Pakistan J. Zool., vol. 43 (6), pp. 1101-1109, 2011.

Dorcatherium cf. *nagrii* from the Chinji Type Locality (Chakwal, Northern Pakistan) of the Chinji Formation, Lower Siwaliks, Pakistan

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Abstract. – This paper reports the first discovery of complete lower molar series ascribed to *Dorcatherium* cf. *nagrii* from the Chinji type locality of the Chinji Formation. The material, discovered by the team of Palaeontology of the Punjab University, Lahore, Pakistan in the past year comes from the Middle Miocene continental deposits of the Lower Siwaliks (Chinji Formation, northern Pakistan) dated approximately from 14.2 to 11.2 My, and provides new information about the lower dentition of *D. nagrii*. The new material extends the presence of *D. nagrii* to the type locality of the Chinji Formation and suggests a humid habitat with abundant cover, based on *D. nagrii* and the already recorded taxa from the locality.

Keywords: Siwaliks, tragulids, Chinji Formation, *Dorcatherium*, Miocene.

INTRODUCTION

The majority of fossil tragulids and the totality of fossil Siwalik species have been included in the extinct genus *Dorcatherium*, which was first described from the late Miocene of Europe with the type species *D. naui* (Kaup and Scholl, 1834; Lydekker, 1876; Colbert, 1935; West, 1980; Farooq *et al*., 2007a,b, 2008). As noted by earlier researchers, this genus embraces the major part of the Miocene–Pliocene diversity of the Tragulidae, with 22 recognized species, exceeding other genera such as *Siamotragulus*, *Dorcabune*, *Afrotragulus* and *Yunnanotherium* by far in species diversity (Rössner, 2007; Quiralte *et al*., 2008; Sánchez *et al*., 2010). *Dorcatherium* includes a varied array of bunoselenodont and selenodont tragulids that show a great degree of variation in both body size and dental morphology (Rössner, 2007). Mostly, the variation in the body size has been classically overused to diagnose and assign *Dorcatherium* species (Arambourg and Piveteau, 1929; Colbert, 1935; Whitworth, 1958; West, 1980; Gaur, 1992; Pickford, 2001; Morales *et al*., 2003; Farooq *et al*., 2007a-b, 2008; Quiralte *et al*., 2008) with much less emphasis put on the description of morphologically diagnostic characters (Morales *et al*., 2003; Geraads *et al*., 2005; Hillenbrand *et al*., 2009).

Dorcatherium has a widespread biogeographic distribution that covers Africa, Eurasia, the Greco-Iranian province and the Siwaliks from the early Miocene to the early Pliocene (Arambourg, 1933; Whitworth, 1958; Janis, 1984; Fahlbusch, 1985; Gaur, 1992; Gentry *et al*., 1999; Pickford, 2001; Morales *et al*., 2003; Pickford *et al*., 2004; Farooq *et al*., 2007a-b, 2008; Quiralte *et al*., 2008; Rössner, 2007, 2010). The association of *Dorcatherium* with *Dorcabune*, *Tragoportax Miotragocerus*, *Pachyportax*, *Selenoportax*, *Giraffokeryx* and *Hydaspitherium* is common in the Siwaliks, implying that they probably had same feeding resources at this time period (Colbert, 1935; Pilgrim, 1937, 1939; Farooq *et al*., 2007a-d, 2008; Khan *et al*., 2009, 2010). Bouvrain (1994) suggested that '*Tragoportax*' lived in a more wooded environment, because it is more often associated with cervids and tragulids (Farooq, 2006; Khan, 2007; Khan *et al*., 2010). Merceron *et al*. (2006) suggests that *Tragoportax* were engaged in both browsing and grazing. The taxonomic composition indicates the paleoecological conditions of the tragulids compatible with earlier reconstructions of the riverine environment and a covering of woods, bushes and shrubs (Barry *et al*., 2002).

