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Lower Dentition of *Dorcatherium majus* (Tragulidae, Mammalia) in the Lower and Middle Siwaliks (Miocene) of Pakistan

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Abstract: *Dorcatherium majus* is one of the 4 Asian species of *Dorcatherium* found in the Siwaliks of Pakistan. Many fossiliferous sites in the Lower and Middle Siwaliks of Pakistan (Middle and Late Miocene) were visited in the last 14 years and many specimens of *D. majus* were found. Some specimens are well preserved and some are in a poor state of preservation. Among the collected specimens, 8 were included in this study due to their good preservation. All the selected specimens belong to the lower dentition of *D. majus* and document intraspecific size variation.

Key Words: Tragulidae, *Dorcatherium majus*, Siwaliks, Miocene, lower dentition

Introduction

Dorcatherium is one of the 5 extinct genera of the family Tragulidae along with *Dorcabune*, *Siamotragulus*, *Yunnanotherium,* and *Archaeotragulus*. The genus *Dorcatherium* was found by Kaup (1833). *Dorcatherium naui* Kaup is the type species and known from Late Miocene deposits of Eppelsheim in Germany, Europe (Kaup, 1833; Gentry, 1978). The dental formula of the genus is 0.1.3.3/3.1.4.3. The first lower premolar is sometimes absent as indicated by Whitworth (1958). Other diagnostic features exhibited are the larger length of the premolar row compared to the selenodont molar row in *Dorcatherium* and the presence of the *Dorcatherium* fold in the lower molars. In larger species of *Dorcatherium,* such as *D. peneckei* and *D. vindobonense,* the cheek teeth are more bunodont. Relative to their breadth, premolars are usually longer than the recent tragulids. The upper canines of males are large and trenchant (Whitworth, 1958). At least a vestige of ectostylid is present in almost all forms of the genus; in some, the ectostylid is even rather robust and very prominent. The external styles and the basal cingulum are well developed in the upper molars (Colbert, 1935). *Dorcatherium* resembles the extant African genus *Hyemoschus* in terms of the presence of a first lower premolar in *Dorcatherium* (but it is often absent in *Dorcatherium crassum* (Whitworth, 1958)), less selenodont cheek teeth, a cingulum, more robust jaws, and a contact between premaxilla and nasals. *Dorcatherium* seems to be a specialized genus of the family Tragulidae, which was developed in parallel to the recent African genus *Hyemoschus,* but the cheek teeth of *Dorcatherium* are higher crowned than that of *Hyemoschus*. The lateral sides of the basioccipital are divergent posteriorly and straight in *Dorcatherium* and *Hyemoschus* in contrast to divergent posteriorly and concave ones in *Leptomeryx* and certain species of *Tragulus* (Vislobokova, 2001). The coronal suture is posteriorly almost straight or slightly curved in *Dorcatherium* like in *Tragulus* as well as in *Hyemoschus* and in contrary to posteriorly slightly curved ones in *Archaeomeryx* and posteriorly strongly curved ones in *Hypertragulus*, *Leptomeryx* (AMNH, Dick 28-934), and *Prodremotherium* (Jehenne, 1977); and almost straight or slightly curved posteriorly in *Dorcatherium*, *Tragulus*, and *Hyemoschus*. *Dorcabune* was found by Pilgrim (1910) from the Siwaliks of Pakistan and the genus comprises large tragulids with bunodont teeth. The upper

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molars are with isolated parastyle and mesostyle, prominent cingulum, and the enamel is rugose. The anterior median rib is very bulky in *Dorcabune,* which distinguishes it from *Dorcatherium*. This genus comprises 3 more species from the Siwaliks of Pakistan in addition to the type species *Dorcabune anthracotherioides,* which was also founded by Pilgrim (1910). These 3 species are *Dorcabune hyaemoschoides* Pilgrim; *Dorcabune latidens* Pilgrim, and *Dorcabune nagrii* Pilgrim (Pilgrim, 1910). Colbert (1935) did not agree with Pilgrim (1910) and recognized only 2 species of *Dorcabune* instead of 4. These 2 species are *Dorcabune anthracotherioides* and *Dorcabune nagrii.* An additional species of *Dorcabune sindiense*, from the Sindh province of Pakistan, was found by Pilgrim (1910). The aim of the paper is to comprehensively describe the lower dentition of *D. majus* from the Lower and Middle Siwaliks of Pakistan.

