



## NEW MATERIALS OF *PARARHIZOMYS* FROM NORTHERN CHINA

Zhang Zhaoqun, Lawrence J. Flynn, and Zhuding Qiu

### ABSTRACT

Several new specimens of the poorly known late Neogene muroid *Pararhizomys*, known mainly from the holotype jaw from Fugu, Shaanxi Province, and a skull from western Mongolia, help to characterize the genus more fully. We review all known specimens representing the genus, including new material from Lantian, near Xi'an in Shaanxi Province, 600 km south of Fugu. The dental material from Lantian is found to be primitive in having shorter reentrant folds and a less undulating enamel base, and is used to diagnose a new species. The Lantian *Pararhizomys qinensis* is smaller than the type species and, being early late Miocene in age, is likely geologically older. We find no compelling argument to support attribution of *Pararhizomys* to known families, although Rhizomyidae remains a possibility. Alternatively, *Pararhizomys* is a late-surviving member of an independent archaic muroid lineage.

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**Key Words:** *Pararhizomys*; muroid rodents; Miocene; China; Lantian

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### INTRODUCTION

One of the enigmatic rodent genera of the late Tertiary of China is *Pararhizomys*, a rare fossil taxon. One might expect that *Pararhizomys*, a relatively large rodent, would be found more frequently as the fossil record of China becomes better known. Although it remains poorly repre-

sented, important new material has been found, and our purpose is to make this known in the full tradition of exploration and discovery practiced by Will Downs.

*Pararhizomys* was named by Teilhard and Young (1931) for a peculiar jaw from the "Pontian Red Clays" of Locality 10, Chenchiangpao, Fugu County, eastern margin of Shaanxi Province. It

was compared to *Rhizomys*, and affiliated with spalacines (represented today by the highly fossorial *Spalax*) at a time when *Rhizomys* and *Spalax* were generally classified together. Teilhard and Young (1931) also tentatively referred one M2 from Dalai Nor to *Pararhizomys* (it had been described as "*Dipoides* sp." by Teilhard 1926). Young and Liu (1950) grouped *Pararhizomys* in the *Brachyrhizomys* group of Rhizomyidae. Kowalski (1968) included the genus in Rhizomyidae when he described a nearly complete skull with lower jaws from Altan Teli, Mongolia. Flynn (1982) considered Rhizomyidae to be distinct from Spalacidae and observed that *Pararhizomys* is possibly spalacid, but without detailed discussion. The systematic position of this genus has remained uncertain for a long time due to fossil scarcity.

New fossils have been found in northern China in recent years. Two upper molars were listed as "Incertae familiae gen. et sp. indet." from Loc. 13 of the Bahe Formation (Lantian, Shaanxi Province; Zhang et al. 2002; Qiu et al. 2003). A skull fragment without teeth is also known from this locality. A partial jaw was found from Qin'an (Gansu Province; Guo et al. 2002). During a 2003 excursion, a partial maxilla was obtained from a local farmer in Fugu County (Shaanxi Province).

The new fossil material described in this paper is housed in the Institute of Vertebrate Paleontology and Paleoanthropology, Beijing. Measurements (in millimeters) were taken using a Wild II microscope.

## SYSTEMATIC PALEONTOLOGY

Order RODENTIA Bowdich, 1821  
Superfamily MUROIIDEA Illiger, 1811  
Family *incertae sedis*

*PARARHIZOMYS* Teilhard and Young, 1931

**Type species:** *Pararhizomys hipparionum* Teilhard and Young, 1931

**Type locality:** Loc. 10, Chenchiangpao, Fugu County.

**Geographic distribution:** Fugu, Shaanxi Province; Qin'an, Gansu Province; Altan Teli, Mongolia; Lantian, Shaanxi Province.