The Siwalik *Dorcatherium* is represented by 4 species namely *D. minimus*, *D. nagrii*, *D. minus* and *D. majus* (Lydekker, 1876; Colbert, 1935;

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0030-9923/2011/0006-1101 $ 8.00/0

Prasad, 1968; West, 1980; Gaur *et al*., 1983). During the past decades, many new *Dorcatherium* specimens (*D. minus* and *D. majus*) have been recovered from the Siwaliks (Farooq, 2006; Khan, 2007; Farooq *et al*., 2007a-b, 2008), but only two additional species *D. minimus* and *D. nagrii* have been recognized (West, 1980; Gaur *et al*., 1983). *Dorcatherium minimus* is extremely rare, only two specimens having been collected by West (1980) at Dued Khel (Mianwali district) from the Chinji Formation of the Lower Siwaliks. West (1980) reveals that the only material available to him was an isolated upper third molar and a left astragalus, and he mentions the second upper third molar in addendum.

Remains of *D. nagrii* are normally scarce and they constitute a very rare faunal element in the Siwaliks of Pakistan (Colbert, 1935; Farooq, 2006). Earlier scientists who have worked on the Siwalik *D. nagrii* are Colbert (1935), Prasad (1968), Shani *et al*. (1980), Gaur *et al*. (1983) and Gaur (1992). Colbert (1935, p. 312) placed the specimens AMNH 19306, AMNH 19613, AMNH 29854 in *D*. sp. Later on Gaur *et al*. (1983) erected *D. nagrii*, based on Colbert's specimens and the specimens collected from Uttar Pradesh and Himachal Pradesh, Indian Siwaliks. Since the discovery of *D. nagrii* by Colbert in 1935 in northern Pakistan, no one described any material of *D. nagrii* from the Pakistani Siwaliks. Recently, a mandibular ramus ascribed to *D.* cf. *nagrii* has been recovered from the type area of the Chinji Formation. This contribution documents a new lower molar series (m1-3) of rare tragulid *D. nagrii* recovered from the outcrops south of the Chinji village (Fig. 1).

Biostratigraphy and age

The occurrence of tragulid *D. nagrii* in the Chinji type locality outcrops, northern Pakistan could indicate the first appearance in the Chinji Formation of the Lower Siwaliks. Earlier specimens of *D. nagrii* are excavated from the Middle Siwaliks at Nagri level (Colbert, 1935; Gaur *et al*., 1983; Gaur, 1992). Colbert (1935) attributes the *D. nagrii*'s samples to the localities 5 and 12 miles east of the Chinji Bungalow, and he estimated that they were situated in the upper Chinji Formation. If these were the exact localities, the samples would have an Eocene origin. The geological map of Colbert (1935) shows the Chinji – Nagri formation boundary further south than is now recognized. New maps with better formation boundaries within the Siwaliks show the areas south of the Chinji Bungalow, which belong to the topmost part of the Chinji Formation (Raza *et al*., 1983). This erroneous age assignment was based on incomplete locality information of the earlier recovered samples. The new discovery of *D. nagrii* from the Chinji type locality outcrops enables us to calibrate the stratigraphic position of this species.

The Chinji outcrops have yielded a rich and diversified vertebrate fauna. The fauna from the Chinji Formation includes at present the following species: *Sivapithecus sivalensis, S. indicus, Ramapithecus punjabicus, Rhizomyoides punjabiensis, Hyanailouros bugtiensis, Dissopsalis carnifex, Chalicotherium salinum, Listriodon pentapotamiae, Conohyus chinjiensis, Merycopotamus pusillus, Palaeohypsodontus* sp., *Dorcatherium majus, D. minus, Dorcabune anthracotherioides*, *Eotragus* sp., *Miotragocerus gluten, Kubanotragus sakolovi, Sivoreas eremite, Gazella* sp., *Giraffokeryx punjabiensis, Giraffa priscilla* (Matthew, 1929; Colbert, 1933, 1935; Pilgrim, 1937, 1939; Raza, 1983; Akhtar 1992; Barry *et al*., 2002; Badgley *et al*., 2008; Khan *et al*., 2008, 2009, 2010). This faunal association contains enough significant elements to allow comparison with some other middle Miocene to early late Miocene faunas from Europe and Greco-Iranian Province. The Chinji Formation fauna is clearly of middle Miocene to early late Miocene age, as above-mentioned taxa represent an association of the late middle Miocene and the earliest late Miocene.

