内蒙古宝格达乌拉晚中新世副竹鼠化石[1]

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摘要：描述了 1996−2007 年间在内蒙古阿巴嘎旗晚中新世宝格达乌拉组采集的副竹鼠化石。材料包括下颌骨 1 件、牙齿 14 枚和肢骨 4 件，分别采自该组的 2 个地点。根据标本较大的尺寸、形态特征，以及颊齿的釉质曲线高度，宝格达乌拉材料被归入三趾马层副竹鼠 *Pararhizomys hipparionum* Teilhard de Chardin & Young，1931。

　　Pararhizomys 是一类具高冠、脊形和冠面构造简单颊齿的啮齿动物。该属目前发现的化石地点少，材料也不多，主要集中于中国北方和蒙古高原周缘，其地史分布为晚中新世早期至上新世中期。

　　与鼢鼠类（siphneids）和䶄类（arvicolids）一样，*Pararhizomys* 属的颊齿有由低冠到高冠发展的趋势，具体表现为牙齿侧面釉质曲线（dentine tract）由平直、远离内外两侧谷底到起伏、接近甚至超过内外两侧谷底。为方便比较，本文为釉质曲线的高度设立"H"指数，即从每侧最深谷的谷底和釉质曲线的最高处取平行于冠面的平行线，此两平行线之间的垂直距离为"H"。H 值越大，表明齿冠越低，反之则齿冠越高。尽管目前发现的副竹鼠标本不多，但似乎可以看到从早期到晚期，其颊齿的个体有从小变大，釉质曲线高度 H 值逐渐减小，即齿冠逐渐增高的趋势。

　　由于 *Pararhizomys* 的牙齿形态多少与竹鼠类的低冠竹鼠 *Brachyrhizomys* 和竹鼠属 *Rhizomys* 及拟速掘鼠属 *Tachyoryctoides* 有相似之处，故常被与 *Brachyrhizomys* 和 *Rhizomys* 一起归入竹鼠科（Rhizomyidae），但该属的牙齿不具中脊和下中脊，褶沟少，一般为 2−3 个，与上述三属有明显的不同。本文对下门齿所作的切片观察也表明，*Pararhizomys* 的釉质层结构与 *Brachyrhizomys*，*Rhizomys* 和 *Tachyoryctoides* 者相差甚远，其内层（PI）明显增厚，釉柱和釉柱间质（IPM）的排列方式存在明显差别。颊齿的冠高、冠面形态，以及下门齿的釉质层结构，似乎都表明了 *Pararhizomys* 属不大可能归入竹鼠科或速掘鼠科（Tachyorictoididae）。而下门齿釉质层切片显示了 *Brachyrhizomys* 与 *Rhizomys* 有着高度相似的釉质结构，进一步证明了两者有较接近的亲缘关系。

　　地理分布上，*Pararhizomys* 与 *Tachyoryctoides* 属只发现于古北区，伴生的哺乳动物显示了其可能适应偏冷、干旱的草原环境，而 *Brachyrhizomys* 和 *Rhizomys* 主要局限于东洋区，共生的哺乳动物多能适应温暖、湿润的树林环境。

关键词：内蒙古，晚中新世，宝格达乌拉组，副竹鼠，釉质微结构，地理分布

PARARHIZOMYS (RODENTIA, MAMMALIA) FROM THE LATE MIOCENE OF BAOGEDA ULA, CENTRAL NEI MONGOL

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Abstract　New material of *Pararhizomys* from the Late Miocene Baogeda Ula Formation of central Nei Mongol are described, which is referred to *P. hipparionum* Teilhard de Chardin & Young, 1931 based on the size, morphology and dentine tract height of teeth. *Pararhizomys* are scarcely known from the area around the Mongolian Plateau chronologically from the early Late Miocene throughout Middle Pliocene. The genus is similar to *Brachyrhizomys*, *Rhizomys* and *Tachyoryctoides* in having a simple dental pattern, but can be distinguished from them by its absence of mesoloph(id)s and having only 2–3 reentrants on the molars. For expediently judging and comparing of this genus with others, an "H" index has been set for measuring the height of dentine tract of molars, and the lower incisor of *P. hipparionum* from Baogeda Ula was sectioned to observe the enamel microstructure. The dentine tract of *Pararhizomys* seems to have the gradually heightening and undulating tendency in its evolution, as the same in siphneids and arvicolids. The enamel microstructure of lower incisor of *P. hipparionum* is remarkably different from those of the rhizomyines *Brachyrhizomys* and *Rhizomys* and tachyoryctoidid *Tachyoryctoides* by the very thick inner portion of enamel and arrangement of prisms and interprismatic matrix. According to the morphology of cheek teeth and enamel microstructure of incisor, it seems that *Pararhizomys* could not be included in Rhizomyidae, and possibly represents a separate lineage. *Pararhizomys* and *Tachyoryctoides*, restricted biogeographically within the Palaearctic Region appears to be adapted for temperate, arid and steppe environment, whereas *Brachyrhizomys* and *Rhizomys* are the typical factors of the Oriental Realm, living in a warmer, more humid and forested environment.
Key words　Nei Mongol, Late Miocene, Baogeda Ula Formation, *Pararhizomys hipparionum*, enamel microstructure, biogeography

The genus *Pararhizomys* is a group of muroid rodents with lophodont and hypsodont cheek teeth. There are usually three or two transverse reentrants and no mesoloph(id) on the teeth. Only two species, *Pararhizomys hipparionum* Teilhard de Chardin & Young, 1931 and *P. qinensis* Zhang et al., 2005, thus far have been attributed to this genus. *P. hipparionum* are known from Loc. 10, Chengqiangpao and Lamagou, Fugu County, Qin'an and Linxia, Gansu Province, Gaotege, Nei Mongol and Altan Teli, Mongolia, while *P. qinensis* is only known from Lantian, Shaanxi Province (Teilhard de Chardin, 1926; Teilard de Chardin and Young, 1931; Teilhard de Chardin and Leroy, 1942; Kowalski, 1969; Deng, 2004; Zhang et al., 2005). Scattered material of this animal was also reported from the Qaidam Basin (Qiu and Li, 2008). In brief, this genus was restricted geographically in northern China, and chronologically from the early Late Miocene throughout Middle Pliocene (Fig. 1). In recent years, some new material of *Pararhizomys* was collected from Baogeda Ula in central Nei Mongol (Inner Mongolia)(Qiu et al., 2006). This paper describes the material from Baogeda Ula and discusses the possible family assignment of the genus based on its teeth morphology and incisor enamel microstructure.