**Diagnosis:** Large muroid rodent with the origin of the anterior part of the lateral masseter muscle on the maxillary portion of the zygomatic arch, the infraorbital foramen is restricted in a high position with the ventral slit partially closed. Upper tooth rows diverge somewhat posteriorly. Molars high crowned but still rooted when mature. M1/m1 have one lingual and two labial reentrants, M2/M3/m3 have only one lingual and one labial reentrant,

while m2 has one lingual reentrant but two on the labial side.

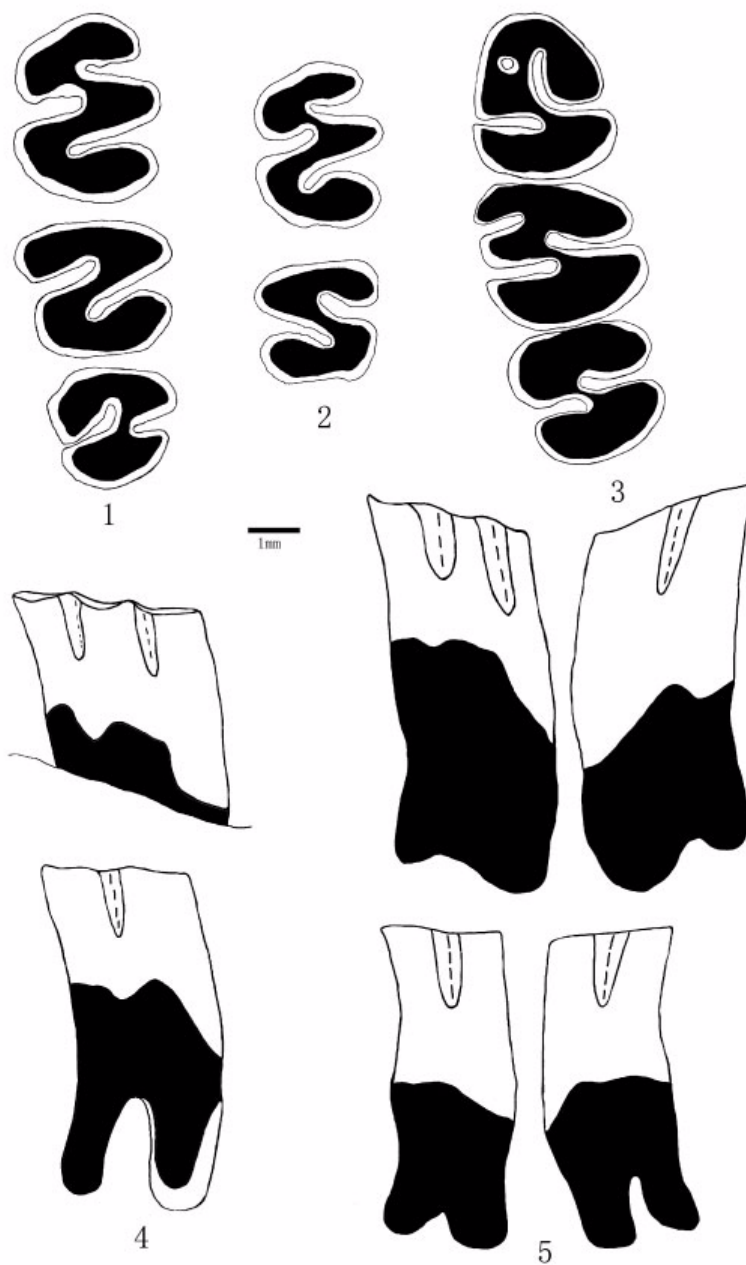
**Discussion:** In their description Teilhard and Young (1931, p. 11), listed the type specimen erroneously as from Loc. 1, but corrected this in errata to Loc. 10. Kowalski (1968) did not notice this change, citing the type locality as Loc. 1, near Chinglo in Shanxi, northern China, and thus associating all the fossils from Chinglo together with *Pararhizomys*. The Chinglo (Jingle in Chinese spelling) fauna is now considered late Pliocene, equivalent to MN16 according to the small mammals (Zhou 1988). Paleomagnetic data restrict it to the 2.5~3.0 Ma interval (Yue and Zhang 1998). In contrast, Loc. 10 is a very poor locality with (in addition to *Pararhizomys*) only a partial lower jaw of *Yangia omegodon* (current identification of Zheng 1997). All the more confusingly, the latter rootless siphneid is typical of forms found no earlier than the late Pliocene Loess. The occurrence and geological age of fossils at the type locality should be verified by future work.

