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## New discoveries of glirids and eomyids (Mammalia, Rodentia) in the Early Miocene of the Junggar basin (Northern Xinjiang province, China)

Olivier Maridet, Wen-Yu Wu, Jie Ye, Xi-Jun Ni, Jin Meng

**Keywords:** Gliridae, Eomyidae, Early Neogene, Central Asia, Palaeoenvironment

**Abstract** We report herein new discoveries of Gliridae and Eomyidae (Mammalia, Rodentia) from the new Early Miocene locality XJ 200604, located northwest to the Burqin city, northern Xinjiang province, China. These specimens represent three taxa of Gliridae, including a new species (*Miodryomys asiamediae* nov. sp., *Microdryomys* aff. *orientalis* and *Eliomys*? sp.), and four taxa of Eomyidae (*Asianeomys* aff. *engesseri*, *Asianeomys* sp., *Keramidomys* sp. and Eomyidae indet). The identification of two forms that are closely related to *Microdryomys orientalis* and *Asianeomys engesseri* suggests an Early Miocene age of the locality but does not allow a more precise age determination. The new discoveries of Gliridae and Eomyidae again reveal the relative scarcity of the two families in the Early Miocene of Central Asia, in contrast to the coeval rich European record. Such a discrepancy in taxonomic diversity and abundance is hypothesized as resulting from different environmental evolutions during the Early Miocene, most notably the onset of a mid-latitude dry climate in Central Asia linked to combine effects of the Tibetan Plateau uplift and the retreat of the Paratethys Sea.

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O. Maridet (corr. author) W.-Y. Wu, J. Ye, X.-J. Ni, J. Meng  
Key Laboratory of Evolutionary Systematics of Vertebrates,  
Institute of Vertebrate Paleontology and Paleoanthropology,  
Chinese Academy of Sciences, Beijing 100044, Chinae-mail:  
olivier.maridet@ivpp.ac.cn

J. Meng  
Division of Paleontology, American Museum of Natural History,  
New York, NY 10024, USA

### Introduction

Neogene Gliridae and Eomyidae are inherited from the Palaeogene, and both families experienced a successful diversification in the Early Miocene of Europe (e.g., Daams 1981, 1999; Engesser 1999), whereas their record of these families in the Early Miocene of China, and generally of Central Asia, is relatively poor compared to Europe. Indeed, according to the review of Neogene glirids done by Daams (1999) about 45 species belonging to 19 genera are known in the Early Miocene of Europe. In contrast, *Microdryomys orientalis* Wu, 1986 is so far the only species of Gliridae described in the Early Miocene of China (Sihong locality, Jiangsu province; Wu 1986). Glirids have been discovered in a few other Early Miocene localities, but their determination does not go over the genus level: Qiu et al. (2006) mentioned the presence of *Microdryomys* sp., *Miodryomys* sp. and *Prodryomys* sp. in the locality Gashunynadege (Inner Mongolia), and Meng et al. (2006) mentioned the presence of *Microdryomys* sp. in the XJ99005 section of the Suosuoquan Fm. (Xinjiang province). More generally, as already stated by Qiu and Li (2003), the genera *Microdryomys* de Bruijn, 1966 and *Miodryomys* Kretzoi, 1943 are quite rare in the Neogene of China. Daxner-Höck and Badamgarav (2007) also indicated a *Microdryomys* sp. from the late Early Miocene of the Loh Fm. (Central Mongolia).

For what concerns eomyids, Engesser (1999) in his review reported 27 Early Miocene species belonging to 8 genera in the Early Miocene of Europe. In China, Wu et al., (2006) reported the discovery of new specimens in the Late Oligocene and Early Miocene of the Junggar basin, and invented the new genus *Asianeomys* Wu et al., 2006 because of their morphological particularities compared to the genera *Eomys* Schlosser, 1884, *Pseudotheridomys*

