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CREODONT AND CONDYLARTH FROM THE CAMBAY SHALE (EARLY EOCENE, ~ 55-54 MA), VASTAN LIGNITE MINE, GUJARAT, WESTERN INDIA

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ABSTRACT

This paper describes two new mammalian taxa from the basal Eocene Cambay Shale deposits of the Vastan Lignite Mine, Gujarat, western India. One of these, a hyaenodontid creodont, pertains to a new taxon based on several dentaries (*Indohyaenodon raoi* n. gen. & n. sp.), and the other is an unnamed condylarth, possibly an arctocyonid, with a tribosphenic, bunodont upper molar morphology. The new finds augment the diversity of the Vastan mammal fauna significantly.

Keywords: Creodonta, Condylartha, Eocene, Vastan, India

INTRODUCTION

In recent years, a diverse terrestrial mammal fauna has been described from the Vastan Lignite Mine of Gujarat, western India (Bajpai *et al.*, 2005 a, b, c ; Bajpai *et al.*, 2006, 2007a, b; Smith *et al.*, 2007; Bajpai *et al.*, 2008; Rana *et al.*, 2008; Rose *et al.*, 2008). As presently known, placental mammals from Vastan include artiodactyls, perissodactyls, primates, insectivores, proteutherians, apatotherians, rodents, bats and lagomorphs. A number of additional mammals were documented by Kapur (2006) in his Ph. D. dissertation, and a brief description of some of these is published here. Detailed analysis of these and other taxa will be published elsewhere.

The Vastan mammals are now considered to be earliest Eocene or Sparnacian (~ 55-54 Ma) in age (Garg *et al.*, 2008), rather than the previously determined middle Ypresian age which was based on the larger benthic foraminifer *Nummulites burdigalensis*. The new age determination (Garg *et al.*, 2008) is based on dinoflagellate cysts recovered from several levels in the Vastan sequence, which include *Muratodinium fimbriatum, Heteraulacacysta granulata, Kenleyia complex (K. lophophora, K. leptocerata,* and *Kenleyia* spp.), *Lanternosphaeridium lanosum* and *Operculodinium severinii*. Consistent with a ~54-55 Ma age of the Vastan mammals, recent work (Saravanan, 2007) on larger benthic foraminifers from Vastan suggests that *Nummulites* from this section may actually pertain to *N. globulus* (Shallow Benthic Zone 8, Serra-Kiel *et al.* 1998), and not to *N. burdigalensis*.

The material described in this paper is housed in the Vertebrate Paleontology Laboratory, Department of Earth Sciences, Indian Institute of Technology, Roorkee under the acronym IITR/SB/VLM.

SYSTEMATIC PALEONTOLOGY

Class **Mammalia**
Order **Creodonta** Cope 1875
Family **Hyaenodontidae** Leidy 1869
Subfamily **Proviverrinae** Matthew 1909
Genus ***Indohyaenodon*** n. gen.

Type species: *Indohyaenodon raoi* n. sp.

Derivation of name: The genus name is in reference to the country of its origin and to its familial relations.

Diagnosis: A small proviverrine hyaenodontid. Distinguished from *Paratritemnodon* by its lower trigonid, and narrower M/3 talonid. Lower molars increase significantly in size from M/1 to M/3, unlike *Arfia, Galecyon, Pyrocyon, Prototomus, Boualitomus* and prolimnocyonines. P/1 single rooted, unlike *Tritemnodon* in having a single-rooted P/1 and an M/2 trigonid significantly smaller than M/3 trigonid, and from most other North American proviverrines (*Arfia*, *Prototomus*, *Galecyon*, *Pyrocyon* and *Sinopa*) in being much smaller. Differs from *Acarictis* in having a higher trigonid. Distinct from *Cynohyaenodon*, *Alienetherium* and *Paracynohyaenodon* in having smaller M/1 metaconid than paraconid, well-developed labial cingulum on molars and in having smooth enamel. Differs from European *Proviverra* in having an anteriorly shifted paraconid; cristid obliqua angled towards and in progressive size reduction of metaconid from M/1-M/3. Differs from *Prolimnocyon* in having an M/3 larger than M/2 and from *Pyrocyon* in having smooth enamel. Distinguished from South Asian proviverrines *Yarshea* and *Kyawdawia*, by its much smaller size.