The type specimen of *Pararhizomys*, a left lower jaw with both ends broken, was only briefly described in 1931, and superficially discussed in subsequent literature. Thanks to Li Chuankui, Everett Lindsay was able to mold the holotype (about the year 1980) and we have a cast. To the original description, we add the following observations. The masseteric fossa is indeed prominent as Teilhard and Young (1931) indicated. It is delimited by a heavy masseteric crest projecting laterally from the horizontal ramus. The ascending ramus is thus well separated from the tooth row. The lingual surface of the mandible is depressed. The mental foramen is exceptionally low on the jaw, under the anterior root of m1 and below the level of the front of the masseteric crest. Molar patterns are simple, m2 shows an anterolabial reentrant behind the labial arm of its anterolophid, and m3 is the smallest molar. The incisor enamel is flattened and does not extend far laterally. A faint ridge runs the length of the incisor, somewhat lateral to its midline. Incisor width is 3.47 mm.

*Pararhizomys hipparionum* Teilhard and Young,  
1931

**Referred Material:** Partial left maxilla with M1-M3 (V 14178); partial left mandible with m1-m3 (V14179).

**Locality:** V 14178 from Lamagou gully, Fugu, eastern Shaanxi Province, 50 km north of Baode; V 14179 from Qin'an, 200 km southeast of Lanzhou, Gansu Province.

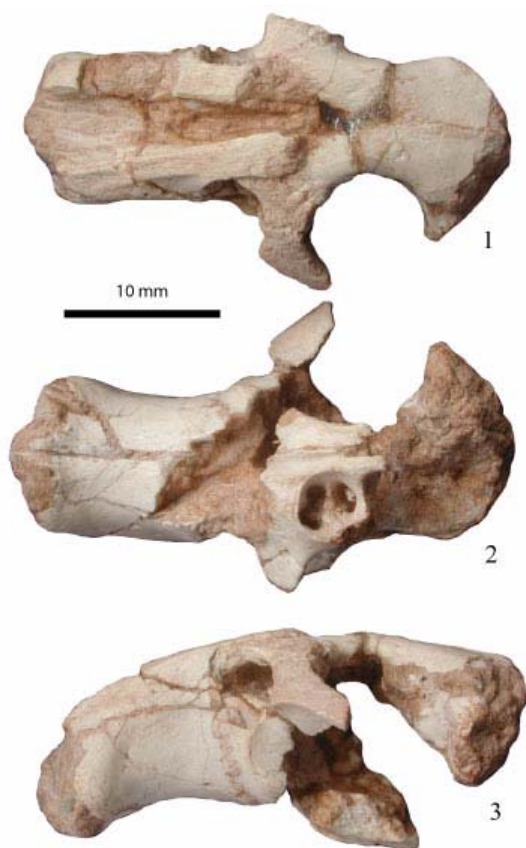


**Figure 1.** Molars of *Pararhizomys hipparionum* (Figures 1.1, 1.3, 1.4) and *Pararhizomys qinensis*, n. sp. (Figures 1.2, 1.5). 1. left M1-M3 (V 14178), occlusal view; 2. left M1 (V 14177.1) and right M2 (V 14177.2), occlusal view; 3. left m1-m3 (V 14179), occlusal view; 4. left molars in labial view (V 14178): M1 (top) and M2 (bottom); 5. on top are labial (left) and lingual (right) views of M1 V 14177.1, below are the lingual (left) and labial (right) views of M2 V 14177.2.

