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UPPER SIWALIK MAMMALIAN FAUNAS OF THE HIMALAYAN FOOTHILLS

A. C. NANDA

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN 248 001
E-mail: nandaac@rediffmail.com

ABSTRACT

The Tatrot and Pinjor faunas belonging to the Upper Siwalik Subgroup are well known from Pakistan, India and Nepal. The faunas along with proposed biostratigraphic interval-zones/range-zones/faunal-zones for the Upper Siwalik Subgroup of Potwar Plateau, Mangla-Samwal area and Pabbi Hills (all in Pakistan), Chandigarh-Jammu regions (India), and Surai Khola, Rato Khola and Kathmandu Valley (all in Nepal) are discussed. Despite the presence of a two-million year unconformity at the base of the Tatrot Formation, the type locality has yielded rich Tatrot Fauna. The Mangla-Samwal, Chandigarh-Jammu, Surai Khola and Rato Khola areas have yielded both Tatrot and Pinjor faunas, whereas Pabbi Hills and Lokhundol Formation of the Kathmandu Valley have yielded Pinjor Fauna. The Pinjor Fauna is well developed in the type locality of Chandigarh as compared to other localities in Pakistan, India and Nepal. In the last five decades, 54 characteristic taxa for the Pinjor Fauna are recorded from the Chandigarh region. In Pakistan, abundant magnetostratigraphic data are available and workers clubbed mammalian taxa and proposed biostratigraphic zones for the Middle and Upper Siwalik subgroups. However, the rich Tatrot and Pinjor faunas are known from the Chandigarh and Jammu regions, but magnetostratigraphic data are scanty. Two biostratigraphic interval-zones, *Elephas planifrons* Interval-Zone (3.6-2.6Ma) and *Equus sivalensis* Interval-Zone (2.6-0.6 Ma), are recognized for the Indian Upper Siwalik. In Nepal, scanty Tatrot and Pinjor faunas are developed and the associated magnetostratigraphic dates do not tally with the recovered characteristic mammalian taxa. Thus, it is not possible to recognize the interval-zones in Nepal.

Keywords: Upper Siwalik, Tatrot and Pinjor faunas, biostratigraphic zones, Himalayan foothills

INTRODUCTION

Southernmost foothills of the Himalaya are the youngest mountain range involved in the folding of the last mountain building phase of the Himalaya. These foothills are characterized by freshwater deposits and are referred to as the 'Siwalik Group'. The Siwalik succession is about 7 km thick, ranges in age from 18.3 Ma (Johnson *et al*., 1985) to 0.22 Ma (Ranga Rao *et al*., 1988), and extends between Indus River in the west and Brahamputra River in the east. The Siwalik Group is known for its very rich vertebrate, particularly mammalian, assemblage of fossils. It is divided into three subgroups, Lower, Middle and Upper. The subgroups are further divided into formations: Kamlial and Chinji (Lower Siwalik), Nagri and Dhok Pathan (Middle Siwalik), and Tatrot, Pinjor and Boulder Conglomerate (Upper Siwalik). The Siwalik Group is not uniformly fossiliferous and the fossils are confined to pockets. The Upper Siwalik fossils are known from Potwar Plateau, Pabbi Hills and Mangla-Samwal (all in Pakistan), Chandigarh and Jammu regions of India, and Irrawaddy Valley, Myanmar. The Upper Siwalik faunas of all the regions, except that of Irrawaddy valley, are discussed. In Myanmar, this freshwater succession is called Irrawaddy Group. The Tatrot and Pinjor formations of the Upper Siwalik are richly fossiliferous. The Boulder Conglomerate Formation, the youngest formation of the Siwalik Group, is devoid of fossils. The Tatrot and Pinjor formations are sandstone-mudstone units, whereas Boulder Conglomerate Formation is essentially a conglomeratic deposit.

The Lower and Middle Siwalik subgroups are very rich in vertebrate fossils. Pilgrim (1913-1934) based the type localities of the various formations of the Lower and Middle Siwalik and Tatrot Formation of the Upper Siwalik in Potwar Plateau. However, he based the type area of the Pinjor Formation near Chandigarh, which lies about 400 km southeast of the type locality of the Tatrot Formation. Pilgrim (1932, 1938) was aware of the presence of Tatrot fossils from the type area of the Pinjor Formation, but exact location was not known to him. Now, rich Tatrot Fauna is known from the Siwalik Hills and will be discussed later. The biostratigraphy of the Upper Siwalik, based on mammalian fossils, is discussed in brief.

A location map depicting significant fossil localities of the Siwalik Group is provided (Fig. 1).

Upper Siwalik faunas of Pakistan

Three prominent fossiliferous areas of Pakistan are Hasnot-Kotal Kund – Tatrot-Andar Kas, Mangla-Samwal and Pabbi Hills.

Tatrot area, Potwar Plateau

The Upper Siwalik sediments are exposed in the upper part of the Tatrot-Andar Kas and Kotal Kund sections. The American workers, including Barry *et al*. (1982), called these sections as Hasnot Composite Section. The Kotal Kund section lies 10 km south of Hasnot village. The Tatrot-Andar Kas section of Barry *et al.* (1982) combines two partial sections. The upper part of the section is exposed 4 km north of Hasnot and lower part at Andar Kas about 4 km east of Hasnot. Combined magnetostratigraphic and palaeontologic studies were carried out by Barry *et al*. (1982). According to these workers (p. 107), "The Tatrot part of the section has an unconformity below the uppermost 60 metres which, on the basis of magnetic polarity stratigraphy and faunal evidence, may represent of hiatus of more than 2 m.y." This missing part of the Tatrot-Andar Kas succession is marked in the Kotal Kund section. Colbert (1935) and Pilgrim (1939) in their respective faunal list mentioned several taxa from the Tatrot Formation. At that time, Tatrot Fauna was only known from the Potwar Plateau. The reported taxa include *Anancus* (= *Pentalophodon*) *falconeri*, *Stegodon bombifrons*, *Sivachoerus giganteus*,. *Propotamochoerus hysudricus* (= *Dicoryphochoerus vagus*), *Hippopotamodon sivalense* (= *D. titanoides*), *Hippohyus sivalensis* (= *H. grandis*),