The described fossils were collected from two sites, IM0702(44°08′19.3″N, 114°35′39.3″E), about 6 km northeast of Baogeda Ula Sumu, Abaga Qi, and IM0703(44°09′51.5″N, 114°35′50.0″E), ~2.8 km north from IM0702(Fig. 2). Association with the remains is *Hipparion* fauna from the middle part of the Baogeda Ula Formation, which is at least 70 m thickness in average (BGMRNMAR, 1991; Qiu and Wang, 1999; Qiu et al., 2006; Tseng and Wang, 2007). Sediments of this formation consist predominantly of a series of grayish green and brown yellow silty mudstones and muddy siltstones, and are capped by a layer of basalt dated to (7.11 ±0.48) Ma (Luo and Chen, 1990).
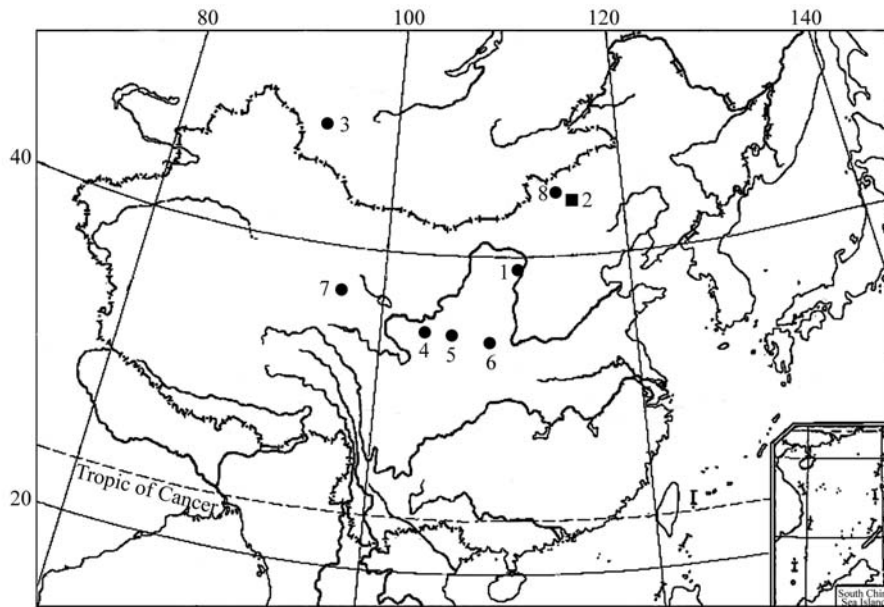
Fig. 1   Geographical distribution of the *Pararhizomys*
1. Fugu, Shaanxi; 2. Gaotege, Nei Mongol; 3. Altan Teli, Mongolia; 4. Linxia, Gansu; 5. Qin'an,
Gansu; 6. Lantian, Shaanxi; 7. Shengou, Qinghai; 8. Baogeda Ula, Nei Mongol
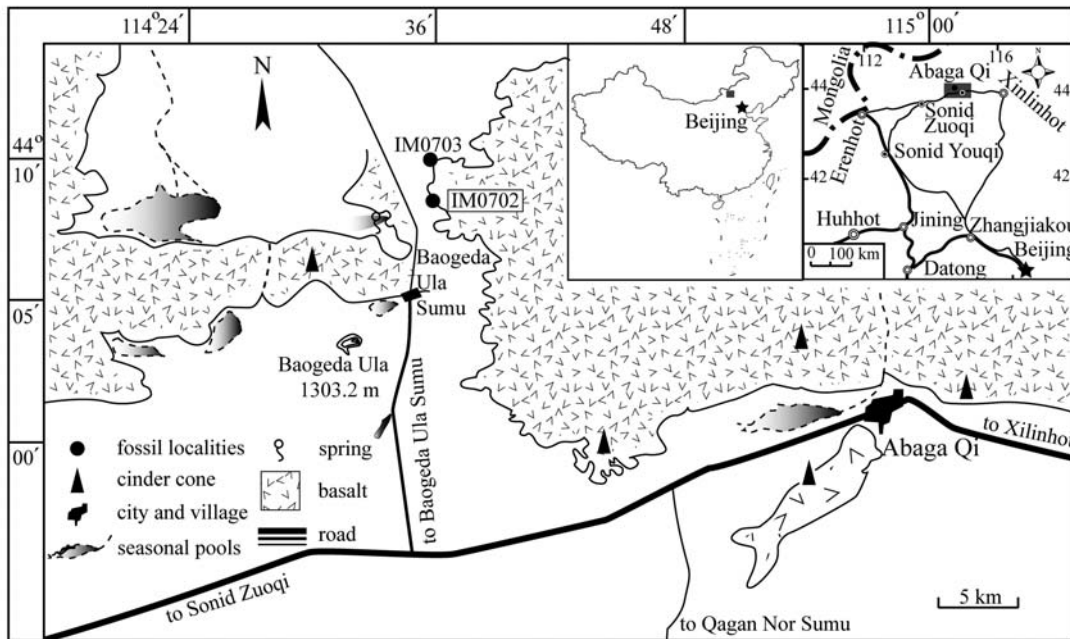filled circle, Miocene; square, Pliocene

Fig. 2   Geographic location of the fossil site Baogeda Ula in central Nei Mongol

Similar to that of other hypsodont rodents such as arvicolids (Repenning, 2003) and siph-neids (Zheng et al., 2004), the "dentine tract" (= DT, Repenning, 2003) is a potentially important character in *Pararhizomys*. In the evolution of these hypsodont rodents, DT becomes gradually heightened. To measure the relative heights of the dentine tracts on the cheek teeth of *Pararhizomys*, here the author sets an index H, which is defined as the vertical distance between the lines that go through the bottom of the deepest reentrant and the top of DT, respec-

tively, and that parallels the occlusal line from the lateral sides (Fig. 3).

Teeth were measured with a Wild Heerbrugg microscope to the nearest 0. 01 mm.

Terms for enamel microstructure (cited from Martin 1993; Koenigswald and Sander, 1997 and Koenigswald, 2004): EDJ, enamel-dentine junction; HSB, Hunter-Schreger bands; IPM, interprismatic matrix; PE, outer portion of enamel; PI, inner portion of enamel.

IVPP, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences; V, prefix to vertebrate fossils of IVPP; OV, prefix to specimens in the recent vertebrates collection of IVPP; IM, Inner Mongolia (Nei Mongol), prefix to the field numbers of IVPP; Z. Pal., Institute of Systematic Zoology, Polish Academy of Sciences, Kraków, Poland.

Fig. 3　Measurement indexes of the height of the "dentine tract"
L. maximal occlusal length; W. maximal occlusal width; LNH. lingual DT height; LAH. labial DT height

Superfamily Muroidea Illiger, 1811
Family *incertae sedis*
Pararhizomys Teilhard de Chardin & Young, 1931
Pararhizomys hipparionum Teilhard de Chardin & Young, 1931
(Figs. 4–6)

2006 *Pararhizomys* sp. Qiu et al., p. 181, appendix

Material and measurement　Nineteen specimens: IM0702, a broken mandible with m1−3 (V 16306. 1), 2 fragments of I (V 16306. 2−3), 2 fragments of i (V 16306. 4−5), 1 left M1 (V 16306. 6), 1 right M1(V 16306. 7), 4 left M2(V 16306. 8−11), 1 left M3(V 16306. 12), 1 right m1(V 16306. 13), 1 rihgt m2(V 16306. 14), 1 left talus (V 16306. 15), 3 metatarsals (V 16306. 16−18). V 16306. 1−8 and V 16306. 15−18 possibly belong to the same individual; IM0703, 1 right M2(V 16307)(Measurements see Table 1).