**Description:** V 14178 has the maxillary process of the zygomatic arch originating from a position about opposite the middle part of M1. The maxilla anterior to M1 slopes strongly. Molars are high crowned, and in both M1 and M2, the base of the enamel undulates and descends to its greatest depth anteriorly (Figure 1.4). M1, the largest molar, has a slight inflection on the lingual surface

of the anteroloph. There is one lingual reentrant, spanning about half the tooth, and angled slightly anteriorly. Of the two labial reentrants, the anterior one is slightly shorter and transverse; the other angles slightly posteriorly. The posterior wall of M1 is rounded.

M2 is wider anteriorly than posteriorly and has gently rounded anterior and posterior walls. The



**Figure 2.** Partial cranium of *Pararhizomys qinensis* from Lantian (V 14176); top: dorsal view; middle: ventral view; bottom: lateral view. Ten millimeter scale.

labial reentrant bends gently anteriorly. Posterolingual to it is a slightly longer diagonal lingual reentrant. M3 is the smallest molar in the tooth row. It also has only one labial and one lingual reentrant. However, the labial reentrant is much shallower, and extends across about one third of the occlusal surface. The deeper lingual reentrant, strongly anteriorly oriented, crosses the central longitudinal axis. Anteriorly M3 is flattened, but its posterior end is round. Two roots are visible on M3.

The mandible from Qin'an (V 14179) has the ascending ramus arising well lateral to m2. There is a wide valley between the tooth row and the ascending ramus. The specimen has well worn teeth, but is not in advanced wear. The occlusal surface of m1 is oval shaped with the anterior part narrower. The one lingual reentrant extends transversely and then bends strongly anteriorly from about its middle point. One small enamel island is situated on the anterolabial side. The transverse posterior labial enamel loop spans about half the molar width.

There are three (two labial and one lingual) reentrants on m2. The anterior labial reentrant is

much shorter, and slightly anteriorly oriented, while the posterior labial reentrant is about twice its size and is basically transverse. The lingual reentrant curves slightly anteriorly. The anterior surface is nearly straight, with very thin enamel at the contact wear facet. The posterior surface is rounded. The occlusal surface of m3 is generally rectangular, with only one lingual and one equal labial reentrant.

*Pararhizomys qinensis* new species  
(Figures 1.2, 1.5, 2; Table 1)

**Holotype:** Left M1 (V 14177.1)

**Paratypes:** Right M2 (V 14177.2) and a partial skull (IVPP V 14176).

**Type locality:** Lantian, Shaanxi Province, Loc. 13, lower part of the Bahe Formation.

**Diagnosis:** Snout robust, deeper than in *Pararhizomys hipparionum*, but with a shorter diastema. Tooth dimensions less than 90% of *Pararhizomys hipparionum*. M1 and M2 with less undulating enamel base on both labial and lingual sides, and shorter striae.

**Etymology:** "qin", Chinese Mandarin spelling for central Shaanxi Province and the Ancient dynasty.

**Description:** The partial skull from Loc. 13 has only the premaxillae, the nasals, the maxillae with the anterior part of the left zygomatic arch and the alveolar surface for right M1 preserved, the frontals and portions of parietals. The snout is short and strongly built, with a short diastema (16.5 mm from incisors to M1 alveolus). The origin of the anterior part of the lateral masseter is on the maxillary portion of the zygomatic arch, under the large infraorbital foramen, and just posterior to the premaxilla-maxilla suture. The zygoma shows modified myomorphy, as do fossil rhizomyids (Flynn 1982) in that the ventral slit of the keyhole infraorbital foramen is constricted, nearly closed, with the larger part of the foramen shifted dorsally. The anterior margin of the incisive foramen is at the middle point of the diastema.

