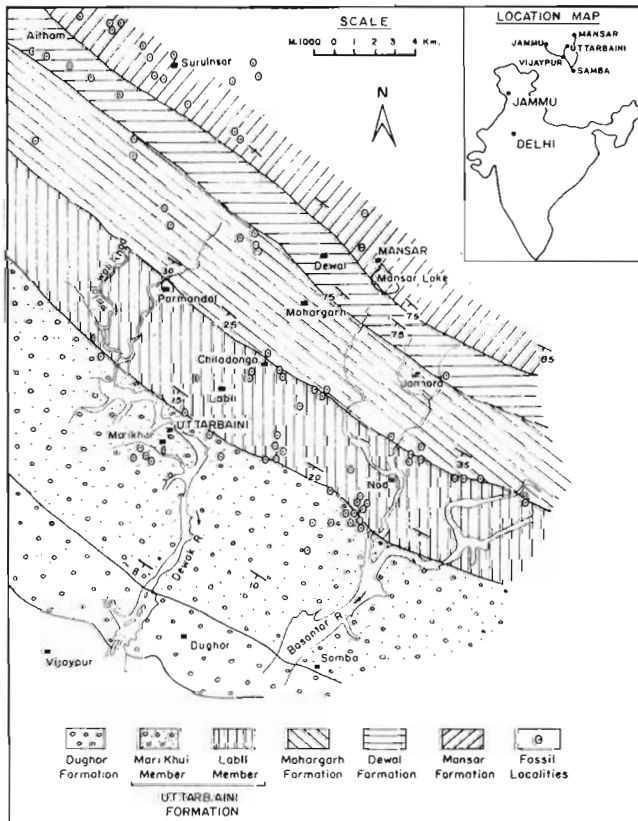


Fig. 1. Geological Map of the Mansar-Uttarbaini area showing different lithologic units of the Siwalik Group and vertebrate fossil sites, Jammu district, J&K.

STRATIGRAPHY AND VERTEBRATE FAUNA

The Siwalik Group in the Suruin-Mastgarh Anti-cline consists of an enormous sequence of molassic sediments having an estimated thickness of about 700 m in the Mansar-Uttarbaini-Dughor section (Fig. 1). The sequence is divisible into three subgroups, i.e., the Lower, Middle and Upper Siwalik, and further five mappable litho-units namely the Mansar, Dewal, Mohargarh, Uttarbaini and Dughor formations from the base to the top. The different units are traceable over long distances to the southeast and northwest throughout the extension of the foot hills in J&K. On the basis of gross lithologies and physical characters of the sediments, the following stratigraphic succession is workable in the Mansar-Uttarbaini-Dughor section (Fig. 2):-

Group	Subgroup	Formation	Member	Age	
S I W A L I K	Upper	Terraces (T ₁ - T ₃) unconformity	Dughor	Lower	
			Siwalik	Pleistocene	
	Middle	Siwalik	Uttarbaini	Marikhui (1524 m)	Upper
				Labli (1000m)	Pliocene
				Mohargarh (915 m)	Middle
Lower	Siwalik	Dewal	(1753 m)	Pliocene	
	Siwalik	Mansar	(1977 m)	Upper	
			(Base not exposed)	Miocene	

The Siwalik strata exposed in this limb of the anticline have a N50°W - S50°E trend with southwesterly dips. The beds dip steeply (75° to 85°) in the core of the anticline and gradually become gentle (10° to 5°) in the younging sequence. The contact between the Mansar and Dewal formations is conformable and gradual, but an angular unconformity exists between the Dewal and the overlying Mohargarh Formation which is traceable towards northwest and southeast throughout their extension. The Mohargarh and overlying Uttarbaini Formation though have a conformable contact but it is rather sharp and a change in the environment of deposition and lithology is clearly indicated. The Dughor Formation is distinguished from the underlying Uttarbaini Formation from the presence of intense orange coloration in the matrix of the sediments. The entire sequence exhibits its best development along the nearby Samba-Mansar road and is easily accessible (Fig.2.)