Table 1　Measurements of cheek teeth of *Pararhizomys hipparionum* from Baogeda Ula　(mm)

locality	inventory No.	molars	L	W	LNH	LAH
IM0702	V 16306. 6	LM1	4. 25	3. 50	—	1. 10
	V 16306. 7	RM1	4. 20	3. 45	—	0. 80
	V 16306. 8	LM2	3. 00	3. 30	—	0. 75
	V 16306. 9	LM2	3. 10	3. 75	—	—
	V 16306. 10	LM2	2. 85	3. 00	—	—
	V 16306. 11	LM2	2. 65	3. 10	—	—
IM0703	V 16307	RM2	2. 95	3. 30	1. 70	1. 25
IM0702	V 16306. 12	LM3	2. 00	2. 45	0. 20	0
	V 16306. 1	Lm1	3. 90	3. 20	1. 00	1. 70
		Lm2	3. 50	3. 70	0. 95	—
		Lm3	3. 10	3. 15	0. 25	—
	V 16306. 13	Rm1	3. 60	3. 00	1. 00	—
	V 16306. 14	Rm2	3. 25	3. 60	0. 90	1. 40

Description　Mandible is robust，preserved the middle portion（Fig. 4）. The diastema is steeply concave and ～4. 92 mm in length. The depth between alveolar line and the bottom of the diastema is 2. 90 mm. The elliptic and anterior-ventrally opened mental foramen is located beneath the anterior wall of the m1. The height between the mental foramen and the alveolar line is 6. 80 mm. The superior crest and inferior masseteric crest converge anteriorly in the shape of a "V", with the latter being stronger than the former. The apex of the masseteric crests reaches the level of the posterior root of m1 and is obviously higher than the mental foramen. The ascending ramus begins laterally from the labial side of m2. The foramen mandibulae is elliptic and situated between the ascending ramus and the dentition. The incisor root cavity curves anterior-lingually and crosses through between the anterior and posterior rootlets of m3.
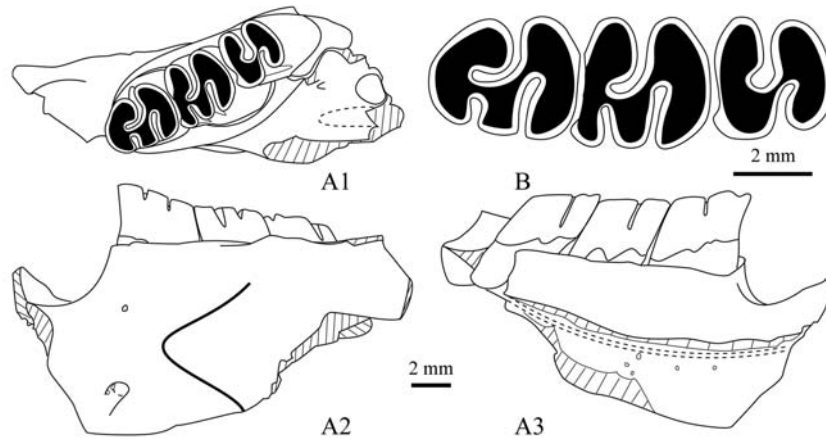

Fig. 4　Mandible and dentition of V 16306. 1
A1. occlusal view；A2. labial view；A3. lingual view，A1–3 are in the same scale；
B. occlusal view of dentition

Dentition：The length of m1–m3 is 10. 4 mm. In occlusal view, the dentition curves postero-lingually. The molars are anteriorly oblique and moderately worn. The m1 – m2 have three open reentrants, but m3 has only two. There is no cement in the reentrants. The lingual reentrants are deeper than the labial ones. The occlusal outline of m1 is oval shaped. The inflated metaconid on the m1 fuses with anteroconid and forms a converse C type loph as the cap of the tooth. The occlusal surface of the protoconid is nearly worn into a square. The protosinusid is transverse and short, and less than half width of the crown. The mesosinusid extends transversely to the ordinate axis of the tooth and then curves strongly anteriorly to end in the same level as the protosinusid. The sinusid extends transversely about one third of the occlusal surface then curves postero-lingually and exceeds the ordinate axis. The morphology of m2 is similar to that of m1, except for its wider anterior part with rounder protoconid, and the protosinusid and sinusid extending more antero-lingually and transversely, respectively. The m3 is the smallest one with a simple S-shaped occlusal pattern. The lingual dentine tracts are uplifting and undulated from rearward to foreside. The LNHs from m1 to m3 are 1. 0 mm, 0. 95 mm and 0. 25 mm, respectively.

Incisors are isolated and damaged. They are triangular in section（Fig. 5）. It is difficult to distinguish the upper incisors from the lower one. Differences of the degree of curvature and the lengths of the worn facets between upper and lower incisors is assumed and potentially used to distinguish them. Provided the incisor curves into a simple circle, the radius of curvature should just be the radius of the circle. Using a kind of new digital viewer—Aigo GE-5（Beijing Huaqi Information Digital Technology Co., Ltd（aigo）），we can expediently choose three random dots on the dorsal surface and figure out the radius of circle by its accessory software. Incisors preserved on two extant *Rhizomys* skulls have been measured together with the fossil inci-

sors to show the metrical differences between the upper incisors and lower ones (Table 2). The measurements show that in the same individual of *Rhizomys*, the length of worn facet and the radius of curvature of upper incisors are remarkably shorter than those of the lower ones. However, the width of worn facet and the depth of the upper incisor approximate those of the lower ones. Based on the obvious different lengths of worn facet and the radiuses of curvature, V 16306.2 and V 16306.3 should be attributed to upper incisors, and V 16306.4 and V 16306.5 to lower ones. Besides the metric differences mentioned above, a weak ridge is developed only on the dorsal surface of the upper incisors, whereas smooth in the lower ones. Furthermore, the enamel layers wrap around the sides of the tooth to a larger extent on the lower incisors compared to the uppers.

Table 2　Measurements of incisors of *Pararhizomys hipparionum* and extant *Rhizomys*　（mm）