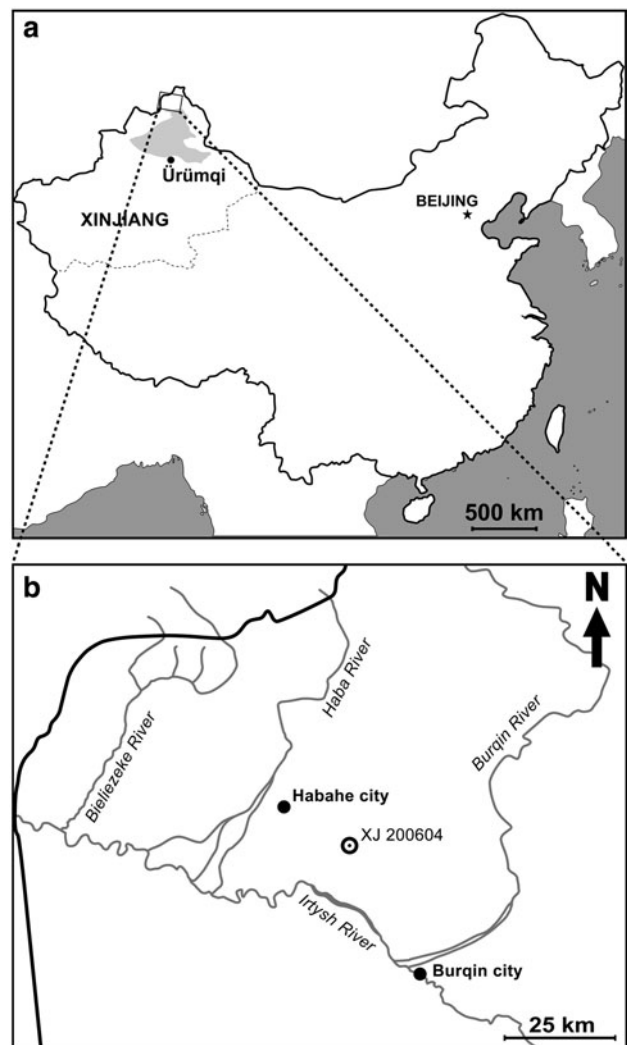
Schlosser, 1926 and *Eomyodon* Engesser, 1987. They defined two Early Miocene species *Asianeomys fahlbuschi* Wu et al., 2006 and *A. engesseri* Wu et al., 2006. Furthermore, Wu et al., (2006) recognized that different species previously found in the Late Oligocene of Inner Mongolia (Saint Jacques), Gansu (Yandantu Gou), Xinjiang (Mammal zone I of the Tiersihabahe Formation), Central Mongolia (biozone C of the Valley of Lakes), and Kazakhstan's North Aral Region (Bone bed II of the Aral Formation, Altynshokysu) actually belong to *Asianeomys*, making this genus a widespread taxon in this period. In contrast, in the Early Miocene, *Asianeomys* is so far only known from North Junggar Basin (Mammal zone II of the Suosuoquan Formation). It is, however, noteworthy that other undetermined eomyids ('Eomyidae indet. 2' and 'Eomyidae indet. 3') have been mentioned by Daxner-Höck and Badamgarav (2007) in the Early Miocene of the Loh Fm. (Central Mongolia). In addition, Qiu and Li (2003) stated that *Keramidomys* Hartenberger, 1966 and *Leptodontomys* Shotwell, 1956 have also been identified from Early Miocene of Gashunyinadege (Inner Mongolia).

We report here the discovery of new specimens of Gliridae and Eomyidae (Mammalia, Rodentia) from the Early Miocene of the Junggar basin (Northern Xinjiang, China). These specimens come from a new locality, XJ 200604 discovered in 2006. The site is located northwest of Burqin city (47°58'46.80"N–86°38'15.96"E; Fig. 1), northwest to the previously known Early Miocene localities from the Junggar basin (Meng et al. 2006). The locality was sampled during a field survey in 2010, and several hundred kilograms of sediment from a blackish yellow coarse sandstone bed have been screenwashed. Together with the Gliridae and Eomyidae described below, the locality also yielded some teeth of Cricetidae, Aplodontidae, Sciuridae, Mylagaulidae, Erinaecidae and Soricidae, and numerous teeth of ochotonid lagomorphs (very abundant at the surface of the sandstone layer but also often badly preserved).

## Materials and methods

All specimens are isolated teeth, and deposited in the collections of the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, and are catalogued with the numbers: IVPP V18129 to V18131 for glirids, and IVPP V18132 to V18135 for eomyids.

Observation and measurements were done with a binocular microscope Olympus SZX7 allowing precision to 0.01 mm. The terminology used to describe molars follows Daams and de Bruijn (1995) for glirids, and Engesser (1990) for eomyids. In addition, the term "weak" is used to