About 500 megavertebrate fossils representing

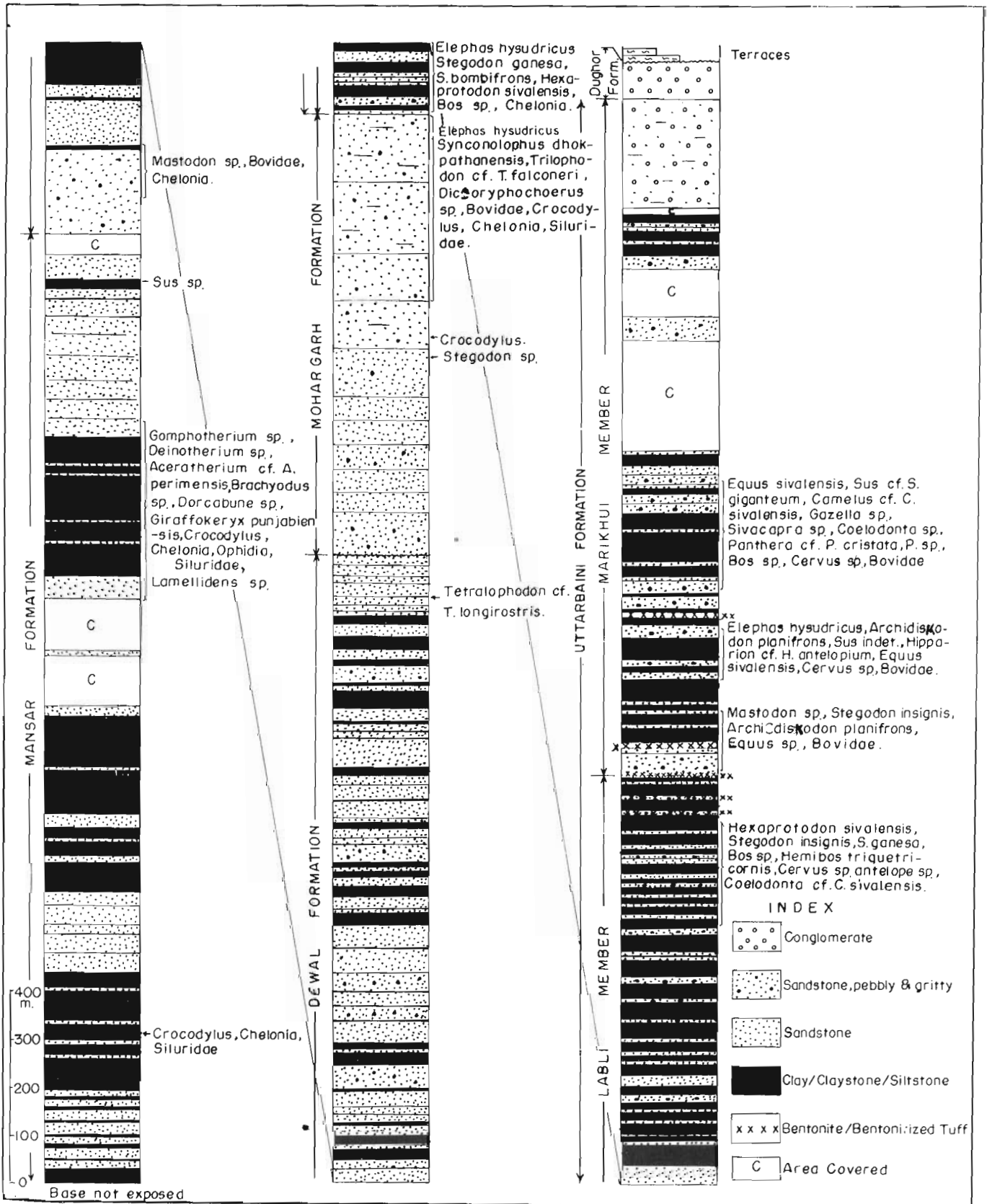


Fig. 2. Lithostratigraphic column of the Siwalik Group along the Samba-Mansar section, Jammu district, J&K.

numerous mammalian groups were collected from nearly 85 sites falling in the different litho-units (Fig.1.). Though each unit has its characteristic faunal assemblage (Fig.2.), some of the forms especially cheloneans, crocodiles, mastodonts and bovids have long stratigraphic ranges. The various taxa represented in the collection are listed here for biozonation of the group at a later stage when adequate fossil material becomes available.