Remarks: The record of proviverinne hyaenodontids from the early Tertiary of South Asia is extremely poor. Aside from *Indohyaenodon* n. gen., the only other hyaenodontids described from this region are *Paratritemnodon* from the middle Eocene (Ranga Rao, 1973; West, 1980; Thewissen *et al.*, 1987; Kumar, 1992; Thewissen *et al.*, 2001), *Kyawdawia*, *Yarshea* and an indeterminate proviverrine from the late middle Eocene Pondaung Formation, Myanmar (e.g. Egi *et al.*, 2005). The Vastan find augments the diversity and stratigraphic distribution of Eocene hyaenodontids in South Asia. Gingerich *et al.* (2001) mentioned hyaenodontids in his faunal list for Ghazij Formation of Pakistan, but these have not yet been described.

Age and distribution: Basal Eocene of India.

Indohyaenodon raoi n. sp.
(Pl. I, figs. A-D; Pl. II, figs. A-B; Tables 1, 2)

Holotype: IITR/SB/VLM 899 (left dentary with alveolus for P/1 and crowns for P/2-M/3, M/1 damaged).

Referred specimens: IITR/SB/VLM 742 (right dentary with crowns for P/2-P/4, damaged area of M/1 and crowns for M/2-M/3); IITR/SB/VLM 782 (right dentary with alveolus for M/1

Table 1: Measurements of lower dentition (in mm) of *Indohyaenodon raoi* n. gen. & n. sp.

Dentition →	P/2		P/3		P/4		M/1		M/2		M/3	
Specimen ↓	L	W	L	W	L	W	L	W	L	W	L	W
IITR/SB/VLM 899 (holotype)	5.1	2.2	5.5	2.2	5.8	2.4	4.6	2.6	5.8	3.6#	6.9	4.3
IITR/SB/VLM 926		-		-	4.9	2.1	4.6	2.6	6.2	3.7		-
IITR/SB/VLM 742	4.7	2.4	5.6	2.2	5.2	2.4		-	6.0	2.8#	7.4	-
IITR/SB/VLM 782		-		-		-		-	5.9	3.7	7.4	4.3

maximum width of trigonid.

and crowns for P/2-P/4 and M/2-M/3); IIITR/SB/VLM 926 (left dentary with alveoli for C/1-P/3 and crowns for P/4-M/2, P/4 damaged)

Derivation of name: This species is named after the late Mr. A. Ranga Rao, in recognition of his contributions to the knowledge of Indian Eocene land mammals.

Type Horizon and Locality: Cambay Shale, Vastan Lignite Mine, District Surat, Gujarat, India.

Diagnosis: generic and specific diagnoses cannot be distinguished.

Description: The mandible of *Indohyaenodon raoi* is ventrally convex, the mandibular depth decreasing anteriorly from beneath the M/3. The mandibular symphysis reaches posterior to P/2 or P/3. The anterior mental foramen is small and is positioned about 4 mm beneath the anterior portion of P/2. A larger mental foramen is present beneath the P/3.

The canine is large, as indicated by alveolus preserved in one of the referred dentaries (IITR/SB/VLM 926). Following it posteriorly without any diastema is the alveolus for a single-rooted P/1. No diastema is present between the alveoli for P/1 and P/2 in the holotype. In one of the referred specimens (IITR/VLM/SB 742), there is no alveolus for P/1. However, the texture of the bone in this area is rough, suggesting that the tooth was lost during life and its alveolus resorbed. This left a diastema of 4 mm between C/1 and P/2. The diastema between P/2 and P/3 varies from 0.4 mm (IITR/SB/VLM 926) to 1.0 mm (IITR/SB/VLM 782).There is no diastema between P/3 and P/4.,

The premolar size decreases from P/1 to P/4. P/2-P/4 are all double-rooted, triangular in labial view with a large centrally located protoconid, and a small posterior cusp (metaconid). An anterior and a posterior crest descend from the large protoconid. A labial cingulid is present in the premolars but there is no lingual cingulid. The enamel surface is more or less smooth.