| Species	Specimens	Incisors		Depth of incisor	Length of worn facet	Width of worn facet	Radius of curvature
Rhizomys sinensis	OV 1077	upper	left	5.80	8.40	5.50	12.91
			right	5.70	8.84	5.10	14.30
		lower	left	6.20	12.50	5.30	23.14
			right	6.30	12.00	—	27.76
Rhizomys sp.	OV 1055	upper	left	5.00	6.40	4.64	16.81
			right	5.10	6.60	4.60	19.39
		lower	left	5.20	9.60	4.30	33.52
			right	5.40	9.90	4.50	28.67
Pararhizomys hipparionum	V 16306.2	upper	left	4.30	7.20	3.50	12.50
	V 16306.3		right	4.26	7.36	3.60	12.79
	V 16306.4	lower	? left	—	—	3.40	21.51
	V 16306.5		right	4.40	9.00	3.54	22.59
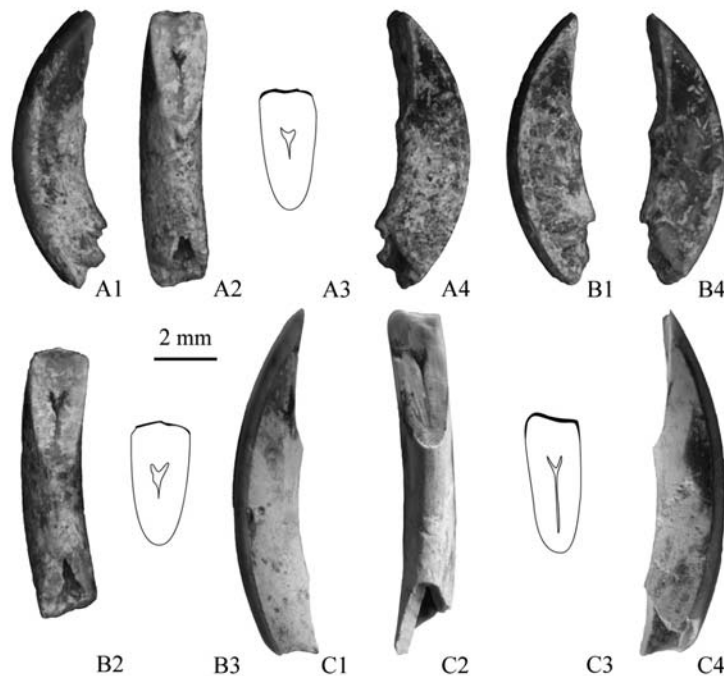
Fig. 5　Incisors of *Pararhizomys hipparionum* from Baogeda Ula
A. left I, V 16306.2; B. right I, V 16306.3; C. right i, V 16306.5
1. medial view; 2. ventral view; 3. worn facet; 4. lateral view

Seven isolated upper molars are in the collection. All the upper molars are obviously recurved in lateral view. There is no cement in the reentrants.

M1s have oval occlusal outline. A lingual and two labial reentrants form a "ω" occlusal pattern. The sinus and parasinus are directed forwards and alternately arranged, reaching about half width of the tooth. The mesosinus extends transversely to the occlusal ordinate axis then bends backwards. The entire mesosinus occupies about two-thirds of the width of the crown. In the lingual side of V 16306.7, a small conule is developed at the bottom of sinus. Due to the erosion, the LNHs of the two M1s are unrecognized, while the LAHs on V 16306. 6 and V 16306.7 are measured 1. 10 mm and 0. 80 mm, respectively. M1s have two flat and wide roots. A small rootlet can be seen in the lingual side of V 16306.6, while this rootlet is fused into the posterior rootlet on V 16306.7(Fig.6).

Two M2s, V 16306.8 and V 16307 are well preserved. The occlusal pattern is a very sim-ple "S" type. On V 16306.8, a distinct small nodule is present at the edge of the valleys, and the dentine tract rises sharply to join to the nodule on lingual side but does not reach on labial side. The LAH of V 16306.8 is 0.75 mm. V 16307 lacks a small nodule, and its dentine tract is relatively smooth. The LNH and LAH of the tooth are 1. 70 mm and 1. 25 mm, respectively. Two rooted.
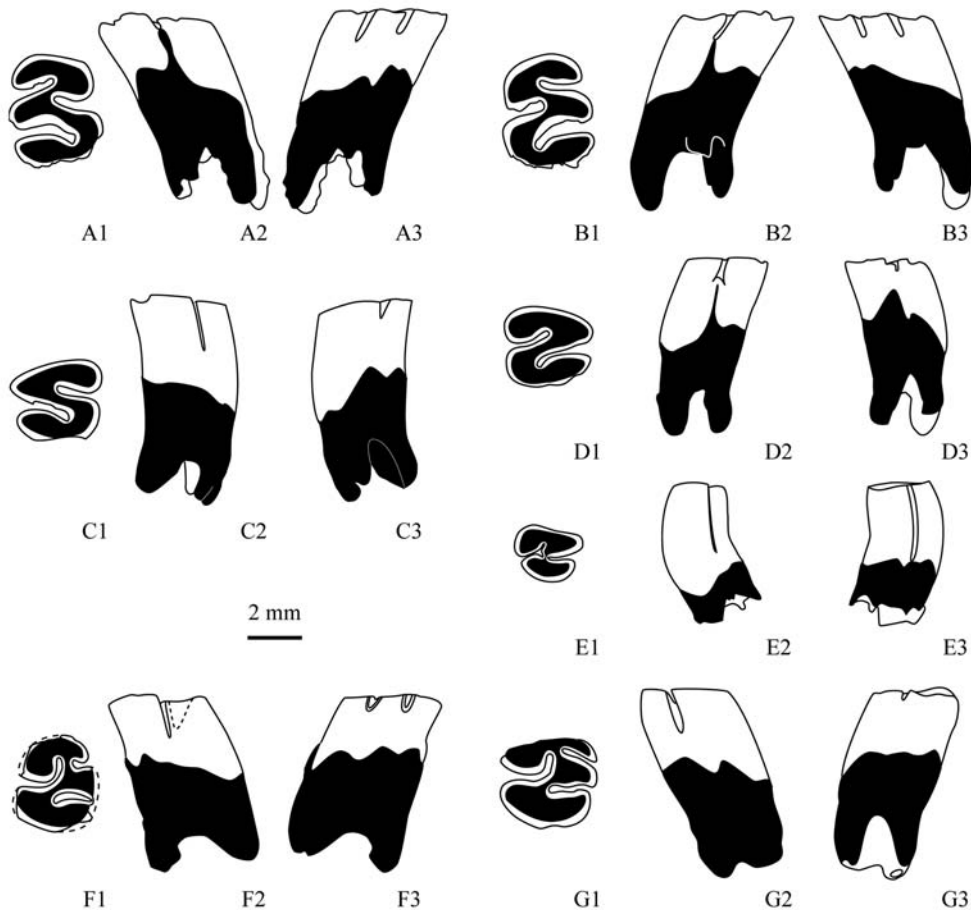
Fig. 6　Cheek teeth of *Pararhizomys hipparionum* from Baogeda Ula
A. V 16306.7, right M1; B. V 16306.6, left M1; C. V 16307, right M2; D. V 16306.8, left M2;
E. V 16306. 12, left M3; F. V 16306. 13, right m1; G. V 16306. 14, right m2
1. occlusal view; 2. lingual view; 3. labial view

M3 is slightly worn. The occlusal pattern is similar to that of M2, but the posterior portion is laterally pinched, and the ridge between anterior and poster loph is weak and the lateral reen-trants are relatively oppositely arranged. The LNH measures 0. 20 mm, while the LAH is zero. Two rooted.

The size, morphology and worn degree of the isolated m1 are very similar to that of the m1 in the mandible. Its LNH is 1.0 mm. The isolated m2(V 16306.14) agrees with the m2 in the mandible in size and morphology, except for its more antero-lingually directed protosinusid. The dentine tract is jagged lingually, while gently descending from front to back labially.