MANSAR FORMATION

The oldest litho-unit of the Siwalik Group, the Mansar Formation is exposed in the core of the Suru-in-Mastgarh Anticline in Mansar (lake) area having an estimated thickness of 1730 m (Fig.2). The base is not exposed. It consists of alternating layers of fine grained, hard and compact sandstone, siltstone, mudstone and clay. The sandstone are buff, grey and light greenish grey in colour. The clays are purple, brown, red and yellowish red. The massive sandstone bands stand out as prominent small mounds and ridges, while the clay and siltstone generally form depressions. At places the sandstone bands contain lenticles of pseudoconglomerate consisting of pellets and fragments of mudstone, claystone and shale cemented in an arenaceous matrix. The clays invariably contain interbedded siltstone which at places have been lithified into hard mudstone. The sandstone are frequently traversed by thin calcite veins along the joint planes. Towards the top frequency of the red clay layers decreases and arenaceous facies dominate in this section.

The beds strike N50°W and S50°E with 85° to nearly vertical dips towards southwest.

Vertebrate fossils collected from eighteen sites in this litho-unit include the following taxa:

Pisces	Siluridae	Fragmentary cranial bones, gen & sp. indet
Reptilia	Chelonia	
	Trionychidae	<i>Trionyx</i> sp., mostly scutes.
	Ophidia	Isolated vertebrae, gen. & sp. indet.
	Crocodylia	<i>Crocodylus</i> sp. <i>Gavialis</i> sp.
Mammalia	Proboscidea	
	Gomphotheriidae	<i>Gomphotherium</i> sp.
	Deinotheriidae	<i>Deinotherium</i> sp.
	Perissodactyla	
	Rhinocerotidae	<i>Aceratherium</i> cf. <i>A. perimense</i>
	Artiodactyla	
	Suidae	(?) <i>Propotamochoerus</i> sp.

Anthracotheriidae	<i>Brachyodus</i> sp. <i>Dorcabune</i> sp.
Giraffidae	<i>Giraffokeryx punjabiensis</i>

In addition to these forms, numerous specimens of fossil wood (*Palmoxylon* sp.) and lamellibranchs (*Lamellidens* sp.) were also collected from this unit.

Although the Mansar Formation lies in a different tectonic unit, it appears homotaxial to the Lower Siwalik of Ramnagar (Vasishat *et al.* 1978) and may be Vindobonian in age.

DEWAL FORMATION

The next litho-unit, conformably overlying the Mansar Formation, is designated here as the Dewal Formation. It mainly consists of grey (salt and pepper colour) to dull grey, comparatively fragile, fine to medium grained, occasionally pebbly sandstone and interbedded layers of reddish brown, orange, yellow, carbonaceous, grey and earthy grey clay. The sandstone frequently contain lenticles of pseudoconglomerate made up of pellets of clay, mudstone and siltstone. The sandstone/clay ratio is about 70/30 per cent in this section. Current bedding in sandstone is rare but mud-cracks are common in siltstone layers. The beds dip 75° to 50° towards southwest.

The Dewal Formation measures 1753 m thick in the Mansar-Uttarbaini section. These sediments are rather poor in vertebrate fossils. A few specimens collected from six sites near Aitham and Jamora contain the following forms:

Reptilia	Chelonia	Unidentifiable fragmentary bones.
Mammalia	Proboscidea	
	Gomphotheriidae	<i>Gomphotherium</i> sp. <i>Gomphotherium</i> sp. cf. <i>Tetralophodon longirostris</i> .
	Artiodactyla	
	Bovidae	Fragmentary limb bones representing mostly smaller bovids.

Carbonised fossil wool fragments are frequently noticed in the sandstone strata.