The crowns of M/1 to M/3 increase significantly in size posteriorly but the basic morphology of all lower molars is similar. The trigonid is triangular, high and wide open labially, with a high protoconid, and paraconid larger than metaconid. The talonid is narrow, with a single, weak cusp placed posteriorly, and its basin is rimmed by labial and/or lingual crests. A steep crest descends anterolingually from the protoconid and a strong but gentle crest descends posterolabially from the paraconid. These crests join to form a V-shaped cutting edge. There are no crests present between the paraconid and metaconid. The paraconid in M/2 and M/3 is anteriorly directed, more so in M/3. A prominent lingual vertical groove occurs between the paraconid and metaconid in lingual aspect. The trigonid wall is nearly vertical in the M/2 and M/3. The molar talonids are moderately deep. The cristid obliqua reaches the trigonid wall beneath the vertical notch separating the protoconid and the metaconid. The talonid cusp is indistinct in the holotype due to wear. The molars have a labial cingulid whereas the lingual cingulid is absent. The enamel is more or less smooth.

The coronoid and angular processes are well preserved in IITR/SB/VLM 742. The coronoid process is about 15 mm in width. The coronoid crest is prominent and the masseteric fossa is moderately deep. The anterior margin of the coronoid process is straight but directed posteriorly with an angle of about 120° with the dorsal margin of the ramus. The posterior margin of the coronoid process curves posteriorly. The mandibular foramen is present at a distance of about 17 mm from the M/3 talonid. The angular process is hook-like, and the mandibular condyle is located in the plane of the teeth.

Remarks: Hyaenodontids are common elements in the Eocene faunas of North America, Europe, Asia and Africa. Their first appearance, along with perissodactyls, artiodactyls and primates, is at the beginning of the Wasatchian in North America, and Sparnacian in Europe (McKenna and Bell, 1997; Gunnell, 1998). In Asia, early hyaenodontids have been recorded from the Gashatan Bayan Ulan fauna of Nei Mongol Autonomous Region, China (Meng *et al.*, 1998) and from the

EXPLANATION OF PLATE I

A. ***Indohyaenodon raoi*** (holotype), IITR/SB/VLM 899, left dentary, occlusal view.

A 1. ***Indohyaenodon raoi*** (holotype), IITR/SB/VLM 899, enlarged view of left M/2- M/3.