Geology

In Pakistan, the Siwalik sediments are especially extensive on the Potwar Plateau, where they belong to a folded belt extending from the Salt Range to the Margala Hills in the north, and from the Jhelum River in the east to the Indus in the west. At the Potwar Plateau, the fossil record is good for the interval from 18 to 6 million years ago (Lihoreau et al., 2004). The Lower Siwaliks (Kamlial, Chinji) consist of a sequence of sandstone-mudstone couplets with a marked dominance of the mudstones over the sandstones. The occurrence of paleosol horizons is also fairly frequent. The Middle Siwaliks (Nagri, Dhok Pathan) are dominantly arenaceous and consist of multistoried coarse to medium-grained, blue-gray, massive sandstones (30 to > 60m) with subordinate representation of clays, mudstones and siltstones. Clay-mineral suites incorporated in fluvial deposits are mostly detrital in nature and are a useful tool to understand the provenance of fine-grained sediments, as well as the environmental conditions of the source terrains (Chamley, 1989). Many researchers (Bhattacharya and Misra, 1963; Bhattacharya, 1970; Chaudhri and Gill, 1983; Bagati and Kumar, 1994; Biswas, 1994; Raiverman and Suresh, 1997; Raiverman, 2002) have discussed the clay mineralogy of the late Neogene sediments from the Middle Siwaliks. They consist of abundant illite and smectite (Bagati and Kumar, 1994; Raiverman and Suresh, 1997; Kumar et al., 1999; Raiverman, 2002; Ghosh et al., 2003).

Material and Methods

A number of field trips were carried out to various localities of the Lower and Middle Siwaliks and many specimens of *Dorcatherium* were discovered. During the fieldworks by the authors, most of the specimens were found partly exposed and were excavated, while a few more were found lying completely exposed on the surface. The embedded material was carefully excavated with the help of chisels, geological hammers, fine needles, pen knifes, hand lances, and brushes. In the laboratory, the material was carefully washed, cleaned, prepared, and broken parts were assembled by various types of gums (resins) such as Araldite, Peligom, Magic stone, Elfy, Elite, and Fixin. The specimens catalogued by numbers that consist of the collection year and serial number of that year. For example, numerator 86/2 denotes the collection year and the serial number of the respective year. Various measurements of the specimens in millimeters were taken by a metric vernier. Tooth length and breadth were measured at the occlusal level. Heights were measured on the metastylid of the lower molar and the protoconid of the lower premolar. Tooth cusp nomenclature in this paper follows that of Janis and Scott (1987a, b) and Gentry (1994). In the discussion, comparisons are made with the fossils from the American Museum of Natural History (AMNH), the Geological Survey of India (GSI), and the specimens of the Paleontology laboratory of the Zoology department of the Punjab University (Institutional abbreviation, PUPC). The studied material is the property of the Paleontology laboratory of the Zoology department of the Punjab University in Lahore, Pakistan.

Systematic Palaeontology

Suborder: Ruminantia Scopoli, 1777

Family: Tragulidae Milne-Edwards, 1864

Genus: *Dorcatherium* Kaup, 1833

Type Species: *Dorcatherium naui* Kaup, 1833.

Diagnosis: The cheek teeth are high crowned. The upper molars bear strongly developed buccal styles. The lower molars are characterized, either by a well-developed ectostylid or by a vestigial ectostylid and presence of a Dorcatherium fold.

