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EARLY EOCENE LAND MAMMALS FROM VASTAN LIGNITE MINE, DISTRICT SURAT (GUJARAT), WESTERN INDIA

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ABSTRACT

We report the discovery of an early Eocene (middle Ypresian, approximately 52 Ma) land mammal fauna from sediments associated with the lignite deposits of Vastan Mine, District Surat, Gujarat. The fauna represents the oldest known Cenozoic land mammals from India. As presently identified, the assemblage comprises a total of 12 species, all new, representing perissodactyls (4 species placed in a new family); proteutherians (2 species representing two families); apatotherians (one species); insectivores (2 species, one belonging to a new family); artiodactyls (one species representing a new genus); rodents and bats (one species each). This is a largely endemic fauna with some holarctic elements. A detailed study of the assemblage and its implications is in progress and is expected to provide significant insight into our understanding of mammalian dispersal and India's evolving biogeographic affinities in the context of India-Asia collision.

Key words: Eocene, land mammals, India-Asia collision

INTRODUCTION

The discovery of fossil vertebrates in the early Eocene lignite mines of Gujarat was made a few years ago (Samant and Bajpai, 2001; Bajpai and Thewissen, 2002). These finds included some mammal remains, including whales. Since then, concerted efforts have been made to recover land vertebrates, particularly mammals, from the early Eocene lignite mines of Gujarat. This paper reports the discovery of a diverse terrestrial mammal fauna from the Vastan Lignite mine (GIPCL), located about 3 km northeast of the village Nani Naroli, District Surat, in the western Indian state of Gujarat (fig. 1a). The collection, comprising perissodactyls, artiodactyls, proteutherians, apatotherians, insectivores, rodents and bats, was recovered from dark grey siltstones with abundant plant matter at a level about 2m above the second seam in the Vastan lignite mine (fig. 1a). The last two groups (rodents and bats) are not being discussed here and will be described separately. Associated fauna includes fish (e.g. Bajpai and Kapur, 2004), amphibians, lizards, snakes, crocodiles, turtles and birds, besides molluscs and foraminifera (unpublished data). The age of the land mammals is constrained by the age diagnostic early Eocene foraminifer *Nummulites burdigalensis* which occurs about 10 m above the mammal horizon. This foraminifer corresponds to the shallow benthic Zone SBZ 10, indicating a middle Ypresian age (ca. 52 Ma, Serra-Kiel *et al.,* 1998) for the mammal level.

In the Indian subcontinent, the only other land mammal fauna of definite early Eocene age is known from three intervals in the Ghazij Formation, Baluchistan, Pakistan. (Gingerich *et al.*, 1997, 1998, 2001). Much of the Ghazij fauna, however, is yet to be described.

The entire collection described in this paper is housed in the Vertebrate Paleontology Laboratory, Indian Institute of Technology, Roorkee.

SYSTEMATIC PALAEONTOLOGY

Order **Proteutheria** Romer, 1966

Family **Palaeoryctidae** Winge, 1917

Genus ***Anthraryctes*** n. gen.

Type and only species: *A. vastanensis* n. sp.

Derivation of name: Prefix *anthra-* refers to a Latin word for coal, since the specimen was found in a lignite mine; suffix *–ryctes* is common for this family of mammals.

Diagnosis: pre- and postprotocrista present; paracone and metacone closely placed (zalambdodont), but distinct; parastyle positioned far labially, cingulum present.

Age and Distribution: early Eocene of India.

Anthraryctes vastanensis n. sp.

(Pl. III, figs. 13-15)

Derivation of name: *vastanensis* refers to the type locality, the Vastan Lignite Mine.

Diagnosis: specific and generic diagnosis cannot be distinguished at present.

Holotype: IITR/SB/VLM 506 (isolated left M3).

Description: The holotype is 1.07mm long and 2.48mm wide. There are three large cusps. The protocone is broad and triangular in posterior view. The preprotocrista is high and extends labially to the small paraconule from which a