M1 (V 14177.1) is high crowned, cylindrical, and slightly recurved anteriorly in lateral view. On the occlusal surface there are one lingual and two labial reentrants that yield a sigmoid outline, which recalls the M2 of siphneines. The lingual reentrant extends anteriorly to the central longitudinal axis. The anterior labial reentrant bends slightly anteriorly and extends to just in front of the deepest part of the lingual reentrant. The posterior labial reentrant is deepest and extends posterolingually beyond the midline of M1. The base of the enamel approaches closest to the roots anteriorly. On the

**Table 1.** Tooth measurements for *Pararhizomys* (in mm)

	m1		m2		m3		M1		M2		M3		m3/ m1@	M3/M1@
	L	W	L	W	L	W	L	W	L	W	L	W		
<i>P. hipparionum</i> Loc. 10, holotype	3.9	3.0	3.7	3.55	3.15	3.05							0.79	
Fugu (V 14178)							3.67	2.8	2.67	3.04	2.33	2.52		0.64
Dalai nor*									3	3.5				
Altan Teli	3.8	3.2	3.3	3.6	3	2.9	4.4	3.6	3	3.3	2.4	2.5	0.79	0.55
Qin'an (V 14179)	3.2	2.77	2.84	3.04	2.49	2.71							0.78	
<i>P. qinensis</i> Lantian (V 14177.1, .2)							3.20	2.47	2.38	2.34				

\* Measurements from Teilhard (1926, figure 21A)

@ Ratios of lengths

lingual side, the reentrant terminates well short of the base of the enamel, not quite as far on the labial side. Two roots can be seen at the base of the tooth, the anterior one much larger.

M2 is smaller than M1. There are only one labial and one lingual reentrant, which yield a general "S" shape. The lingual reentrant is shorter and bends gently anteriorly; the labial one extends posterolingually beyond the central longitudinal axis. Anteriorly, the lingual corner of the tooth is sharply triangular. Anterior and posterior walls of M2 are flattened; the anterior width is larger. Two roots are observed.

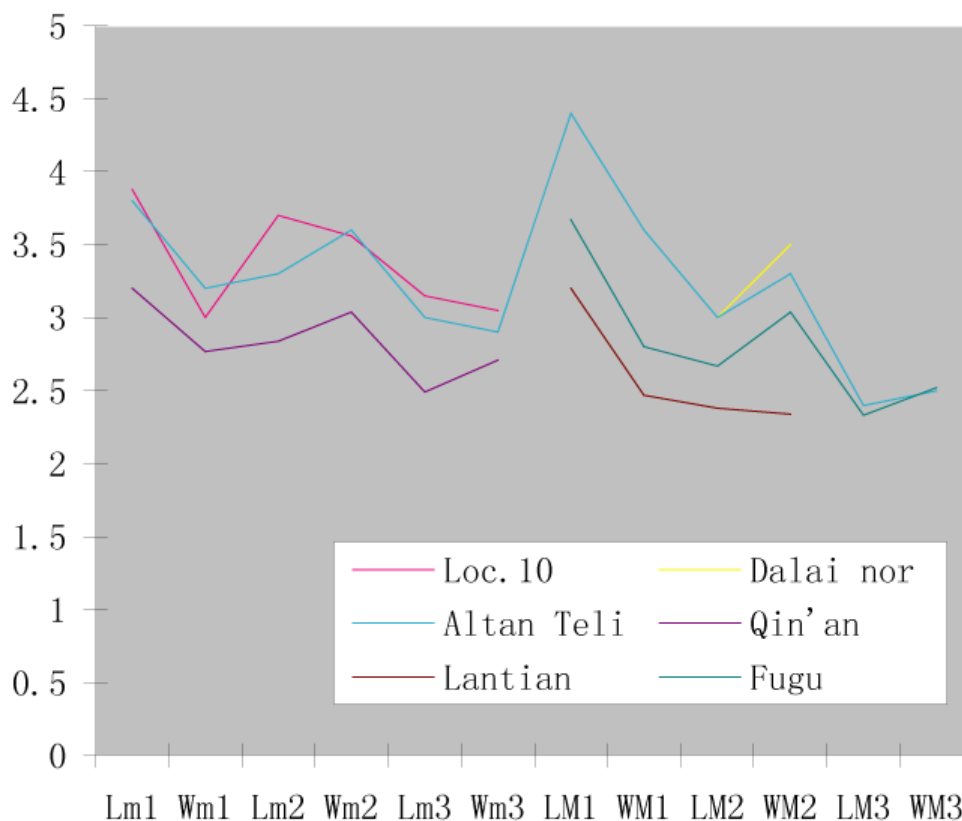
**Comparison of Species:** The single specimen of *Pararhizomys hipparionum* from its type locality has only lower molars, plus the incisor. Fortunately, the complete skull with lower jaws from Altan Teli allows comparison among all fossils attributed to the genus. The Altan Teli lower dentition is very similar to that of the holotype, differences (Table 1) due to more advanced wear of the Altan Teli individual. The upper dentition of the cranium from Altan Teli resembles that of the Fugu maxilla, but dimensions are greater, again reflecting its advanced wear stage (occlusal size of M1 is considerably greater, but the less worn M3 is nearly the same in the two specimens). Figure 3 shows these size differences in M1, the less contrasting M2, and the similar M3.