Comparisons and discussion　According to the characters of absent mesoloph(id) and having less 2–3 reentrants on molars, the material from Baogeda Ula belongs to the genus *Pararhizomys*. In size, the Nei Mongol taxon is closest to *P. hipparionum* from Altan Teli and type-locality at Fugu, but distinctly larger than the *P. hipparionum* (V 14179) from Qin'an and *P. qinensis* (V 14177.1–2) from Lantian. However, it is slightly smaller than the indeterminate species from Shengou (Table 3; Fig.7).

Table 3　Teeth measurements for *Pararhizomys* 　　　　　　　　　(mm)

Species	M1 L	M1 W	M2 L	M2 W	M3 L	M3 W	m1 L	m1 W	m2 L	m2 W	m3 L	m3 W
P. hipparionum												
Loc. 10 Fugu holotype							3.7	2.45	3.5	3.45	2.55	2.95
Gaotege			3.0	3.5								
Altan Teli	4.4	3.6	3.0	3.3	2.4	2.5	3.8	3.2	3.3	3.6	3.0	2.9
Lamagou (V 14178)	3.75	3.0	2.7	3.1	2.4	2.5						
Qin'an (V 14179)							3.3	2.85	3.4	3.4	2.95	2.85
Shengou (V 15468)									3.65	3.85		
Baogeda Ula	4.20~4.25	3.45~3.50	2.65~3.10	3.0~3.75	2.0	2.45	3.6~3.9	3.0~3.2	3.25~3.5	3.6~3.7	3.1	3.15
P. qinensis												
Lantian (V 14177.1–2)	3.3	2.5	2.4	2.5								

No distinct morphological differences among the teeth from Baogeda Ula and other localities can be detected. Minor difference is the existence of a small tubercle on the bottom of the sinus in some M1 and M2s from Baogeda Ula (Fig.6). The Baogeda Ula *Pararhizomys* differs from the *P.* sp. from Shengou in having a narrow m2 with less transverse reentrants.

The heights of dentine tracts on the teeth from Baogeda Ula are close to those of *P. hipparionum* from all the known localities except Qin'an, but distinctly smaller than those of *P. hipparionum* from Qin'an and *P. qinensis* from Lantian. The *Pararhizomys* from Gaotege is higher crowned, on which the labial dentine tract is uplifted to the bottom of valley.

Considering all of above features, the material from Baogeda Ula can be referred to *P. hipparionum*. Based on the small size and larger dentine tract height of teeth, "*P. hipparionum*" from Qin'an seems to be possibly not suitable referred to this species.

The earliest *Pararhizomys* was *P. qinensis* found from lower part of Bahe Formation, Lantian, considered to be around 10 Ma based on commensal fossil mammals and paleomagnetic results (Zhang et al., 2002; Qiu et al., 2003; Kaakinen and Lunkka, 2003). *P.* sp. from Shengou was found in coexsistence with *Lophocricetus*, *Protalactaga*, *Myocricetodon*, *Huerzelerimys* and *Ochotonoma*, which is very close to but slightly younger than the fauna of the lower part of Bahe Formation. The age of Shengou fauna was contributed to early Late Miocene around 9 Ma (Qiu and Li, 2008). The site of the maxilla V 14178 of *P. hipparionum* from Lamagou, Fugu was dated about 8 Ma in Xue et al. (1995). The lower jaw V 14179 of *P. hipparionum* was found at about 9 m level in the first section of Qin'an, which was paleomagnetically dated at about 7 Ma (Guo et al., 2002). The new material of *P. hipparionum* from Baogeda Ula co-occurred with *Hyaenictitherium*, *Hipparion*, *Lophocricetus*, *Paralactaga*, *Dipus*, *Kowalskia*, *Microtoscoptes*, *Hansdebruijnia*, *Abudhabia* and *Prosiphneus*, which was suggested an MN 12 equivalence of the late Baodean (Qiu et al., 2006). The basalt capped section of Baogeda Ula Formation was once dated at (7.11±0.48) Ma (Luo and Chen, 1990). The recent K-Ar testing results of the basalt measured by the State Key Laboratory of Earthquake Dynamics, Institu-

Fig. 7　Log ratio diagram comparing the lower teeth of *Pararhizomys hipparionum* C/90（holotype）
from type locality, Chengqiangpu, Fugu（filled circle, as standard）, Z. Pal. No. MgM-V/65 from Altan
Teli, Mongolia（open circle）, V 14179 from Qin'an, Gansu（square）and V 16306.1 from Baogeda Ula,
Nei Mongol（triangle）
Measurement data of Z. Pal. No. MgM-V/65 from Altan Teli was cited from Kowalski（1969）

te of Geology, China Earthquake Administration（SKLED）ranges（6. 8±0. 2）~（6. 3±0. 2）
Ma. Thus the fossil level should be at least older than 6. 3 Ma. The holotype of *P. hipparionum*
was collected from Loc. 10, Fugu, which age is still uncertain. According to the greater size
and uplifted dentine tract, its age seems to be between of those of Qin'an and Baogeda Ula.
Gaotege is the only Pliocene locality producing *Pararhizomys*. Judged from the fauna composi-
tion and paleomagnetic data（Li et al., 2003; Xu et al., 2007）, the fossil level should be about
4. 2 Ma in age.

　　The depth and direction of reentrants on molars of *Pararhizomys* is changeable with the
wear of teeth. Dentine tract is an important character for the Neogene hypsodont teeth of ro-
dents, such as arvicolids and siphneids. It is usually unbent and far away from the valleys in
brachydont teeth, but undulant and close or exceeding the bottom of valleys in hypsodont teeth.
The uplifting and undulating of dentine tract also could be observed in *Pararhizomys*（Table 4;
Fig. 8）, but could not be observed in *Brachyrhizomys*, *Rhizomys* and *Tachyoryctoides*.

Table 4　Dentine tract measurements for *Pararhizomys* （mm）

Species	M1		M2		M3		m1		m2		m3	
	LNH	LAH	LNH	LAH	LNH	LAH	LNH	LAH	LNH	LAH	LNH	LAH
P. hipparionum Baogeda Ula		1. 10	1. 70	0. 75 ~1. 25	0. 20	0	1. 00		0. 90 ~0. 95	1. 40	0. 25	
Loc. 10 Fugu holotype							0. 90		0. 80		0. 30	
Lamagou（V 14178）	1. 25	0. 70	1. 15	0. 85	0. 85	0. 55						
Qin'an（V 14179）							1. 30		1. 50		0. 45	
P. qinensis Lantian（V 14177. 1–2）	1. 40	1. 25	1. 50	1. 50								
P. sp. Shengou（V 15468）									0. 80	1. 15		
P. sp. Gaotege			0									

