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A New Species of Fossil *Mus* (Muridae, Mammalia) from the Late Quaternary Deposits of Narmada Valley, Central India

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Abstract

A new species of fossil *Mus* (Muridae, Rodentia) is described from the Pleistocene fluviatile deposits of the Narmada valley (Central India). The species, *Mus narmadaensis* sp. Nov., has a comparatively smaller lower molar which is characterized by a narrow molar with well connected cusps, small anterior expansion of lingual anteroconid, protoconid and metaconid, reduced posterior cingulum in addition to hypoconid and entoconid nearly at the same level. The large M_3 has centrally placed bulbous hypoconid. Among the extant species, the present one is closest to *M. shortridgei* in having similarly placed protoconid and metaconid in M_1 and a well developed hypoconid in M_3.

Keywords: Fossil *Mus*, Late Quaternary, Narmada basin, Central India

1. Introduction

Considered to be the most successful groups of living mammals, the murid rodents were originated in the Indian sub-continent about 14 ma ago. At present, they are found all over the world with ability to adapt themselves to varied environmental conditions and show marked species diversity. Today more than 70% of the murid species are found in the Indo-Australian region, whereas, 26% murid taxa are found in Africa [1]. The oldest known fossil murid, *Antemus chinjiensis* was evolved from a cricetid *Potwarmus primitivus* and was recovered from the Chinji Formation (Siwalik sub-group) in the Potwar Plateau [2]. The study of fossil murids in the Indian subcontinent was initiated by [3-6] and followed by [2] who made significant contribution to the study of Pakistan Siwalik by describing various murid taxa. Subsequently, a sizeable work on the Afghanistan murids was done by [7-11]. As far as the Indian murids are concerned, a number of researches, e.g. [12-26] have shown that the murids were widespread in the country from the Pliocene onwards.

Among the murids, the genus *Mus* has been reported from various parts of India, e.g., from Kurnool caves [27], Saketi [19], Kashmir basin [22], Narmada valley [21,25,28], Upper Pleistocene of Bhimtal [23,24], and Dulam [25]. The great diversity of *Mus* both in terms of number and taxa indicates that the probable place of its origin was the Indian subcontinent. However, an early stock migration to the African continent during Mio-Pliocene time has been suggested [29]. Elsewhere in Asia, *Mus* has been described from China [30], Crete [31], former USSR [32], Hungary [33], Japan [34] and Thailand [35].

We report here the lower molars of a new species of *Mus* from the Devakachar section of the Hirdepur Formation of the Narmada deposits.

2. Area of Study, Litho-Chronology and Fossil Material

Narmada, the largest river in the Central India, originates at the plateau of Amarkantak (22° 40'N; 81° 40'E) and after traversing across the middle of the Indian subcontinent, it joins the Gulf of Cambay near Baroda. The course of the river is controlled by the east-west lineament. Between Bhedaghat (23° 8'N; 79° 48'E) and Hoshangabad (22° 45'N; 77° 45'E), the river forms a trough in which about 50m thick Quaternary fluviatile deposits are preserved. Though the deposits are much thicker in the south, the fossiliferous deposits are exposed in the northern fringe in the sections exposed along river Narmada and its tributaries.

The Narmada deposits have been divided into seven lithostratigraphic Formations [36]. The present study area forms a part of the flood plain facies of the Hirdepur Formation (**Figure 1(a)**), comprising greyish homogenous calcareous silt, interlayered with coarse sand, gravel and conglomerate with high degree of calcification. We studied a 17m thick profile at Devakachar (23º 23'N; 79º 07'E), exposed by the Sher River (see **Figures 1(a) and (b)**). It consists of sand, silt and cemented conglomerate including a fossil bearing horizon. The fossiliferous layer is 0.5 m in thickness and is composed of medium to coarse grained brownish coloured sand. It is about 9 m above the base of the profile (**Figure 1(b)**).