MOHARGARH FORMATION

A gentle but distinct angular unconformity is observed between the Dewal and the overlying litho-unit, named as Mohargarh Formation. The earlier name of this unit, the Parmandal Sandstone (Ranga Rao *et al.* 1981), should be discarded as the locality after which it has been designated is actually situated on the contact zone of the two formations,

i.e., the Parmandal Sandstone and the succeeding Uttarbaini, which is confusing. One cannot make out in the field conveniently whether the name refers to the underlying or the overlying unit. Moreover, the upper and the lower limits of the Parmandal Sandstone have not been clearly defined.

The Mohargarh Formation is mostly an arenaceous sequence comprised of bright grey, massive, medium to coarse, pebbly and conglomeratic sandstone with occasional clay partitions of yellow, orange, brown and dark grey colours. Frequency of clay is hardly 10% as compared to the sandstone. The latter, being more resistant to weathering than clays, have resulted in the formation of an extremely rugged topography characterised by vertical scarps and deep ravines. The sandstone bands are multistoried, exhibit frequent torrential current bedding, and contain fragments of reworked sediments. Pockets of coal, carbonised wood and sulphurous encrustations in carbonaceous clay are occasionally seen. Good outcrops of this formation are seen around Nawi kali, Babnergarh, Mohargarh and Jamora. It is distinguishable from the underlying Dewal by its bright grey sandstone and comparatively lesser proportion of clay. The erosional gap between the two formations is also a distinguishing criteria even though they have closely similar lithological characters.

The Mohargarh Formation measures 915 m thick with southwesterly dips ranging from 35° to 25° against the 75° to 50° of the underlying Dewal beds.

Vertebrate fossils were collected from fifteen sites in this formation. These include the following forms:

Pisces	Siluridae	Fragmentary limb bones, gen. & sp. indet.
Reptilia	Chelonae	Scutes and limb bones, gen. & sp. indet.
	Crocodylia	<i>Crocodylus</i> sp.
Mammalia	Gomphotheriidae	<i>Trilophodon</i> cf. <i>T. falconeri</i> <i>Synconolophus</i> cf. <i>S. dhokpathanensis</i>
	Elephantidae	<i>Elephas</i> cf. <i>E. hysudricus</i>
	Artiodactyla	
	Suidae	<i>Dicoryphochoerus</i> sp.
	Cervidae	<i>Cervus</i> sp.
	Bovidae	Fragmentary limb bones and isolated teeth, gen. et sp. indet.

There are two well preserved molars in the present collection assignable to *Synconolophus dhokpathanensis*. This form is known from the Dhokpathan beds of Pakistan (Osborn, 1936) and the Nagri of

Haritalyangar (Prasad, 1970). Thus it is likely that the Mohargarh Formation is correlatable with the Dhokpathan beds of Pakistan.

In addition, there are three well preserved molar specimens of *Elephas* cf. *E. hysudricus* with some atavistic characters. The specimens were collected from the top beds of Mohargarh Formation. This form is well distributed in the succeeding Uttarbaini Formation. It is likely that the *Elephas hysudricus* made its first appearance in the later part of Mohargarh times.

UTTARBAINI FORMATION

The massive sandstone strata of the Mohargarh Formation are conformably overlain by another litho-unit, named as Uttarbaini Formation, with a sharp contact. However, in some sections this contact is gradual and transitional with no visible discontinuity.

The Uttarbaini Formation consists of a thick sequence of sandstone, variegated clay and conglomerate with a total thickness of 2524 m. The basal part of this unit is sandstone/red clay dominant facies. In the middle, variegated clays and sandstone predominate and have almost equal proportion. Towards the top conglomerate beds and interbedded sandstone are frequent. Most of the sandstone layers in this succession are pebbly with occasional and impersistent conglomerate bands. Siltstone layers are also common and contain quartzitic pebbles and angular to subangular fragments of sandstone derived for the earlier Siwalik strata. The formation as a whole is a red clay dominant unit and quite distinct from the preceding Mohargarh Formation.

The Uttarbaini Formation is divisible into two members in this section, namely, the lower Labli and the upper Marikhui, both having considerable lateral extensions. Numerous vertebrate fossils were recovered from this formation listed under each member.