The importance of considering wear stage cannot be overemphasized. Molar size is, of course, constant during an individual's life, but measurements, usually made with respect to the occlusal surface, are affected by wear. In *Pararhizomys*, like many high crowned rodents, some occlusal dimensions increase greatly with wear.

The wear surface of upper molars increases dramatically in width during life; lower molars, especially m3, show increase in length. Some researchers measure only occlusal surfaces, as did, apparently, Teilhard and Young (1931). We recorded maximum crown dimensions, and remeasured a cast of the holotype of *P. hipparionum* (Table 1). Note that measurements in late wear could exceed our estimates, due to ontogenetic shift of the angle of the wear surface with respect to the base of the enamel; holotype m1 length could approach 4.0 mm and, m3 length could exceed 3.5 mm. Given this consideration, the worn Altan Teli specimen is quite consistent with the Fugu specimens.

However, this logic suggests that the lower molars from Qin'an, which appear to be smaller than those of the holotype, yet have achieved nearly the same wear stage, are perhaps too small for this species allocation (Table 1, Figure 1.3). Apparent size of the molars in the Qin'an jaw would increase in more advanced wear, but it is at almost the same wear stage as the holotype. This specimen appears small for *Pararhizomys hipparionum*, but being lower dentition, it is difficult to compare with the Lantian fossils.

The upper molars from Lantian show significantly smaller size of *Pararhizomys qinensis* than *Pararhizomys hipparionum*. Dimensions of the specimens from Lantian are less than 90% those of the upper dentition from Fugu, including molar length, which would not change much with wear (possibly decreases). Width of M2 in V 14177.2 is less than 80% that of the Fugu maxilla. These specimens, approximately at the same wear stage, show different vertical penetration of reentrants in



**Figure 3.** Diagram showing relative tooth measurements for known specimens of *Pararhizomys*. Lengths and widths in millimeters are both indicated on the vertical axis.

M2; the striae (lateral views of reentrants) do not approach the base of the enamel as deeply as in the Fugu specimen.

The Lantian skull (Figure 2) has the same modified myomorphous zygomatic structure as that of the Altan Teli specimen. The origin of the anterior part of the lateral deep masseter is on the maxillary portion of the zygomatic arch, which expands anteriorly, and the infraorbital foramen is in a high position, with abbreviated ventral slit. The Altan Teli skull is larger; its diastema between upper the incisor and M1 is 24.5 mm (16.5 in V 14176). The snout is relatively longer and less deep dorsoventrally in the Altan Teli specimen, lending a robust appearance for the Lantian skull. Despite the difference in size, the Altan Teli upper molars have almost exactly the same structures as those from Lantian, although the deeply worn lingual and anterior labial reentrants are enclosed as enamel lakes. The M2/M1 length ratio for Lantian is 0.74, in contrast to 0.68 for the Altan Teli individual.