MATERIALS AND METHODS

The mandible fragment that is described in this paper has been recovered from the outcrops south of the Chinji village (72° 22′ E, 32° 41′ N), district Chakwal, northern Pakistan (Fig. 1). The outcrops belong to the Chinji Formation of the Lower Siwaliks (Barry *et al*., 2002; Khan *et al*., 2008, 2009). The outcrops dominantly comprise bright red and brown orange siltstones interbedded

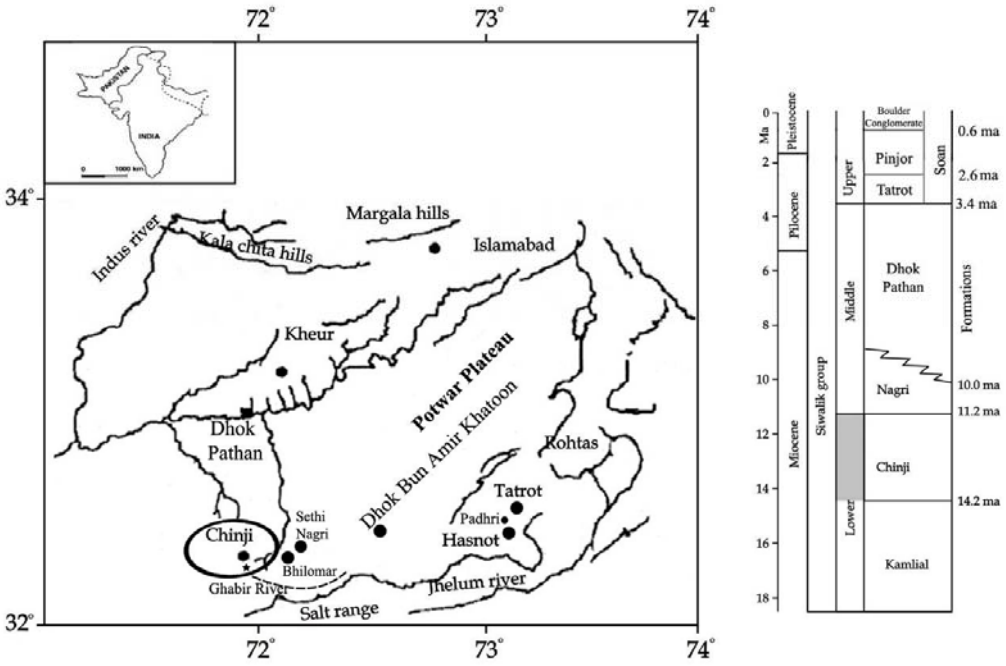

Fig. 1. Map of the Potwar Plateau and a generalized stratigraphic section of the main Siwalik formations. Map modified from Behrensmeyer and Barry (2005) and the boundary dates are from Barry *et al.* (2002), Dennell *et al.* (2008) and Nanda (2008). Circle marks the studied area with asterisk showing the exact locality position.

with soft, ash grey sandstones. The sediments were probably deposited in a fluvial environment leaving behind the fine-grained and fossil-bearing flood plains. For a detailed description of the geological and biostratigraphical setting of the area see Behrensmeyer (1987, 1988), Willis (1993), Behrensmeyer *et al*. (1995) and Barry *et al*. (2002).

The morphological and metrical characters of the sample are described and their systematic determination is discussed. The specimen is housed in the Zoology Department of the Government College University, Faisalabad, Pakistan. The specimen is registered by the year and a serial catalogued number (*e.g.* PC-GCUF 10/23). All measurements are given in millimeters (mm). The dental length (L) and width (W) were measured at the occlusal level. The tooth height (H) equals the height of the metaconid on lower molars. The terminology and measurement of the tragulid teeth follow Gentry *et al*. (1999) and Rössner (2010).

Abbreviations

PC-GCUF, Paleontological Collection of Government College University Faisalabad; PUPC, Punjab University Paleontological Collection; AMNH, American Museum of Natural History; My, million years; ma, million years ago; m, lower molar; L, largest length; W, largest width; H, maximum height; L(hypc), length of hypoconulid; W(hypc), width of hypoconulid; H(hypc), height of hypoconulid; r, right; l, left.