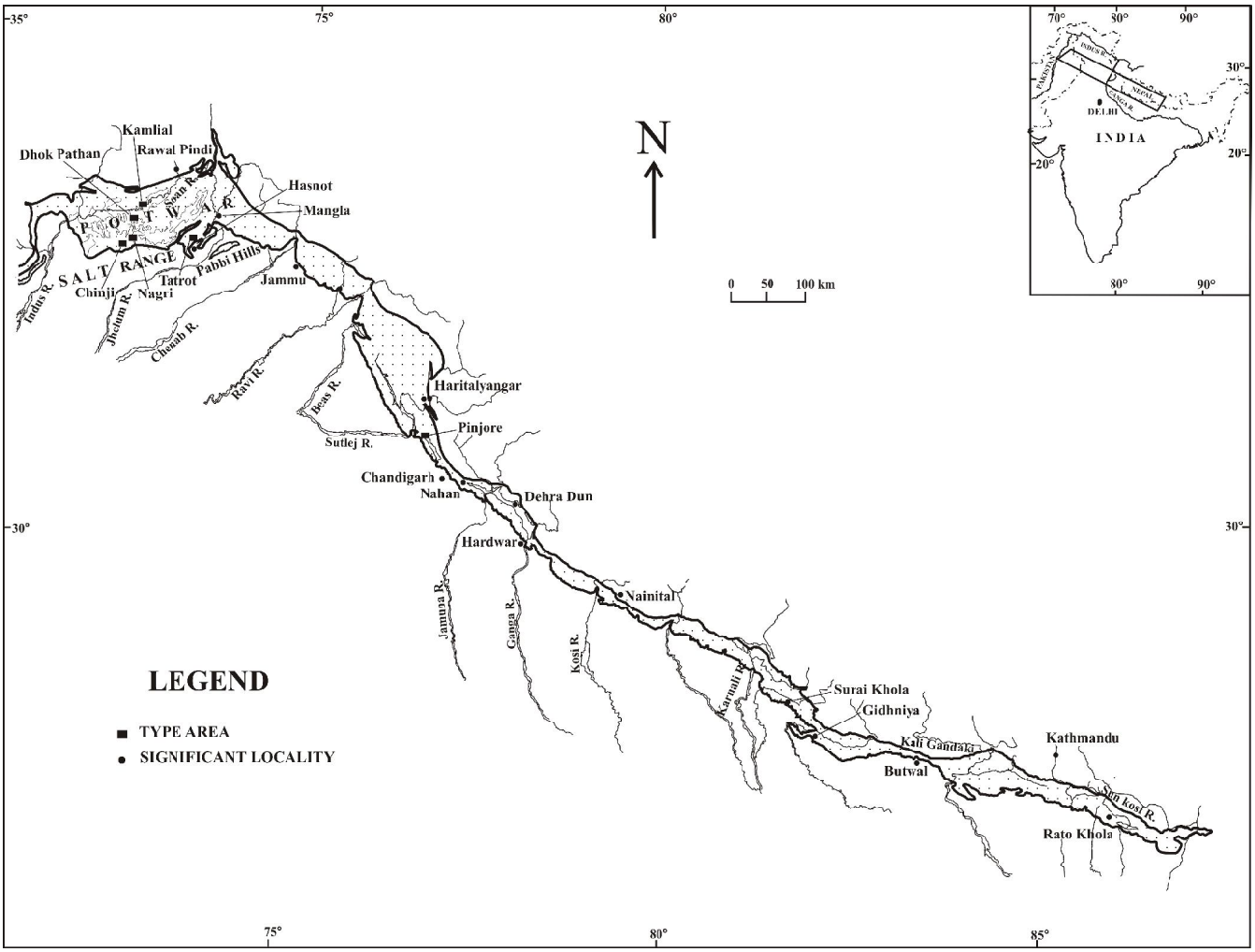

Fig. 1. Part of the Siwalik belt showing important stratigraphic localities.

H. lydekkeri (= *H. tatroti*), *Hexaprotodon sivalensis*, *Sivatragus*? *brevicornis*, *Hydaspicobus auritus* and *Proamphibos lachrymans*. Barry *et al.* (1982, p.122) considered *Hexaprotodon sivalensis* Interval-Zone roughly equivalent to the Tatrot faunal zone (now referred to as 'formation') and reported additional taxa from the *H. sivalensis* Interval-Zone.

Based on vertebrate and palaeomagnetic studies, Barry *et al.* (1982) recognized two biostratigraphic interval–zones. The zones are *Hexaprotodon sivalensis* Interval-Zone (5.3-2.9 m.y.) and *Elephas planifrons* Interval–Zone (2.9–1.5 m.y.). The boundaries of these zones are based on magnetostratigraphic studies and faunal characterization. While marking these zones, workers took into consideration the appearance, local extinction, common or characteristic taxa, restriction of the taxa and relation to local magnetic polarity sequence, etc. In the *Hexaprotodon sivalensis* Interval–Zone, these workers did not find a single taxon, which is restricted to this zone. Fauna of this zone includes *Percrocuta grandis*, *Stegodon* sp., *Hipparion* s.l., *Hippopotamodon sivalense*, *Hexaprotodon sivalensis*, *Dorcatherium* sp., *Selenoportax lydekerri*, *Proamphibos lachrymans*, *Sivahyus punjabiensis* and *Mus* spp. The lower boundary of this zone is marked by the extinction of *Propotamochoerus hysudricus* and joint occurrence of *Hippopotamodon sivalense*, *Percrocuta grandis* and with lowest occurrence of *Hexaprotodon sivalensis*.

The *Elephas planifrons* Interval–Zone is not richly fossiliferous. *E. planifrons*, *Equus sivalensis*, *Sivachoerus prior,* cervids and *Sivatherium giganteum* made their first appearance. *Kolpochoerus* sp. along with *Sivachoerus prior* are found restricted to this zone. Other common taxa include *Proamphibos lachrymans, Hexaprotodon sivalensis*, *Sivahyus punjabiensis* and *Sivatragus brevicornis*. The lower boundary is marked at the lowest occurrence of *E. planifrons.*

E. planifrons Interval–Zone is also recognized and discussed by Hussain *et al.* (1992) in the Mangla-Samwal area, and Dennell *et al*. (2006) in the Pabbi Hills. The works of these authors will be discussed later.

Mangla-Samwal Area

The Mangla-Samwal area is located in the Jhelum Re-entrant molasses basin. Arif (1985) identified three formations of the Upper Siwalik. These are bottom to top, Samwal, Kakra and Mirpur. Hussain *et al.* (1992) gave description of the Samwal and Kakra formations (ca 3.4 to 1.1 Ma) and carried out combined mammalian fauna and magnetostratigraphic studies. The lower part of the Samwal Formation is sand dominated, whereas upper part is mudstone dominated. The boundary between the lower and upper Samwal

Formation is characterized by the presence of a bentonite layer. Two prominent bentonite layers are known in Potwar as described by Johnson *et al.* (1982). These two layers extend along strike to several sections of Potwar and in the Jammu region of India. However, in the Mangla-Samwal area, only one bentonite layer is present and assigned age is 2.4 ± 2.20 Ma (Hussain *et al.*, 1992, fig.3). The Kakra Formation consists of alternation of conglomerate, sandstone and mudstone. The Samwal Formation is richly fossiliferous. Hussain *et al.* (1992) modified the *Elephas planifrons* Interval – Zone of Barry *et al.* (1982) and proposed an additional younger zone. The two proposed zones are *E. planifrons* Range- Zone (3.3 – 2.7 Ma B.P.) and *Elephas hysudricus* Range – Zone (2.7- ? Ma B. P.). Thus, they split the *E.planifrons* Interval –Zone of Barry *et al.* (1982) into two range–zones and did not assign any upper age to their new range–zone. In Fig. 5, they provided the distribution of taxa with respect to palaeomagnetic scale. The Tatrot- Pinjor faunal boundary concides with Gauss- Matuyama boundary as is agreed virtually by all the Siwalik workers of Indo-Pakistan subcontinent. The distribution of the taxa in the Tatrot and Pinjor intervals is tabulated in Table1. *Anancus* sp., *E. planifrons*, *Merycopotamus dissimilis*, *Hemibos* sp. and cf. *Leptobos kashmiricus* (?= cf. *Proamphibos kashmiricus*) are present in Tatrot faunal interval. Pinjor faunal interval contains numbers of taxa, which include *Caprolagus sivalensis, Pachycrocuta brevirostris* (synonym *Crocuta sivalensis*), *Equus* sp. A. (small horse), *Equus* cf. *sivalensis*, *Rhinoceros* s.l., *Cervus triplidens* and *Sivatherium giganteum*. The presence of *Pachycrocuta, Equus*, *Rhinoceros*, *Cervus* and *Sivatherium* are the characteristic for the Pinjor Fauna.

Table 1: Distribution of the Upper Siwalik Mammalian taxa with respect to Tatrot and Pinjor faunal intervals in the Mangla-Samwal area of Pakistan* (compiled after Hussain *et al.*, 1992).

ORDER/ taxon	TATROT	PINJOR
LAGOMORPHA		
Caprolagus sivalensis	-	X
CARNIVORA		
Pachycrocuta brevirostris		
(= *Crocuta sivalensis*)	-	X
PROBOSCIDEA		
Anancus (= *Pentalophodon*) sp.	X	-
Stegodon sp.	X	X
Elephas planifrons	X	-
E. hysudricus	**	X
PERISSODACTYLA		
Equus cf. *E. sivalensis*	-	X
Rhinoceros s.l.	-	X
ARTIODACTYLA		
Merycopotamus dissimilis	***	***
Hexaprotodon sivalensis	X	X
Cervus triplidens	-	X
Sivatherium giganteum	-	X
Hemibos sp.	X	-
cf. *Leptobos kashmiricus*	X	-
(= ? *Proamphibos kashmiricus*)		

* Tatrot interval below Gauss- Matuyama boundary, whereas Pinjor interval is above this boundary, **: in the Upper Gauss, ***: just at the contact of Gauss – Matuyama boundary.