B. ***Indohyaenodon raoi*** (holotype), IITR/SB/VLM 899, left dentary, labial view.

C. ***Indohyaenodon raoi*** (holotype), IITR/SB/VLM 899, left dentary, lingual view.

D. ***Indohyaenodon raoi***, IITR/SB/VLM 742, right dentary, occlusal view.

Plate I

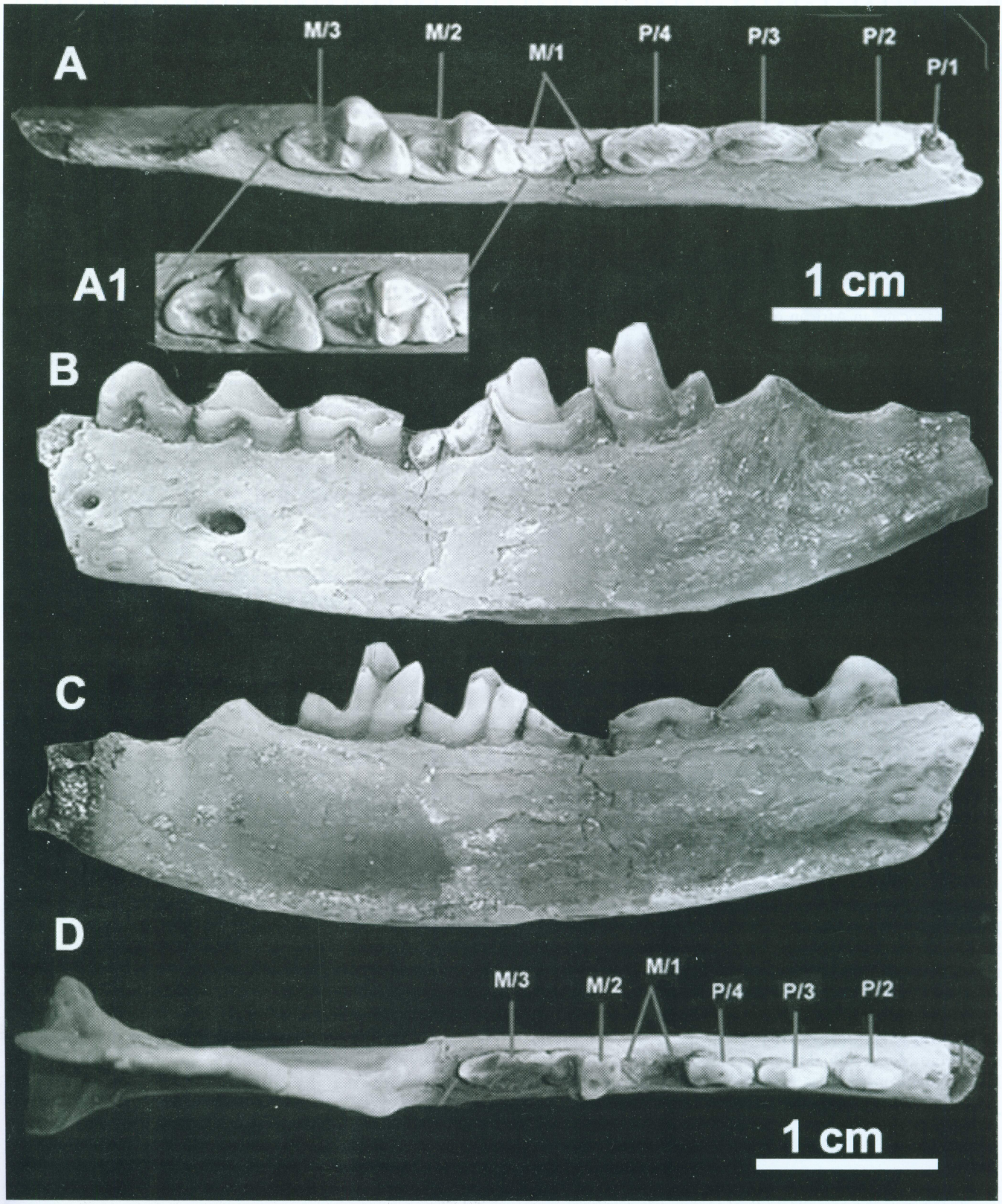

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Table 2: Scores of *Indohyaenodon raoi* n. gen. & n. sp., based on characters discussed in Egi *et al.* (2005).

Character	1	2	27	28	29	30	31	33	34	35	36	37	39	40	41	43	45	49	51	53	54	55	56	57	58	60	61	63	64	65
I. raoi	1	0	0	0	0	0	1	0	0	0	0	1	0	0	2	1	1	1	0	0	0	1	0	0	0	0	1	1	1	1

Gashatan Member of the Naran Bulak Formation of the Nemegt Basin, southern Mongolia (Dashzeveg, 1985). Known African hyaenodontids include the late early Eocene *Koholia atlasense* from El Kohol, Algeria (Crochet, 1988), and the recently described new proviverrine hyaenodontid creodont *Boualitomus marocanensis* from the earliest Eocene of Morocco (Gheerbrant *et al.*, 2006). It has been suggested (Barry, 1988; Holroyd, 1999) that the south Asian, African and some of the European taxa form a monophyletic group of hyaenodontids ("Advanced proviverrines").