In early Late Miocene, the teeth of *P. qinensis* are small in size with relatively smooth dentine tract. A little later, *P. hipparionum* occurred in late Late Miocene with large size, high crown and dentine tract undulating teeth. In Middle Pliocene, tooth of *Pararhizomys* shows the higher crown, on which the dentine tract is uplifting to the level of the bottom of valley. Fig. 8 shows a possible tendency of increasing size and heightening dentine tract (equal increasing of the height of teeth crown) in *Pararhizomys*.
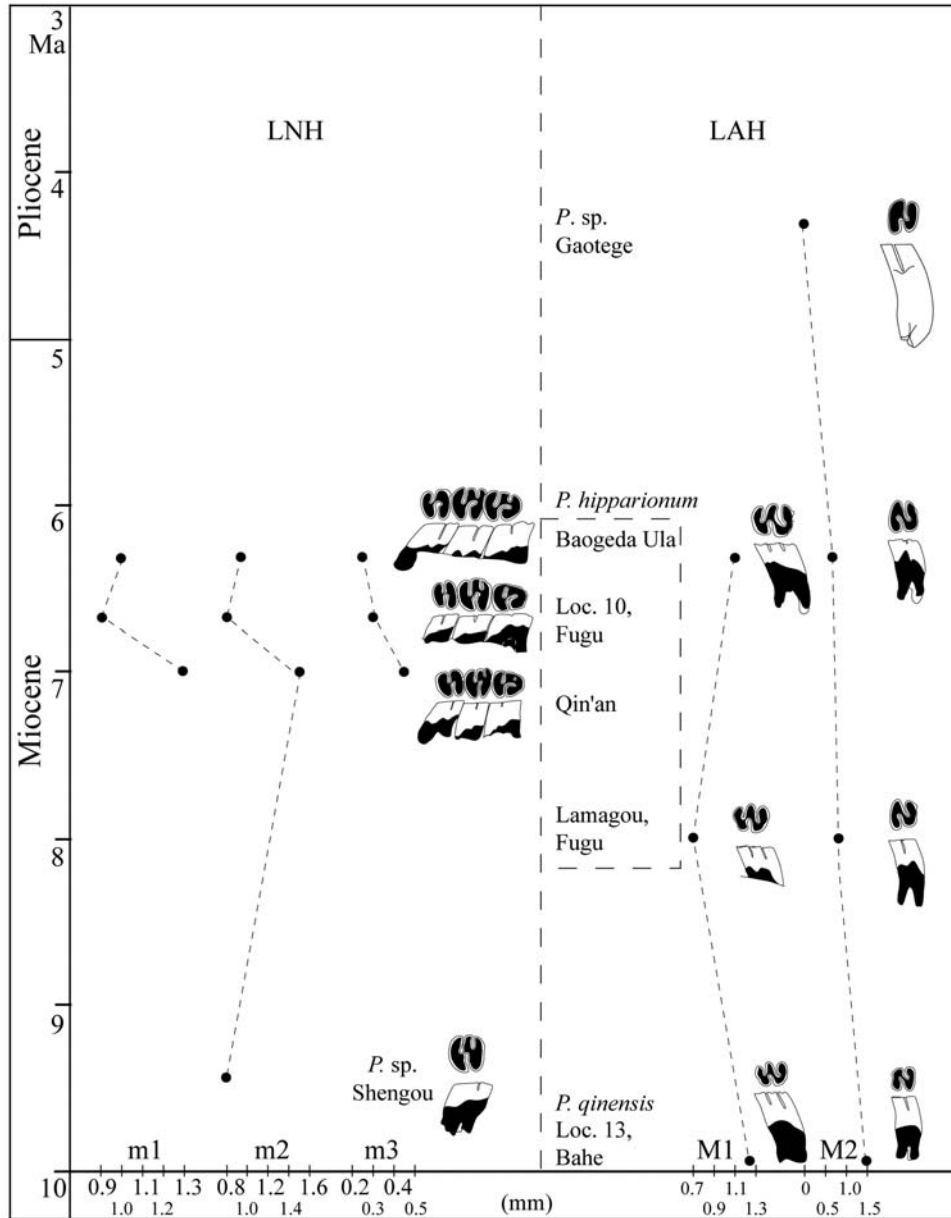
Fig. 8　Evolutionary tendency of the molars of *Pararhizomys* showing heightening of dentine tracts
X-axis, lingual and labial heights of dentine tracts of lower and upper molars, respectively; Y-axis,
estimated ages of localities yielding *Pararhizomys*
Teeth outlines of *P.* sp. from Shengou and Gaotege are reversed

Enamel microstructure of lower incisor　The material chosen for the investigation and comparison of enamel microstructure are listed in Table 5. All the four specimens are isolated lower incisors because the associated skulls and mandibles are rare.

Table 5 ***Pararhizomys hipparionum* and relevant rodent lower incisors examined**

Taxon	Locality	Age
Pararhizomys hipparionum	Baogeda Ula, Nei Mongol	Late Miocene
Rhizomys sp.	Baotanshi, Damiao, Wushan, Sichuan	Middle Pleistocene[*]
Brachyrhizomys sp.	Lufeng, Yunnan	Late Miocene[**]
Tachyoryctoides sp.	Aoerban, Nei Mongol	Early Miocene[***]

[*] cited from Zheng (1993); [**] cited from Qi (1986); [***] cited from Wang et al. (2009).

Specimens were imbedded in artificial resin, and then sectioned longitudinally and transversely. After abrading and polishing, they were etched for 35 ~ 45 seconds with 0.1 mol phosphoric acid. After rinsing and drying, the specimens were coated with gold and examined with a scanning electronic microscope (JSM–6100).

The lower incisor of *Pararhizomys hipparionum* from Baogeda Ula is subtriangular in cross section, with a slightly flat lingual side. The ventral surface of incisor is flat and smooth, and has no groove or ridge (Fig. 9).
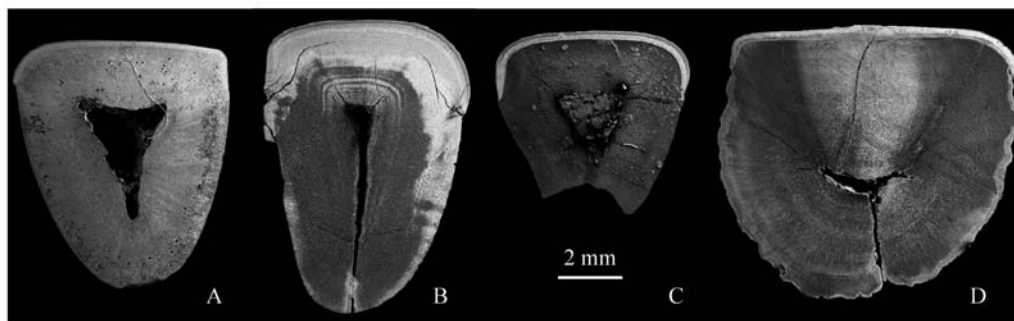
Fig. 9　Cross sections showing the outline of lower incisors
A. *Pararhizomys hipparionum*, Baogeda Ula; B. *Brachyrhizomys* sp., Lufeng; C. *Rhizomys* sp., Wushan;
D. *Tachyoryctoides* sp., Aoerban

Observed both from longitudinal and cross sections (Fig. 10, 11), the total enamel thickness is ~190 μm in *P. hipparionum*, while ~246 μm in *Rhizomys*, ~269 μm in *Brachyrhizomys* and ~246 μm in *Tachyoryctoides*, respectively. The outer portion of enamel (PE) of *P. hipparionum* is very thin with only ~36 μm in thickness, and the ratio of PE/PI is about 3/13. On the contrary, PE of the other three is relatively thicker, and their ratios of PE/PI are about 1.1/1 in *Rhizomys*, 1.06/1 in *Brachyrhizomys* and 3/5 in *Tachyoryctoides*, respectively.