Pabbi Hills

Pabbi Hills are about 35 km away from Mangla-Samwal area and have yielded rich Pinjor Fauna (Table 2). Keller *et al.* (1977) carried out magnetostratigraphic studies and dated the appearance of equids in the succession. Dennell *et al.* (2006) carried out combined magnetostratigraphic and palaeontologic studies of the Upper Siwalik succession. This succession belongs to Matuyama-Brunhes epochs and thus it is equivalent to the Pinjor faunal interval. The Siwalik successions between

Table 2: Mammalian taxa representing Pinjor Fauna in the Matuyama (time range 2.2 to 0.9 Ma) magnetic epoch, Pabbi Hills, Pakistan (after Dennell *et al.*, 2006, pp. 168, 181).

CARNIVORA	*Crocuta crocuta, Pachycrocuta brevirostris, Hyaenictis/Lycyaena, Panthera uncia, Magantereon cultridens, Felis, Canis cautleyi*
PROBOSCIDEA	*Stegodon*, *Elephas hysudricus*
PERISSODACTYLA	*Equus sivalensis*, *Rhinoceros sivalensis*
ARTIODACTYLA	*Hexaprotodon*, cf. *Cervus*, *Sivatherium giganteum, Gazella* sp., *Hemibos triquetricornis*, *Damalops palaeindicus*

2.2 -1.7 Ma and 1.4-1.2 Ma are found particularly rich. The successions in between 1.7-1.4 Ma and 1.2-0.9 Ma yielded limited fossil material (Dennell *et al.*, 2006, p.180). According to them, the main extinction took place after 1.7 Ma. *Sivatherium giganteum* is only known between 2.2 and 1.7 Ma and is absent in the succession younger than 1.7 Ma. However, *Sivatherium* is reported from Chandigarh area from early Brunhes (i.e., around 0.78 Ma) (Ranga Rao *et al*., 1995, fig.5). According to Dennell *et al*. (2006, p.180, fig. 10), medium sized bovids, *Hexaprotodon*, probably *Stegodon,* Anthracotheriidae, *Hyaenictis*/ *Lycyaena* and *Canis cautleyi* became extinct after 1.2 Ma event. *Stegodon* and *Hexaprotodon* are recorded just below Jaramillo event in Parmandal – Utterbeni section of Jammu region (Ranga Rao *et al*., 1988, fig. 4). In Chandigarh region, *Stegodon* extends up to Brunhes (Ranga Rao *et al*., 1995, fig.5). Both *Stegodon* and *Hexaprotodon* are well known from the Middle Pleistocene fauna of Peninsular India. *Stegodon* is even known from the Upper Pleistocene of Peninsular India and Indo-Gangetic Plain (Nanda, 2008, table 2). Thus, the absence of *Sivatherium*, *Hexaprotodon* and *Stegodon* in Pabbi Hills may be attributed to local extinction. Dennell *et al.* (2006, p. 180, fig 10.) collected *Crocuta crocuta*, ursid and snow leopard (*Panthera uncia*) from the time period of 1.4 - 1.2 Ma. However, in Figure 10, these workers marked their first appearance just after 1.2 Ma. *C.crocuta* and *P.uncia* are reported for the first time from the Upper Siwalik succession of Indo-Pakistan subcontinent. *C. crocuta* occurs in wild form in Africa and is not known from India. *P. uncia* (snow leopard) occurs in Himalaya at altitude 3660- 3965m (12, 000 – 13, 000ft) and comes down in summer as low as 1830 m (6000ft) (Prater, 1965, p. 70). The snow leopard is definitely a high altitude carnivore and the Siwalik succession is foothills deposit. However, Dennell *et al.* (2006, p. 180) interpreted cooler conditions at the time period of 1.4 – 1.2 Ma and this taxon migrated to lower elevation, due to uplifting and folding of Karakoram Mountains. They state "By the time of deposition of sandstone 12 [time period 1.4 – 1.2 Ma], it is assumed that *S.*[*Sivatherium*] *giganteum, C.*[*Canis*] *cautleyi, Hyaemictis* or *Lycyaena* (i.e. smaller hyaenid), anthracotheres and

hippopotamids, and possibly *Stegodon* had become locally extinct. This may indicate the expansion of grassland at the expense of woodland." Pinjor Fauna of the Pabbi Hills is tabulated in Table 2.

Dennell *et al.* (2006, p. 181) subdivided the *E. hysudricus* Range-Zone of Hussain *et al.* (1992) into two faunal-zones. These are:

E. hysudricus – Sivatherium faunal- zone (2.7 – 1.7 Ma)

This zone is marked by the local extinction of *S.giganteum,* hippopotamids, anthracotheres and a large canid.

E. hysudricus – Crocuta – Ursus- Panthera faunal- zone (1.7 – 0.9 Ma)

According to Dennell *et al*. (2006), the last appearance datum of *E. hysudricus* is not clear and this taxon in Middle Pleistocene is replaced by *E. namadicus*. According to Nanda (2008, table 2), several workers have reported *E. hysudricus* from the Middle and Upper Pleistocene of Peninsular India. Thus, the taxon has a wide time range.

Upper Siwalik faunas of India

There are two regions, Chandigarh and Jammu, which have yielded rich Tatrot and Pinjor faunas.

Chandigarh region

Hilly terrain near Chandigarh- Panchkula cities is known as Siwalik Hills (Colbert, 1935, fig. 17). Pilgrim (1913) based the type area of his Pinjor 'faunal-zone' after the township of Pinjore, which lies about 11 km east of Chandigarh. Baker (1835a-c) and Baker and Durand (1836 a,b) were the earliest workers, who made collection from this region. Subsequently, Falconer and Cautley (1846-1849) published classic pictorial monograph of the Upper Siwalik vertebrates entitled 'Fauna Antiqua Sivalensis'. Falconer (1868) published 'Palaeontological Memoirs' on the Siwalik mammals. Recently, numbers of workers including Hooijer (1949,1950, 1955, 1958), Sahni and Khan (1964), Nanda (1973-2008), Gupta *et al.* (1976-1981), Badam (1979), Azzaroli and Nepoleone (1982), Azzaroli (1985), Gaur (1987), Verma (1989), Nanda *et al.* (1991), Patnaik (1995, 1997, 2001), Verma *et al.* (2002) and Patnaik and Nanda (2010) gave details about the biostratigraphy and faunas.

Tatrot Fauna

Pilgrim (1932, pp. 2-3; 1938, p. 446) was aware of the presence of the Tatrot fossils from the type area of the Pinjor Formation. However, he was not aware of localities, which yielded this fauna. The fossils mentioned by him are *Hipparion*, *Hippohyus* and *Anancus* (= *Mastodon*) *sivalensis*. Sahni and Khan (1964) were the first to report these pre- Pinjor beds of the Upper Siwalik and called these as 'Tatrot beds'. They published the geological map of the area lying east of Chandigarh and distinguished the 'Tatrot' and Pinjor beds, both based on the lithology and fauna. Lithologically the pre-Pinjor beds consist of grey and variegated bright mudstones, which are interbedded with medium to coarse grained, soft to medium hard sandstones. The presence of *Hipparion* and *Proamphibos*, and complete absence of *Equus* and *Bubalus* were taken as the characteristic for the Tatrot Fauna. Both *Equus* and *Bubalus* are the marker for the Pinjor beds. Later various workers including Nanda (1981), Gaur (1987) and Verma (1989) described the pre-Pinjor beds from different areas of the Siwalik Hills of Chandigarh. In fact, these pre- Pinjor beds occur as isolated outcrops and different workers referred these beds to different names. Sahni and Khan (1964) called the upper part of the succession as 'Quaranwala Zone'. Pandey (1971) referred those to the 'Masol Member' and equated with the lower part of the Tatrot Formation of the type area. Sastry (1981) referred these beds to 'Dhamala Formation' after the village Dhamala, near Chandigarh. Verma (1989) worked in the Saketi area of Himachal Pradesh and refers these pre-Pinjor beds to the Saketi Formation. These beds yielded rich 'Tatrot Fauna'. Type area of Tatrot Formation lies about 400 km away from Chandigarh and the exposures referred to the 'Tatrot beds' in Chandigarh region can not be traced by strike mapping to the type area in Potwar Plateau. Moreover based on lithology, these cannot be correlated as lithology is time transgressive (Nanda and Sehgal, 1993, 2005). However, based on fauna, these can be correlated. Thus, there is a need to refer these beds to a new formation. Nanda (2002) followed Verma (1989) and referred these pre-Pinjor beds of the Upper Siwalik to the Saketi Formation. In the last five decades, about 30 characteristic taxa are collected and these are absent in the overlying Pinjor Formation (Table 3).