Included Species: *Dorcatherium majus*, *Dorcatherium minus*, *Dorcatherium minimus*, *Dorcatherium nagrii*, *Dorcatherium crassum*, *Dorcatherium peneckei*, *Dorcatherium vindebonense*, *Dorcatherium guntianum*, *D. jourdani*, *D. puyhauberti*, *D. bulgaricum*, *D. pigotti*, *D. chappuis*, *D. parvum*, *D. songhorenis*, *D. iririensis*, *Dorcatherium moruorotensis*, *D. libiensis*, *D. orientale*, *D. birmanicus*.

Distribution: Europe, Africa, South and Southeast Asia.

Dorcatherium majus Lydekker, 1876

Type Specimen: GSI B197, 2 upper molars (Colbert, 1935).

Material: PUPC 86/2 (Figure 1), a right mandibular ramus with P_4-M_3, collected from Markhal, Chakwal district, the Punjab province, Pakistan. **PUPC 86/5**, a left mandibular ramus bearing P_4-M_2, collected from Markhal, Chakwal district, the Punjab province, Pakistan. **PUPC 98/61**, a left mandibular ramus having $M_{2\text{-}3}$, collected from Dhokpathan, Chakwal district, the Punjab province, Pakistan. **PUPC 63/243**, an isolated second lower molar, collected from Chinji, Chakwal district, the Punjab province, Pakistan. **PUPC 84/115** (Figure 2), a fragment of right mandible having $M_{2\text{-}3}$, collected from Chinji, Chakwal district, the Punjab province, Pakistan. **PUPC 86/152**, a right mandibular ramus having $M_{2\text{-}3}$, collected from Dhokpathan, Chakwal district, the Punjab province, Pakistan. **PUPC 86/3**, a left mandibular ramus having M_3, collected from Markhal, Chakwal district, the Punjab province, Pakistan. **PUPC 96/64** (Figure 3), a right mandibular ramus with M_3, collected from Hasnot, Jhelum district, the Punjab province, Pakistan.

Stratigraphic Range: Lower to Middle Siwaliks (Middle to Late Miocene).

Diagnosis: *Dorcatherium majus* is a species larger than *Dorcatherium minus* and is equal in size to *Dorcabune anthracotherioides*. It is characterized by a strong parastyle and mesostyle, a well-developed cingulum in upper molars and a stoutly developed ectostylid.

Description

All the cheek teeth are well preserved and show the pronounced morphology. PUPC 86/2 (Figure 1) is a well-preserved right mandibular ramus having P_4-M_3. The incisive region and the ascending ramus are missing. The mandible is moderately deep (vertically, as well as transversely). The maximum preserved height under the M_3 is about 28 mm and the thickness is about 4 mm. The

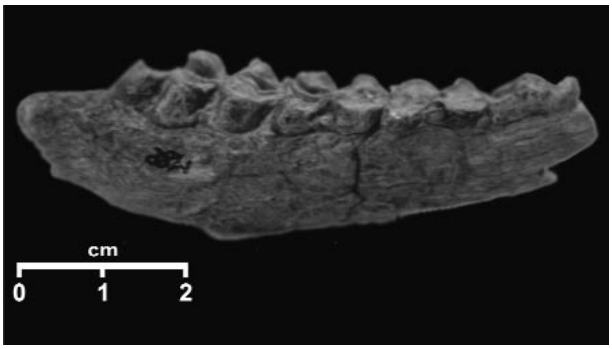

Figure 1. *D. majus* (PUPC 86/2): Right mandibular ramus with P4-M3; buccal view.

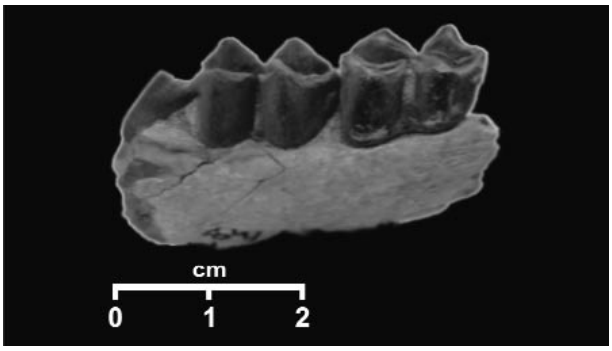

Figure 2. *D. majus* (PUPC 84/115): A part of a right mandibular ramus with M2-3; buccal view.