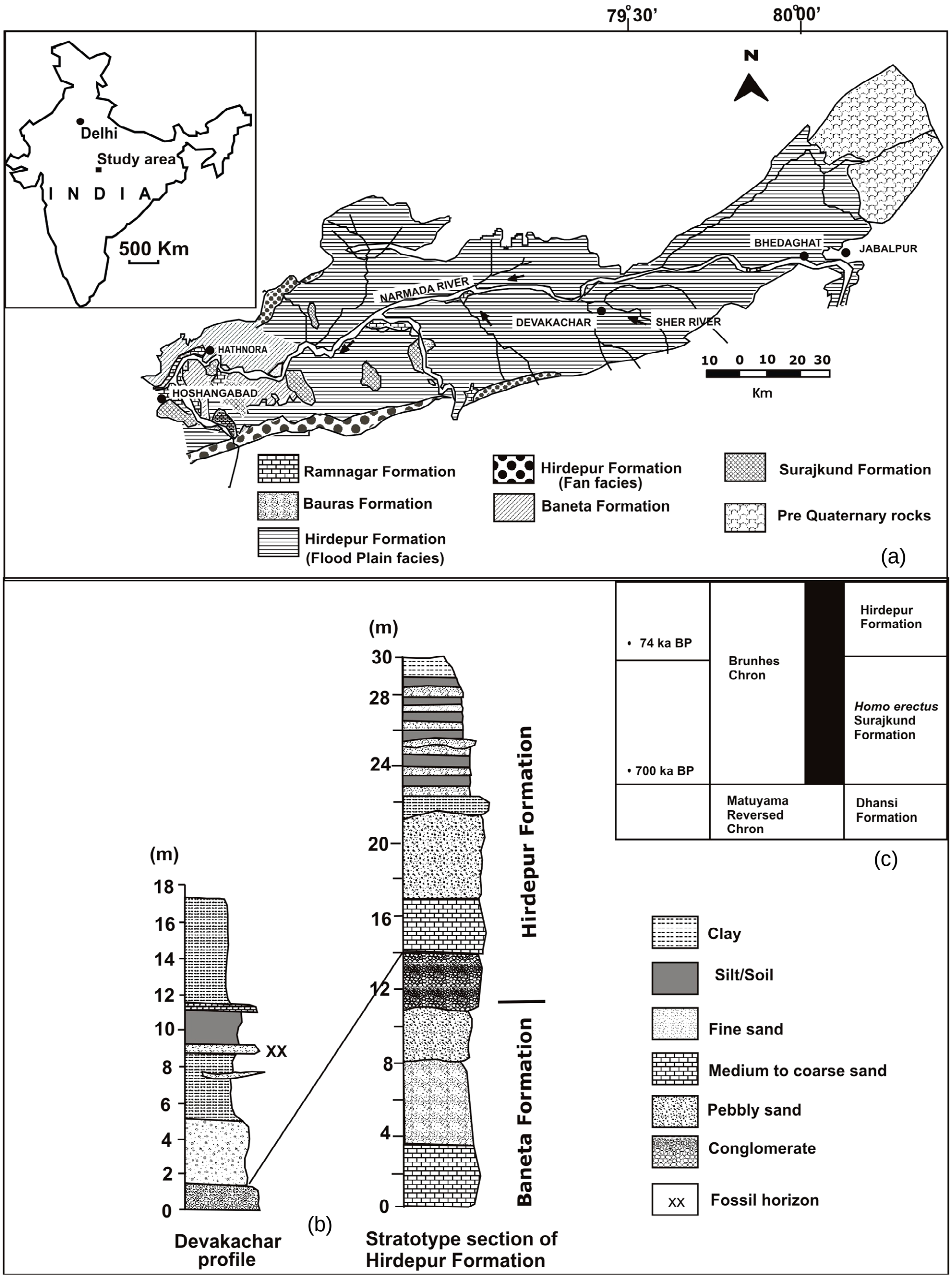

Figure 1. (a) Geological map of the Narmada Valley showing the study sites; modified after [36]; (b) Lithology of the Devakachar sections (present work) and Hirdepur Formation (stratotype section of the Hirdepur Formation is taken from [36]; 1(c) Chronology around *Homo erectus* locality in the Narmada valley after [26].