The two species of *Pararhizomys* are similar in molar and skull structure. Differences include smaller size of *Pararhizomys qinensis* (usually presumed as a primitive condition), less undulating base of the enamel (primitive), and shorter striae

(considered primitive in other high crowned rodents, such as siphneines). M2 is relatively shorter, slightly more reduced (derived), in *Pararhizomys hipparionum*, based on the few specimens available.

**Summary:** With the Fugu maxilla V 14178 as a standard for *Pararhizomys hipparionum*, the Lantian specimens are proportionally smaller in size (Figure 3), and with a less undulating base of the enamel on both labial and lingual sides. The striae are longer in *P. hipparionum*. Considering these dental features and the more robust snout with shorter diastema, new species status is proposed for the Lantian specimens. The species *Pararhizomys qinensis* is considered more primitive and likely older than *P. hipparionum*. Both species show the derived zygomatic condition of modified myomorphy.

#### Family Attribution

The large body size, molar lophodonty, high crowns, and simple tooth structures suggest comparison of *Pararhizomys* with the muroid rodent groups Tachyoryctoididae, Siphneinae, Spalacidae, and Rhizomyidae. Members of all of these (with the possible exception of the extinct Tachyo-

ryctoididae) show fossorial adaptations in the humerus, incisor morphology, and occipital and cervical structures. Such adaptations are not definitively expressed in known specimens of *Pararhizomys*.

**Tachyoryctoididae:** *Tachyoryctoides* occurs widely across China and Kazakhstan, for example in the Oligocene deposits of Shargaltein-Tal and Taben-Buluk, Gansu Province (Bohlin 1937, 1946), and the early Miocene of Xining and Lanzhou basins (Li and Qiu 1980). The mandibles are strongly built, with prominent masseteric crests under m1/m2 as in *Pararhizomys*. A cranium of *Tachyoryctoides* (V 5999) from Xining Basin, has the anterior part of the lateral masseter extending below the infraorbital foramen. The lower cheek teeth all have two labial reentrants, reminiscent of m1 and m2 of *Pararhizomys*. The posterior reentrants are much deeper and more strongly posteriorly oriented, unlike the shallower and more transverse reentrants in *Pararhizomys*. The lingual reentrants on upper cheek teeth are strongly anteriorly oriented and opposite to the anterior labial reentrants in *Tachyoryctoides*. We see no special features shared to support phylogenetic relationship with *Pararhizomys*.

**Siphneinae:** The hypsodonty and simple tooth morphology of *Pararhizomys* are superficially consistent with siphneines, the living fossorial zokors of China. Recent study shows that the group is probably derived from middle Miocene *Plesiodipus* (Zheng et al. 2004). The molar pattern differs significantly in some respects, for example the simple, small third molars of *Pararhizomys*, in contrast to the large, complex posterior teeth of the zokors. Similarities are likely shared primitive conditions (two labial reentrants on m2) and convergences.

**Spalacidae:** Extinct spalacids are grouped in four genera: *Debruijnina*, *Heramys*, *Sinapospalax*, and *Pliospalax* (Ünay 1999; Sarica and Sen 2003). The fossil and extant spalacids are restricted to western Asia, southeastern Europe and northern Africa. Mesoloph(id)s are present in primitive genera, and reduced in later genera. There is no lingual reentrant on M3, except for *Debruijnina* having a shallow and narrow reentrant. The labial anterior reentrant in Spalacidae diminishes from very shallow in early taxa to being absent in extant species. The labial posterior reentrants are shallow and strongly posteriorly orientated. These features argue that *Pararhizomys* is related to neither primitive nor derived genera. Flynn (1982) felt that the rounded infraorbital foramen of *Spalax* was more consistent with hystri-comorphy than myomorphy and that the Altan Teli skull appeared to be hystri-

comorphous. Re-examination of the Altan Teli specimen and observations on the new Lantian skull affirm that *Pararhizomys* exhibits modified myomorphy.