SYSTEMATIC PALAEONTOLOGY

Suborder Ruminantia Scopoli, 1777
Infraorder Tragulina Flower, 1883
Family Tragulidae Milne-Edwards, 1864
Genus *DORCATHERIUM* Kaup and Scholl, 1834

Dorcatherium cf. *nagrii* Gaur,
Vasishat, Suneja and Chopra, 1983
(Fig. 2, Table I)

Material

PC-GCUF 10/23 a right mandible fragment with m1-3 (m1: L = 8.0, W = 4.8, H = 5.0; m2: L =

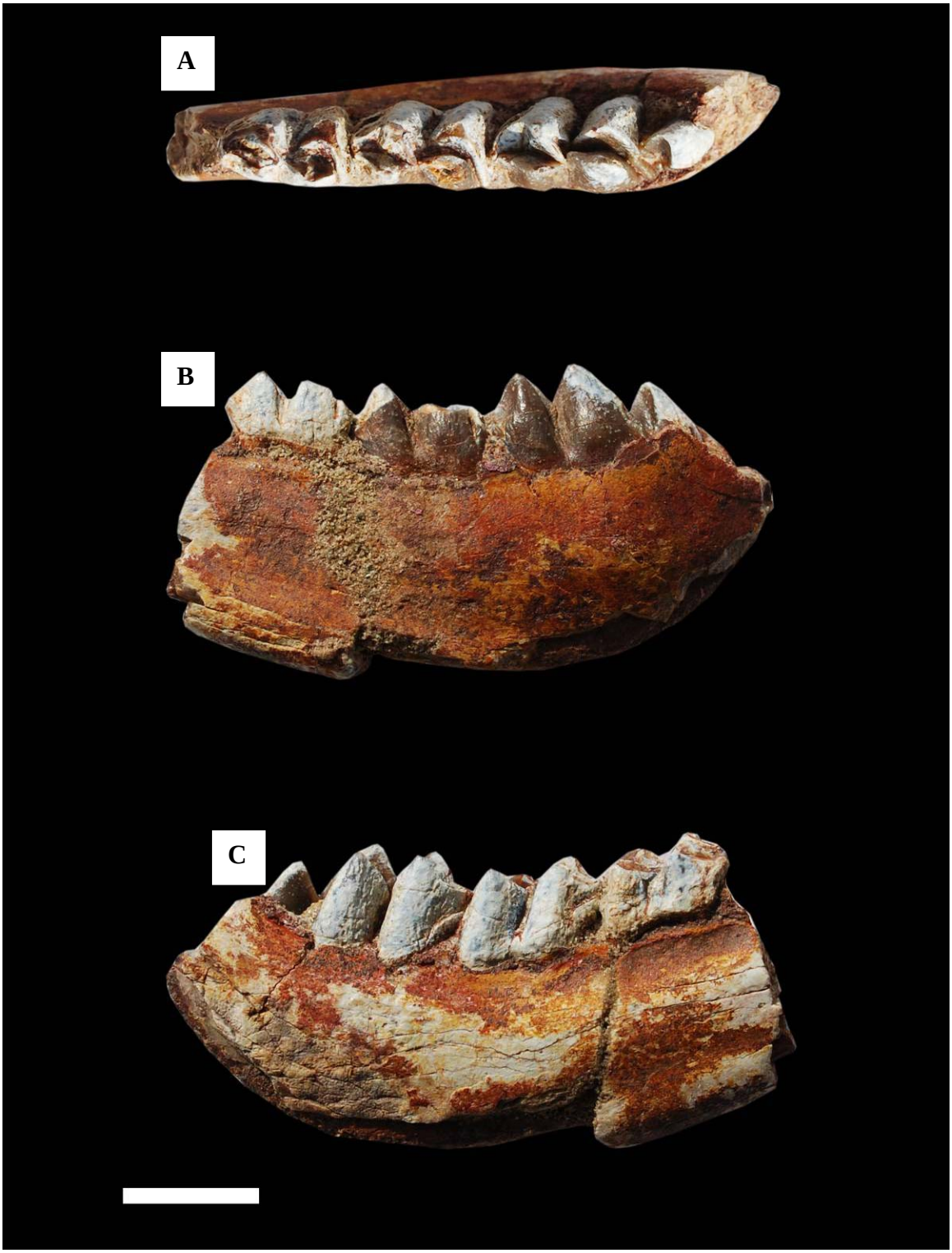

Fig 2. *Dorcatherium* cf. *nagrii*. PC-GCUF 10/23 – a right mandibular fragment with m1-3. A, occlusal view; B, lingual view; C, labial view. Scale bar equals 10 mm.