The basin is very well known for a large number of vertebrate fossils including *Elephas*, *Equus*, *Bos* and several others [37,38]. Lately, a discovery of the skull-cap of *Homo erectus* [39] and additional *Homo* material [40] has made Narmada valley an important site for palaeontological studies. However, the microvertebrates have only been mentioned in a handful of reports, e.g. [21,41,42]. The detailed magnetic stratigraphy of the Surajkund and Hirdepur Formations [36,43] and absolute date of the Toba volcanic ash found in the sediments [44] suggest that the boundary of both the formations lies at 74 ka BP and the top of the Narmada sequence is Holocene [40,42]. Several lithics recovered from the Dhansi Formation (**see Figure 1(c)**) may represent the first unequivocal evidence for an early Pleistocene hominin presence in India [45]. The *Homo erectus* horizon is only slightly older than the present fossil horizon.

We recovered a large number of microvertebrate remains, such as, murid rodents, lizards and fish from the Devakachar section. The murids are represented by lower molars and incisors. The lizards consist of dentaries, whereas, the cyprinid and channid fishes have teeth and spines. Here, we report only the murid material.

3. Systematic Palaeontology

Order: Rodentia

Family: Muridae

Genus: *Mus*

***Mus narmadaensis* sp. nov.**

***Type locality*:** Devakachar, 120 km southwest of Jabalpur (Madhya Pradesh).

***Horizon and age*:** The horizon, a medium to coarse grained sand, is Middle to Upper Pleistocene in age.

Referred material: Two LM_1s (NAR/1, NAR/2), One LM_3 (NAR/3). Broken incisors (NAR/I1-NAR/I6 (**Figures 2(a)-(e)**).

Etymology: The species has been named after the type area.

Holotype: LM_1 (NAR/1, **Figure 2(a)**).

Paratype: LM_1 (NAR/2, **Figure 2(b)**).

Measurements: See **Table 1** for measurements.

3.1. Differential Diagnosis

Smallest *Mus* ever reported, M_1 with highly reduced posterior cingulum, M_3 with a large second chevron; differing from *Mus auctor* [2] in having narrower M_1 and centrally placed hypoconid in M_3; from *Mus* sp. [2] in having a smaller M_1 and from *Mus* sp. [19] in having a reduced posterior cingulum in M_1; from *M. flynni* [19] in having a larger hypoconid in M_3; from *M. jacobsi* [22] in having poorly developed labial cingulum and lack of accessory cusps in M_1; and differing from *M. dhailai* [23] in having a smaller M_1 and much larger hypoconid in M_3.

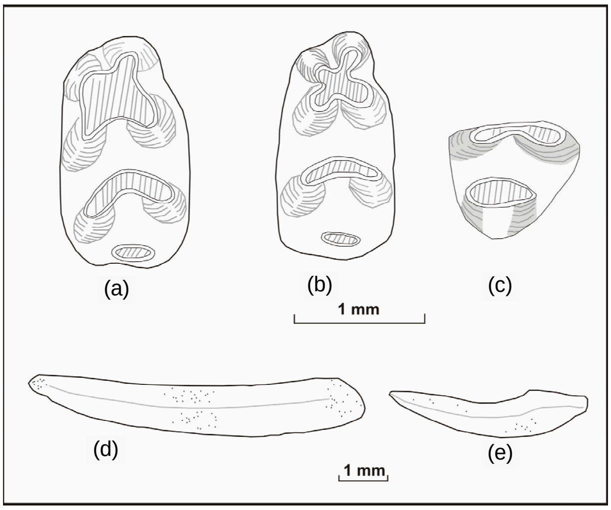

Figure 2. Lower molars of Mus narmadaensis sp. nov. (a) LM_1 (NAR/1); (b) LM_1 (NAR/2); c LM_3 (NAR/3); (d) and (e), murid incisors (NAR/11 and NAR/16).