The problem of the geographic origins of hyaeonodontids is not yet resolved. Gingerich (1989) and Gingerich and Deutsch (1989) advocate an African origin for Hyaeonodontidae based on their abundance and diversity in the late Paleogene faunas of North Africa. Krause and Maas (1990) argued for an Indian origin of this group, whereas Beard (1998) and Bowen (2002) favoured an Asian origin. The African origin has again been supported in more recent analyses by Godinot and de Lapparent de Broin (2003), Egi *et al.* (2005) and Gheerbrant *et al.* (2006). Egi *et al.* (2005) favoured the monophyly of proviverrines of Africa and South and Southeast Asia.

The Vastan hyaeonodontid belongs to a new genus (*Indohyaenodon*) of proviverrine hyaenodontids (for a discussion of hyaenodontid relations, and subfamilies, see Polly, 1996). Where possible, the dental characters have been scored for the Vastan hyaenodontids, following the recent analysis of Eocene proviverrine hyaenodontids (Egi *et al.*, 2005). Based on this exercise (Table 2), *Indohyaenodon* appears to exhibit a combination of primitive and derived characters. *Indohyaenodon* is primitive relative to *Paratritemnodon* in the characters 37, 39, 49, and 56. However, *Indohyaenodon* is derived relative to *Paratritemnodon* in having a single cusp on a short P/4 talonid (characters 41 and 43 of Egi *et al.*, 2005). It is further noted that *Indohyaenodon* is primitive in several dental aspects relative to the European genus *Proviverra,* regarded as the most primitive hyaenodontid by Polly (1996) and Beard (1998). However, the relationships of the new Indian taxon to hyaenodontids from the Gashatan fauna of Inner Mongolia and Mongolia (Dashzeveg, 1985; Meng *et al.*, 1998) and to some from Europe (*Prolimnocyon, Arfia* from the Dormaal fauna, Smith and Smith, 1996) are open to question. Similarly, precise relations of the Vastan hyaenodontid with the recently described hyaenodontid (*Boualitomus marocanensis*) from the earliest Eocene of Morocco (Gheerbrant *et al.*, 2006) are under study. However, it is noted that *Indohyaenodon* shares a few basal hyaenodontid synapomorphies with *Boualitomus* as well as with the late Paleocene *Tinerhodon* from Morocco. These primitive characters include the paraconid and paracristid development in molars.

Order **Condylartha** Van Valen, 1969
Family **?Arctocyonidae** Giebel, 1855
(Pl. II, Figs C-E)

Referred material: IITR/SB/VLM 960 (unworn left upper M1/ or M2/).

Description: Large, bunodont, tritubercular molar with indistinct conules. The protocone is the largest cusp, followed by paracone and the metacone. The paracone is also slightly higher than the metacone. The paracone and metacone are joined at their bases by a well-developed postparacrista and premetacrista. The preparacrista extends anteriorly, curving slightly lingually before merging with the cingulum. The parastylar shelf is distinct but there is no metastyle. Also, unlike the paracone, there is no crest on the lingual face of metacone. A faint postmetacrista is "weak in comparison" present, better seen in the lower half of the metacone. The protocone is well developed with a rather steeply sloping lingual face. A prominent preprotocrista descends from the protocone, climbs the lingual face of the paracone and fades before reaching the apex of the latter. The postprotocrista is "weak is comparison", somewhat irregular and much lower than the preprotocrista. It terminates near the anterolingual margin of the metacone, making the trigon basin restricted and somewhat asymmetric. The posterolabial margin of the protocone is conspicuously bulbous and is delineated posteriorly by a shallow, arcuate groove. The paraconule and metaconule are indistinct. A cingulum is present on the labial, anterior and posterior sides but is discontinuous lingually around the protocone. The enamel surface is somewhat wrinkled. The length and the width of this tooth are 12.2 mm and 15.1 mm, respectively.