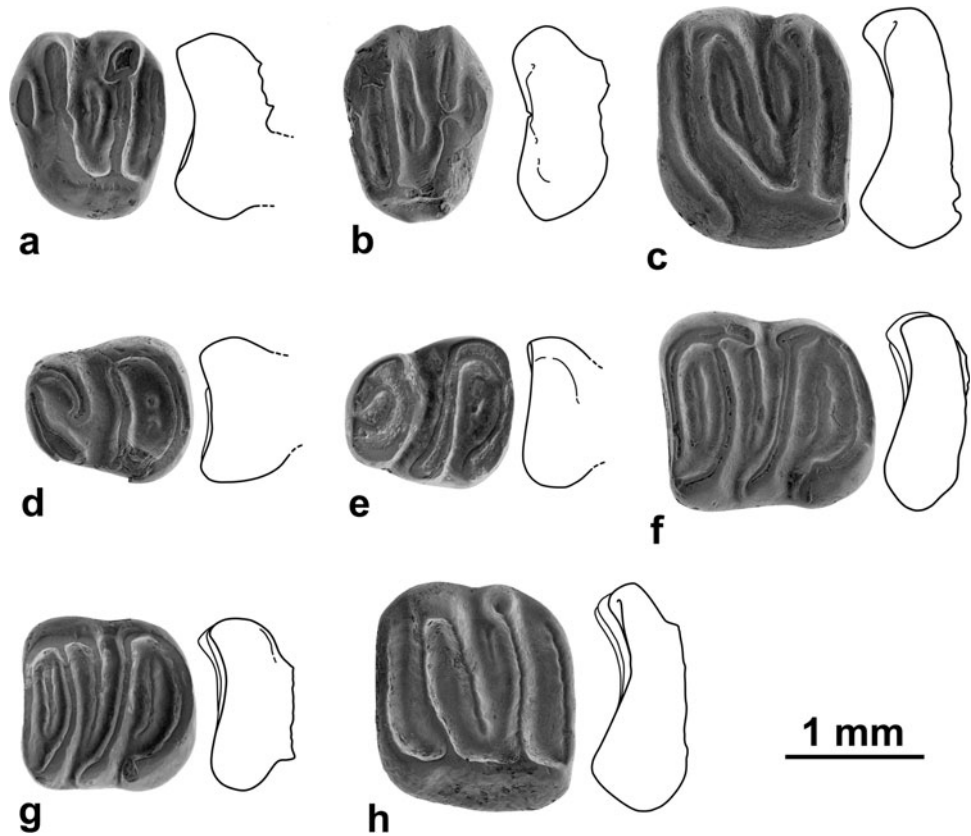
**Fig. 1** Sketch map of the working area showing: **a** the location of the Habahe County northwest to the Junggar Basin (in light gray); **b** the location of the locality XJ 200604 north of the Irtysh River

describe a weakly developed spur on the longitudinal crest or a crest limited to a triangular-shaped bump. Concerning eomyids, a clear distinction between the first and second molars was not always possible; both teeth are not separated and described as M1/2 and m1/2. All the measurements are given in millimetres.

## Systematic palaeontology

- Class Mammalia Linnaeus, 1758
- Order Rodentia Bowdich, 1821
- Family Gliridae Thomas, 1897
- Genus *Miodyromys* Kretzoi, 1943
- Miodyromys asiamediae* nov. sp.
- Figure 2a–f

**Fig. 2** *Miodyromys asiamediae* nov.sp: **a** left P4, IVPP V18129.1 (photo of the occlusal view and sketch of the posterior view); **b** right P4, IVPP V18129.2 (photo of the occlusal view and sketch of the anterior view); **c** left M1, IVPP V18129.3 (photo of the occlusal view and sketch of the posterior view); **d** left p4, IVPP V18129.4 (photo of the occlusal view and sketch of the posterior view); **e** left p4, IVPP V18129.5 (photo of the occlusal view and sketch of the posterior view); **f** left m2, type specimen, IVPP V18129.6 (photo of the occlusal view and sketch of the posterior view). *Microdyromys* aff. *orientalis* Wu, 1986: **g** left m1, IVPP V18130 (photo of the occlusal view and sketch of the posterior view). *Eliomys*? sp.: **h** left M2, IVPP V18131 (photo of the occlusal view and sketch of the posterior view)



*Holotype* left m2, IVPP V18129.6 (1.21 × 1.17 mm, Fig. 2f)

*Type locality* Early Miocene section XJ 200604, county of Habahe, northern Xinjiang.

*Etymology* Named *Miodyromys* of Central Asia (latin *Asia Media*)

*Referred specimens* All together 8 cheek teeth: left P4, IVPP V18129.1 (0.89 × 1.11 mm, Fig. 2a); right P4, IVPP V18129.2 (0.90 × 1.19 mm, Fig. 2b); left M1, IVPP V18129.3 (1.16 × 1.43 mm, Fig. 2c); left p4, IVPP V18129.4 (1.00 × 0.87 mm, Fig. 2d); left p4, IVPP V18129.5 (1.02 × 0.92 mm, Fig. 2e); two extremely damaged dp4/p4, IVPP V18129.7 and IVPP V18129.8.

*Diagnosis* Middle-sized *Miodyromys* with the following unique combination of characters: the metacone is better developed than the paracone in upper cheek teeth; P4 is large relatively to M1 and have a U-shaped trigon; M1 is proportionally wide (L/W = 0.81) with the anterior centroloph longer than the posterior one, and a well-developed extra ridge between the protoloph and anterior centroloph; the extra ridge between the posterior centroloph and metaloph is absent; in m2, both the extra ridges between the anterolophid and the metalophid and between the mesolophid and the posterolophid are well developed, but the central extra ridges are absent; lower premolars are noticeably elongated (mean L/W = 1.13), and two roots merged into a single one (with two pulp cavities).