Table 1. Length/width measurements of lower molars (mm) in *Mus narmadaensis* sp. nov.

Sp.no.	tooth type	length	Width
NAR/1	LM_1	1.27	0.73
NAR/2	LM_1	1.26	0.75
NAR/3	LM_3	0.76	0.64

3.2. Description

M_1 is a small and narrow cusp. The asymmetrical 'X' pattern is formed by the four anterior cusps. The labial cusps lie posterior to the lingual cusps in the first chevron. The labial anteroconid is smaller than the anteriorly displaced lingual anteroconid. The cusps are very strongly connected and the connection between the labial anteroconid and protoconid is stronger than between the lingual anteroconid and metaconid. The hypoconid and entoconid are more or less at the same level, the former being slightly bigger than the later. The posterior cingulum is small, oval, transversally flattened and highly reduced. M_1 has two roots.

M_3 is roughly triangular in outline. The protoconid and metaconid are at the same level and are more or less of the same size in the anterior chevron. The hypoconid and entoconid are merged together to form a bulbous chevron which is centrally placed. The specimen has one complete root.

3.3. Comparisons

Mus narmadaensis sp. nov. can be differentiated from *M. auctor* [2], *Mus* sp.[19] and *M. jacobsi* [22] in having the following characters; smaller M_1, marginal anterior displacement of lingual anteroconid relative to the labial anteroconid, protoconid and metaconid at the same level, poorly developed labial cingulum and highly reduced posterior cingulum in M_1. However, M_3 of the present species is bigger than that of *M. jacobsi* and *M. auctor*. In the M_3 of the present species, the hypoconid is centrally placed, whereas, it is displaced lingually in *M. auctor* and labially in *M. jacobsi.*

The present M_1s differ from *M. flynni* [19] in having a much smaller M_1 with lingual anteroconid showing small anterior displacement relative to labial anteroconid, hypoconid and entoconid occupying the same plane and a highly reduced posterior cingulum. M_3 of *M. narmadaensis* sp. nov. is larger than that of *M. flynni* and also has a larger hypoconid. The Narmada species is close to *Mus* sp. [2] in the relative position of cusps in the anterior chevron and a reduced posterior cingulum in M_1 but it has a much smaller size. Also, the connection of cusps is much stronger in the Narmada species. The present species is similar to *M. dhailai* [23,24] in the relative position of the labial and lingual anteroconid, protoconid, metaconid and in having a reduced posterior cingulum in M_1 and similarly placed hypoconid in M_3 but differs from it in having a much smaller M_1 and a bigger M_3 with a better developed hypoconid (**Tables 2 and 3**). A comparison of various species of *Mus* is shown in **Figure 3**.

3.4. Enamel Ultrastructure in Murid Incisor

The rodent enamel microstructure has the highest degree of complexity among mammals [46-50]. In most rodents, the incisor enamel is made up of two layers, an inner portion known as Portio Interna (PI) with intersecting prisms which appear as Hunter-Schreger Bands (HSB) in the longitudinal section, and an outer portion known as Portio Externa (PE) with radial enamel in which the prisms are oriented parallel to each other. The presence of these two layers in the rodent incisor enamel is regarded as a characteristic feature which distinguishes it from lagomorphs where only Portio Interna with HSB is developed [51]. Biomechanically, the HSBs serve as strengthening device inhibiting crack propagation [49,52-54], whereas the radial enamel of the Portio Externa helps to maintain a sharp cutting edge because of its higher resistance to wear [55-57]. The evolution of enamel of the rodent incisor is independent from that of the molar enamel [58].

In rodent incisors, three are three basic types of HSBs, e.g., pauciserial, multiserial and uniserial [46]. Pauciserial HSBs are primitive with highly variable band thickness [59,60]. This condition gave rise to the uniserial and multiserial HSBs. In the multiserial enamel, the HSBs are 3-6 prisms wide and are inclined to the Enamel Dentine Junction (EDJ) [61]; whereas, in the uniserial HSBs, the band thickness is reduced to a single prism and the Interprismatic Matrix (IPM) may be parallel or angular to the prism direction [50-61]. In the highly derived uniserial HSBs, the IPM runs rectangular to the prism direction and serves to strengthen the enamel in the third dimension. We studied the enamel ultrastructure of the incisor in the longitudinal section.