In the four specimens, their "Schmelzmuster" of incisor enamel is all uniserial HSB (Hunter-Schreger bands) type. In the longitudinal section, the structure of "basal ring of lamellar enamel (BRLE)" (Koenigswald and Sander, 1997) is not present in *P. hipparionum*, but distinctly developed in *Rhizomy*, *Brachyrhizomys* and *Tachyoryctoides*. In the longitudinal sections, two parallel layers of prisms form the planar thick PI of *P. hipparionum*, while perpendicular prisms form the three-dimensional thin PI of the other three specimens (Fig. 12). Prisms of adjacent layers of PE in *Rhizomys* and *Brachyrhizomys* are decussating with an angle of about 90°, while parallel and oblique about 45° relative to the EDJ in *Tachyoryctoides* and parallel and vertical to the EDJ in *Pararhizomys*, respectively. In the PI of cross section, two parallel layers of prisms are decussating with an angle of about 90° in *Rhizomys* and *Brachyrhizomys*, while only one layer vertical to the cross section and oblique to the EDJ is present in *Pararhizomys* and one layer of robust, parallel and oblique prisms is present in *Tachyoryctoides*. In cross section, prisms of PE in *Rhizomys*, *Brachyrhizomys* and *Tachyoryctoides* are present in net style, whereas in *Pararhizomys* they are parallel each other and vertical to the EDJ (Fig. 12). Compared with that of *Pararhizomys*, the enamel microstructure of the lower incisor of *Tachyo-*

ryctoides is rather close to those of *Rhizomys* and *Brachyrhizomys*.
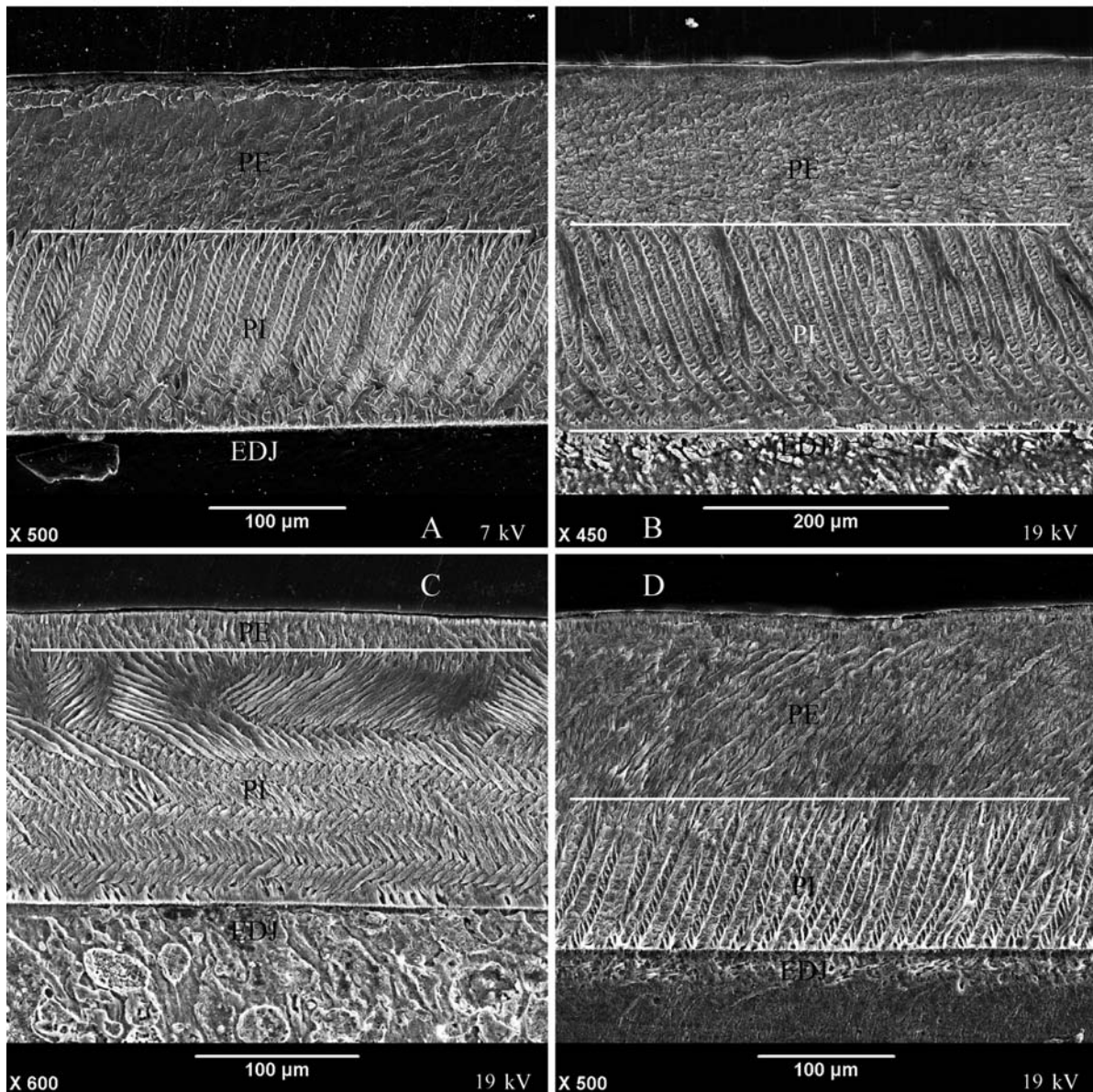

