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Eocene fossil rodent assemblages from the Erlian Basin (Inner Mongolia, China): Biochronological implications

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Abstract

Rodents from the Nuhetingboerhe-Huheboerhe area in the Erlian Basin, Inner Mongolia, differ stratigraphically: primitive ctenodactyloids such as *Chenomys* and *Yuanomys* are dominant in the upper part of the Nomogen Formation; *Tamquammys* dominates in the Arshanto Formation; *Asiomys*, *Pappocricetodon*, and *Yuomys* appear in the lower part of the Irdin Manha Formation and *Tamquammys* is rarer in this formation than in the Arshanto Formation. The assemblage of the upper part of the Nomogen Formation is similar to that of the Lingcha Formation of Hunan, the Wutu Formation of Shandong, the Yuhuangding Formation of Hubei, and the Bumban Member of the Nara-Bulak Formation of Mongolia. The assemblage in the upper part of the Arshanto Formation is correlated with that from the locality Andarak 2 in Kyrgyzstan. The assemblage from the lower part of the Irdin Manha Formation resembles that of the lower part of the Hetaoyuan Formation of Henan.

On the basis of the comparison of the rodent assemblages, I consider that the age of upper part of the Nomogen Formation corresponds to the Bumbanian land mammal age. The Bumbanian, Arshantan, and Irdinmanhan land mammal ages are correlated respectively to the early Ypresian, the middle–late Ypresian, and the early Lutetian of the Geological Time Scale. The Bumbanian and Irdinmanhan land mammal ages are also correlated to the early Wasatchian and the early Uintan (or the later Bridgerian) of the North American Land Mammal Ages.

Keywords: Inner Mongolia; Nuhetingboerhe-Huheboerhe area; Early–Middle Eocene; Rodent fossil assemblages

1. Introduction

Paleogene strata rich in fossil mammals (Li and Ting, 1983; Russell and Zhai, 1987) are well exposed in central Inner Mongolia, China, especially in the Erlian Basin. The Tertiary beds in the Erlian Basin were first explored by the Central Asiatic Expeditions (CAE) in the 1920s (Granger and Berkey, 1922; Berkey and Granger, 1923; Berkey and Morris, 1924, 1927; Matthew and Granger, 1926). A number of Paleogene lithological units were named in this area and several Asian Land Mammal Ages (ALMAs) are based on local mammalian faunas (Romer, 1966; Tong et al., 1995; Wang et al., 2006). The Erlian Basin is important in Asian Paleogene mammalian biostratigraphy and biochronology; however, the great lateral variation of lithology and partial exposure of outcrops at the sites where the lithologic units were named have resulted in the misinterpretation of the lithostratigraphic divisions and their correlations. These geological problems have caused confusion of faunas and have not been completely resolved to date (Radinsky, 1964; Qi, 1980, 1987; Meng, 1990).

During the last decade, significant progress has been made in clarifying the stratigraphy of the Erlian Basin, particularly in the area of Bayan Ulan and Huheboerhe-Nuhetingboerhe (Bowen et al., 2005; Meng et al., 2007c). Since the investigations of the CAE, numerous fossils have been collected from this area, but rodents and other micromammals were rare, partly because their small size made surface collecting difficult. Several fossil