*Differential diagnosis* In the Early Miocene of China, the new species differs from *Miodyromys orientalis* in being larger but having proportionally smaller upper premolars, and in missing the ornamentation on the lingual wall of upper cheek teeth. By comparison with the species known in the Early Miocene of Europe, the new species differs from *Miodyromys biradiculus* Mayr, 1979 in having a well-developed extra ridge between anterolophid and metalophid in m2. The new species also differs from *Miodyromys praecox* Wu, 1993 in having proportionally wider upper and lower molars; and in having a longer extra ridge between the anterolophid and the metalophid and missing an extra ridge between the centrolophid and the metalophid in the lower molar. Differs from *Miodyromys vagus* Mayr, 1979 in having a simple morphology, larger premolars, less numerous and shorter extra ridges in upper and lower molars. Differs from *Miodyromys aegercii* (Baudelot, 1972) in having a shorter posterior centroloph and in missing the extra ridge between the posterior centroloph and the metalophid in upper molars; in addition, it lacks the extra ridge between the centrolophid and metalophid.

*Description* Cheek teeth with thick crests and concave occlusal surfaces. The P4 is wider than long, with well-developed paracone, protocone and metacone, the metacone being more developed than the paracone. The trigon is U shaped. The anteroloph is short and almost centrally

located. The protoloph is interrupted in one tooth (Fig. 2b), or constricted at the base of the paracone (Fig. 2a). The centroloph is isolated in one tooth (Fig. 2a), longer and slightly connected to the basis of the paracone in the other one (Fig. 2b), no extra ridge exists. The roots are only partially preserved, but the remains suggest three roots, the two labial ones being possibly merged together.

The M1 is wider than long with a strongly concave occlusal surface. The paracone and metacone constitute well-developed cusps, whereas the protocone is elongated in the same line as the posteroloph. The metacone is more developed than the paracone. The anteroloph is long and isolated, whereas the protoloph, metaloph and posteroloph are connected to the endoloph. Both centrolophs are present, the anterior one being longer and thicker than the posterior one. The extra ridge between the protoloph and anterior centroloph is as well developed as the posterior centroloph; the posterior extra ridge is absent. The M1 has three roots, two labial roots and one large lingual root.

Both p4 (one being damaged) have a slightly concave occlusal surface. The posterolophid and mesolophid are well developed with a small posterior extra ridge reduced to one or two points in between. In both teeth, the endolophid is absent. One tooth has a complete metalophid joining the protoconid and metaconid but an interrupted anterolophid (Fig. 2e), and the other tooth has a complete anterolophid but the metalophid is interrupted and does not reach the protoconid (Fig. 2d). Two roots merged into a single one (with two pulp cavities).

The m2 is longer than wide; all cuspids are well developed and differentiated from the main crests. Both extra ridges between the anterolophid and the metalophid, and between the mesolophid and the posterolophid are long, even slightly undulated for the posterior one; the central extra ridges are absent. The anterolophid almost reaches the protoconid, leaving a narrow opening at the antero-labial extremity of the anterior valley. The centrolophid is long and clearly separated from the endolophid by a constriction. The endolophid is interrupted between the centrolophid and entoconid. The roots are not preserved, but their marks at the bottom of the crown suggest three roots: two anterior and one large posterior.

*Remarks* The thick crests of the new species together with the absence of endoloph justify its ascription to *Miodyromys* rather than *Microdyromys* de Bruijn, 1966 or *Eliomys* Wagner, 1840. Furthermore, the protoloph and metaloph separately connected to the protocone and absence of anterior extra ridge reaching the paracone in the new species also exclude an ascription to the genus *Peridyromys* Stehlin and Schaub, 1951. This identification confirms the presence of *Miodyromys* in the Early Miocene of China (Qiu et al. 2006).

Qiu (1996, p74) described four teeth of *Miodyromys* sp. from the Moergen II locality. The size of these specimens is similar to those described above, but the morphology displays some noticeable differences: one upper molar has a metaloph which does not reach the metacone; the other upper molar has a posterior centroloph longer than the anterior one and a well-developed extra ridge between the posterior centroloph and the metaloph whereas the one between the protoloph and anterior centroloph is absent; the p4 has no connection between the metaconid and the protoconid, and the posterior extra ridge is well developed. Keeping in mind that we do not know much about the morphological variability of *M. asiamediae* and *Miodyromys* sp. it is not possible to state so far if they are somehow related.

Genus *Microdyromys* de Bruijn, 1966

*Microdyromys* aff. *orientalis* Wu, 1986

Figure 2g

*Referred specimen* One left m1, IVPP V 18130 (1.09 × 1.03 mm)

*Description* m2 with low crown and concave occlusal surface. The shape of the tooth in occlusal view is slightly longer than wide (L/W = 1.058). The labial cuspids are well developed, but the lingual ones are faint and integrated in the crests. The anterolophid joins the protoconid with a thin crest that closes the anterior valley antero-labially. The extra ridge between the anterolophid and the metalophid is long and the metalophid merges with the metaconid. The centrolophid starts from the metaconid and almost joins the mesoconid. The endolophid is interrupted but a cingulum remains, partially closing the central valley lingually. The extra ridge between the mesolophid and the posterolophid is long and slightly curved forwardly in its labial extremity. The roots are not preserved.