Table I.- Comparative measurements of the cheek teeth of the Siwalik *Dorcatherium* in mm (millimeters). * The studied specimens. Reference data are taken from Colbert (1935), Gaur *et al*. (1983) and Farooq *et al*. (2007a-b, 2008).

Taxa	Number	Nature/Position	Length	Width	W/L ratio
D. cf. *nagrii*	PC-GCUF 10/23*	rm1	8.00	4.8	0.60
		rm2	8.4	5.0	0.59
		rm3	12.6	5.0	0.39
D. nagrii	AMNH 19306	rm2	8.00	5.0	0.62
		rm3	11.5	5.0	0.43
	GSI 18079	m1	6.50	3.0	0.46
		m2	6.6	3.0	0.45
D. minus	PUPC 02/158	rm1	10.6	6.70	0.63
	GSI B594	rm1	10.8	6.80	0.62
	PUPC 68/294	rm2	11.0	6.40	0.58
	PUPC 68/311	rm2	10.0	6.60	0.60
	PUPC 68/312	lm2	10.0	6.20	0.62
	PUPC 68/313	rm2	10.2	6.70	0.65
	PUPC 02/158	rm2	12.7	8.20	0.64
	AMNH 19365	rm2	13.0	7.50	0.57
	AMNH 19366	rm2	12.0	7.50	0.62
	GSI B594	rm2	12.5	7.50	0.60
	PUPC 68/294	rm3	16.1	6.80	0.42
	PUPC 68/311	m3	14.8	7.80	0.53
	PUPC 68/313	lm3	15.6	7.40	0.47
	PUPC 83/610	lm3	18.5	8.50	0.45
	PUPC 83/626	lm3	12.5	8.00	0.64
	PUPC 84/82	rm3	18.4	8.30	0.45
	PUPC 85/35	lm3	15.0	7.00	0.64
	PUPC 85/59	lm3	14.2	7.00	0.49
	PUPC 86/266	rm3	14.5	6.40	0.44
	PUPC 96/66	lm3	13.0	6.30	0.48
	PUPC 02/158	rm3	18.5	8.70	0.46
	AMNH 19365	rm3	18.0	8.00	0.44
	AMNH 19366	rm3	16.0	8.00	0.50
	GSI B594	rm3	16.7	8.30	0.49
D. majus	PUPC 86/02	m1	14.3	9.00	0.62
	PUPC 86/05	m1	13.0	9.30	0.71
	AMNH 19524	m1	13.5	9.00	0.66
	GSI B593	m1	15.7	9.50	0.60
	PUPC 63/243	m2	17.0	10.1	0.59
	PUPC 84/115	m2	16.0	12.0	0.75
	PUPC 86/02	m2	15.6	9.80	0.62
	PUPC 86/05	m2	15.0	11.1	0.74
	PUPC 86/152	m2	16.2	12.0	0.74
	PUPC 98/61	m2	17.0	10.5	0.61
	AMNH 19520	m2	17.0	10.5	0.61
	AMNH 19524	m2	16.0	11.0	0.68
	GSI B593	m2	17.5	10.0	0.57
	PUPC 84/115	lm3	24.0	11.0	0.45
	PUPC 86/2	lm3	25.1	11.0	0.43
	PUPC 86/3	lm3	25.0	11.4	0.45
	PUPC 86/152	lm3	23.0	11.0	0.47
	PUPC 96/64	lm3	22.0	11.0	0.50
	PUPC 98/61	lm3	16.0	11.0	0.68
	AMNH 19939	lm3	25.5	12.0	0.47
	GSI B593	lm3	25.0	11.4	0.45

8.4, W = 5.0, H = 5.3; m3: L = 12.6, W = 5.0, H = 7.0, L(hypc) = 2.0; W(hypc) = 2.0, H(hypc) = 3.0).