Pinjor Fauna

The Pinjor Fauna is rich and known for its quality and quantity. Collections made in the last five decades reveal that about fifty-four taxa are found restricted to the Pinjor Formation (Table 3). In addition, ten genera are common in the Pinjor and pre-Pinjor beds of the Upper Siwalik. Earlier, Opdyke *et al.* (1979) have taken the presence of *Equus, Cervus* (cervid with antler) and *Proamphibo*s as characteristic for the Pinjor Fauna of Potwar Plateau, Pakistan. Pilgrim (1939, p.7) has considered the range of *Proamphibos* from Dhok Pathan to Tatrot. Dennell *et al*. (2006) have replaced *Proamphibos* with *Damalops palaeindicus* and this taxon ranges from Matuyama to Brunhes and considered it as characteristic for the Pinjor. *D. palaeindicus* is abundant in Pabbi Hills, but not dominant in the type area near Chandigarh.

Lithologically, the Pinjor Formation is characterized by the alternation of brown and pink mudstones and grey-green sandstones. Mudstones are dull, concretionary and of brown–pink in color. Sandstones are medium to coarse grained, soft to medium hard, current bedded and pebbly. Dips are low and beds can be traced along the strike and dip slopes form excellent sites for fossil collection.

Upper Siwalik faunas, Tatrot and Pinjor, are very rich and a modified list of faunas after Nanda (2002) is given in Table 3.

Nanda (1997) recognized two biostratigraphic interval-zones for the Upper Siwalik mainly for Chandigarh region. These are *Elephas planifrons* Interval-Zone (3.6- 2.7 Ma) and *Elephas hysudricus* Interval–Zone (2.7 to 0.6 Ma). Later in 2002, he modified his zones and the proposed zones are *Elephas planifrons* Interval–Zone (3.6 – 2.6 Ma) and *Equus sivalensis* Interval – Zone (2.6- 0.6 Ma). Thus, he modified the upper limit of older zone and renamed *E.hysudricus* Interval – Zone as *Equus sivalensis* Interval – Zone. This was necessary, as the dispersal event of *Equus* at 2.6 Ma is most distinctive faunal events of the Upper Siwalik. *E. sivalensis* occurs profusely as compared to *E.hysudricus* and the most common taxon of this interval-zone. Moreover, the *Elephas planifrons* Interval – Zone and *Elephas hysudricus* Interval –Zone can be distinguished by generic rather than specific differences (Nanda, 2002, p.54). The brief description of these zones is provided below.

Table 3: Distribution of various genera/species in the Pinjor and Saketi beds (=Tatrot beds, =pre-Pinjor beds of the Upper Siwalik Subgroup) of Chandigarh region (based on collection of last five decades, modified after Nanda, 2002).

PINJOR BEDS	
PRIMATES	*Procynocephalus pinjorii*, *?Homo erectus*
LAGOMORPHA	*Caprolagus* sp.
RODENTIA	*Rattus* sp., *Hystrix leucurus*, *Mus linnaeusi*, *M.* cf. M. *flynni*, *Cremnomys* cf. *C. blanfordi*, *Golunda* sp., *Dilatomys* sp., *Hadromys loujacobsi*, *Tatera pinjoricus, Rhizomys pinjoricus*, *Bandicota* sp.
CARNIVORA	*Canis pinjorensis*, *Mellivora sivalensis*, *Pachycrocuta brevirostris* (=*Crocuta felina*, = *C. sivalensis*, = *C. colvini*), *Panthera* cf. *P. Cristata, Hyaenictis bosei, Megantereon palaeindicus, Sivapanthera* (=*Sivafelis*) *potens*
PROBOSCIDEA	*Anancus* (=*Pentalophodon*) *sivalensis*, *Stegolophodon stegodontoides*, *Stegodon pinjorensis, Elephas hysudricus*, *E. platycephalus*
PERISSODACTYLA	*Equus sivalensis, ? E. namadicus*, *Coelodonta platyrhinus (=Punjabitherium platyrhinus)*, *Rhinoceros palaeindicus*, *R. sivalensis*
ARTIODACTYLA	*Potamochoerus theobaldi*, *Hippohyus sivalensis*, *Sus falconeri*, *S. hysudricus*, *S. giganteus*, *S. choprai, Rucervus simplicidens*, *Cervus. punjabiensis*, *Sivatherium giganteum*, *Sivacapra subhimalayaensis, Damalops palaeindicus*, *Oryx sivalensis*, *Sivacobus palaeindicus*, *Antilope subtorta, Vishnucobus* (=*Indoreduncа*) *sterilis, Hemibos acuticornis*, *H. triquetricornis*, *H. antilopinus*, *Bubalus palaeindicus*, *B. platyceros*, *Leptobos falconeri*, *Bison sivalensis*, *Bos acutifrons*
EXTEND FROM THE SAKETI TO PINJOR BEDS	*Golunda kelleri*, *Crocidura* sp., *Prototocyon* (=*Sivacyon*) *curviplatus, ?Pachycrocuta brevirostris* (=*Crocuta sivalensis, =C. felina, = C. colvini*), *Elephas planifrons*, *Stegodon insignis, S. katliensis, Potamochoerus palaeindicus, Hexaprotodon sivalensis, Camelus sivalensis*
SAKETI BEDS	
INSECTIVORA	*Suncus* cf. *S. murinus*
LAGOMORPHA	*Pliosiwalagus whitei*
RODENTIA	*Palaeomys* sp., *Rhizomyides saketiensis*, *Rhizomyides* cf. *R. sivalensis*, *Mus flynni*, *M. jacobsi*, *Parapelomys robertsi*, *Hadromys primitivus*, *H. moginandensis, Cremnomys* cf. *C. cutchicus, Bandicota sivalensis*, *Protatera* cf. *P. kabulense*, *Golunda tatroticus*, *Dilatomys moginandensis*, *Brachyrhizomys pilgrimi*, *Abudhabia* cf. *A. kabulense*
PROBOSCIDEA	*? Anancus perimensis*, *Anancus* (=*Pentalophodon*) *khetpuraliensis*
PERISSODACTYLA	*Cormohipparion theobaldi, Hipparion antilopinum*, ? *Chilotherium intermedium*
ARTIODACTYLA	*Merycopotamus dissimilis*, *Hippohyus tatroti*, *Proamphibos kashmiricus*, *Probison dehmi*
ADDITIONAL CHARACTERISTIC TAXA FOR SAKETI BEDS (= TATROT BEDS)*	*Stegodon bombifrons*, *Sivachoerus* sp., *Hydaspitherium megacephalum*, *Gazella* sp.

*These taxa are known from the Dhok Pathan Formation and extend into Saketi beds, but are absent in the Pinjor beds

Elephas planifrons Biostratigraphic Interval- Zone (3.6 – 2.6 Ma)

The suggested reference section is Saketi section, Himachal Pradesh. Twenty-five taxa make their first appearance or restricted to this zone. These are *Suncus* cf. *S. murinus*, *Pliosiwalagus whitei*, *Rhizomyides saketiensis*, *Rhizomyides* cf. *R. sivalensis*, *Mus flynni*, *M. jacobsi*, *Parapelomys robertsi*, *Hadromys primitivus*, *H. moginandensis*, *Cremnomys* cf. *C. cutchicus*, *Bandicota sivalensis*, *Protatera* cf. *P. kabulense*, *Golunda tatroticus*, *Dilatomys moginandensis*, *Brachyrhizomys pilgrimi*, *Abudhabia* cf. *A. kabulense*, *Palaeomys* sp., *?Anancus perimensis*, *Anancus* (=*Pentalophodon*) *khetpuraliensis*, *Hippohyus tatroti*, *Propotamochoerus hysudricus*, *Camelus sivalensis, Sivatherium giganteum, Proamphibos kashmiricus* and *Probison dehmi*.