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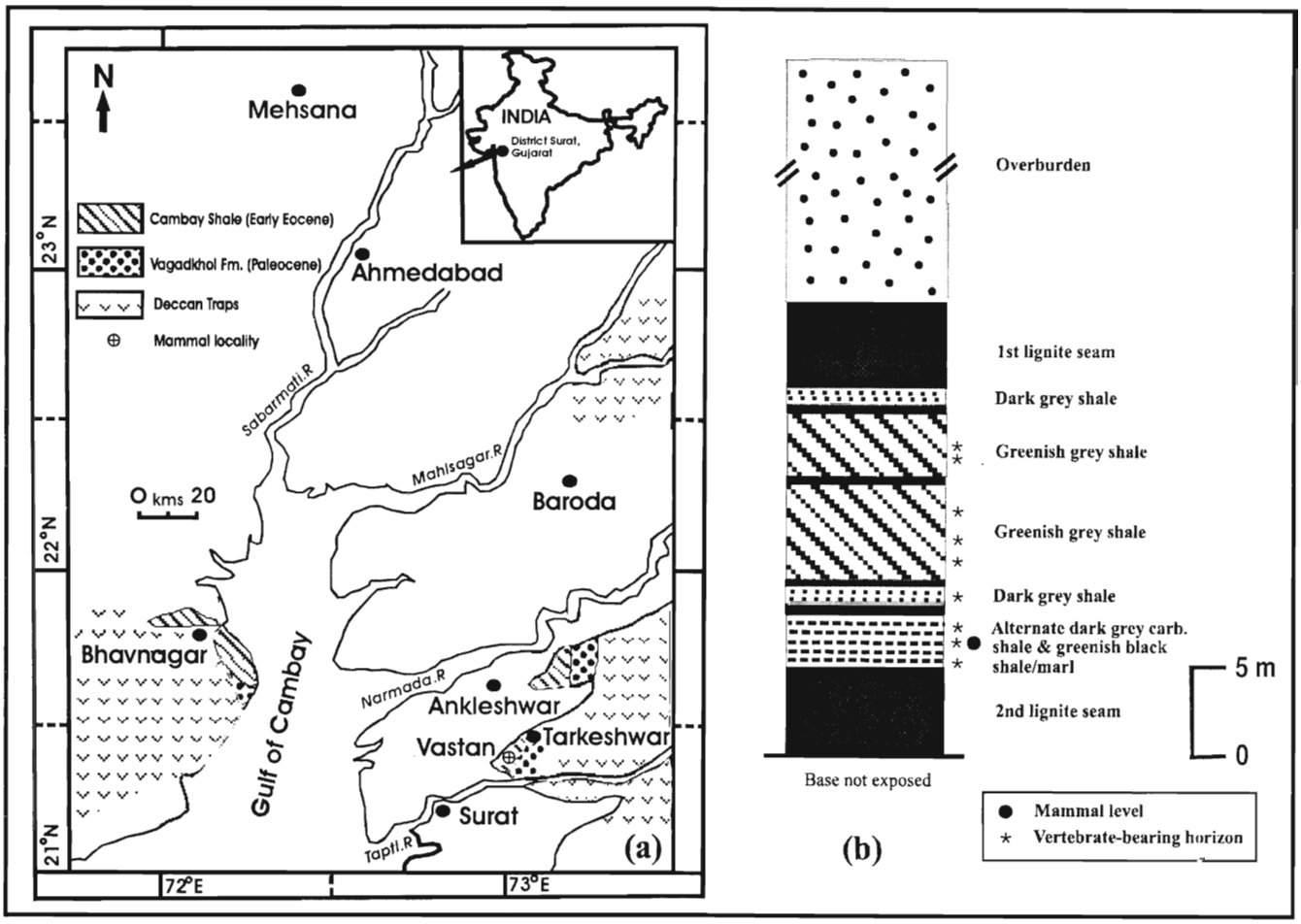


Fig. 1. Map and lithostratigraphic section of the mammal-yielding locality.

preparaconule crista continues into the anterolabial cingulum and a postparaconule crista to the tip of the paracone. The postprotocrista is lower than the preprotocrista and ends at the low metaconule. The metaconule is smaller than the paraconule. The labial cusps are high and narrow and the paracone is larger than the metacone. There is a very short and narrow cingulum on the anterior and posterior side of the tooth. The centrocrista is straight and the preparacrista extends labially and anteriorly. The parastyle is positioned far labially on the stylar shelf. It is less high, but as broad as the paracone. The cingulum posterior to the parastyle undulates.

Remarks: This is the first palaeoryctid to be described from the Eocene of India. Gingerich and Russell (1981) described *Pakilestes* from the Eocene of Pakistan, a species based on lower teeth only, and thus not comparable directly. However, it appears smaller than *Anthraryctes*. *Anthraryctes* is larger than *Pararyctes*, but similar in size to *Eoryctes* from western North America (Thewissen and Gingerich, 1989).

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

EXPLANATION OF PLATE I

(scale bar equals 1 cm in all cases)

1. ***Cambaytherium thewissi*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 505), lingual view.
2. ***Cambaytherium thewissi*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 505), labial view.
3. ***Cambaytherium thewissi*** n. gen. & sp., right dentary, cast of holotype (IITR/SB/VLM 505), occlusal view.
4. ***Cambaytherium bidens*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 503), labial view.
5. ***Cambaytherium bidens*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 503), lingual view.
6. ***Cambaytherium bidens*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 503), occlusal view.
7. ***Cambaytherium minor*** n. gen. & sp., left lower molar (IITR/SB/VLM 540), occlusal view.
8. ***Cambaytherium minor*** n. gen. & sp., left lower molar (IITR/SB/VLM 540), lingual view.

Plate I

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Family **Cimolestidae** Marsh 1889

Genus ***Suratilestes*** n. gen.

Type and only species: *S. gingerichi* n. sp.

Derivation of name: Named for Surat, the District in which the type locality is located. *Lestes* is a common suffix for insectivores with sharp-cutting teeth.

Diagnosis: Cimolestid with relatively long p4 and anteriorly placed paraconid on m1.

Remarks: The affinities of this species are best indicated by the large difference in height between trigonid and talonid combined with the simple, unmolarized p4. In these respects, *Suratilestes* is similar to *Didelphodus* (Bown and Schankler, 1982) and *Cimolestes* (Clemens, 1973).

Age and Distribution: early Eocene of India.

Suratilestes gingerichi n. sp.

(Pl. III, figs. 1-3)

Referred Material: IITR/SB/VLM 573 (p3).

Derivation of name: Named for Dr. Philip D. Gingerich in recognition of his contribution to the knowledge of Eocene mammals from Pakistan.

Diagnosis: Generic and specific diagnosis cannot be distinguished at present.

Holotype: IITR/SB/VLM 509 (left dentary with alveoli for p2-3, crowns for p4, m1, m2 trigonid, and m3).