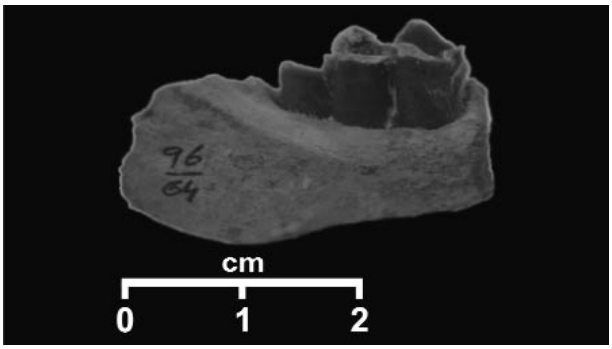

Figure 3. *D. majus* (PUPC 96/64): Fragment of a right mandibular ramus with M3; buccal view.

molars are long and narrow. They are medium worn. The enamel is moderately thick and rugose. The anteroposterior length of P_4-M_3 is 67.9 mm. The lower fourth premolar is high- and narrow-crowned. The paraconid is quite distinct from the metaconid. The tooth under study has a wide and deep cavity between the paraconid and the metaconid. The entostylid is well developed and can be distinguished from the entoconid. The hypoconid is also very prominent. The crown of the first molar is low and narrow. It is so deeply worn that the central cavities have been disappeared forming 2 separate dentinal plates. The enamel is fairly thick and uniform in thickness. The cingulid is lacking on the lateral as well as on the posterior sides. A slight indication of the cingulid can be seen around the hypoconid. A small ectostylid is present at the entrance of the transverse valley towards the buccal side, and seems to be more closely associated with the postprotocristid. The protoconid is looking less crescentic in shape due to high degree of wear. The hypoconid is more crescentic in shape than the protoconid. As far as the lingual conids are concerned, both are highly worn and were definitely vertically higher than the buccal conids in the early stage of wear. Only a weakly developed metastylid is visible of the stylids. The second molar (M_2) is present in the alveolus into the right mandibular ramus. Although the molar is in advance stage of wear but less worn than M_1. The protoconid is more worn than the other conids. The ectostylid is moderately developed and seems to be associated with the posterior side of the protoconid. It is slightly worn bearing a comparatively small diameter than that of the basal pillar of the M_1. The buccal and lingual sides of the second molar show very fine plications. The central cavities are narrow. The third molar is well preserved and hardly worn. The enamel indicates very fine plications and an almost uniform thickness all over the crown with an average of 1.0 mm. The cingulid is weakly developed on the buccal side especially at the entrance of the transverse valley along the prehypocristid. The ectostylid is very small and unworn exhibiting a close association with the postprotocristid. The protoconid is anteroposteriorly longer than the metaconid. It is crescentic in shape with preprotocristid and postprotocristid. The postprotocristid is bifurcated at the point where it is attached to the postmetacristid. The dentinal islet of the protoconid is roughly triangular. The Dorcatherium fold is present in the first, second, and third molars. The metaconid and the entoconid are higher than their opposite cusp. The metaconid is pointed in the middle with anterior and posterior sloping ridges. The postmetacristid is also slightly bifurcated by a vertical groove and is slightly more worn than the premetacristid. The premetacristid has produced a very narrow but elongated dentinal islet. The entoconid is well developed but slightly damaged at the posterior side. The hypoconid is more crescentic than the protoconid. The hypoconulid is very well developed and lies in line with the lingual conids. It is crescentic in appearance. Its median valley is shallow and opens towards the buccal side. PUPC 86/5 is a well preserved left mandibular ramus having P_4-M_2, whereas P_3 is represented by a small portion of the roots. The portions of the ramus anterior to P_3 and the posterior to M_2 are missing. The ramus is vertically moderately deep and transversely thick. The vertical height of the ramus below the M_1 is about 24 mm and transverse width is about 10.5 mm. The anteroposterior length of the P_4-M_2 series is 44.8 mm. PUPC 98/61 is a left mandibular ramus having $M_{2\text{-}3}$. The molars are well preserved and in a very early stage of wear. The enamel is very finely wrinkled. The wrinkles are equally prominent and distinct on all sides of the molars. The cingulid is lacking lingually, whereas anteriorly and posteriorly it is very strongly developed and high enough. The conids are well developed, pointed at the apex and the Dorcatherium fold is present in the postprotocristid.