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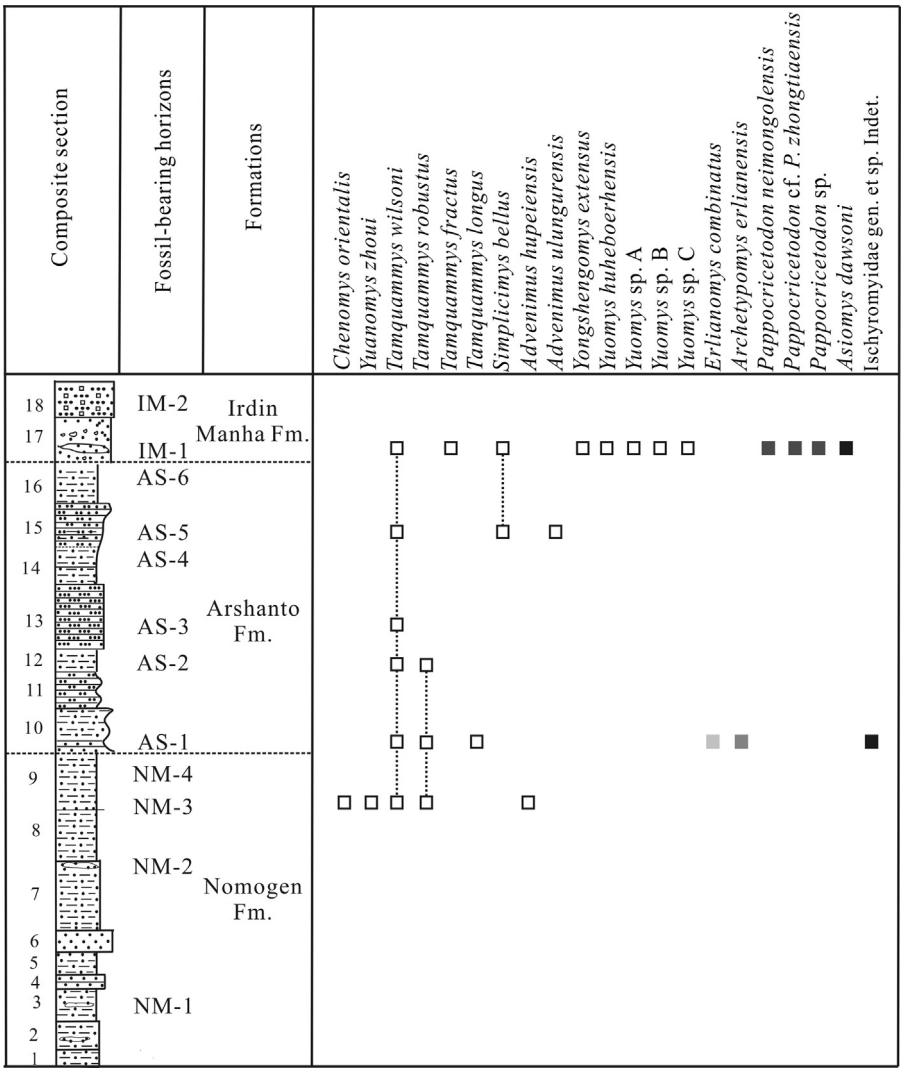

Fig. 1. Stratigraphic distributions of rodent taxa in the Huheboerhe-Nuhetingboerhe area, plotted on a composite section modified from Wang et al. (2010). (A same colour chart is used for all the diagrams, Ctenodactyloidea in white, Myodont in 20% black, Archetypomyidae in 50% black, Cricetidae in 80% black, Ischromyidae in black.)

localities have been found in the Huheboerhe-Nuhetingboerhe area, which significantly expanded the fossil record (Meng et al., 2004, 2007a, 2009; Li et al., 2007; Ni et al., 2007, 2009; Bai et al., 2010; Wang et al., 2010, 2012; Jin, 2012; Mao and Wang, 2012), particularly for rodents (Meng et al., 2007b; Li and Meng, 2010, 2013, 2015; Meng and Li, 2010; Li, 2012), of this region. These rodents are distributed in different layers, and in different assemblages that will provide important evidence for stratigraphic division and correlation between sections, will clarify the lithological and biostratigraphic correlations and the stratigraphic occurrences of fossils in the region. Rodent data, along with a paleomagnetic study and ages based on other mammals, have improved the mammalian biochronology in the Erlian Basin.

2. Geological setting

The Erlian Basin is located in central Inner Mongolia, close to the border with Mongolia. Paleogene deposits are well exposed in the basin. All specimens reported here were collected from the Nuhetingboerhe-Huheboerhe area in the Erlian Basin including the escarpment through which several sections have been measured, i.e., the Huheboerhe section, Nuhetingboerhe section, Daoteyin Obo section, and Wulanboerhe section (Meng et al., 2007c). Stratigraphic data show that the sequence in the Nuhetingboerhe-Huheboerhe area comprises three lithological units, the Nomogen, Arshanto, and Irdin Manha Formations, with a total thickness of 82.4 m (Meng et al., 2007c). Twelve mammal-bearing horizons have been recognized in the Paleogene of the area, including four in the Nomogen Formation, six in the Arshanto Formation, and two in the Irdin Manha Formation. These horizons are labelled as follows, in ascending order, NM-1 to NM-4, AS-1 to AS-6, and IM-1 to IM-2 (Wang et al., 2010; Fig. 1).

3. Rodent assemblages

The rodent specimens reported here were collected from the NM-3 horizon of the upper part of the Nomogen

Table 1
Relative abundance of fossil rodents from Nomogen to Irdin Manha Formation of the Nuhetingboerhe-Huheboerhe area.