Description: p4 (length 1.16 mm, width 0.60 mm) has a high protoconid, but lacks paraconid and metaconid. A sharp crest extends anteriorly from the protoconid and reaches the anterior cingulum, which is thickened in this area. Another sharp crest descends the posterior side of the protoconid, and a weak hypoconid occurs where this crest reaches the cingulum. The lower molars are similar in shape, with high sharp cusps on the trigonid, and a low talonid with weak cusps and a shallow basin. m1-m3 are, respectively, 1.33, 1.26 and 1.33mm long and 0.60, 0.86 and 0.93 mm wide. The trigonid basin opens lingually in all molars, but this opening decreases in width from m1 to m3. The protoconid is the highest cusp, followed by meta-, and paraconid. The talonid of m1 bears a single cusp, the hypoconid. The cristid obliqua touches the trigonid posterior to the protoconid. Another crests extends posteriorly from the hypoconid and surrounds the entire posterior and labial talonid basin. The talonid of m3 is similar to that of m1 except that it is smaller and the size of the hypoconid is disproportionately smaller.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10).

Order **Apatotheria** Scott and Jepsen, 1936

Family **Apatemyidae** Matthew, 1909

Genus ***Frugivastodon*** n. gen.

Type and only species: *P. cristatus* n. sp.

Derivation of name: *Frugi* refers to the similarity of this tooth with certain fruit-eating mammals, *vasto* refers to the type locality, and *don* is for tooth.

Diagnosis: Apatemyid lacking paraconid, and with low talonid cusps.

Remarks: The most characteristic feature of this species is the crescentic shape of the paracristid, which is strongly convex anteriorly and forms an expanded trigonid basin. This is similar to apatemyids such as *Labidolemur* (Gingerich and Rose, 1982) and *Apatemys* (Bown and Schankler, 1982). The paracristid ends without giving rise to a paraconid, unlike other apatemyids.

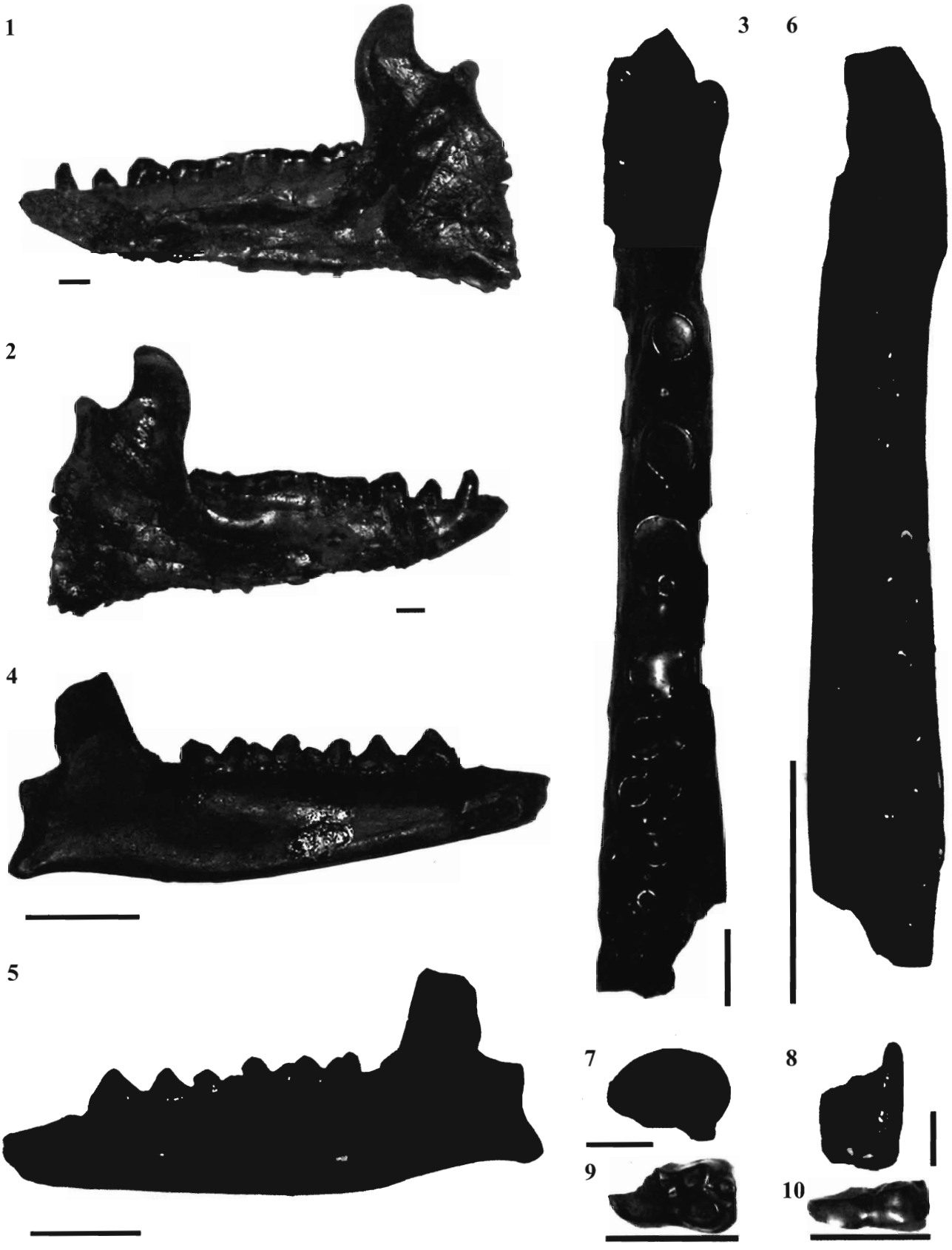
Age and Distribution: early Eocene of India.