3.5. Lower Incisor of *Mus*; NAR/I4 (Figures 4(a)-(b))

The longitudinal section reveals a PI with typical uniserial HSBs which are two prisms thick and a PE with the radial enamel. The HSBs are inclined at an angle of 60° to the Enamel-Dentine Junction (EDJ) (**Figure 4(b)**). As

Table 2. Comparative length/width measurements of different species of *Mus*.

Name	Reference	Locality	Age	measurements (mm)			
				(M_1)		(M_3)	
				Length	width	length	width
Mus auctor	[2]	Dhok Pathan Fm., Upper Siwalik	5.7 ma	1.472	0.928	0.680	0.800
Mus sp.	[19]	Tatrot Fm., Upper Siwalik	2.5 ma	1.400	0.940	----	----
Mus flynni	[19]	Tatrot Fm., Upper Siwalik	2.5 ma	1.687	1.040	0.617	0.653
Mus jacobsi	[22]	Kashmir basin, NW India	2.4 ma	1.550	0.956	0.560	0.520
Mus sp.	[2]	Dhok Pathan Fm., Pakistan Siwalik	Early Pleistocene	1.490	0.90	----	----
Mus narmadaensis sp. nov.	present work	Devakachar, Narmada valley	Upper Pleistocene	1.270	0.730	0.760	0.640
Mus dhailai	[23]	South-central Kumaun Himalaya	Upper Pleistocene	1.582	0.968	0.613	0.645

Table 3. Characters and position of various cusps in different species of *Mus*

sp.	*Mus auctor*	*Mus* sp.	*Mus flynni*	*Mus jacobsi*	*Mus* sp.	*Mus narmadaensis* sp. nov.	*Mus dhailai*
locality	Dhok Pathan Fm., Pakistan	Tatrot Fm., Upper Siwalik	Tatrot Fm., Upper Siwalik	Kashmir basin, NW India	Dhok Pathan Fm. Pakistan	Devakachar, Narmada valley	South-central Kumaun Himalaya
age	Late Miocene	2.5 ma	2.5 ma	2.4 ma	Early Pleistocene	Late Pleistocene	Late Pleistocene
author	[2]	[19]	[19]	[22]	[2]	present study	[24]
M_1 lingual antero-conid	twice the size of labial anteroconid	twice the size of labial anteroconid	thrice the size of labial anteroconid	thrice the size of labial anteroconid	twice the size of labial anteroconid	slightly bigger than labial anteroconid	thrice the size of labial anteroconid
labial antero-conid	smaller and posteriorly displaced	very small/ posteriorly displaced	very small/ posteriorly displaced	very small/ posteriorly displaced	almost at same level of lingual anteroconid	almost at same level of lingual anteroconid	very small and posteriorly displaced
protoconid	posterior to metaconid	posterior to metaconid	almost at the level of metaconid	posterior to metaconid	posterior to metaconid	almost at the level of metaconid	posterior to metaconid
metaconid	smaller than protoconid	smaller than protoconid	almost equal to protoconid	almost equal to protoconid	smaller than protoconid	almost equal to protoconid	smaller than protoconid
hypoconid	posterior to entoconid	posterior to entoconid	almost at same level	posterior to entoconid	more or less at same level	more or less at same level	more or less at same level
posterior cingulum	medium large	large	large	large	Medium	small	medium
M_3 hypoconid	large, lingually placed	----	medium, centrally placed	large, labially placed	----	very large, centrally placed	small, lingually placed