Stegodon bombifrons, *Sivachoerus*, *Hydaspitherium megacephalum* and *Gazella* have their last appearance in this zone. *E.planifrons*, *Stegodon insignis* and *Hexaprotodon sivalensis* are the most common taxa. *Sivatherium* occurs only in the upper most part. Hipparionines (i.e. *Hipparian* / *Cormohipparion*) are rare.

Equus sivalensis Biostratigraphic Interval–Zone (2.6 – 0.6 Ma).

The Patiali Rao section lying west of the Pinjore township near Chandigarh is chosen as referred section. This zone is very rich and forty-seven taxa made their appearance. These are *Procynocephalus pinjorii*, *?Homo erectus*, *Mus linnaeusi*, *Mus.* cf. *M. flynni*, *Caprolagus* sp., *Cremnomys* cf. *C. blanfordi*, *Golunda* sp., *Dilatomys* sp., *Rattus* sp., *Hystrix leucurus*, *Hadromys loujacobsi*, *Tatera pinjoricus*, *Rhizomys pinjoricus*, *Bandicota* sp., *Mellivora sivalensis*, *Canis pinjorensis*, *Panthera* cf. *P. cristata*, *Pachycrocuta brevirostris* (= *?Crocuta felina*, *C. colvini*), *Stegolophodon stegodontoides*, *Anancus* (=*Pentalophodon*) *sivalensis, Elephas hysudricus*, *E. platycephalus*, *Equus sivalensis, ?E. namadicus*, *Rhinoceros palaeindicus*, *R. sivalensis*, *Coelodonta platyrhinus* (= *Punjabitherium platyrhinus*), *Rucervus simplicidens, Cervus punjabiensis*, *Potamochoerus theobaldi*, *Sus falconeri*, *S. hysudricus*, *S. giganteus*, *S.*

choprai, *Hippohyus sivalensis*, *Hemibos acuticornis*, *H. triquetricornis*, *H. antilopinus*, *Leptobos falconeri*, *Sivacobus palaeindicus*, *Sivacapra subhimalayaensis*, *Damalops palaeindicus*, *Oryx sivalensis*, *Bubalus palaeindicus*, *B. platyceros*, *Bos acutifrons* and *Bison sivalensis*.

Hipparioninaes, ?*Chilotherium*, *Merycopotamus dissimilis* and *Proamphibos* made their last appearance and confined to the oldest part of the zone. The most common taxa include *Elephas hysudricus*, *Stegodon insignis*, *Equus sivalensis*, *Rhinoceros* spp., *Cervus* spp., *Sivatherium giganteum, Hemibos* spp. and *Bos acutifrons*.

Jammu region

Upper Siwalik vertebrate fossils are well known from the areas adjoining Jammu city. The prominent fossiliferous sections are Jammu-Nagrota, Parmandal- Utterbeni and Samba-Mansar. De Terra and Teilhard (1936, p.803) made collection from the Nagrota area and collection includes *Elephas planifrons*, *Equus* and *Bos*. *Equus* and *Bos* indicate the presence of Pinjor Fauna. Since then number of workers including Yakoyama *et al*. (1987), Gupta and Verma (1988), Ranga Rao *et al.* (1988), Agarwal *et al.* (1993), Nanda (1997, 2002), Nanda and Kumar (1999), Gupta and Prasad (2001) and Basu (2004) carried out work in the area. The Siwalik succession near Jammu forms an anticline, which is referred to as Surinsar-Mastgarh Anticline (Karunakaran and Ranga Rao, 1979, sheet A). On the southern limb of this anticline Lower, Middle and Upper Siwalik subgroups are exposed. Gupta and Verma (1988) carried out investigations in Mansar–Utterbeni section and mapped the area. Ranga Rao *et al.* (1988) and Agarwal *et al*. (1993) carried out combined vertebrate palaeontologic and magnetostratigraphic studies of the fossiliferous sections. Gupta and Prasad (2001) and Prasad *et al.* (2005) described micromammals.

The Upper Siwalik Subgroup is divided into three formations, Parmandal Sandstone, Nagrota and Boulder Conglomerate. The Parmandal Sandstone is arenaceous facies and sandstones are of grey and bluish grey, coarse grained, pebbly, multistoried, current bedded and virtually unfossiliferous. Mudstones are in subordinate position. The Nagrota Formation is sandstone-mudstone alternation unit. In central part, it has two bentonitized tuff beds. Based on Fission Track analysis, these are dated 2.8± 0.56 Ma and 2.31± 0.54 Ma (Ranga Rao *et al.*,1988). Yakoyama *et al*. (1987) have assigned an age of 1.6± 0.2 Ma to the lower bentonitized bed, whereas Mehta *et al.* (1993) have given the age of 1.59± 0.32 Ma to one of the bed. Fission Track data of Ranga Rao *et al.* (1988) is supported by combined magnetostratigraphic and palaeontologic studies. Moreover, the dates given by Ranga Rao *et al.* (1988) tally with the Fission Track dates, given by Johnson *et al.* (1982), for the two-bentonitized beds occurring in the Upper Siwalik succession in the adjoining region of Pakistan.

The Nagrota Formation has yielded both Tatrot and Pinjor faunas. Based on work carried out by the above-mentioned workers, it is found that about eight and twelve taxa represent the Tatrot and Pinjor faunas respectively. Characteristic taxa of the Tatrot Fauna include *Golunda kelleri*, *Dilatomys pilgrimi*, *Rhizomyides sivalensis*, *Abudhabia* cf. *A. kabulense*, *Stegodon bombifrons*, *Hipparion antelopinum*, *Cormohipparion theobaldi* and *Propotamochoerus hysudricus*. The Pinjor Fauna is characterized by *Panthera* cf. *P. cristata*, *Pachycrocuta brevirostris*, *Elephas hysudricus*, *Equus sivalensis, Rhinoceros palaeindicus*, *Coelodonta platyrhinus*, *Sus giganteus*, *Cervus* spp., *Sivatherium giganteum*, *Sivacapra* sp., *Hemibos acuticornis* and *Bos* sp.

Range and Extinction of the Pinjor Fauna of the Chandigarh and Jammu regions

Magnetostratigraphic studies carried out by Azzaroli and Nepoleone (1982), Tandon *et al.* (1984), Ranga Rao *et al.* (1988, 1995) and Kumaravel *et al.* (2005) put the lower limit of the Pinjor Formation at the Gauss-Matuyama boundary. This age is same as given by various workers of Potwar Plateau (Opdyke *et al.*, 1979; Barry *et al.*, 1982; Johnson *et al*., 1982); and in Mangla-Samwal by Hussain *et al.* (1992). Virtually all the Siwalik workers discussed the lower boundary of the Pinjor Formation, but did not comment on the upper boundary i.e., the contact between the Pinjor Formation and Boulder Conglomerate Formation. This boundary is discussed by Nanda (1997, 2002, 2008), The contact of the Pinjor Formation (or Nagrota Formation having Pinjor Fauna) with the Boulder Conglomerate Formation is time transgressive and ranges from 1.79 to 0.6 Ma. The data after Nanda (2008) is reproduced in Figure 2. In Jammu region, this contact is dated 1.72 Ma in Nagrota-Jammu section. However, 20 km southeast in Parmandal – Utterbeni section, it is dated 0.6 Ma (Ranga Rao *et al*., 1988, fig.12). Thus in 20 km distance, it is time transgressive by 1.12 Ma. The Samba-Mansar section lies 20 km southeast of Parmandal-Utterbeni section and this contact is dated 1.32 Ma (Ranga Rao, 1993). Thus, it is time transgressive by 0.72 Ma. The Chandigarh region lies about 300 km southeast of Jammu. Here in Nadah section, it is dated 1.67 Ma (Azzaroli and Nepoleone, 1982). The Patiali Rao section lies 16 km northwest of Nadah section and contact is dated 0.63 Ma (Ranga Rao *et al*., 1995). Thus, it is time transgressive by 1.04 Ma. The Ghaggar section is adjoining the Nadah section and contact is dated 1.79 Ma. Haripur Khol is at about 60 km southeast of Nadah and the contact between the Pinjor and Boulder Conglomerate formations is dated 1.77 Ma (Kumaravel *et al*., 2005). Thus, the time transgressive nature of the contact varies from 1.79 Ma (Ghaggar section) to 0.6 Ma (Parmandal-Utterbeni section). This variation in the contact throws light on various aspects including the sedimentation pattern, extinction or migration of the Pinjor Fauna and intensification of the last phase of Himalaya Orogeny. All these changes took place around 1.77 Ma.