EXPLANATION OF PLATE II

(scale bar equals 1 cm in all cases)

1. ***Cambaytherium bidens*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 503), lingual view.
2. ***Cambaytherium bidens*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 503), labial view.
3. ***Cambaytherium bidens*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 503), occlusal view.
4. ***Gujaratia indica*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 511), lingual view.
5. ***Gujaratia indica*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 511), labial view.
6. ***Gujaratia indica*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 511), occlusal view.
7. ***Cambaytherium*** sp. A, ?right P2 (IITR/SB/VLM 549), occlusal view.
8. ***Cambaytherium*** sp. A, ?right P2 (IITR/SB/VLM 549), lingual view.
9. ***Cambaytherium minor*** n. gen. & sp., right lower molar (mx), holotype (IITR/SB/VLM 539), occlusal view.
10. ***Cambaytherium minor*** n. gen. & sp., right lower molar (mx), holotype (IITR/SB/VLM 539), lingual view.

Plate II



Frugivastodon cristatus n. sp.

(P1. III, figs. 7-9)

Derivation of name: The specific name refers to the presence of sharp, but low crests on this tooth.

Diagnosis: specific and generic diagnosis cannot be distinguished at present.

Holotype: IITR/SB/VLM 507 (isolated left lower molar).

Description: The tooth is 1.92mm long and 1.03 mm wide. The base of the crown of IITR/SB/VLM 507 is high, and the cusps are relatively low elevations above this base. The trigonid is higher than the talonid, and nearly equal in occlusal area. The trigonid bears two cusps, the proto- and metaconid, the latter of which is smaller. The paracristid is low and extends anteriory from the protoconid, curving widely and reaching the anterior side of the metaconid without climbing it. Paracristid and metacristid are low, but sharp. The talonid is an expansive basin bordered by sharp low crests on all sides. The hypoconid is the largest cusp, followed by entoconid and hypoconulid. The cristid obliqua touches the trigonid on the lingual side of the protoconid.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Order **Insectivora** Cuvier 1817

Suborder **Erinaceomorpha** Gregory, 1910

Family **Vastanidae** n. fam.

Type and only genus: ***Vastania*** n. gen.

Diagnosis: Erinaceomorphs with high protoconid on p4 and straight and lingual cristid obliqua, lacking talonid basin.

Genus ***Vastania*** n. gen.

Type and only species: *V. sahnia* n. sp.

Derivation of name: Named for the Vastan Lignite Mine, where the specimen was discovered.

Diagnosis: m1 and m2 of similar size, low cuspate paraconid.

Remarks: Novacek *et al.* (1985) diagnosed Erinaceomorpha and the present genus matches their diagnosis well. However, it does not match the diagnoses of any of the families of erinaceomorphs described by these authors.

Age and Distribution: early Eocene of India.

Vastania sahnia n. sp.

(P1. III, figs. 4-6)

Derivation of name: The species is named after Dr. Ashok Sahni, in recognition of his contributions to Indian vertebrate palaeontology.

Diagnosis: specific and generic diagnosis cannot be distinguished at present.

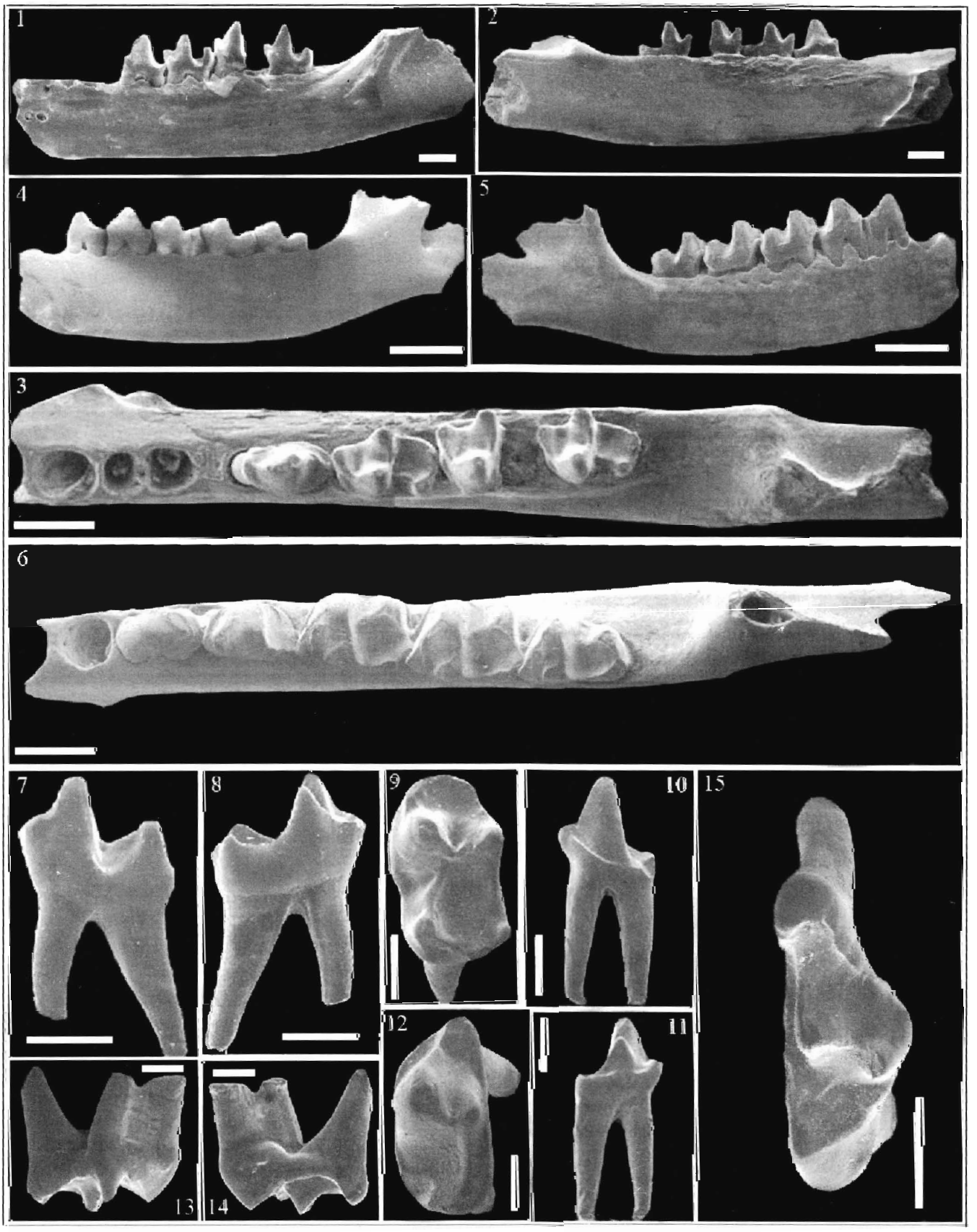
Holotype: IITR/SB/VLM 510 (right dentary with one alveolus for p2, and crowns for p3-m3).