LABLI MEMBER

This member named after the Labli village, where it is best exposed, forms the basal part of the Uttarbaini Formation and is characterised by predominance of massive grey, pebbly and conglomeratic fragile sandstone and interbedded variegated clays of red, yellow, grey and carbonaceous grey colour having a total thickness of 1000 m. Siltstone layers, containing reworked angular to subangular fragments of sandstone, are common. Bodies of hard sandstone, formed due to the secondary action of percolating calcitic waters, are commonly seen within the arenaceous bands. Good sections and fossiliferous sites

occur in this member around Nad, south of Chila-danga and Labli villages. In the upper part, this unit contains at least three bentonitic tuff layers with varying thicknesses and laterally changing characters. These occur interbedded in the sandstone and clay at intervals of about 30 m from the top downward. The Labli Member culminates in the topmost bentonitic tuff which is 3 m thick at places (near Badakhetar) and has a considerable lateral extension. The tuff band has been dated to be 1.6 ± 0.2 m.y. by fission-track method (Yokoyama *et al.*, *in press*). In a recent publication, Ranga Rao *et al.* (1988) have obtained the date of this bentonitic tuff to be 2.8 ± 0.56 m.y. by the same method. The two ages for the same band are conflicting and obviously require verification of facts to remove the ambiguity.

Vertebrate fossils were collected from 24 sites in this member which contain:

Pisces	Siluridae	Fragmentary bones, gen. & sp. indet.
Reptilia	Chelonia	<i>Colossochelys</i> cf. <i>C. atlas</i> , <i>Geoclemys</i> cf. <i>G. hamiltoni</i> , <i>Trionyx</i> sp.
	Crocodylia	<i>Crocodylus</i> sp. <i>Gavialis</i> sp.
Mammalia	Gomphotheriidae	<i>Gomphotherium</i> sp.
	Elephantidae	<i>Elephas hysudricus</i> , <i>Archidiskodon (Protelephas) planifrons</i> , <i>Stegodon insignis</i> , <i>Stegodon ganesa</i>
	Perissodactyla	
	Rhinocerotidae	<i>Coelodonta</i> cf. <i>C. sivalensis</i>
	Artiodactyla	
	Hippopotamidae	<i>Hexaprotodon sivalensis</i>
	Camelidae	<i>Camelus sivalensis</i>
	Cervidae	<i>Cervus</i> cf. <i>C. sivalensis</i>
	Bovidae	<i>Antilope</i> sp., <i>Hemibos</i> cf. <i>H. triquetricornis</i> , <i>Hemibos acuticornis</i> , <i>Gazella</i> sp.

The Labli Member shows a higher frequency of aquatic forms like hippopotamids, crocodiles and chelonians in the lower part. Gomphotheriids and elephants are common throughout the succession.

The Labli when traced to the northwest encompasses the entire Nagrote beds of Lahri (in West, 1949) and most of the Nagrota Formation of Ranga Rao *et al.* (1988) in the type locality which is about 30 km from the present section. The Nagrota Beds/Nagrota Formation, thus, represent the Labli Member in Nagrota area and the two are homotaxial.

The vertebrate fauna of the Labli Member is correlatable with the Tatrot beds (Astian) north and east of Chandigarh (Sahni and Khan, 1964), Khetpurali (Nanda, 1981) and Saketi beds of Markanda Valley (Verma, 1972). The Labli Member, thus may be Astian or Piacenzian in age.

MARIKHUI MEMBER

This member, named after a village in the vicinity of Uttarbaini, conformably overlies the Labli and consists of pebbly, buff, earthy grey and brownish fragile sandstone and interbedded yellow, red, buff and brownish clays having a thickness of about 1524 m. The sandstone are medium to coarse grained, occasionally gritty and conglomeratic. The pebbles are mostly of metamorphic and Terliary source. Red clays are frequent in this member in the basal part, in the middle dirty grey, buff and reddish sandstone and interbedded clay dominate. Towards the top conglomerate layers are common. Two bentonitic tuff layers, occurring at levels of about 30 m and 500 m above the base have been recorded in this unit.