Description

PC-GCUF 10/23 is a dainty broken hemimandible with bunoselenodont morphology (Fig. 2; Table I). The ascending ramus begins right at the posterior end of the hypoconulid, so there is no gap between m3 and the ascending ramus. The hemimandible is shallow and the ascending ramus is broken off. The lingual surface of the jaw is marked by a shallow groove distally. The labial side of the hemimandible is clearly convex anteriorly and the lingual side is slightly concave below m1. The anteroposterior length of the hemimandible is 43 mm and the depth of the hemimandible at m1 is 14 mm. The length of the molar series is 31 mm. The lingual conids are strongly compressed transversely and higher than the labial ones, which are crescent-shaped.

m1: The tooth is complete, sub-hypsodont, narrow-crowned and has the typical rounded shape of the anterior contact facet for the premolar (Fig. 2). It is in early stage of wear. All the conids are well preserved. The lingual conids are slightly more pointed and higher than the labial conids. The anterior cingulid is well developed. The anterior fossette is not crescent shaped but it is somewhat compressed and straight. However, the posterior fossette is crescentic and opens disto-lingually. The vestigial ectostylid is present at the base of the transverse valley. A slight cingulid is present on the base of the labial side. The *Dorcatherium* fold is present. It is formed by the bifurcation of the post-metacristid resulting formed a 'M'- structure, a diagnostic feature of *Dorcatherium* (Colbert, 1935; Rössner, 2007, 2010). The lingual ribs are separated by a vertical groove.

m2: This tooth is sub-hypsodont, slightly worn and rugose molar (Fig. 2). The conical metaconid is pointed and higher than the protoconid and the hypoconid. The entoconid is broken at the apex. The tubercle-like ectostylid occurs between the labial crescent conids (protoconid and hypoconid). The posterior fossette is crescentic and opens lingually. The cingulid is present anteriorly. The 'M'-shaped *Dorcatherium* fold is visible in occlusal view. The anterior rib and the stylid are comparatively weaker than the posterior ones. The pre-metacristid joins the pre-protocristid, while the post-hypocristid contacts the post-entocristid at the base, opening up the posterolingual end of the posterior fossette and forming a weak entostylid. Strong median ribs are present on the lingual side of the tooth and a narrow vertical groove occurs between the two conids. The talonid is slightly larger in length than the trigonid. The stylids are not very bulbous.

m3: The third molar is unworn and completely preserved (Fig. 2). It is higher than m1 and m2. All the conids are pointed and their tips are sharp. No ectostylid occurs in the transverse valley. The enamel is rugose especially on the buccal side of m3. All the crown features are preserved and the 'M' structure of the *Dorcatherium* fold can be seen pretty clearly. The anterior fossette on the occlusal surface is isolated mesially and the posterior one is comparatively narrow. The fossettes are deeper than those of m1 and m2. The anterior cingulid and the weak metastylid are present anteriorly. The anterior and posterior ribs are strong. The hypoconulid is present, isolated, obliquely situated between entoconid and hypoconid, and comparatively lower in height than the other four major conids. The hypoconulid has a shallow vertical groove mesially. This groove opens lingually. The antero-labial end of the hypoconulid contacts the post-hypocristid at the midline of the tooth. There is a short, low crest along the lingual edge of the hypoconulid which fails to reach the posterior of the entoconid, leaving the lingual wall incomplete.

Comparison

The semi-selenodonty pattern of the molars confirms the inclusion of this specimen in Tragulidae (Colbert, 1935; Pickford, 2001; Morales *et al*., 2003; Pickford *et al*., 2004). The presence of cingulid, stylids and *Dorcatherium*-fold (M-structure) are characters that correspond to genus *Dorcatherium* (Lydekker, 1876; Colbert, 1935; Whitworth, 1958; Gaur, 1992; Pickford *et al*., 2004; Farooq *et al*., 2007a, b, 2008; Rössner, 2007, 2010). *Dorcatherium* is represented by four Siwalik species *D. minimus*, *D. nagrii*, *D. minus* and *D. majus* (Lydekker, 1876; Colbert, 1935; West, 1980; Gaur *et al*., 1983; Farooq *et al*., 2007a-b, 2008).