**Rhizomyidae:** Echoing Teilhard and Young (1931), McKenna and Bell (1997) grouped *Pararhizomys* with the living *Rhizomys* and *Cannomys*, plus extinct *Anepsirhizomys* and *Brachyrhizomys*, in the tribe Rhizomyini. There are indeed some characters shared with these taxa, such as incisors deeply rooted with well-developed capsules, lophodont cheek teeth, and modified myomorphy with anterodorsally shifted origin of the lateral masseter, which restricts and partially closes the ventral slit of the infraorbital foramen. However, *Pararhizomys* differs from most rhizomyines in its reduced third molars, extra anterolabial reentrant on m2, and otherwise simplified tooth morphology. Flynn (1990) excluded *Pararhizomys* from Rhizomyidae based on several features, and thought the most important character to be the lower second molar with two labial reentrants. The extra anterior labial reentrant in m2 of *Pararhizomys* could result from a hypertrophied labial arm of the muroid anterolophid, that is, a condition derived from a primitive muroid feature, present in early rhizomyids, and therefore not a falsification of classification in Rhizomyidae. Also, the new Lantian skull confirms that the zygomatic structure of *Pararhizomys* shows a condition of modified myomorphy, consistent with fossil rhizomyids. Further, the retained ridge on the lower incisor of *Pararhizomys* is a feature seen in early rhizomyids (and retained in tachyoryctines). Other common features could represent shared ancestry and parallel evolution.

While there is no compelling case for assignment of this genus to any living family, we consider two likely scenarios. *Pararhizomys* may be a rhizomyid, as Teilhard and Young (1931) postulated, but it would not be closely related to modern rhizomyines such as *Brachyrhizomys shansius*. Instead, *Pararhizomys* may be derived from earlier forms retaining a distinct labial arm of the anterolophid on m2 and the ridge on the lower incisor. The second possibility is that *Pararhizomys* is a late-surviving member of an independent muroid lineage. It remains for more fossils to be discovered in China to clarify the affinity of *Pararhizomys* and to determine whether this taxon represents a separate muroid lineage, heretofore unrecognized.

### Biochronology

Lantian Loc. 13, which is located about 20 m above the rich small mammal site Loc. 19, produced *Progonomys sinensis* (Zhang et al. 2002; Qiu et al. 2004a) and *Abudhabia baheensis* (Qiu et

al. 2004b). Loc. 19 yielded additional taxa (Qiu et al. 2003). Together with Loc. 12, these three sites document the earliest fauna in the Bahe Formation. Preliminary paleomagnetic data (Kaakinen and Lunkka 2003) and faunal comparisons (Zhang et al. 2002; Qiu et al. 2003; Qiu et al. 2004a) argue that the fossil mammals from the lower part of Bahe Formation can be compared with European Vallesian faunas. Thus the type locality for *Pararhizomys qinensis* is early late Miocene, perhaps around 10 Ma.

*Pararhizomys hipparionum* is advanced with respect to *Pararhizomys qinensis* in greater size, longer striae, and more undulating base of the enamel. Consistent with the derived nature of this species, *Pararhizomys hipparionum* evidently is found in younger localities. The Fugu maxilla V 14178 is from Lamagou, which produced abundant mammalian fossils (Xue et al. 1995) and has a paleomagnetic age of about 8 Ma. The Fugu type locality "Loc. 10," as previously discussed, is of uncertain age, but seems to be later based on greater size of the holotype of *Pararhizomys*. The fossil level of the Qin'an material at about the 9 m level in the first section of Guo et al. (2002) has a projected paleomagnetic date of ca. 7 Ma. Altan Teli and Dalai Nor both might be latest Miocene. The more advanced *Pararhizomys hipparionum* is apparently from younger deposits than *Pararhizomys qinensis*.

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