PUPC 63/243 is very nicely preserved and in an early stage of wear. The degree of wear is greater in the buccal conids than in the lingual conids. The buccal conids are selenodont, whereas the lingual ones have a trend towards the conical form. The preprotocristid seems to be linked with the metastylid. The postprotocristid is deeply bifurcated into 2 daughter cristids, of which the outer one is free and the inner one is linked with the postmetacristid, it is separated from the preentocristid by a crack, which is perhaps due to some weathering effect.

PUPC 84/115 (Figure 2) is a part of the right mandibular ramus having $M_{2\text{-}3}$. The ramus is damaged

anteroposteriorly. The height below the M_3 is about 23.5 mm and the thickness is about 12 mm. The worn condition of the molar proves it to have been originally higher crowned. The buccal conids are selenodont, while the lingual ones exhibit a conical form. The stylids are poorly developed. The metastylid is weakly developed and the rest of the stylids are not properly developed. The median ribs are well developed enclosing a wide furrow between them. A small spur of enamel layer projects outwards from the anterior side of the anterior central cavity. PUPC 86/152 is a part of a right mandible with M_{2-3}. It is damaged anteroposteriorly. The height below the M_3 is about 30 mm and the thickness is about 12 mm. The anteroposterior length of the M_{2-3} series is 40 mm.

PUPC 86/3 is in a fine state of preservation. The tooth was in a medium stage of wear. The enamel shows an almost uniform thickness all over the crown with an average thickness of 1.4 mm. The cingulid is weakly developed on the buccal side. The protoconid is anteroposteriorly longer than the metaconid. The specimen PUPC 96/64 (Figure 3) includes a third molar inserted into a fragment of a right mandibular ramus. The ramus fragment including a part of the ascending ramus is well preserved but its part anterior to M_3 is missing. The vertical height of the ramus in front of the M_3 is about 27 mm and the transverse depth is about 16 mm. The comparative measurements are provided in Tables 1, 2, 3, and 4.

Table 1. Comparative dental measurements (mm) of the fourth lower premolars in *D. majus*.

	PUPC 86/2 PUPC 86/5 AMNH 19524 GSI B593
L	13.3 13.1 14.5 17.3
W	6.0 5.7 5.0 6.2
W/L index	45.11 43.51 34.0 35.0
H	8.0 6.2 - 8.7
H/W index	133.33 108.77 - 140.32
H/L index	0.6 0.47 - 0.5

Table 2. Comparative dental measurements (mm) of M1 in *D. majus*.

	PUPC 86/2	PUPC 86/5	AMNH 19520	AMNH 19524	GSI B593
L	14.3	13.0	14.0	13.5	15.7
W	9.0	9.3	9.0	9.0	9.5
W/L index	62.93	71.53	64.0	66.0	60.5
H	6.3	5.0	-	-	-
H/W index	70.0	53.76	-	-	-
H/L index	0.44	0.38	-	-	-

Table 3. Comparative dental measurements (mm) of M_2 in *D. majus*.

	PUPC 63/243	PUPC 63/243	PUPC 86/2	PUPC 86/5	PUPC 86/152	PUPC 98/61	AMNH 19520	AMNH 19524	GSI B593
L	17.0	16.0	15.6	15.0	16.2	17.0	17.0	16.0	17.5
W	10.15	12.0	9.8	11.1	12.0	10.5	10.5	11.0	10.0
W/L index	59.7	75	62.82	74.0	74.07	61.76	62.0	69.0	62.3
H	12.7	13.0	8.5	8.1	10.0	14.0	13.5	12.0	13.3
H/W index	125.12	108.33	86.73	72.97	83.33	133.33	128.57	109.0	133.0
H/L index	0.74	0.81	0.54	0.54	0.61	0.82	0.79	0.75	0.76

Table 4. Comparative dental measurements (mm) of M_3 in *D. majus*.