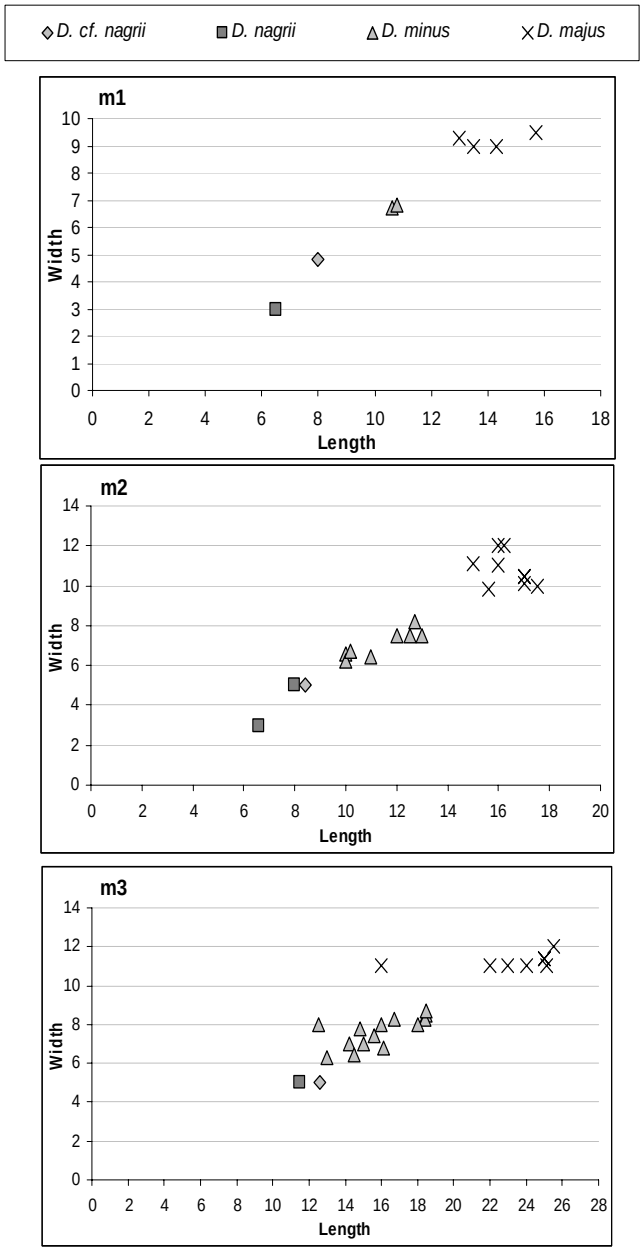

Fig. 3. Scatter diagram showing dental proportions of the Siwalik *Dorcatherium.* Reference data are taken from Colbert (1935), Gaur *et al*. (1983) and Farooq *et al*. (2007a-b, 2008).

Morphological and metrical features of the specimens clearly indicate a small-sized Miocene tragulid (Table I, Fig. 3). The teeth are too small for *D. minus* and *D. majus* (Fig. 3) (Farooq *et al*., 2007a-b, 2008). Cingulid and stylid cingula are weaker than those of *D. minus* and *D. majus.* In addition, the obliquely situated hypoconulid with an incomplete lingual wall can be observed in the small-sized Siwalik *Dorcatherium*. Nevertheless, *Dorcatherium minimus* is small enough to exclude the studied sample (West, 1980).

The overall pattern of the described molars is clearly different from that of *D. minus* and *D. majus*, and much more similar to the pattern observed in *D. nagrii.* Morphometrically, the described sample agrees with the earlier specimens of *D. nagrii* (Table I, Colbert, 1935; Gaur *et al*., 1983; Gaur, 1992). The teeth positions clearly overlap in size with the already studied material and fall pretty well within the range of *D. nagrii* (Fig. 3, Table I). Lacking adequate material, it is referred to as *D.* cf. *nagrii*. Nevertheless, more material is needed for precise identification.

CONCLUSIONS

The presence of *Dorcatherium* indicates more or less closed and humid habitats (Kohler, 1993; Gentry, 2005; Eronen and Rössner, 2007). The faunal composition suggests a humid habitat pocket with abundant cover indicating the dominance of forested landscapes during the middle Miocene and the early late Miocene times of the Chinji Formation. The presence of *D. nagrii* with *D. minimus*, *D. minus* and *D. majus* in the Chinji Formation suggests a strong connection to wet, forested habitats with dense understory, where the animals could hide in vegetation or water from predators (Colbert, 1935; West, 1980; Farooq *et al*., 2007a-b; Badgley *et al*., 2008; Khan *et al*., 2008). A significant representation of tragulids with adaptations to ecotonal wet and swampy habitats indicates humid conditions in the Chinji Formation of the Lower Siwaliks.

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(Received 2 January 2011, revised 16 February 2011)