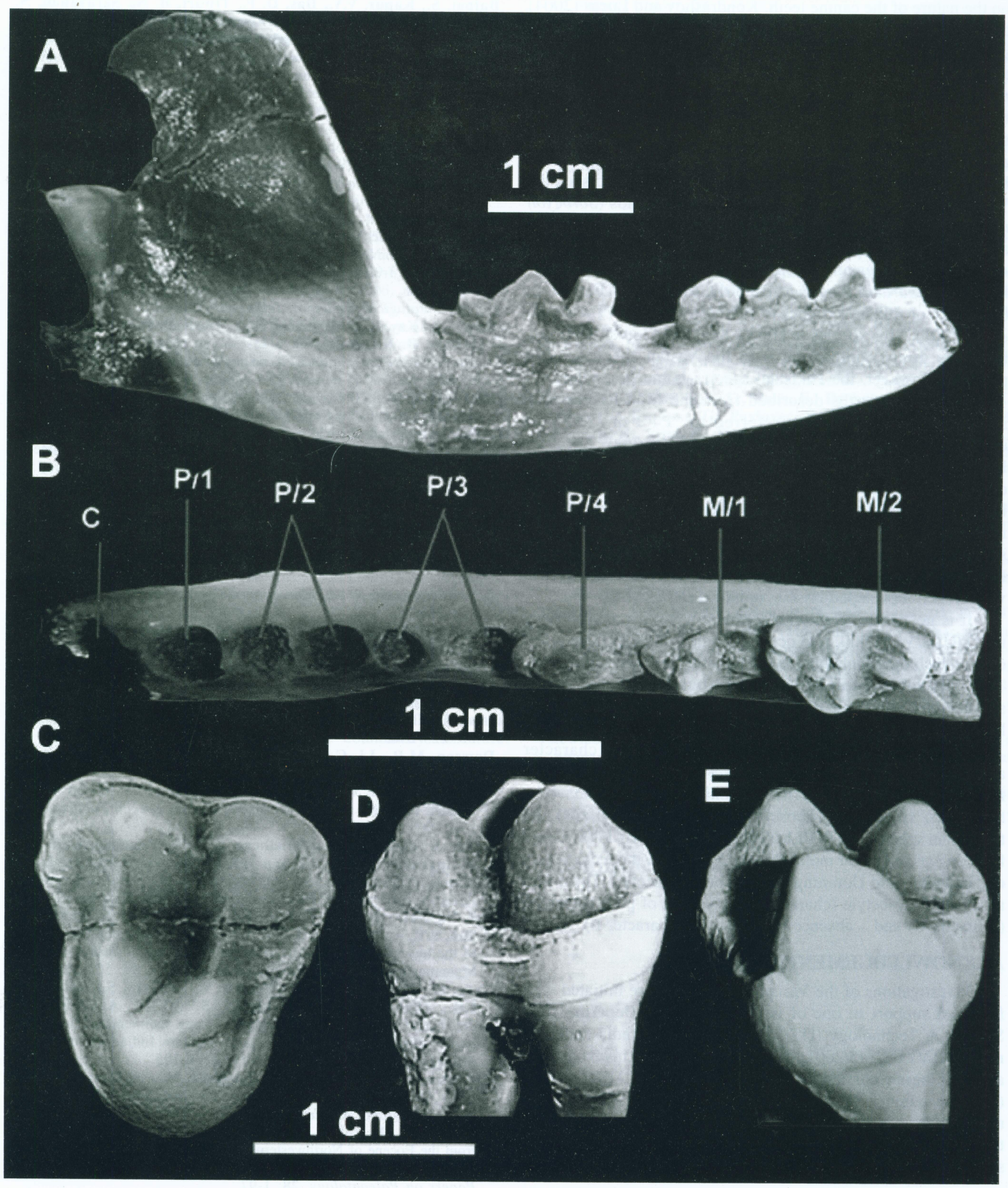
Discussion: This single tooth is clearly of a species that has not been recognized in the Vastan fauna, or elsewhere in the Indian continent before. However, a single tooth is inadequate as a holotype, and we refrain from formally naming it.