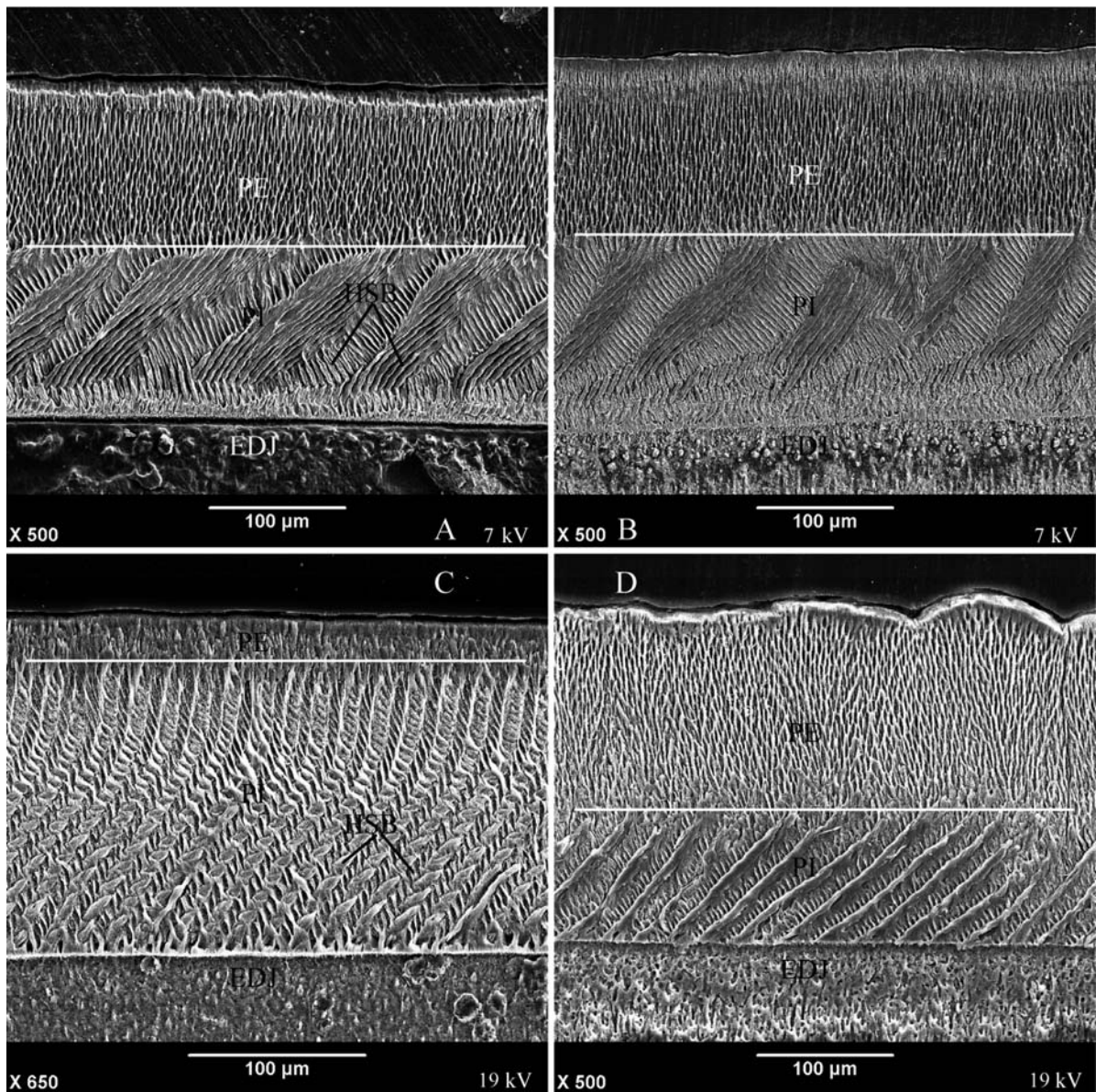Fig. 10　Longitudinal sections of lower incisors
A. *Rhizomys* sp. from Wushan; B. *Brachyrhizomys* sp. from Lufeng; C. *Pararhizomys hipparionum* from Baogeda Ula; D. *Tachyoryctoides* sp. from Aoerban

Biochronology and biogeography of *Pararhizomys* *Brachyrhizomys* was regarded as the direct ancestor of extant *Rhizomys*, and found from Late Miocene Siwalik south of Himalaya Mountain and southern China to Pliocene Yushe of northern China (Flynn, 1982, 1993; Qi, 1986). Based on the morphology of teeth and masseteric crests of mandible, Flynn (1993) referred *Brachyrhizomys* as a subgenus of *Rhizomys* under family Rhizomidae. Thus the broad sense genus *Rhizomys* possibly survive from early Late Miocene to today. The arrangement of prisms and interprismatic matrix in both longitudinal and cross sections of *Rhizomys* is similar to that of *Brachyrhizomys*, which possibly indicates a close phylogenetic relationship between them.

All the known localities of *Pararhizomys* are restricted in the Palaearctic region, while those of *Brachyrhizomys* and *Rhizomys* are mainly in the Oriental area. Judged from the co-oc-

Fig. 11　Cross sections of lower incisors
A. *Rhizomys* sp. from Wushan; B. *Brachyrhizomys* sp. from Lufeng; C. *Pararhizomys hipparionum* from Baogeda Ula; D. *Tachyoryctoides* sp. from Aoerban
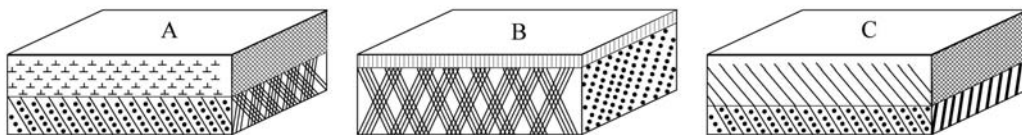
Fig. 12　Schematic drawings of the different types of Schmelzmuster in Rhizominae
Brachyrhizomys and *Rhizomys* (A), *Pararhizomys* (B) and *Tachyoryctoides* (C)

curred taxa, *Brachyrhizomys* should be adapted to a warm, humid and forest environment, similar to the extant *Rhizomys*. However, *Pararhizomys* was usually found along with jumping mice, jerboas, gerbils, pikas and zokors, reflecting a temperate and arid steppe environment. The differences of incisor enamel microstructure among *Pararhizomys*, *Brachyrhizomys* and *Rhizomys*

may also be interpreted as their different adaptation of foods and environments.

Family attribution　The genus *Pararhizomys* was firstly attributed to the superfamily of "Myoidea" and postulated to be a rhizomyid (Teilhard and Young, 1931). Young and Liu (1950) assigned *Pararhizomys* and *Brachyrhizomys* as "*Brachyrhizomys* group" under family Rhizomyidae, and considered *Tachyoryctoides* as a possible ancestor of the family Rhizomyidae. Kowalski (1969) also referred *Pararhizomys* in Rhizomyidae on the basis of the skull and jaws from Altan Teli. Compared with skulls and teeth of Tachyoryctoididae, Siphneinae, Spalacidae and Rhizomyidae, however, Zhang et al. (2005) recognized that *Pararhizomys* could not be attributed to any family or subfamily aforementioned, and considered that *Pararhizomys* are not closely related to modern rhizomyines. They referred *Pararhizomys* under an unrecognized family.

Although *Pararhizomys* shares certain similarities in morphology of cheek teeth with *Brachyrhizomys*, *Rhizomys* and *Tachyoryctoides*, it differs from these genera in having a simpler dental pattern. Molars in *Pararhizomys* are distinct hypsodont with only 2–3 reentrants, and lack mesoloph(id)s, whereas those of *Brachyrhizomys*, *Rhizomys* and *Tachyoryctoides* are brachydont or semi-hypsodont with developed mesoloph(id)s and at least 3 reentrants. Furthermore, the enamel microstructure of lower incisor of *Pararhizomys* has very thick PI and remarkably different arrangement of prisms. *Pararhizomys* had a distinctly different biogeographical distribution compared with rhizomyids *Brachyrhizomys* and *Rhizomys*. All of these issues indicate *Pararhizomys* possibly represent a separate lineage of muroids, probably derived from *Tachyoryctoides*-like taxa and differentiated from the modern rhizomyines before early Late Miocene. The confirmation and recognition of the precise attribution of *Pararhizomys* at the family level is still relying on more specimens to be discovered.

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