Description: p3 is a two-rooted tooth with a single cusp: a protoconid that is triangular in labial view. The talonid is small and somewhat worn. p4 (length 1.0mm, width 0.61 mm) also bears a single cusp. The labial cingulum is broad, especially posteriorly giving the tooth an asymmetrical shape. The postprotocristid descends the protoconid on the posterolingual side of the tooth and reaches the cingulum. The lower molars are respectively 1.11, 1.27 and 1.33 mm long, and 0.66, 0.88 and 0.77 mm wide. The lower molars have a trigonid that is moderately higher than the talonid. The trigonid is progressively smaller from m1 to m3. Paraconid and metaconid are connected by weak crests to the protoconid. In m1-m3, all three cusps of the trigonid are similar in proportions,

EXPLANATION OF PLATE III

(scale bar equals 1 mm for figures 1-3, 6, 8; 2mm for 4, 5; 900μm for figures 7, 15; 800 μm for figures 10, 11; 700 μm for figures 9, 13, 14; 300 μm for figure 12)

1. ***Suratilestes gingerichi*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 509), labial view.
2. ***Suratilestes gingerichi*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 509), lingual view.
3. ***Suratilestes gingerichi*** n. gen. & sp., left dentary, holotype (IITR/SB/VLM 509), occlusal view.
4. ***Vastania sahnia*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 510), lingual view.
5. ***Vastania sahnia*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 510), labial view.
6. ***Vastania sahnia*** n. gen. & sp., right dentary, holotype (IITR/SB/VLM 510), occlusal view.
7. ***Frugivastodon cristatus*** n. gen. & sp., left lower molar (mx), holotype (IITR/SB/VLM 507), labial view.
8. ***Frugivastodon cristatus*** n. gen. & sp., left lower molar (mx), holotype (IITR/SB/VLM 507), lingual view.
9. ***Frugivastodon cristatus*** n. gen. & sp., left lower molar (mx), holotype (IITR/SB/VLM 507), occlusal view.
10. ***Cambaya complexus*** n. gen. & sp., left p4, holotype (IITR/SB/VLM 508), labial view.
11. ***Cambaya complexus*** n. gen. & sp., left p4, holotype (IITR/SB/VLM 508), lingual view.
12. ***Cambaya complexus*** n. gen. & sp., left p4, holotype (IITR/SB/VLM 508), occlusal view.
13. ***Anthraryctes vastanensis*** n. gen. & sp., left M3, holotype (IITR/SB/VLM 506), posterior view.
14. ***Anthraryctes vastanensis*** n. gen. & sp., left M3, holotype (IITR/SB/VLM 506), anterior view.
15. ***Anthraryctes vastanensis*** n. gen. & sp., left M3, holotype (IITR/SB/VLM 506), occlusal view.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and also the paraconid is smaller than the metaconid. The trigonid opens lingually as a narrow cleft between para- and metaconid. The talonid of m1 and m2 is similar in shape, with the hypoconid as the largest cusp. Entoconid and hypoconulid are similar in size and twinned in position near the postero-lingual corner of the tooth. The cristid obliqua is weakly developed and a pre-entocristid closes the talonid basin lingually. In m3 there are only two cusps on the talonid, the labial hypoconid and a posteriorly situated hypoconulid.

Remarks: *Vastania* has a simple p4, dominated by a single cusp, and with a talonid with a straight and labial cristid obliqua. In these features, it is similar to *Litocherus* (Novacek *et al.* 1985), and this may be a close relative.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Family **Nyctitheriidae** Simpson, 1928

Genus ***Cambaya*** n. gen.

Type and only species: *C. complexus* n. sp.

Derivation of name: Named for the Cambay Formation which yielded the specimen.

Diagnosis: Nyctitheriid with small paraconid and strong cingulum on p4. Protoconid height moderate.

Age and Distribution: early Eocene of India.

Cambaya complexus n. sp.

(P1.III, figs. 10-12)

Derivation of name: Specific indication refers to the molarized morphology of the p4.

Diagnosis: specific and generic diagnosis cannot be distinguished at present.

Holotype: IITR/SB/VLM 508 (isolated left p4).

Description: The holotype is 1.05 mm long and 0.51mm wide. The trigonid has a large protoconid and a smaller metaconid. The paraconid is distinct and located on the cingulum. Pre- and postprotoconid crista form a sharp triangle. The cingulum extends from the paraconid caudally on both lingual and labial side, and is continuous around the rest of the tooth. The talonid bears a single, low cusp that is located on the posterior cingulum. This cusp is connected by a straight crest to the posterior side of the metaconid. The talonid basin slopes labially from this crest and is wide open labially. A small piece of enamel is missing posterolabially.