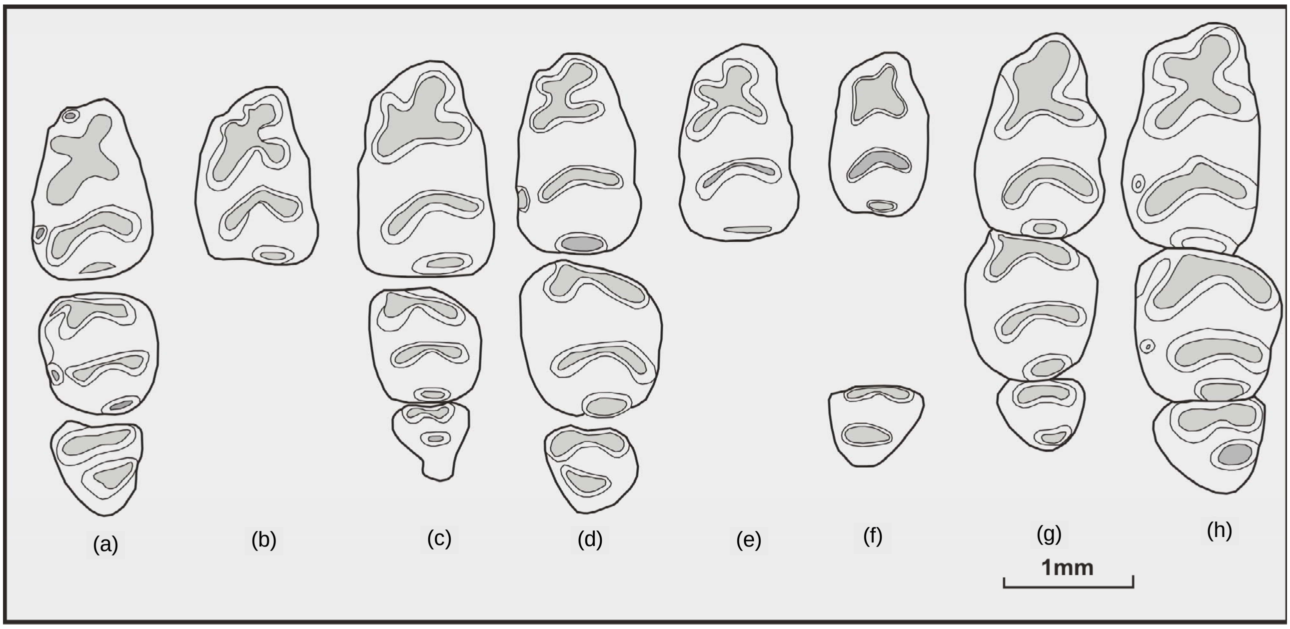

Figure 3. Comparative morphology of the lower molars in various species of Mus. (a) Mus auctor [2]; (b) Mus sp. [19]; (c) M. flynni [19]; (d) M. jacobsi [22]; (e) Mus sp. [2]; (f) M. narmadaensis sp. nov. (present study); (g) M. dhailai [23]; (h) M. shortridgei.

the bands move towards the outer enamel, the angle of inclination gradually decreases from 60º to 30º and the prisms become parallel to the EDJ. The prisms of alternating bands intersect at an angle of 90º at the PE-PI junction and the crystallites of the IP run perpendicular to the long axis of the prisms. The outer and thick enamel is made up of horizontal interlocking prisms. The IP makes an angle of about 90º with the longitudinal prisms of HSB.

