Elephas cf. E. planifrons (Elephantidae, Mammalia) from Upper Siwalik Subgroup of Samba district, Jammu and Kashmir, India (Postprint)

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Date: 2017-08-10T00:00:00+00:00

Abstract

A left M3 fossil of Elephas cf. E. planifrons is reported and described. The new material was recovered from the mudstone horizon underlying the volcanic ash bed exposed near Nangal village, which is an extension of the volcanic ash layer dated to 2.48 Ma and exposed at Barakhetar in the Nagrota Formation of the Upper Siwalik Subgroup in Samba district, Jammu and Kashmir. Based on crown morphological parameters including plate number, molar length and width, crown length, width and height, enamel and dentine thickness, plate length and width, lamellar frequency, hypsodonty index, and cement thickness, it is tentatively assigned to Elephas cf. E. planifrons. The discovery of this new material extends the upper limit of the range zone of this species from 2.6 Ma to 2.48 Ma.

Full Text

Preamble

Vertebrata PalAsiatica, Vol. 55, No. 1, Jan. 2017, pp. 59-70, figs. 1-3

Elephas cf. E. planifrons (Elephantidae, Mammalia) from Upper Siwalik Subgroup of Samba district, Jammu and Kashmir, India

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Abstract
One specimen of *Elephas* cf. *E. planifrons* is reported and described here in the

present paper. The specimen was recovered from the mudstone horizon underlying the volcanic ash bed exposed near the Nangal village, which is the extension of geochronologically dated (2.48 Ma) volcanic ash beds exposed at Barakhetar in the Nagrota Formation of Upper Siwalik Subgroup of Samba district, Jammu and Kashmir, India. Based on the crown morphological parameters (plate numbers, molars length and width, crown length, width and height, enamel thickness, dentine thickness, length and width of plates, lamellar frequency, hypsodonty index and cement thickness), the specimen has been identified and is tentatively referred to *Elephas* cf. *E. planifrons* (LM3). The recovery of this specimen is of great significance as it extends its upper limit of range zone from 3.6–2.6 to 3.6–2.48 Ma.

Key words
Jammu, India; Nagrota Formation, Upper Siwalik Subgroup; *Elephas*

Citation
Kundal SN, Bhadur G, Kumar S, 2017. *Elephas* cf. *E. planifrons* (Elephantidae, Mammalia) from Upper Siwalik Subgroup of Samba district, Jammu and Kashmir, India. *Vertebrata PalAsiatica*, 55(1): 59–70

1 History of Research

Various authors have carried out work on elephant origin, evolution, palaeoecology, taxonomy, distribution, classification, anatomy, ecology, behaviour, phylogenetic analysis, and fossil elephantid lineages (Aguirre, 1969; Maglio, 1973; Sarwar, 1977; Tassy, 1983; Shoshani and Tassy, 1996, 2005; Wei et al., 2006; Gheerbrant and Tassy, 2009; Todd, 2010a,b) from different parts of the world.

In the Indian subcontinent, the genus *Elephas* is represented by four species (*E. planifrons*, *E. hysudricus*, *E. namadicus*, and *E. maximus*). Among these, the first three (*E. planifrons*, *E. hysudricus*, *E. namadicus*) are completely extinct from the Indian subcontinent, while the last one (*E. maximus*) survives to date. Detailed studies on geology, palaeontology, phylogeny, and age of the elephantoid fauna (*Steglophodon nathotenis*, *Steglophodon latidens*, *Steglophodon cautleyi*, *Stegodon clifti*, *Stegodon bombifrons*, *Stegodon pinjorensis*, *Archidiskodon planifrons*, *Elephas hysudricus*, *E. maximus*, *E. hysudrindicus*, *E. planifrons*, *Palaeoloxodon namadicus*) from the Siwalik of India, Pakistan, and Burma have been carried out by various authors (Osborn, 1942; Sahni and Khan, 1959; Chakravarti, 1965; Opdyke et al., 1979; Azzaroli and Nepoleone, 1981; Badam and Kumar, 1982; Tripathi and Basu, 1983; Nanda et al., 1991; Samiullah et al., 2014).