Remarks: *Cambaya* is similar to *Bumbanius* from the Eocene of Mongolia (Russell and Dashzeveg, 1986) in the general arrangement of cusps on the trigonid, and the shape and position of cusps and crests on the talonid. The paraconid of *Bumbanius* is larger than that of *Cambaya*.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Order **Artiodactyla** Owen 1848

Family **Dichobunidae** Turner 1849

Genus ***Gujaratia*** n. gen.

Type species: *G. pakistanensis* Thewissen *et al.*, 1983.

Referred species: *G. indica* n. sp.

Derivation of name: The generic name refers to the State of Gujarat, in which the species is found.

Diagnosis: Dichobunid with symmetrical protocone lobe: there is no trace of a hypocone, a posteriorly expanded cingulum, or a posteriorly deviated metacrista. Paraconid present in at least the anterior molars.

Remarks: Thewissen *et al.* (1983) referred a new species of early artiodactyls from the Eocene of Pakistan to the genus *Diacodexis*, calling the species *D. pakistanensis*. *Diacodexis* is mainly known from North America, although material from Europe has also been referred to it. Most *Diacodexis* from North America and Europe has a posterior extension of the lingual side of the upper molars, in the area where the hypocone occurs in derived dichobunids. *G. pakistanensis* shows no such expansion. In addition, *G. pakistanensis* has a large paraconid on the first molar, a small paraconid on the second molar, and sometimes a paraconid on the last molar. In this regard it is similar to *G. indica*. We here propose a new genus name for these two Indo-Pakistani species of early dichobunids.

Age and Distribution: early Eocene of India and Pakistan.

Gujaratia indica n. sp.

(P1. II, figs. 4-6)

Derivation of name: *indica*, named for India.

Differential Diagnosis: larger than *G. pakistanensis*.

Holotype: IITR/SB/VLM 511 (left dentary with p3 – m3)

Description: The lower dental formula of IITR/SB/VLM 511 is ?.1.4.3. The posterior part of the alveolus for the canine is preserved as well as alveoli for the single rooted p1 and the double-rooted p2. A diastema occurs between c1 and p1. p3 and p4 are both double-rooted, they are triangular in labial view and bear a large protoconid. The posterior cingulum of p3 and p4 is expanded. Prominent crests descend from the protoconid anteriorly and posteriorly reaching the cingulum. A small hypoconid is present where the posterior crest reaches the cingulum.

The three lower molars have a trigonid that is higher but smaller than the talonid. The paraconid is present in all molars and is smaller than the metaconid. There are three cusps on the talonid. The hypoconid is the largest and highest of these, while the hypoconulid of m1 and m2 is a tiny cusp immediately labial to the entoconid. In m3 there is a third lobe with a large hypoconulid connected to the entoconid and hypoconid by strong crests. The talonid basin is lingually wide open.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, State of Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Order **Perissodactyla** Owen, 1848

Family **Cambaytheriidae** n. fam.

Type and only genus: *Cambaytherium* n. gen.

Diagnosis: perissodactyls with large bunodont teeth, lacking any even incipient loph development. Paraconule and metaconule prominent. Mandibular symphysis fused.

Remarks: Perissodactyls are characterized by lophodont teeth, although the early species (such as *Cardiolophus, Systemodon, Hyracotherium sandrae, Karagalax and Sastrilophus)* are relatively bunodont. However, all these early perissodactyls retain many of the crests originally present in a tribosphenic tooth. The new family is more bunodont than any of these described forms, even though the pattern of cusps on lower and upper molars is perissodactyl-like. Perissodactyl affinities are further suggested by the position of the conules anterior to the line connecting proto- and paracone as well as hypo- and metacone. In addition, the talonid of m3 is expanded, tapers posteriorly, and has accessory cusps on the third lobe.

Cambaytheres are similar to the phenacodontid condylarths *Phenacodus* and *Tetraclaenodon* (reviewed by Thewissen, 1990) in being bunodont and in overall shape of the upper and lower molars. Cambaytheres differ from these phenacodontids in the large size of the m3, with its characteristically shaped third lobe, and the fused mandibular symphysis. The p4 of cambaytheres is less molarized than that of phenacodontids, and there is sexual dimorphism. Unlike *Phenacodus*, cambaytheres lack a mesostyl.

Cambaytheres are also similar to quettacyonid condylarths, described from early Eocene sediments in Pakistan (Gingerich *et al.*, 1997, 1998). Quettacyonids have a short m3, which is smaller than the m2 and has a talonid with cusps that are in close proximity. Cambaytheres have a large m3, larger than m2 and with a significant third lobe.

Age and Distribution: early Eocene of India.

Genus ***Cambaytherium*** n. gen.

Type species: *Cambaytherium thewissi* n. sp.

Referred species: *C. bidens* n. sp., *C. minor* n. sp., *C.* sp. A.

Derivation of name: The generic name is a combination of the name of the formation in which the type specimen was found with *-therium*, a common suffix for perissodactyls.

Diagnosis: Familial and generic diagnoses cannot be distinguished at present.

Age and Distribution: early Eocene of India.

Cambaytherium bidens n. sp.

(Pl. II, figs, 1-3; Pl. III, figs. 3-5; Table 2)

Referred Material: IITR/SB/VLM 502 (left dentary with p1 – p3, m1, m3, right dentary with p3 – m3, right premaxilla with C1 – P1, left C, right P2 and P4, mandibular symphysis, maxilla fragment, nasals, atlas); IITR/SB/VLM 520 (m1 – m2); IITR/SB/VLM 521 (left mandibular fragment with m3 and Mx); IITR/SB/VLM 532 (left c1, m1 – m3, mandibular fragments); IITR/SB/VLM 535 (right proximal astragalus) IITR/SB/VLM 541 (left C1); IITR/SB/VLM 542 (left c1); IITR/SB/VLM 543 (p1); IITR/SB/VLM 544 (unworn left p4); IITR/SB/VLM 545 (unworn left p4); IITR/SB/VLM 546 (left mx); IITR/SB/VLM 547 (unworn left mx); IITR/SB/VLM 558 (unworn left p2 –p3 and three unicuspid teeth).