As per IUGS decision (Gibbard *et al*., 2010), the Neogene\Quaternary boundary is now placed at 2. 58 Ma (i.e. between the Gauss and Matuyama) and not at the top of the Olduvai subchron, which is dated 1.77 Ma by Cande and Kent (1995). In Nagrota-Jammu, Nadah, Ghaggar and Haripur sections, this coincides virtually with the contact of Pinjor and Boulder Conglomerate formations and indicates the change in sedimentation pattern from sandstone-mudstone alternation (Pinjor Formation) to thick conglomerate beds (Boulder Conglomerate Formation). The presence of thick succession of cobble and boulder conglomerates indicates intensification of the Himalayan Orogeny in the provenance of the Siwalik Group and its signature in the form of thick coarse conglomerates was evident at the foothills. The process of extinction or migration of the Siwalik mammals started at 1.79 Ma and at 0.6 Ma, the fauna became extinct or migrated from

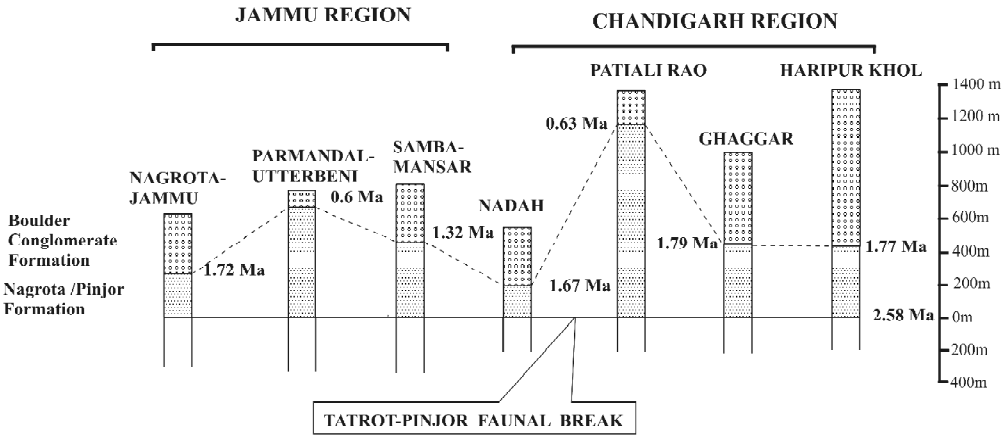

Fig. 2. Upper limit of the extinction and migration of the Pinjor Fauna in various sections of Jammu and Chandigarh regions (after Nanda, 2008).

the Himalayan foothills. The very coarse lithology of Boulder Conglomerate Formation, containing cobbles and boulders (sometimes exceeding one meter) was not suitable for the survival of animals and thus they became extinct or migrated elsewhere or to Peninsular India and Indo-Gangetic Plain. However, there are only two sections, Parmandal-Utterbeni and Patiali Rao, where the Pinjor Fauna survived for longer duration above the Olduvai subchron without any interruption and change. The succession of the fauna in these two sections is given after Nanda (2002) (Fig. 3).

Upper Siwalik faunas of Nepal

There are three significant Upper Siwalik fossil localities in Nepal. These are Gidhniya, Surai Khola (both in western Nepal) and Rato Khola (in eastern Nepal). In addition, from the intermontane deposits of Kathmandu Valley, the Pinjor Fauna is recorded. The history of the fossil collection is not old in Nepal. Sharma (1977) mentioned about the existence of vertebrate fossils in Nepal. Since then, a number of workers including West and Munthe (1981, 1983), West (1984), West *et al*. (1988), Nanda and Corvinus (1992, 2000), Corvinus and Nanda (1994), Nanda (1997), Corvinus and Rimal (2001) and Corvinus (2006) collected fossils and discussed the biostratigraphy based on the mammalian fossils.

Fauna of Gidhniya (western Nepal)

Gidhniya locality yielded Upper Siwalik fauna of the range between 2.9 to 1.5 Ma and is considered equivalent to the Pinjor and Karewas faunas (West and Munthe, 1983, p.24). Gidhniya fauna includes *Stegodon insignis*, *Elephas planifrons*, *Equus sivalensis*, *Hexaprotodon sivalensis* and *Cervus* sp. *Equus* and *Cervus* indicate the presence of the Pinjor Fauna.

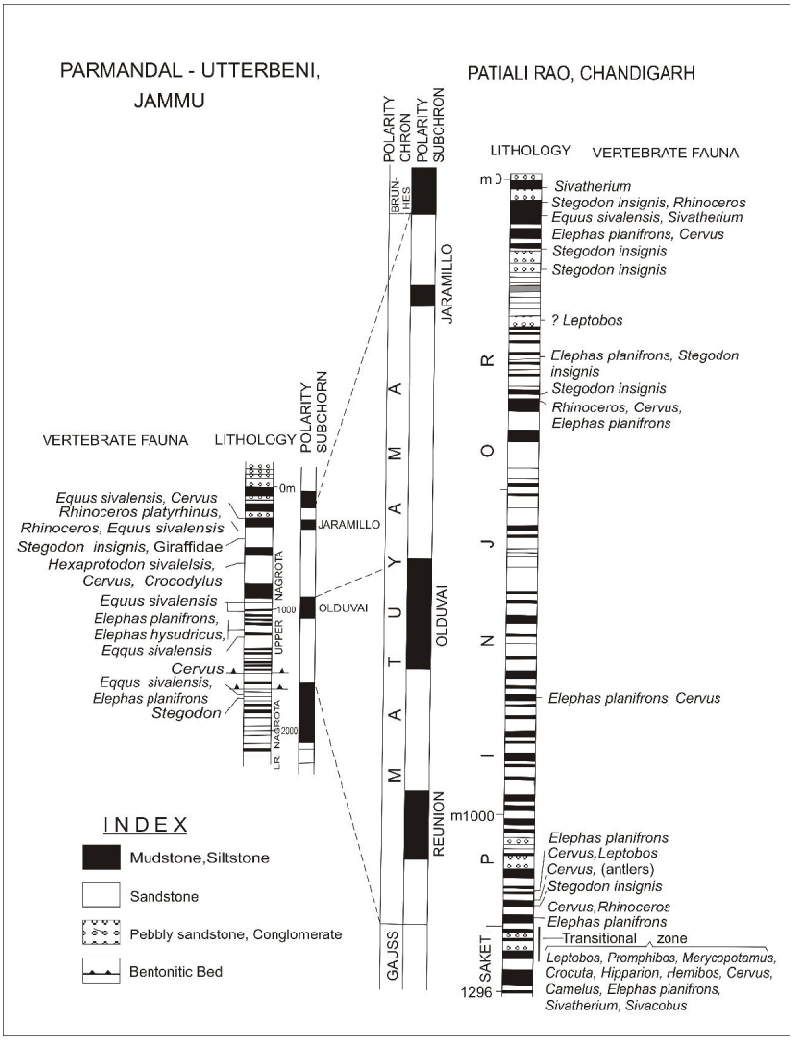

Fig. 3. Successions of the Pinjor Fauna in Parmandal-Utterbeni section of Jammu and Patiali Rao section of Chandigarh (data mainly after Ranga Rao *et al.*, 1988, fig. 4; 1995, fig. 11, Nanda, 2002).