In the Siwalik Province of Jammu, Jammu & Kashmir State, India, no detailed work on Elephantidae fauna was carried out except by a few workers (Wadia, 1925; Ganjoo, 1985; Nanda, 1994; Kundal and Kundal, 2011; Sankhyan and Sharma, 2014). Wadia (1925) first recovered a tusk (about 3.43 m) of *Stegodon ganesa* from near the Jagti village of Nagrota Formation of Upper Siwalik Subgroup of Jammu. Ganjoo (1985) recovered dental remains of *Stegolophodon* sp.,

Stegodon insignis, *Stegodon ganesa*, and *Elephas* sp. from the Pleistocene deposits of Khanpur Formation (Pinjor Formation) and Tawi Formation (Boulder Formation) of Upper Siwalik Subgroup of Jammu region. Nanda (1994) commented on certain faunal discrepancies on Upper Siwalik mammalian faunas from Chandigarh and Jammu area.

A lot of specimens of proboscideans were collected by the Geological Survey of India from the Siwalik of Jammu and other parts of Siwalik of India, and these specimens have been published in the Catalogue series no. 5 in the year 2002. Basu (2004) discussed an appraisal of diversity and habitats of Siwalik mammals of the Jammu Sub-Himalaya. Recently, Kundal and Kundal (2011) recovered an upper right third molar (M3) of *Elephas maximus indicus* from the post-Siwalik deposits of Jammu Province near Kharian village, Jammu and Kashmir, India. A few workers (Prasad et al., 2005; Bhat et al., 2008; Bhandari and Kundal, 2008; Kundal and Prasad, 2011; Kundal et al., 2011; Kundal, 2012, 2013, 2015) carried out detailed studies on fossils recovered from mudstone horizons associated with geochronologically dated volcanic ash occurring in Upper Siwalik of Jammu and its depositional environment. In the present study, the systematics and biochronology of *Elephas* cf. *E. planifrons* recovered from the Nangal village of Nagrota Formation, Upper Siwalik Subgroup of Samba district of Jammu and Kashmir have been carried out. The area in this study is given in Fig. 1A

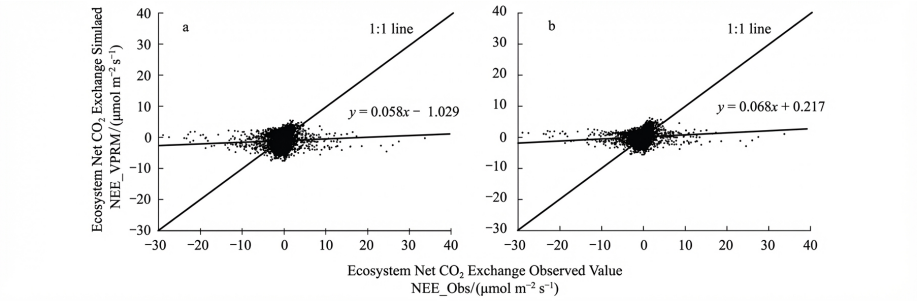

Figure 1: Figure 1

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Geological, palaeontological, and palaeomagnetic studies of type sections of Siwalik in the Indian subcontinent have been carried out from time to time by various workers (Colbert, 1935; Lewis, 1937; Wadia, 1957; Keller et al., 1977; Opdyke et al., 1979, 1982; Johnson et al., 1982, 1985; Barry et al., 1982, 2002, 2013; Barry and Flynn, 1990; Flynn et al., 1995, 2013; Badgley et al., 2005, 2008; Patnaik, 2013) and revealed that the boundaries are time-transgressive between most Formations of the Siwalik Group and that temporal mammal ranges are not usually fixed within the time limits of these Formations. A generalized stratigraphic framework of Siwalik in the Indian Subcontinent is given in Fig.

1D.

The local classifications of Upper Siwalik Subgroup of Jammu-Samba district of Jammu Province based on palaeontology, magnetostratigraphy, and radiometric date of ash beds were given by Ranga Rao et al. (1988), Agarwal et al. (1993), and Gupta (2000). A comparative lithostratigraphic classification of Siwalik Group of Jammu Province in Jammu and Kashmir is given in Fig. 1E. In Pinjor/Nagrota Formation, a volcanic ash bed occurs near Barakhetar and Nagrota villages which have been geochronologically dated to 2.48 Ma. These ash beds straddle across the Gauss-Matuyama boundary in the Siwalik of Jammu-Samba district. The specimen described in the present study was discovered from the mudstone horizon immediately underlying the geochronologically dated 2.48 Ma volcanic ash bed at Nangal village, which is the extension of the Barakhetar ash bed, and is now preserved in the vertebrate palaeontology laboratory, Geology Department of Jammu University, under catalog number JU/GD/VPL/9001.