Vertebrate fossils were collected from nineteen sites in this member. These contain:-

Reptilia	Chelonia	Fragmentary bones.
Mammalia	Carnivora	<i>Panthera</i> cf. <i>P. cristata</i> , <i>Panthera</i> sp., <i>Crocuta felina</i>
	Proboscidea	
	Elephantidae	<i>Archidiskodon (Protelephas) planifrons</i> , <i>Elephas hysudricus</i> , <i>stegodon insignis</i> , <i>S. ganesa</i>
	Perissodactyla	
	Equidae	<i>Hipparion antilopinum</i> (isolated molar, possibly reworked), <i>Equus sivalensis</i>
	Rhinocerotidae	<i>Coelodonta</i> sp.
Artiodactyla	Suidae	<i>Sus</i> cf. <i>S. falconeri</i> , <i>Sus giganteus</i> , <i>Sus</i> sp.
	Camelidae	<i>Camelus</i> cf. <i>C. sivalensis</i>
	Giraffidae	<i>Sivatherium giganteum</i>
	Cervidae	<i>Cervus</i> sp.
	Bovidae	<i>Antilope</i> sp., <i>Bos</i> sp. cf. <i>B. namadicus</i>
	Caprinae	Gen. & sp. indet.
	Gazellinae	<i>Gazella</i> sp.

The fauna recovered from the Marikhui member is characterised by predominance of non-aquatic vertebrate communities. Appearance of *Equus* in the basal part of this member is a significant event. We col-

lected an isolated molar (M^2) of *Hipparion antilopinum* about 200 m above the base of this unit but its provenance is not certain.

The vertebrate faunal assemblage of this member is correlatable with the one from the Boulder Conglomerate north of Jammu (Ranga Rao *et al.* 1988) and the Pinjor beds of type locality (Sahni and Khan, 1964). Accordingly the three sections are homotaxial and of the same age.

DUGHOR FORMATION

Towards the top the Marikhui conglomerate and sandstone develop a typical intense orange coloration in the matrix of the sediments. This is a regional feature of the topmost Upper Siwalik (lower Boulder Conglomerate of Sahni and Khan, 1964) all over north west India and is a significant landmark related to the palaeoclimate. The unit has comparatively a limited thickness in the present section (about 75 m) and only a few bands of conglomerate and interbedded sandstone of red, orange and buff colour are seen as cappings around Gurasalathian and Dughor (after which it is designated). The pebbles and boulders, embedded in an intense orange coloured matrix, constitute major part of this unit. Though the Dughor has a lesser vertical thickness here, most of the outermost gentle dip slopes of the Suruin-Mastgarh anticline are made up of these sediments. It may be mentioned here that this formation, when traced to the south east, across the Ravi River, assumes enormous thickness (about 1000 m) and exhibits its best development along the Dunera-Bakloh section, Kangra district, H.P. Its outcrops are seen around Jammu also, which are distinct from the Boulder Conglomerate of Ranga Rao *et al.* (1988). Towards south west the Dughor is covered by Late Pleistocene and Holocene terraces (T_1 - T_3). No vertebrate fossils have been found in these conglomerates.

The special environmental conditions, characteristic of the Dughor, which resulted in precipitation of the orange pigment in sediments, were evidently of regional distribution and denote a time plane related to the palaeoclimate of the period. The Dughor lithotope, thus, provides a reliable parameter for demarcating the underlying Uttarbaini Formation and its equivalents characterised by extremely heterogeneous nature of their sediments.

To sum up, the concept of Lower, Middle and Upper Siwalik as broad lithologic divisions of the Siwalik Group, holds true for the Siwalik succession in the southern limb of the Suruin-Mastgarh Anti-

cline. This section exposes a complete sequence and seems ideal for developing it as reference section for the group in the Indian part of this subcontinent since most of the classic type sections are not easily accessible for comparison. In the present studies the authors, notwithstanding any of the earlier works, favour regrouping of some of the smaller subdivisions based on lithological and palaeontological criteria. Lithologically the Mohargarh (earlier Parmandal Sandstone) requires inclusion in the Middle Siwalik Subgroup. The Nagrota and Boulder Conglomerate are equivalents of Labli and Marikhui members respectively and have been grouped in the proposed Uttarbaini Formation. The Dughor has been recognised as a distinct formation in the Upper Siwalik. The new names are in accordance with the Code of Stratigraphic Nomenclature of India.