*Remarks* The size of this specimen is similar to the m2 of *Microdyromys wuae* described by Qiu (1996, p71) from the Middle Miocene of Moergen. However, the morphology is simpler in missing extra ridges anterior and posterior to the centrolophid. Furthermore, the m2 has a complete centrolophid whereas it is interrupted for *M. wuae*. In contrast, the morphology of the above specimen described is similar to *M. orientalis* Wu, 1986, but it is slightly larger than all the lower molars described by Wu (1986) and with slightly different proportions (m1 mean L/W = 1.019).

Compared to the species of *Microdyromys* known in the Early Miocene of Europe, our specimen is noticeably larger than *M. monspeliensis* Aguilar, 1977 and *M. hildebrandti* Werner, 1994, but its measurements fall within the size range of *M. koenigswaldi* de Bruijn, 1966, and *M. legidensis* Daams 1981. The morphology also fits within the variability of *M. koenigswaldi* de Bruijn, 1966, and *M. legidensis* Daams 1981. However, the m1 s of *M. koenigswaldi* and *M.*

*legidensis* tend to be wider than long according to the measurements provided by Wu (1993) on the German material: mean L/W = 0.974 for *M. koenigswaldi* from Erkerthofen 2, and 0.989 for *M. legidensis* from Stubersheim 3. We consequently tentatively ascribe this specimen to an affinitive form of the species *M. orientalis*, waiting for more material to secure the identification.

Genus *Eliomys* Wagner, 1840

*Eliomys?* sp.

Figure 2h

*Referred specimen* One left M2, IVPP V18131 (1.21 × 1.36 mm)

*Description* M2 with a low crown and a strongly concave occlusal surface. The morphology is quite simple with thin crests and large valleys. The paracone is antero-posteriorly elongated and rounded, whereas the metacone forms a well-developed cusp at the labial extremity of the metaloph. The endoloph is complete and higher than the other crests. The anterior centroloph is long but the posterior one is short and very weakly developed, limited to a low fold of the enamel starting from the metacone. The roots are not preserved.

*Remarks* Ellerman (1941) stated in his diagnosis of *Dryomys* that the morphology of its teeth is very similar to the one of *Eliomys*, except that *Dryomys* upper check teeth are less concave and with a more developed centrolophs. *Prodryomys* Mayr, 1979 also has a less concave occlusal surface, often misses the endoloph in upper molars, and has thicker crests compared to *Eliomys*. According to these differences, we tentatively ascribe the above described specimen to the genus *Eliomys*, which would be the first occurrence of the genus in Asia and the earliest in Eurasia. However, based on this single specimen it is not possible to secure the taxonomic identification. *Eliomys* is known from several fossil localities in Europe, mostly from the Late Miocene onward; however, *Eliomys truci* Mein and Michaux, 1970 has been recognized in the Middle Miocene of Spain (Daams and Freudenthal 1988) and *Eliomys reductus* Mayr, 1979 in the Middle Miocene of Germany (Mayr 1979; Heissig 1989). Our specimen displays morphology similar to *E. truci* but is slightly larger and longer in proportion (L/W = 0.89), and it also differs from *E. reductus* Mayr, 1979 in having a long anterior centroloph but a weakly developed posterior one.

Family Eomyidae Winge, 1887

Genus *Asianeomys* Wu et al., 2006

*Asianeomys* aff. *engesseri* Wu et al., 2006

Figure 3a–e

*Referred specimen* Left DP4, IVPP V18132.1 (1.03 × 1.08 mm, Fig. 3a); right DP4, IVPP V18132.2

(1.00 × 1.02 mm, Fig. 3b); right P4, IVPP V18132.3 (0.94 × 1.02 mm, Fig. 3c); right M1/2, IVPP V18132.4 (1.11 × 1.21 mm, Fig. 3d); left M3, IVPP V18132.5 (0.86 × 1.14 mm, Fig. 3e).

*Description* All cheek teeth have massive cusps, a brachyodont morphology with buno-lophodont pattern and a concave occlusal surface. The entoloph is connected to the posterior end of the protocone so that syncline II is longer than syncline I.

Both DP4 have a well-developed labial anteroloph but no lingual one; the mesolophs are weak and oriented forwardly. The hypocone is more lingually located than the protocone. One of the DP4 has an interrupted protoloph (Fig. 3b). The DP4 have three roots.

The P4 has no anteroloph, the mesoloph is long and reach the paracone. The longitudinal crest is interrupted between the mesoloph and the protoloph. The posteroloph is clearly differentiated from the hypocone by a constriction at its lingual extremity. The P4 has three roots.

The M1/2 has a higher and more developed labial wall than the lingual one. The metaloph is oblique and connected very anteriorly to the hypocone, delimiting a large fourth syncline. The posteroloph is short and the posterior syncline is labially open. The M1/2 has three roots.

The M3 is linguo-labially elongated with a narrow central syncline and has small but well-developed hypocone and metacone. The labial anteroloph is long and thick, whereas the lingual one is weakly developed. The M3 has three roots.