2 Systematic Palaeontology

Class Mammalia Illiger, 1811
Order Proboscidea Gray, 1821
Family Elephantidae Gray, 1821
Genus *Elephas* Linnaeus, 1735
Elephas* cf. *E. planifrons Falconer & Cautley, 1845 (Fig. 2A

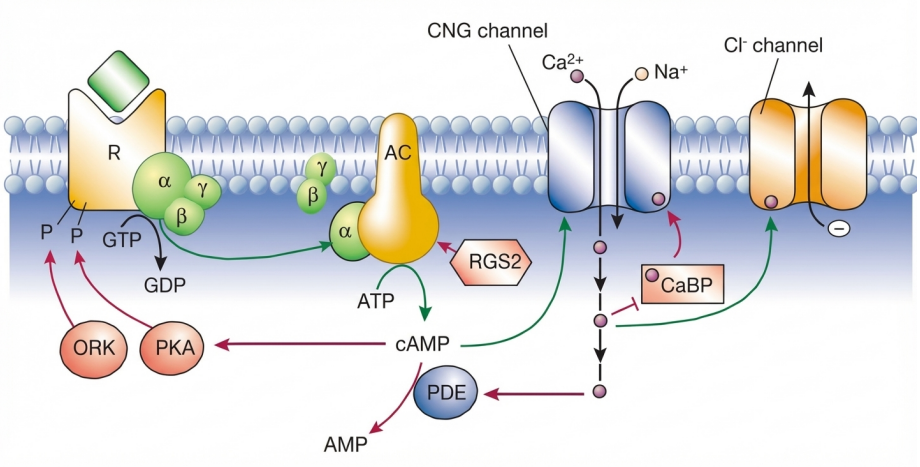

Figure 2: Figure 2

-C)

Referred material
JU/GD/VPL/9001, left M3 with broken roots and broken anterior two plates.

Locality

River cutting section 15 km northwest of Samba city near the village Nangal, J&K, India.

Stratigraphic horizon
Mudstone horizon underlying volcanic ash bed in Nagrota Formation (Ranga Rao et al., 1988)/Uttarbaini Formation (Gupta and Verma, 1988)/Pinjor Formation (Pilgrim, 1934).

Age
Late Pliocene–Early Pleistocene.

Measurements (in mm)
Number of plates: 9 (2½ broken out + 6½ preserved); length of molar: 140+50 (broken anterior two plates); width of molar: 82; length/width ratio: 1.70; number of plates preserved: 6½ (4½ worn + 2 unworn); average length of plates (occlusal): 72; average width of plates (occlusal): 17.16; lamellar frequency (lf): 6; average enamel thickness (et) of worn plates: 3.5; average cement thickness (ct) between plates: 10; average dentine thickness (dt) of worn plates: 4.64; crown length: 140; crown width: 92; maximum crown height: 80; hypsodont index (H/W$\times$$100): 87.

Description
JU/GD/VPL/9001 has well-preserved plates with broken roots. The anterior two and a half plates of the molar are broken out. The shape of the molar tapers at the posterior end (ovate); molar curvature is straight; inclination of plates to occlusal surface is weak; molar roots are strong and broken; enamel height above the cement is high; enamel figures are parallel-sided with median loop, lateral sides of enamel are rounded and turn slightly anteriorly; the enamel is symmetrical in line with the long axis of the molar; medial edges of enamel of two middle plates are in contact, undulating folded; amplitudes of enamel folding in few plates are high to low; and space between enamel folds in few plates are tight to loose. The plates are well compacted with cement and are widely spaced. The plates are slightly slanting towards the posterior side. The specimen has four and a half worn plates and two unworn plates. The width of the molar increased from posterior to centre and then decreased slightly towards the anterior side. Except for the four and a half worn plates, three plates have developed strong expansion of loops at the middle which are in connection with the adjacent ones. The enamel layer is quite simple and thick.