Derivation of name: The species name reflects the presence of two lower incisors.

Diagnosis: Large species of *Cambaytherium* with diastema between p1 and p2; two lower incisors.

Holotype: IITR/SB/VLM 503 (right dentary with c – m3, left dentary with p1 – m3).

Description: The lower dental formula is 2.1.4.3. The c1 is a single-rooted, circular on cross-section, and higher than the premolars. There is considerable difference in canine size between specimens with molars that are similar in size, a difference which we attribute to sexual dimorphism. IITR/SB/VLM 532 has a large canine, whereas this tooth is small in IITR/SB/VLM 503.

p1 is the smallest premolar, and is triangular in labial view. The protoconid is set on the anterior half of the tooth, and the posterior cingulum is larger than the anterior cingulum. The root of p1 is elongate and may be divided into two fused roots (IITR/SB/VLM 503), or it may be double-rooted (IITR/SB/VLM 503 and 542). p 2-4 are double-rooted teeth that form a high triangle in labial view, with a large protoconid and small hypoconid. p4 bears a metaconid postero-lingual to the protoconid (IITR/SB/VLM 544 and 545). A small paraconid is present in IITR/SB/VLM 545, but not in IITR/SB/VLM 544. There is a decrease in tooth size from p2 to p4 (Table 2).

The lower molars have a trigonid that is higher than the talonid. The trigonid bears a large protoconid and an even larger metaconid, but the paraconid is usually absent. The paracristid is weak, it descends from the protoconid and ascends the anterior face of the metaconid. A high metastylid is twinned with the metaconid. The trigonid is wider than the talonid. There are three cusps on the talonid of m1-2 (IITR/SB/VLM 557). The hypoconid and entoconid are similar in size, whereas the hypoconulid is smaller. The hypoconid is placed antero-labial to the entoconid. The hypocristid is barely present and the cristid oblique is a faint trace.

m3 is the largest molar, with a posteriorly tapering talonid and a prominent third lobe. The third lobe of m3 displays intraspecific variation. In all specimens, there are three cusps on the third lobe, antero-labial, postero-labial, and postero-lingual. In IITR/SB/VLM 503, the postero-labial cusp is larger than the postero-lingual cusp, whereas in IITR/SB/VLM 502, the postero-lingual cusp is larger.

Several upper canines are preserved, but these are heavily worn with little enamel remaining. The P1 is double rooted and oval in occlusal outline, it is broader than p1. P2 (IITR/SB/VLM 502) is two-rooted and triangular in lateral view, the postero-lingual cingulum flares lingually allowing identification as an upper premolar. P4 (IITR/SB/VLM 502) has three roots, and there are three main cusps: paracone, metacone and protocone. The paracone is larger than the metacone. The paraconule and metaconule are present but weak. The posterior cingulum is somewhat expanded.

IITR/SB/VLM 521 also includes a bunodont upper molar with similar and low four main cusps: paracone, metacone, protocone and hypocone. The paraconule and metaconule are smaller than the main cusps. The centrocrista is weak. The metastyle is not present. The paraconule lies anterior to the line joining paracone and protocone. The metaconule lies anterior to the line connecting metacone and hypocone. There is no mesostyle present.

Remarks: *C. bidens* is the best known species of *Cambaytherium*. In nearly all specimens, dental wear is extremely heavy, and on many teeth all occlusal surfaces are flat exposures of dentin. *C. bidens* is approximately 118% as large as the type species.

Gingerich *et al.* (1998) named *Sororoyctes ghaznavii* from the early Eocene of Pakistan with, as its holotype, one single-rooted heavily-worn tooth lacking all enamel, interpreted as a "canine or postcanine" found together with a variety of other material (other tooth fragments, humeral fragment) of which the association to the holotype was left in question. The identity of this specimen was not clear to the authors, and they left *Sororoyctes* as the type genus of a new family of an "order indet." This specimen resembles the canine of *G. bidens* (IITR/SB/VLM 502) in some respects, particularly its overall size and shape and its heavy wear. In both, the pulp cavity is exposed, and there is an anterior attritional facet in addition to an apical abrasional facet. However, the similarity ends here, and in specimens such as IITR/SB/VLM 541, in which the canines are more worn than in IITR/SB/VLM 502 and the enamel is lacking, there is neither an attritional facet nor the "spalled surface" described by Gingerich *et al.* (1998). It is unlikely that *Sororyctes* and *Cambaytherium* are synonyms.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Cambaytherium thewissi n. sp.

(Pl. I, figs. 1-3; Table 1)

Referred Material: IITR/SB/VLM 548 (left mx); IITR/SB/VLM 551 (right mx).

Derivation of name: Named for Dr. J. G. M. (Hans) Thewissen in recognition of his contribution to the knowledge of Eocene mammals from Indo-Pakistan. Species name is the dativus of the Latinized version of the last name.

Diagnosis: Medium-sized species of *Cambaytherium*, lacking diastema between p1 and p2; three lower incisors.

Holotype: IITR/SB/VLM 505 (left dentary with p4 – m3, right dentary with p4 – m3)

Description: Overall, the dental morphology of *C. thewissi* resembles that of *C. bidens* (see Table 1 for measurements). We here only discuss those features that are different or not known in *C. bidens*. The holotype shows that there are three alveoli for lower incisors, and that the lower dental formula is 3.1.4.3. There is no diastema between p1 and p2. The p4 and m1 are somewhat worn whereas m2-3 are nearly unworn. p1 is double-rooted, p4 lacks a paraconid, and the posterolabial cusp is the smallest cusp on the third lobe of m3.