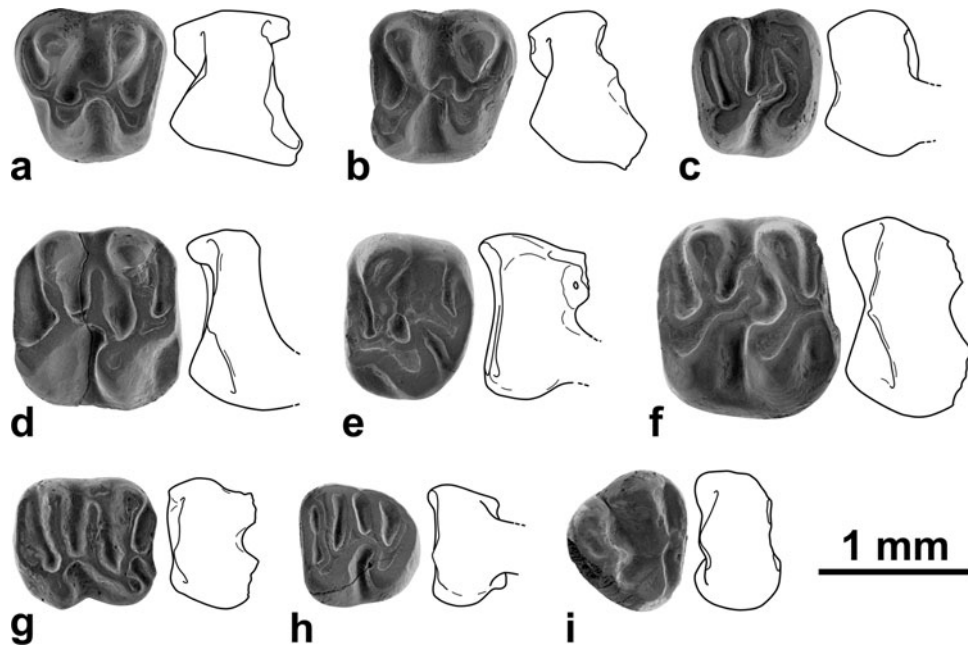
*Remarks* These specimens display all the diagnostic characteristics of genus *Asianeomys* on the upper molars: a brachyodont with buno-lophodont pattern and a concave occlusal surface; syncline II longer than syncline I. The size of the teeth is similar to *A. engesseri* (larger than *A. jungarensis* Wu et al., 2006 and *A. fahlbuschi* Wu et al., 2006) and the morphology is also similar in having a transverse protoloph joining the anterior part of the protocone on M1/2, and the longitudinal crest complete on the upper molars. However, the specimens described above also slightly differ from *A. engesseri* in missing a posterior spur on the paracone, and not having the mesoloph convex anteriorly on M1/2. We consequently ascribe these specimens to an affine form of *A. engesseri*.

*Asianeomys* sp.

Figure 3f

*Referred specimen* Right M1/2, IVPP V18133 (1.21 × 1.33 mm)

*Description* M1/2 having very massive cusps and a slightly concave occlusal surface. The protoloph is slightly oblique backward so the small mesolophid end very close to the paracone. The longitudinal crest is interrupted



**Fig. 3** *Asianeomys* aff. *engesseri*: **a** left DP4, IVPP V18132.1 (photo of the occlusal view and sketch of the posterior view); **b** right DP4, IVPP V18132.2 (photo of the occlusal view and sketch of the anterior view); **c** right P4, IVPP V18132.3 (photo of the occlusal view and sketch of the anterior view); **d** right M1/2, IVPP V18132.4 (photo of the occlusal view and sketch of the anterior view); **e** left M3, IVPP V18132.5 (photo of the occlusal view and sketch of the posterior

view). *Asianeomys* sp.: **f** right M1/2, IVPP V18133 (photo of the occlusal view and sketch of the anterior view). *Keramidomys* sp.: **g** right m1/2, IVPP V18134.1 (photo of the occlusal view and sketch of the anterior view); **h** left m3, IVPP V18134.2 (photo of the occlusal view and sketch of the posterior view). Eomyidae indet.: **i** right M3, IVPP V18135 (photo of the occlusal view and sketch of the anterior view)

between the mesoloph and the protocone. The posteroloph is short. The tooth has three roots.

**Remarks** The morphology is very close to *Asianeomys* aff. *engesseri* from this same locality. It is impossible to state for sure that this molar does not belong to the same population. However, for now, the size of tooth, the more massive cusps and the oblique protolophule lead us to treat this specimen as a different species.

Genus *Keramidomys* Hartenberger, 1966

*Keramidomys* sp.

Figure 3g, h

**Referred specimen** Right m1/2, IVPP V18134.1 (0.98 × 0.95 mm, Fig. 3g); left m3, V18134.2 (0.86 × 0.84 mm, Fig. 3h)

**Description** Both lower molars have narrow cuspids, the metaconid and entoconid being especially small and barely differentiable from the metalophid and the hypolophulid, respectively. The protoconid and hypoconid are oblique and located close to the labial border. The m1/2 has a long mesolophid and a strong lingual cingulum; however, the mesolophid does not reach this cingulum; the labial anterolophid is short; and the longitudinal crest is connected very labially, directly on the protoconid. The m3 has a long mesolophid merging with the lingual cingulum; the anterolophid extends up to the lingual side and labially contacts

the lingual side of protocone. The m1/2 has four roots and the m3 three roots.