Tatrot and Pinjor faunas of Surai Khola (western Nepal)

The Surai Khola succession is having all the three subgroups of the Siwalik Group. These are subdivided by Corvinus (1993), Corvinus and Nanda (1994), Corvinus and Rimal (2001) and Corvinus (2006) into various formations: Bankas (Lower Siwalik), Chor Khola and lower part of Surai Khola (Middle Siwalik) and Upper Surai Khola, Dobatta and Dhan Khola (Upper Siwalik). *Giraffa punjabiensis* is recorded

from the middle part of the Surai Khola Formation (Corvinus and Nanda, 1994; Corvinus and Rimal, 2001; Corvinus, 2006). *Giraffa punjabiensis* is known from the Middle Siwalik (Colbert, 1935, p.36) of Indo-Pak region, but it seems that it survived in the younger horizons of Nepal Siwalik and may represent the Tatrot Fauna. Overlying the *G. punjabiensis*, *Hexaprotodon sivalensis*, *Cervus,* and *Hemibos acuticornis* were collected. Both *Cervus* and *Hemibos* are the characteristic of the Pinjor Fauna in the Siwalik Hills of Chandigarh. However, both taxa are not yet reported from the overlying Dobatta Formation. From the Dobatta Formation, *Elephas planifrons*, *Equus*, *Bos* and *Merycopotamus* (or *M. dissimilis*, fide Nanda and Corvinus, 1992) are recorded (Corvinus and Rimal, 2001, fig.4). The presence of *Equus* and *Bos* in the Dobatta Formation indicates the presence of the Pinjor Fauna, whereas *Merycopotamus dissimilis* ranges in Indian and Pakistan Siwalik from Dhok Pathan to Tatrot formations. Nanda (1994, fig.3) and Nanda and Sehgal (2005, fig.3) have shown that near Chandigarh, *Cervus*, *Hemibos* and *Merycopotamus* survived together for sometimes. In Chandigarh, the contact between the Tatrot and Pinjor faunas is not sharp, but transitional and *Merycopotamus* is taken as characteristic for the Tatrot Fauna, whereas *Cervus* and *Hemibos* are taken as characteristic of the Pinjor Fauna. The Nepal section yielded scanty fauna and there may be transitional zone like Chandigarh. Additional collection may throw better light on the existence of this zone. Thus in Nepal, the presence of *G. punjabiensis* and *Merycopotamus* are considered as characteristic for the Tatrot Fauna. The presence of *Equus*, *Cervus* and *Bos* is taken as characteristic for the Pinjor.

Appel *et al.* (1991) and Roesler (1998) carried out magnetostratigraphic studies of Surai Khola area. However, dates given by them do not tally with the recovered fossils from the Surai Khola and Dobatta formations. *Hexaprotodon sivalensis* made first appearance in Surai Khola and above it, *G. punjabiensis* is recovered (Corvinus 2006, fig.20). However, the succession, which yielded these taxa are dated around 6 million years, whereas *Cervus* is dated around 5.5 million years (Corvinus and Rimal, 2001, fig. 13). The *Cervus* is characteristic of the Pinjor Fauna and recorded above the contact of Gauss-Matuyama, which is dated 2.6 Ma. The occurrence of *Cervus* in older succession is surprising. This problem is discussed by Corvinus and Rimal (2001, p. 276) and according to them "The magnetostratigraphical results for the upper part of the Surai Khola sequence, however, do not correspond well to the ages indicated by the discovered fauna, and seems to endow greater antiquity to the beds." In the Surai Khola area, the *Cervus* occurs just above the 3000m (Corvinus and Rimal, 2001, fig. 13; Corvinus, 2006, fig.2). They further state "If one correlates the normal polarity events just above 3000m with 3n1 to 3n4 the fauna with *Cervus, Hemibos* and *E. planifrons* would be older than reported anywhere else in the subcontinent (between 4.2 and 5.2m.y.)." Thus, there is confusion regarding the appearance of certain mammalian taxa with respect to magnetostratigraphic dates.

Corvinus (2006) has equated the upper part of Surai Khola with *Hexaprotodon sivalensis* Interval – Zone (5.9-3.6 Ma) and *Elephas planifrons* Interval-Zone (3.6 – 1.5 Ma). The latter interval – zone includes most of the Dobatta Formation (Corvinus 2006, table 1). However, many details are not given. The present worker is of the view that the Upper Siwalik faunas of Nepal are scanty and insufficient to identify the interval – zones. Moreover, the available magnetostratigraphic dates do not agree with the appearance of mammalian taxa. More data, both palaeontologic and magnetostratigraphic, are required to interpret the interval – zones.

Fauna from Rato Khola (eastern Nepal)

The other significant Upper Siwalik fossiliferous area is Rato Khola (eastern Nepal). This area has yielded both Tatrot and Pinjor faunas. Lithologically in the lower part of the Upper Siwalik, soft, grey and medium-grained sandstones alternate with grey mudstones. Overlying these are multistoried salt and pepper, medium grained, soft grey sandstone bodies, which yielded *E. planifrons, Stegodon insignis*, *Hippohyus lydekerri* (= *H. tatroti*). The youngest succession includes alternation of sandstones and conglomerates. In addition, the Rato Khola area has also yielded *Proamphibos lachrymans*, *Stegodon bombifrons, Stegotetrabelodon, Equus*, *Potamochoerus* and *Bos* (Corvinus, 2006). The presence of *Stegodon bombifrons*, *Hippohyus lydekerri* and *Proamphibos lachrymans* indicates the Tatrot Fauna. These three taxa in the Chandigarh region are considered marker taxa for the Tatrot Fauna (Nanda, 1981, 1997, 2002). The upper limit of these taxa is up to the Tatrot Formation. *Hippohyus lydekerri* (synm *H. tatroti*, Pickford, 1988) is described by Corvinus and Nanda (1994). The horn-core of *Proamphibos* and a skull of *Stegodon bombifrons* are described by Nanda and Corvinus (1992) and Nanda and Corvinus (2000) respectively. The presence of *Equus* and *Bos*, as reported by Corvinus (2006, p.66), indicates the presence of the Pinjor Fauna. Corvinus (2006) reported *Stegotetrabelodon* and this genus is not known from the Siwalik Group of India and Pakistan. As other details, such as photograph, sketch and description, are lacking, it is not possible to comment about the occurrence of this genus.

Table 4: Distribution of various Mammalian genera or species in the Upper Siwalik exposed at the foothills of Nepal (modified after West and Munthe, 1981, 1983; West *et al*., 1988 Corvinus and Nanda, 1994; West, 1996; Nanda, 1997; Corvinus and Rimal, 2001; Corvinus, 2006).

FAMILY	GENERA/ SPECIES	FAUNA	
		TATROT	PINJOR
ELEPHANTIDAE	*Elephas planifrons*	X	X
	Stegodon bombifrons	X	-
	Stegodon insignis	X	X
EQUIDAE	*Equus sivalensis*	-	X
SUIDAE	*Hippohyus tatroti*	X	-
	Potamochoerus cf.		
	P. theobaldi	-	X
ANTHRACO-THERIDAE	*Merycopotamus dissimilis*	X	-
HIPPOPOTAMIDAE	*Hexaprotodon sivalensis*	X	X
CERVIDAE	*Cervus* sp.	-	X
GIRAFFIDAE	*Giraffa punjabiensis*	X	-
BOVIDAE	*Proamphibos* cf.	X	-
	P. lachrymans		
	Hemibos sp.	?	-
	Bovinae gen. indet.	X	X

A composite list of Upper Siwalik faunas of Gidhniya, Surai Khola and Rato Khola is provided in Table 4.

Fauna of Kathmandu Valley

The intermonte deposits of the Kathmandu Valley are referred to as the Lokhundol Formation and have yielded rich Pinjor Fauna (Table 5). West and Munthe (1981, 1983), West *et al.* (1988), Nanda and Corvinus (1992), Corvinus and Nanda (1994), West (1996) and Nanda (1997) discussed the fauna. Occurrences of *Elephas hysudricus*, *Potamochoerus palaeindicus*, *Potamochoerus* cf. *P. theobaldi*, *Cervus* sp. and *Bos/ Bubalus* indicate the presence of Pinjor Fauna. West *et al.* (1988) reported *Bos namadicus* from the Bhadrabas locality. *B. namadicus* is widely known from the Middle and Upper Pleistocene post-Siwalik deposits of Indo-Gangetic Plain and Peninsular India and unknown from the Pinjor Formation (Pilgrim, 1939, p.7; Nanda, 2008, table 2). Its presence in Nepal also indicates post- Siwalik age for the exposures at Bhadrabas.