Remarks: The single specimen known for this species is barely worn, unlike most specimens of *C. bidens*. Hence, morphology can be studied well on this species and we chose it as the type species for the genus.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10).

Cambaytherium minor n. sp.

(Pl. I, figs. 7, 8; Pl. II, figs. 9, 10; Table 1)

Referred Material: IITR/SB/VLM 540 (left mx with anterior trigonid missing).

Table 1: Measurements (in mm) of *Cambaytherium* dentition.

Dentition	Dimension	*Cambaytherium thewissi* n.sp.				*C. minor* n. sp.	*C.* sp. A
		IITR/SB/VLM-505 (Holotype) Right	IITR/SB/ VLM-505 (Holotype) Left	IITR/SB/ VLM-548	IITR/SB/VLM-551	IITR/SB/ VLM-539 (Holotype) Right	IITR/SB/ VLM-549 ? Right
P/4	Length	9.4	9.4				
	Width	7.4	7.4				
M/1	Length	11.3	11.0				
	Width	8.0	7.9				
M/2	Length	11.9	11.4				
	Width	8.6	8.6				
M/3	Length	14.2	13.5				
	Width	9.0					
P2/	Length						14.8
	Width						9.1
M/x	Length			12.2	12.4	10.5	
	Width			7.7	7.8	5.3	

Table 2: Measurements (in mm) of *Cambaytherium* dentition.

Dentition	Dimension	*Cambaytherium bidens* n.sp.												
		IITR/SB/VLM-503 (Holotype) Right	IITR/SB/VLM 503 (Holotype) Left	IITR/SB/VLM-502 Right	IITR/SB/VLM-502 Left	IITR/SB/VLM-520	IITR/SB/VLM-521	IITR/SB/VLM-532	IITR/SB/VLM-541	IITR/SB/VLM-542	IITR/SB/VLM-543	IITR/SB/VLM-544	IITR/SB/VLM-545	IITR/SB/VLM-558
C/1	Length	8.7						14.3		7.6				
	Width	8.0						11.7		7.0				
P/1	Length	9.5	9.0		7.7						7.5			
	Width	5.5	5.4		5.3						5.0			
P/2	Length	14.0	14.2		13.0									15.8
	Width	8.9	9.0		7.5									8.9
P/3	Length	12.6	13.0	12.7	13.0									12.4
	Width	8.9	9.3	8.0	7.0									8.4
P/4	Length	10.9	11.0	11.0								10.9	10.6	
	Width	9.2	8.9	8.2								7.9	7.5	
M/1	Length	10.8	13.0	12.0		11.4								
	Width	9.1	8.7	8.3		8.0								
M/2	Length	13.2	13.8	13.8		13.2		13.2						
	Width	9.7	10.0	9.6		7.9		10.0						
M/3	Length	17.2	17.5	16.0	16.4		15.8	16.5						
	Width	10.7	10.5	9.4	9.4		9.6	10.0						
C1/	Length			13.7	14.0				14.0					
	Width			9.6	9.6				9.0					
P1/	Length			10.1										
	Width			5.4										
P2/	Length			12.2										
	Width			8.9										
P4/	Length			12.8										
	Width			9.6										

Derivation of name: *minor* refers to the small size of this species.

Differential Diagnosis: smaller than other *Cambaytherium*, approximately 75% as large as *C. thewissi*.

Holotype: IITR/SB/VLM 539 (right mx with anterolabial part missing).

Description: The holotype is a moderately worn anterior lower molar. All topography has been worn off the trigonid, but the talonid displays three cusps. The entoconid is positioned somewhat posterior to the hypoconid, and the hypoconulid is the smallest cusp. Feeble crests connect hypoconid to the posterior side of the protoconid, the hypoconulid, and the entoconid.

Type Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Type Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

Cambaytherium sp. A

(Pl. II, figs. 7, 8; Table 1)

Differential Diagnosis: approximately 130% as large as *C. bidens*.

Material: IITR/SB/VLM 549 (presumed right P2).

Remarks: This tooth pertains to a new, large species of *Cambaytherium*, and is much larger than a morphologically similar, presumed P2 of *C. bidens* (IITR/SB/VLM 502). However, the species will be named subsequently when additional material becomes available.

Locality: Vastan Lignite Mine, Taluka Mangrol, District Surat, Gujarat, India.

Horizon: Cambay Shale, *N. burdigalensis* Zone (SBZ 10)

DISCUSSION

Ongoing work clearly suggests that the Vastan land mammal fauna is likely to be quite diverse. Several vertebrate-bearing levels have been identified in the mine that may eventually help understand stratigraphic change in the composition of Vastan mammal assemblage during the early Eocene, and its possible correlation with one of the three known mammal horizons from the Ypresian of Baluchistan (Gingerich *et al.*, 2001).

Taxa so far identified include perissodactyls, artiodactyls, proteutherians insectivores, apatotherians, rodents (e.g. IITR/SB/VLM 581) and bats (e.g IITR/SB/VLM 582). The last two groups are being described separately. As of now, it is clear that the assemblage consists largely of endemic taxa that include some archaic perissodactyls placed here in a new family (Cambaytheriidae). However, any firm conclusions regarding the implications of the Vastan mammals must wait until completion of ongoing study. Of particular interest will be the implications of this fauna for the current hypothesis advocating an early Tertiary "Out of India" vertebrate dispersal following the initiation of subareal India-Asia contact (e.g. Krause and Maas, 1990; Bossuyt and Milinkovitch, 2001; see Clyde *et al.*, 2004 for an opposing viewpoint).

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