**Remarks** These two teeth are easily differentiable from *Asianeomys* by their more lophodont morphology; indeed the cuspids are narrow and elongated whereas there are more massive in *Asianeomys* species, including the Oligocene species *A. asiaticus* (Wang and Emry 1991) initially ascribed to *Pseudotheridomys*. Furthermore, both teeth differ from *Asianeomys* in having the protoconid and hypoconid more labially located (and an ectomesolophid connected very labially for the m1/2), and having a flat occlusal surface. These morphological characteristics together with the small size and the hypolophulid connected anteriorly to the hypoconid fit the diagnosis of genus *Keramidomys*, however more material will be necessary to allow an identification at the species level.

Eomyidae indet.

Figure 3i

**Referred specimen** Right M3, IVPP V 18135 (0.84 × 0.89 mm), with the postero-lingual border damaged.

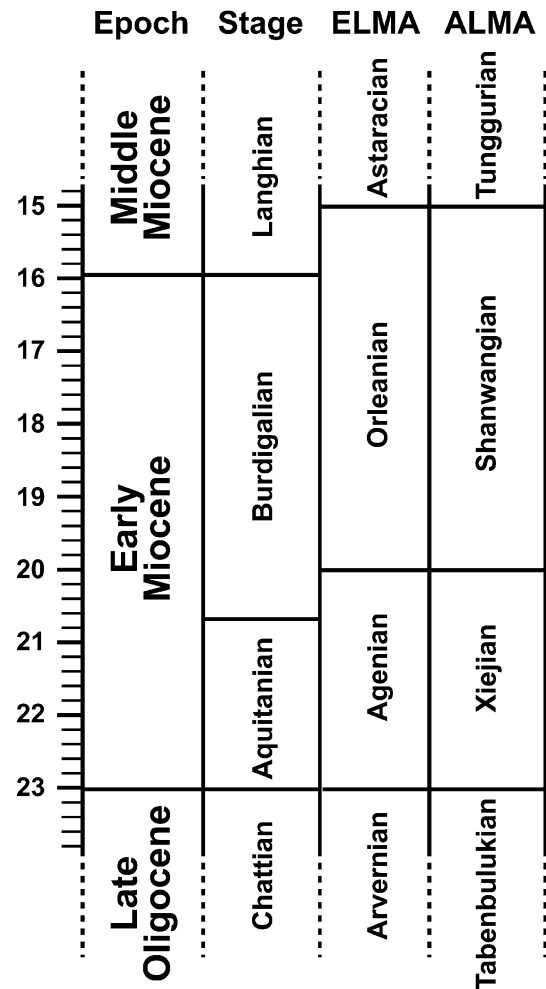
**Description** Middle-sized M3 with a widely open sinus and a flat occlusal surface. Both anterolophs are well developed, the lingual one being even thicker and longer than the labial one. Even if the postero-lingual border of

the tooth is damaged, it is possible to see that the hypocone is weakly developed. The connection between the protocone and the hypocone is located close to the lingual border of the tooth. The posteroloph starts from the middle of the metaloph and is relatively short, delimiting a very small posteroloph. A very short spur (possibly a weakly developed mesoloph) starts from the middle of the metaloph, opposite to the posteroloph. The roots are not preserved.

**Remarks** The very simple morphology of the M3, is uncommon among Neogene eomyids. Some M3 s of *Keramidomys* can display a quite simple morphology (e.g., Daxner-Höck and Höck 2009, fig. 4–12; Prieto 2010, fig. 1–247), but the triangular shape, the absence of mesoloph and the very short posteroloph seem to differentiate our specimen from those M3 of *Keramidomys*. However, this differentiation from *Keramidomys* is uncertain due to the noticeable variability of these characters. Some primitive *Eomys* from the Oligocene also display a very simple morphology of the M3 s (e.g., Maridet et al. 2010) which could also suggest that some Oligocene taxa, possibly belonging to a lineage of *Eomys* from China (Wang and Emry 1991), have subsisted in the Early Miocene.

## Discussion

The discovery of forms closely related to *M. orientalis* and *A. engesseri* suggests an Early Miocene age for the locality. *A. engesseri* is known from the Suosuoquan Fm. Zone II, which is dated between 21.9 and 21.7 Ma based on magnetostratigraphy (Meng et al. 2006), whereas *M. orientalis* is known from the Shanwangian locality Sihong, the Shanwangian being roughly equivalent to the Orleanian according to Deng (2006) (see Fig. 4). Based on absolute dating and correlations proposed by Deng (2006), the Shanwang and Sihong localities are about the same age. The Shanwang Formation overlies a basalt that was dated to  $18.05 \pm 0.55$  Ma (Cheng and Peng 1985) and, therefore, the Shanwang fauna within the formation must be slightly younger than 18.05 Ma. So far it is consequently not possible to state whether the locality XJ 200604 is late Xiejian or Shanwangian in age (Fig. 4) based on glirid and eomyid remains. However, the other taxa (currently under study) include several teeth of *Ansomys* Qiu, 1987 which have been compared with *Ansomys* populations of Sihong and Gashunyinadege localities (unpublished material, comm. pers. Qiu Z.-D.). Despite the fact that *Ansomys* from XJ 200604 likely represents a different species due to noticeable morphological differences, the development of the crown which is similar to Sihong and Gashunyinadege specimens suggests a Shanwangian age for XJ 200604 (late Early Miocene), and a dating probably close to those of Sihong and Gashunyinadege (c. 17–18 Ma, Deng 2006).