REFERENCES

- BHATT, M.L., 1963. Progress report on the Geological Mapping of the Siwaliks in Jammu and Udhampur districts, J&K State for the field seasons 1959-63. *Rep. Geol. Surv. Ind.* (unpublished).
- GANJOO, R.K., 1985. Some vertebrate fossil discoveries from the Upper Siwaliks of Jammu (J&K). *Proc. Symp. Quat. Episodes, Deptt. Geol. M.S.U. Baroda.* 135-138.
- HAZRA, P.C., 1938. Progress Report for F.S. 1936-37 and 37-38. *Rep. Geol. Surv. Ind.* (unpublished).
- KARUNAKARAN, C. & RANGA RAO A., 1979. Status of Exploration for hydrocarbons in the Himalayan Region. Himalayan Geology Seminar, New Delhi 1976 *Geol. Surv. Ind., Miscellaneous Publication* 41 (5): 1-66.
- MEDLICOTT, H.B., 1876. Note upon the Sub-Himalayan Series in the Jammu (Jummoo) Hills. *Rec. Geol. Surv. Ind.* 9:49-57.
- NANDA, A.C., 1981. Occurrence of the pre-Pinjor Beds in the vicinity of Chandigarh. *Neogene/Quaternary Boundary Field Conference, India, 1979. Proceedings* 1981: 113-116.
- OSBORN, H.F., 1936. Proboscidea, I. *New York (American Museum Press). New York.*
- PASCOE, E.H., 1973. A Manual of the Geology of India and Burma. Vol. 3 (III Edition).
- PRASAD, K.N., 1970. The Vertebrate Fauna from the Siwalik Beds of Haritalyangar, Himachal Pradesh. *Pal. Ind. (N.S.)*, 39: 1-55.
- RANGA RAO, A., AGARWAL, R.P., SHARMA, U.N., BHALLA, M.S. & NANDA, A.C., 1988. Magnetic Polarity Stratigraphy and Vertebrate Palaeontology of the Upper Siwalik Subgroup of Jammu Hills, India. *Jour. Geol. Soc. Ind.* 31 (4): 361-385.
- SAHNI, M.R. & KHAN, E.H. 1964. Stratigraphy, Structure and Correlation of Upper Siwalik east of Chandigarh. *Jour. Pal. Soc. Ind.* 4: 61-74.
- VASHISHAT, R.N., GAUR, B. & CHOPRA, S.R.K., 1978. Geology, Fauna and Palaeoenvironments of Lower Siwalik deposits around Ramnagar. *Nature*, 275 (5682): 736-37.
- VERMA, B.C., 1972. Geology of parts of Sirmur District (H.P.) and Ambala District, Haryana, with particular reference to

- stratigraphy and vertebrate fossils of the Upper Siwalik Belt between the rivers Markanda and Yamuna. F.S. 1971-73. Rep. Geol. Surv. Ind. (unpublished).
- VERAM, S.N. & VERMA, B.C., 1969. Geological Mapping of the Siwaliks lying in parts of Kangra district, H.P. and Kathua and Udhampur districts J.&K. with particular reference to collection and study of vertebrate fossils F.S. 1968-69. *Rep. Geol. Surv. Ind. (unpublished)*.
- WADIA, D.N., 1925. *Stegodon ganesa* (Falc. and Caut.) in the outer Siwaliks of Jammu. *Rec. Geol. Surv. Ind.* **56** (4) : 352-355.
- WADIA, D.N. 1928. The Geology of Poonch State (Kashmir) and Adjacent Portions of the Punjab. *Mem. Geol. Surv. Ind.* **51**(2) : 185-370.
- WEST, W.D., 1949. General Report of the Geological Survey of India for the year 1939. *Rec. Geol. Surv. Ind.* **78** (1) : 81.
- YOKOYAMA, T., VERMA, B.C., MATSUDA, T., GUPTA, S.S. & TEWARI, A.P. Fission-track age of a bentonitized ash bed and Mammalian Fauna from Nagrota Formation (Upper Siwalik) of Jammu district (J&K). *Indian Minerals (in press)*.