The enamel thickness decreases towards the incisal

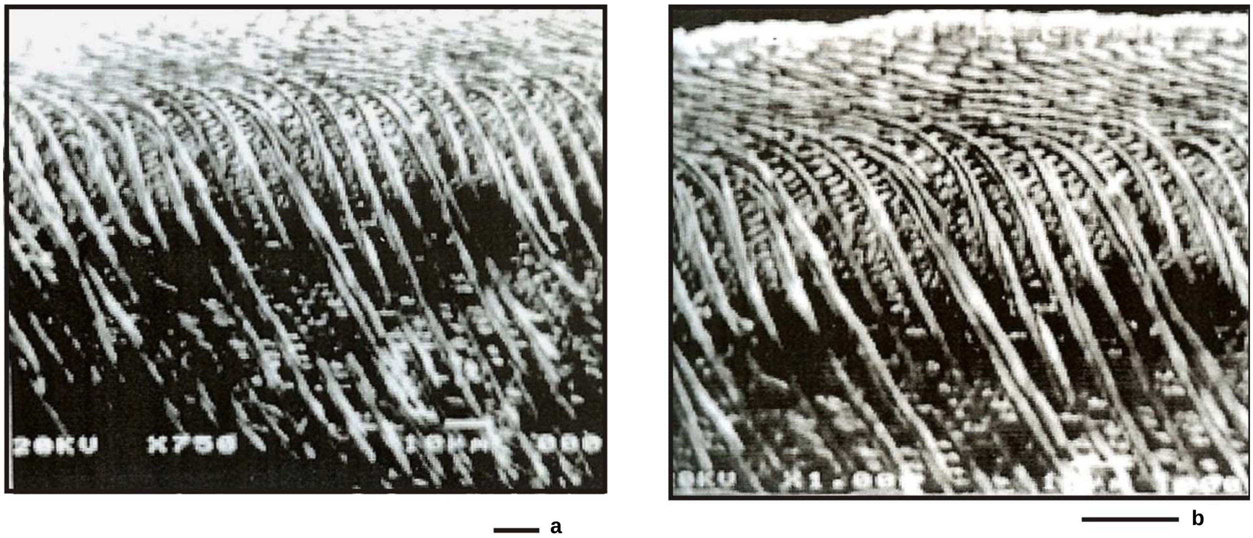

Figure 4. Longitudinal views of the enamel ultrastructure in the lower incisor in *Mus* (Bar represents 1 mm).

direction (**Figure 4(a)**). Near the tip of the incisor, the HSBs are more closely spaced just below the outer enamel and the IPM is dense below the PE. The PI is reduced towards the incisal end. At the tip of the incisor, only the radial enamel of the PE is present (**Figure 3(a)**). The crystallites of the IPM are rectangular and serve to strengthen the enamel in a third dimension. This feature is generally seen in the derived species of murids.

4. Discussion

The reduced posterior cingulum in M_1 in the present specimen points to its affinity with Pahari section of *Mus* [13]. In India, *Mus* is represented by three subgenera, *Mus* with *M. booduga* and *M. dunni*; *Pyromys* with *M. saxicola*, *M. shortridgei* and *M. platythrix;* and *Coelomys* with *M. mayori*, *M. pahari* and *M. crociduroides* [14]. *Coelomys* section includes Asiatic species such as *M. mayori, M. pahari, M. crociduroides* and *M. shortridgei* [13]. The Narmada *Mus* resembles *M. pahari* in general outline and the placement of cusps in the anterior chevron of M_1. However, the second chevron in M_3 of *M. pahari* is weakly developed and shows a small lingually placed hypoconid. *M. crociduroides* has a weak second chevron in M_3 and is therefore different from the present species. *M. mayori* differs from *M. narmadaensis* sp. nov. in having a posteriorly displaced protoconid in M_1 and a lingually placed and weakly developed hypoconid in M_3. Among the extant species, *M. narmadaensis* sp. nov. shows closest resemblance with *M. shortridgei* in having similarly placed protoconid and metaconid in M_1 and a well developed hypoconid in M_3.

A very small size of the *M. narmadaensis* sp. nov. may be attributed to its getting isolated from the stock at the onset of glacial age during the Pleistocene period. Murids are very sensitive to the climatic changes and it is believed that the onset of cold climatic conditions wiped out several species of murids while some migrated to warmer regions [25]. It may be postulated that *M. narmadaensis* sp. nov. was one of those species that migrated towards Central India from the Lesser Himalayan region at the onset of glaciation. It may have lived there in isolation for a considerable period due to which it could not evolve more progressively although its enamel shows some derived characters as much as in other Pleistocene species.

5. Acknowledgements

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