	PUPC 84/115	PUPC 86/2	PUPC 86/3	PUPC 86/152	PUPC 96/64	PUPC 98/61	AMNH 19939	GSI B593
L	24.0	25.1	25.0	23.0	22.0	16.0	25.5	25.0
W	11.0	11.0	11.4	11.0	11.0	11.0	12.0	11.4
W/L index	45.83	43.82	45.60	47.82	50.00	68.75	47.0	45.0
H	15.0	12.5	10.7	9.0	15.7	17.0	12.0	14.3
H/W index	136.36	113.63	93.85	81.81	142.72	154.54	100.0	125.43
H/L index	0.62	0.49	0.42	0.39	0.71	1.06	0.47	0.57

Discussion and Conclusion

The extinct genus *Dorcatherium* is known with many species from Asia (Lydekker, 1876; Matthew, 1929; Corbert and Hill, 1980), Europe, and Africa. Four Pakistani species of the genus *Dorcatherium* are *D. minimus*, *D. minus*, *D. nagrii,* and *D. majus*. The latter was found by Lydekker (1876) on the basis of 2 upper molars and a maxilla from the Middle Siwaliks of Khushalgarh, district Attock, Punjab, Pakistan. In 1935, Colbert reported about the species in the Chinji district Chakwal and in the Hasnot, district Jhelum, Punjab, Pakistan, documented with several specimens of lower and upper dentition. Akhtar (1996) described the fourth upper premolar of the species *D. majus* from the Siwaliks. The lower molars of *D. majus* are high comparatively and narrow crowned (Colbert 1935: Fig. 139, 140). They have ectostylids between the protoconids and hypoconids. The metaconid is recognized as the highest one among all the conids. Stylids are weakly or improperly developed. Their anterior median ribs are well pronounced. All these characteristics exhibited by the present collection of lower dentition indicate very clearly that it belongs to the species *D. majus* (Colbert, 1935).

The studied specimens of the lower dentition are PUPC 63/243, PUPC 84/115, PUPC 86/2, PUPC 86/3, PUPC 86/5, PUPC 86/152, PUPC 96/64, and PUPC 98/61, indicating that mandibular rami have premolars and molars as well as isolated molars. Two last premolars (P_4) belonging to specimens PUPC 86/2 and PUPC 86/5 seem to have close size values regarding their length and width to specimens AMNH 19524 (Colbert, 1935) of the type material, but differ markedly in length from the specimen GSI B593 of the type material (Table 1). In spite of this difference in length, the indices of W/L of all the specimens under study and type specimen exhibit that they all are extremely narrow crowned and the differences in length are in a range of intraspecific variability. There are only 2 first lower molars (PUPC 86/2 and PUPC 86/5). Their measurements in respect of length, width, and indices of W/L are compared with those of type specimen AMNH 19520, AMNH 19524 (Colbert, 1935), and GSI B593 (Pilgrim, 1910). Table 2 displays

overlapping of values, indicating that all compared specimens belong to the same species. The measurements of the second lower molars PUPC 63/243, PUPC 84/115, PUPC 86/2, PUPC 86/5, PUPC 86/152, and PUPC 98/61 are compared with the type specimens AMNH 19520, AMNH 19524, and GSI B593 (Table 3). The comparison indicates that all specimens have the same size and can be attributed conclusively to *D. majus*. The third lower molars, PUPC 84/115, PUPC 86/2, PUPC 86/3, PUPC 86/152, PUPC 96/64, and PUPC 98/61, have overlapping size values with the type specimens AMNH 19939 (Colbert, 1935) and GSI B593 (Pilgrim, 1910), except 1 specimen (PUPC 98/61), which has no talonid anymore (Table 4). All the facts discussed above confirm that the identification of all the specimens described as *D. majus* is beyond any doubt.

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