Table 5: Distribution of various mammalian genera or species in the Lukhundol Formation of Kathmandu valley, Nepal (after West and Munthe, 1981, 1983; West *et al*., 1988; Corvinus and Nanda, 1994; Nanda, 1997).

ELEPHANTIDAE:	*Elephas planifrons*, *E.hysudricus*, *Stegodon insignis*
SUIDAE:	*Potamochoerus palaeindicus*, *Potamochoerus* cf. *P. theobaldi*
HIPPOPOTAMIDAE:	*Hexaprotodon sivalensis*
CERVIDAE:	*Cervus* sp.
BOVIDAE:	*Bos / Bubalus*

Comments on THE Biostratigraphic Interval–Zones AND FAUNAS

As mentioned in the beginning of the paper, Barry *et al.* (1982) combined vertebrate palaeontologic and magnetostratigraphic studies and proposed four biostratigraphic interval- zones for the Middle, and lower part of the Upper Siwalik subgroups. Subsequently, Hussain ***et al.*** (1992), based on their work in Mangla-Samwal (Mirpur district, Pakistan), Nanda (2002) in Chandigarh region and Dennell *et al.* (2006) in Pabbi Hills, Pakistan modified or recognized the biostratigraphic zones for the Upper Siwalik Subgroup. All the zones are tabulated in Table 6. *E. planifrons* Interval-Zone/ Range-Zone was recognized by Barry *et al*. (1982), Hussain *et al*. (1992) and Nanda (1997, 2002). There is variation in the lower limit of *E. planifrons* (Table 6). The first appearance of *E. planifrons* is dated 3.6 Ma in Jammu region by Agarwal *et al.* (1993), whereas Barry *et al.* (1982) and Hussain *et al.* (1992) recorded this at 2.9 Ma and 3.35 Ma respectively. The Pinjor Fauna is very well developed in Indian Siwalik and the youngest appearance is dated 0.6 Ma (Ranga Rao *et al*., 1988).

In Pakistan, abundant magnetostratigraphic data are available and workers were able to demarcate various fossil occurrences very precisely. For example, Dennell *et al*. (2006) were able to demarcate two zones between the periods of 2-7-0.9 Ma, whereas Nanda (2002) demarcated only one zone in the time span of 2.6-0.6 Ma. Despite abundant magneto-stratigraphic data and *in situ* collection, there are certain limitations in Pakistan data. First, there is an unconformity of about two million years in the lower part of the Upper Siwalik of Tatrot – Andar Kas Section of Hasnot Composite Section. Thus, complete section of the Tatrot Formation of Upper Siwalik Subgroup is not exposed at the type locality. Secondly, Pinjor Fauna is scanty as compared to the Siwalik Hills of Chandigarh. In Indian Siwalik, rich Pinjor Fauna is well known, but magnetostratigraphic data is scanty. According to Dennell *et al.* (2006), the portion of the Upper Siwalik of Pabbi Hills between 2.2-0.9 Ma encompasses the 'Pinjor Faunal Stage'. They found that between 2.2- 1.7 Ma and 1.4 –1.2 Ma, fauna was very rich and they were able to divide the *Elephas hysudricus* Range – Zone of Hussain *et al*. (1992) into two faunal – zones. They considered the local extinction of *Sivatherium giganteum* at shortly after 1.7 Ma and completely extinct by 1.4 Ma. They were aware that Ranga Rao *et al*. (1995) reported this taxon at Brunhes (<0.78Ma). However, they

Table 6: Range of various Siwalik biostratigraphic zones, based on magnetostratigraphy, as proposed by different workers.

Barry ***et al.*** (1982)	Hussain ***et al.*** (1992)	Nanda (1997)	Nanda (2002)	Dennell ***et al***. (2006)
	Elephas hysudricus Range-Zone (2.7- ? Ma)	*Elephas hysudricus* Interval-Zone (2.7- 0.6 Ma)	*Equus sivalensis* Interval- Zone (2.6 - 0.6 Ma)	*Elephas hysudricus – Crocuta-Ursus – Panthera* faunal-zone (1.7 – 0.9 Ma) *Elephas hysudricus – Sivatherium* faunal-zone (2.7 – 1.7 Ma)
Elephas planifrons Interval-Zone (2.9 - 1.5 Ma)	*Elephas planifrons* Range- Zone (3.4 - 2.7 Ma)	*Elephas planifrons* Interval-Zone (3.6 - 2.7 Ma)	*Elephas planifrons* Interval-Zone (3.6 - 2.6 Ma)	
Hexaprotodon sivalensis Interval -Zone (5. 3 - 2.9 Ma) *Selenoportax lydekkeri* Interval-Zone (7.4 - 5.3 Ma) *"Hipparion* s.l." Interval-Zone (9.5 - 7.4 Ma)				

prefer to put the upper limit of *E. hysudricus – Sivatherium* faunal-zones to 1.7 Ma. The range of their *E. hysudricus-Crocuta-Ursus-Panthera* faunal-zone is from 1.7 to 0.9 Ma. They have considered that in between 1.4- 1.2 Ma, along with *Sivatherium giganteum, Canis cautleyi, Hyaenictis* or *Lycyaena,* anthracotheres, hippopotamids and possibly *Stegodon* became locally extinct (Dennell *et al.*, 2006, p. 180). *Stegodon* is very abundant in the Siwalik and occurs throughout the Pinjor interval and even known from the Middle and Upper Pleistocene faunas of Peninsular India and Indo-Gangetic Plain. The exact time limits of *C. cautleyi*, *Hyaenictis/ Lycyciena* are not known, as limited magnetostratigraphic data is available for the Upper Siwalik succession of India. However, *Camelus* is well known in Indian Siwalik, but not known from Pakistan Siwalik. A very rich Pinjor Fauna is known and about 54 marker taxa are collected in last five decades (Table 3) and this shows the prominence of the Pinjor taxa in Siwalik Hills in comparison to corresponding localities in Pakistan. However, Dennell *et al.* (2006) have new finding of *Crocuta, Ursus, Panthera uncia* and these are unknown from the Indian Siwalik.

CONCLUSIONS

The Tatrot and Pinjor faunas are well developed in the Siwalik belt of Pakistan, India and Nepal. These faunas are now well known from the Chandigarh and Jammu regions of the Indian Siwalik. About 30 and 54 Tatrot and Pinjor marker taxa respectively are collected in the last five decades from the area lying in the vicinity of Chandigarh. From the type locality of the Tatrot Formation, Potwar Plateau, rich mammalian assemblage is well known. Based on magnetostratigraphic data, an unconformity of two million years is marked at the type locality of the Tatrot Formation. The Pinjor Fauna is now well known from the Mangla-Samwal area and Pabbi Hills of Pakistan. However, the fauna is scanty in comparison to the fauna at the type locality of the Pinjor Formation. Excellent magnetostratigraphic data are available in Pakistan. For better resolution, workers clubbed the mammalian fauna with magnetostratigraphy and were able to distinguish biostratigraphic interval-zones/range-zones/faunal-zones (Table 6). In India, scanty magnetostratigraphic data are available and two biostratigraphic interval–zones, *Elephas planifrons* Interval-zone (3.6-2.6 Ma) and *Equus sivalensis* Interval –Zone (2.6-0.6 Ma), are recognized. However, precise zonation, as given for Pakistan Siwalik, is lacking for Indian Siwalik. The Tatrot and Pinjor faunas are now known from Nepal Siwalik, but faunas are scanty in comparison to India and Pakistan. It is not possible to demarcate the biostratigraphic zones in Nepal as faunas are restricted to a few taxa. Moreover, recovered mammalian taxa do not tally with magnetostratigraphic dates.

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