IITR/VLM/SB 960 is reminiscent of arctocyonids such as *Arctocyon* and *Claenodon* in its large size and simple cusp morphology, although its cusps are higher than those of the latter. The triangular outline of IITR/VLM/SB 960, and its bunodont, tribosphenic morphology of are also reminiscent of the Paleocene arctocyonids of North America. This is the reason for attributing IITR/VLM/SB 960 to ?Arctocyonidae.

Only limited comparison of IITR/VLM/SB 960 can be made with the quettacyonid condylarths described from the early Eocene Ghazij Formation of Baluchistan (Pakistan) because the latter are largely known from the lower dentition (Gingerich *et al.*, 1997, 1998, 1999). Quettacyonids include several taxa: *Quettacyon parachai, Sorocyon usmanii, Obashtakaia*

EXPLANATION OF PLATE II

A. ***Indohyaenodon raoi*,** IITR/SB/VLM 742, right dentary, labial view.
B. ***Indohyaenodon raoi*,** IITR/SB/VLM 926, left dentary, occlusal view.
C. **? Arctocyonidae,** IITR/SB/VLM 960, left M1/ or M2/, occlusal view.
D. ? **Arctocyonidae,** IITR/SB/VLM 960, left M1/ or M2/, labial view.
E. ? **Arctocyonidae**, IITR/SB/VLM 960, left M1/ or M2/, lingual view.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1 cm
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aeruginis and *Machocyon abbasi*. *Quettacyon*, the type genus, was initially placed in the Quettacyoninae, a subfamily of Arctocyonidae (Gingerich *et al.* 1997). Later, Gingerich *et al.* (1998) elevated this subfamily to the family status based mainly on the nature of the canine teeth. Kondrashov and Lucas (2004) considered three of the described quettacyonid genera as junior synonyms of the type genus *Quettacyon*. No upper teeth are known for the type species of this family (*Quettacyon parachai*). Of the remaining taxa included in this family, the referred M1/-M2/ of *Machocyon abbasi,* though generally similar in overall tritubercular outline as well as in size, are easily distinguishable from the Vastan condylarth based on higher cusps in the latter. The same feature distinguishes the Vastan condylarth from the two other quettacyonids (*Sorocyon usmanii* and *Obashtakaia aeruginis*) for which upper molars are known (Gingerich *et al.*, 1998).

The only other arctocyonid described to date from Indo-Pakistan is *Karakia longidens* from the Mami Khel Formation (late early or middle Eocene) of northern Pakistan (Thewissen *et al.*, 2001). This species is known only from lower dentition, hence its direct comparison with the Vastan species is not possible. However, the Pakistani species is much smaller.

Other condylarths described from the Indo-Pak Eocene include two isolated teeth referred to "P4"/ or "M2"/ of unnamed mesonychians, one from the upper Subathu Formation of Kalakot, NW India (Ranga Rao, 1973) and the other from the Ganda Kas area of Pakistan (H-GSP 96134, figured in O' Leary, 1998). The specimen from Kalakot has a lower metacone, a more flattened paracone, weaker crests, and a smaller trigon basin. The Ganda Kas specimen has a very large paracone and lacks a metacone. All mesonychids have very weakly developed cristae, unlike IITR/VLM/SB 960.

It is noted that teeth with a generally similar morphology to IITR/SB/VLM 960, also occur in some middle Eocene artiodactyls including dichobunids (Dehm and Oettingen-Spielberg, 1958; Thewissen *et al.*, 1987, 2001), but the latter are much smaller in size (about four times in linear dimensions), and have much lower cusps.

Thewissen and Domning (1992) presented a character analysis for the phenacodontids (e.g., *Phenacodus* and *Ectocion*) in relation to primitive ungulates (perissodactyls, hyracoids, sirenians, proboscideans and desmostylians). As the Vastan species (IITR/VLM/SB 960) is presently known only from an isolated upper molar (M1/ or M2/), only three characters of Thewissen and Domning (1992) could be scored. These are: absence of mesostyle (character 4); presence of postprotocrista (chatacter 5) and absence of hypocone (character 6).

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