3 Comparative Study of Specimen JU/GD/VPL/9001 with Allied Species of *Elephas*

Using dental morphological characters (number of plates, length of molar, height and width of crown, lamellar frequency, enamel thickness, and hypsodonty index), the specimen JU/GD/VPL/9001 under study is compared with allied species of *Elephas* (*E. namadicus*, *E. hysudricus*, *E. hysudrindicus*, *E. maximus*, *E. naumani*, and *E. planifrons*) described earlier (Maglio, 1973). The details of parameters described are given in Table 1 .

Elephas namadicus differs from JU/GD/VPL/9001 in number of plates (12–16), length of molar (223–317), width of crown (61–101), height of crown (137–218), enamel thickness (1.8–3.0), and hypsodonty index (135.6–298). The parallel lophs and absence of median expansion are very characteristic of *E. namadicus*, which differentiate it from JU/GD/VPL/9001.

Elephas hysudricus differs from JU/GD/VPL/9001 in number of plates (12–15), length of molar (235–302), width of molar (93–107), height of crown (108–137), lamellar frequency (3.9–6.5), and hypsodonty index (112.5–147.2). Lack of median expansion and strong plication of lophs is characteristic of *E. hysudricus*, which differentiates it from JU/GD/VPL/9001 (Ganjoo, 1992).

Elephas hysudrindicus differs from JU/GD/VPL/9001 in number of plates (18–21), molar length (293.2–316.6), crown width (72.3–82.5), crown height (128.4–149.3), lamellar frequency (6.5), enamel thickness (2.6–2.7), and hypsodonty index (177.5–182.3). *E. hysudrindicus* is the most advanced member of the *Palaeoloxodon namadicus* group.

Elephas maximus differs from JU/GD/VPL/9001 in number of plates (22–27), molar length (244–282), crown width (80–98), crown height (187–214), lamellar frequency (5–9), enamel thickness (2.5–3.0), and hypsodonty index (150–250). JU/GD/VPL/9001 has anterior and posterior columns along the median line (lenticular) which are absent in *E. maximus*. *E. maximus* has narrow folding enamel structure, whereas JU/GD/VPL/9001 has thick folded enamel structures.

The molar characters of *Elephas naumani* such as range of hypsodonty index (230–320), enamel thickness (2.0–3.2), lamellar frequency (6–7), height of crown (195–251), width of crown (81–95), length of molar (211–278), and number of plates (17–19) are different from those of JU/GD/VPL/9001, which has hypsodonty index of 87, enamel thickness of 3.5, lamellar frequency of 6, crown height of 80, crown width of 92, molar length of 190, and number of plates of 9.

The JU/GD/VPL/9001 specimen under study is broad and brachydont with expanded strong anterior and posterior columns along the median line (lenticular), which are characteristic features of *Elephas planifrons* (Osborn, 1942). The average enamel thickness of the molar is 3.5 mm, which precisely equals that of *E. planifrons* at the Indian Museum, Calcutta. The lamellar frequency of *E. planifrons* given by different authors is: Osborn (1942): up to 6; Hooijer (1955): up to 5; Maglio (1973): 2.6–5.5.

The lamellar frequency of the molar under study is 6. This specimen is also compared with *Elephas planifrons* collected by Gupta (1981–1982) field session from the Marikhui Member of Uttarbaini Formation, which was published in GSI Catalogue No. 5 (pictorial catalogue of Siwalik vertebrate fossils from NW Himalaya in the year 2002, pp. 130, figure 1). JU/GD/VPL/9001 is compared with the most primitive specimen (M3) of *E. planifrons* (number 19965, American Museum) collected by Barnum Brown from Upper Pliocene Pinjor horizon of the Siwalik near Siswan, India. The specimen resembles JU/GD/VPL/9001

in outline as well as dental characters such as plate numbers, enamel thickness, molar length, etc. JU/GD/VPL/9001 is also compared with specimen No. WIF/A 423 (Nanda et al., 1991) which favors *E. planifrons*.

Based on the above comparative studies of parameters such as plate number, lamellar frequency, hypsodonty index, straight molar curvature, greatest height of crown at posterior end, molar shape tapered at posterior end (ovate), thick cement on the sides and valleys, enamel highly crenulated, molar roots strong and broken, high enamel height above the cement, parallel-sided with median loops expansion, rounded lateral sides of enamel and symmetrical in line with long axis of molar, JU/GD/VPL/9001 shows close affinity to *Elephas planifrons* and is tentatively referable as *Elephas* cf. *E. planifrons*.