**Fig. 4** Correlations between Asian and European Land Mammal Ages (ALMA, ELMA) as proposed by Deng (2006) and correlations with marine stages based on Gradstein et al. (2004)

While the present study improves our knowledge of Asian Early Miocene glirids and eomyids, the Chinese fossil record of these families remains relative poor with regard to the European abundance and species richness. The problem of the scarcity of glirids and eomyids in the Early Miocene of China (and more generally Central Asia) has never been discussed so far. The extensive sampling made in the Early Miocene of the Junggar basin (Bi 2000; Bi et al. 2009; Maridet et al. 2011a, b; Meng et al. 2006; Wu et al., 2006; Ye et al. 2003) exclude sampling biases as reason for such a discrepancy between the European and Central Asian fossil records.

Glirids and eomyids (of which species richness evolution seems to be correlated in the European fossil record Aguilar et al. 1999) might have required similar environment, mostly inhabiting humid environments and partly covered landscape (e.g., Huguency 1984; Daams and van der Meuler 1984; van der Meulen and Daams 1992). Indeed, most of extant glirids are agile climbers and live in forest

environments (Nowak 1995). However as stated by Engesser (1990, 1999), the high diversity of Eomyids could have been the result of a large panel of ecological adaptations in the family, at least for the Early Miocene. Indeed the only clear evidence of forest dependence of eomyid rodents was provided by Storch et al. (1996) thanks the discovery of a complete skeleton of *Eomys quercyi* Comte and Vianey-Liaud, 1987, showing morphologic adaptation for gliding. With regard to this problem, the brachyodont and generally simple morphology of *Asianeomys* suggests, like for *Eomys*, the consumption of a non-abrasive food which coincides better with a humid and closed living environment.

The Early Miocene of Europe is usually considered as a period of subtropical climate in mid-latitudes as deduced by the palynological record (e.g., Bessedik 1985; Jiménez-Moreno et al. 2007; Utescher et al. 2000), and evolving by the end of the Early Miocene (c. 18 My) to a climatic optimum characterized by warmer and more humid conditions (Böhme 2003; Costeur and Legendre 2008) and also the accumulations in some provinces of long sections of continental sediments (e.g., Abdul-Aziz et al. 2008; Abdul Aziz et al. 2010; van der Meulen et al. 2011). The high diversity of glirids and eomyids along the Early Miocene can be interpreted as resulting, at least partially, from this specific climatic context (Daams et al. 1988; Aguilar et al. 1999).

In contrast, some studies of the eolian deposits from the Gansu province (Central China; Guo et al. 2002) and Junggar basin (Northwestern China; Sun et al. 2010) indicated an onset of the aridity in central Asia around the Oligo-Miocene transition. Indeed, during the Early Miocene, the combined effects of the Tibetan uplift with the disappearance of the Paratethys seaways in Asia led a deep climatic change in Central Asia, characterized by the settlement of a monsoon-dominated climate similar to the present days (Guo et al. 2008). A result of this new climatic system is the accumulation of eolian transported by westerly winds (Sun et al. 2010) in the northern Junggar basin between 24 and 11.8 Ma (Meng et al. 2006). Following these observations, tentative hypothesis to explain the scarcity of glirids and eomyids would be a reduction of forest cover during the Early Miocene in central Asia. The ochotonid lagomorphs are also abundant in the locality. Considering that their extant relatives mainly live in temperate-cold stepping environments of Asia, their presence in the locality might also support environments dominated by open landscape.

Yet, even if eomyids and glirids are rare, they are present in the Early Miocene possibly indicating a progressive but not a drastic reduction of forested habitats. Furthermore, another late Early Miocene locality of the northern Junggar basin (Maridet et al. 2011b) also yielded *Karydomys* Theocharopoulos, 2000 which is also interpreted as humid environment dweller (Mörs and Kalthoff

2004). Consequently, a progressive change of Central Asian environments leading to dryer and more open environments linked to the new monsoon-dominated climate is likely. However, a permanent modification of the environments leading to overall aridity and the formation of high-latitude inland deserts in north-western China from 22 Ma onward (Guo et al. 2002, 2008) seems overstated, and has possibly been interrupted by a more a humid phase during the late Early and Middle Miocene which would coincide with the climatic optimum recognized in Europe (Böhme 2003; Costeur and Legendre 2008).

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