4 Biozones/Faunal Interval Zones

Various biostratigraphic interval zones of Siwalik Group of Pakistan have been recognized based on fauna, lithology, and magnetostratigraphy by a number of workers (Pilgrim, 1913; Barry et al., 1982; Azzaroli, 1985; Hussain et al., 1992). In India, Verma (1988) recognized two biozones based on his work in the Markanda valley of Himachal Pradesh. These biozones are *Equus sivalensis–Elephas hysudricus* (EE) Biozone and *Stegodon insignis–Hipparion theoboldi–Hexaprotodon sivalensis* (SHH) Biozone.

The SHH biozone evidently corresponds to the *Hexaprotodon sivalensis* Interval Zone of Potwar Plateau (Pakistan) ranging from 5.3–2.9 Ma B.P. (Barry et al., 1982), and the EE biozone corresponds to the *Elephas planifrons* Interval Zone ranging from 2.9–1.5 Ma B.P. and Pinjor Faunal Zone of the type area, respectively. The SHH biozone is restricted to the Saketi Formation and exhibits a high frequency of aquatic forms in Himachal Pradesh, and the EE biozone is characterized by the presence of *Equus*, absence of *Hipparion*, presence of some aquatic forms, and terminates at the end of Pinjor Formation.

The range of *Elephas planifrons* Interval Zone was modified by Hussain et al. (1992) from 2.9–1.5 to 3.4–2.7 Ma and also recognized a fifth zone known as *Elephas hysudricus* Range Zone (2.7–? Ma). Later, the upper limit of the *E. hysudricus* Range Zone was proposed by Nanda (1997) up to 0.6 Ma based on fossils available in the Indian Siwalik. The lower limit of *E. planifrons* Interval Zone was modified by Agarwal et al. (1993) and extended up to 3.6 Ma based on dated *E. planifrons*. Nanda (1997) recognized two biostratigraphic interval zones of the Upper Siwalik Subgroup with their lower and upper limits as: 1) *E. hysudricus* Range Zone (contains most of taxa of Pinjor fauna), 2.6–0.6 Ma; 2) *E. planifrons* Interval Zone (contains most of taxa of Tatrot fauna), 3.6–2.6 Ma.

Based on the presence of fauna in the Pabbi Hills of Upper Siwalik of Pakistan, Dannell et al. (2006) divided the *Elephas hysudricus* Range Zone of Hussain et al. (1992) into *Elephas hysudricus–Crocuta–Ursus–Panthera* faunal zone, 1.7–0.9 Ma, and *Elephas hysudricus–Sivatherium* faunal zone, 2.7–1.7 Ma.

As the *Elephas* cf. *E. planifrons* in the present study has been recovered from the mudstone horizon underlying geochronologically dated (2.48 Ma) volcanic ash beds (Ranga Rao et al., 1988), the upper limit of the range zone of *Elephas planifrons* may be extended from 2.6 Ma (Nanda, 1997) to 2.48 Ma (proposed). The biostratigraphic interval and range zones of the elephant fauna by various authors and the proposed range zone of *Elephas planifrons* are given in Fig. 3 [FIGURE:3].

5 Conclusion

The recovery of *Elephas* cf. *E. planifrons* specimen from the mudstone underlying geochronologically dated (2.48 Ma) volcanic ash bed indicates that the age of the specimen is not younger than the volcanic ash beds exposed in the Upper Siwalik Subgroup of Samba districts. The upper limit of the *Elephas* cf. *E. planifrons* Interval Zone is also extended from 2.6 Ma (Nanda, 1997) to 2.48 Ma (proposed) in the present study, as the specimen was recovered from underlying geochronologically dated ash bed.

Acknowledgements
The author is thankful to UGC, New Delhi, India for financial support under UGC-BSR project (No. 20-3(6)/2012 dated 30.3.2013) and SERB NO. SR/FTP/ES-71/2013 dated 24.6.2015. Thanks are also due to Liqun Shi, Executive Editor, *Vertebrata PalAsiatica* (IVPP), for closely reviewing the manuscript.

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