Rodentia	Taxa	Horizons	TNS	MNI	PEH
Myodonta	*Erlianomys combinatus*	AS-1	86	10	3.80%
Archetypomyidae	*Archetypomys erlianensis*	AS-1	50	7	2.65%
Cricetidae	*Pappocricetodon neimongolensis*	IM-1	43	9	15.52%
	Pappocricetodon cf. *P. zhongtiaensis*	IM-1	1	1	1.70%
	Pappocricetodon sp.	IM-1	1	1	1.70%
Ischyromyidae	*Asiomys dawsoni*	IM-1	45	10	17.24%
	Ischyromyidae gen. et sp. indet.	AS-1	2	1	0.37%
Ctenodactyloidea	*Yuanomys zhoui*	NM-3	2	1	14.29%
	Chenomys orientalis	NM-3	4	3	42.86%
	Tamquammys longus	AS-1	1	1	0.37%
	Tamquammys wilsoni	NM-3	1	1	14.29%
		AS-1	1429	109	41.30%
		AS-2	57	21	60.00%
		AS-3	44	6	100%
		AS-5	54	13	72.22%
		IM-1	99	11	18.97%
	Tamquammys	NM-3	1	1	14.29%
	robustus	AS-1	1160	136	51.51%
		AS-2	61	14	40.00%
	Tamquammys fractus	IM-1	1	1	1.70%
	Simplicimys bellus	AS-5	8	3	16.67%
		IM-1	106	11	18.97%
	Yongshengomys extensus	IM-1	25	8	13.79%
	Advenimus hupeiensis	NM-3	1	1	14.20%
	Advenimus ulungurensis	AS-5	2	2	11.11%
	Yuomys huheboerhensis	IM-1	17	3	5.17%
	Yuomys sp. A	IM-1	1	1	1.70%
	Yuomys sp. B	IM-1	1	1	1.70%
	Yuomys sp. C	IM-1	1	1	1.70%

TNS: total number of specimens; MNI: minimum number of individuals; PEH: percent of the fauna of each horizon.

Formation, the AS-1, AS-2, AS-3, and AS-5 horizons of the Arshanto Formation, and the IM-1 horizon of the lower part of the Irdin Manha Formation in the Nuhetingboerhe-Huheboerhe area. These materials include the primitive myodont *Erlianomys combinatus* (Li and Meng, 2010), early rodent *Archetypomys erlianensis* (Meng et al., 2007a), the ctenodactyloid *Yuanomy zhoui* (Meng and Li, 2010), *Chenomys orientalis*, *Tamquammys wilsoni*, *Tamquammys robustus*, *Tamquammys fractus*, *Tamquammys longus*, *Simplicimys bellus*, *Advenimus hupeiensis*, *Advenimus ulungurensis*, *Yuomys huheboerhensis*, *Yuomys* sp. A, *Yuomys* sp. B, and *Yuomys* sp. C (Li and Meng, 2015), some cricetids *Pappocricetodon neimongolensis*, *Pappocricetodon* sp., *Pappocricetodon* cf. *P. zhongtiaensis* (Li, 2012), and the ischyromyid *Asiomys dawsoni* and a generically indeterminate ischyromyid (Li and Meng, 2013). These specimens are referred to 16 species and 5 indeterminate species belonging to 11 genera, 3 families, 1 superfamily, and 1 suborder of Rodentia. The bed of the composite section that contains the rodent fossils in each horizon is shown in Fig. 1. The approximately 3300 rodent specimens collected from the Nuhetingboerhe-Huheboerhe area in the Erlian Basin represent at least 388 individuals counted by the minimum number of individuals (MNI) (Table 1). The diagrams (Figs. 2–5) plotted based on MNI show the rodent assemblage compositions from different horizons and a same colour chart is used for all the diagrams.

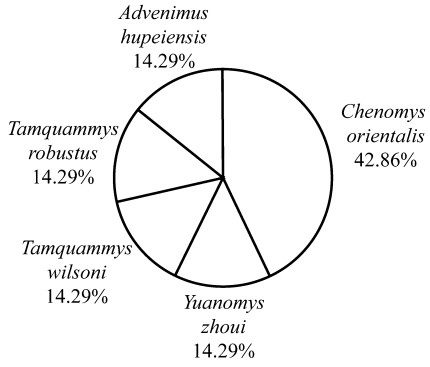

Fig. 2. Diagram of the rodent assemblage compositions from NM-3 (the upper part of the Nomogen Formation), by minimum number of individuals.

NM-3: Only seven rodent specimens are found from this horizon and they are referred to ctenodactyloids. This horizon yields *Chenomys orientalis*, *Yuanomys zhoui*, *Tamquammys wilsoni*, *Tamquammys robustus*, and *Advenimus hupeiensis*. *Chenomys* constitutes 42.90% of the total, and the other four are about equal in abundance (Fig. 2).

AS-1: Total number of rodent specimens from this horizon is far more than other horizons. Based on MNI, ctenodactyloids *Tamquammys wilsoni* and *Tamquammys robustus* from AS-1 account for 92.81% and are dominant species (Fig. 3). There is more *T. robustus* than *T. wilsoni*. *Erlianomys combinatus*,

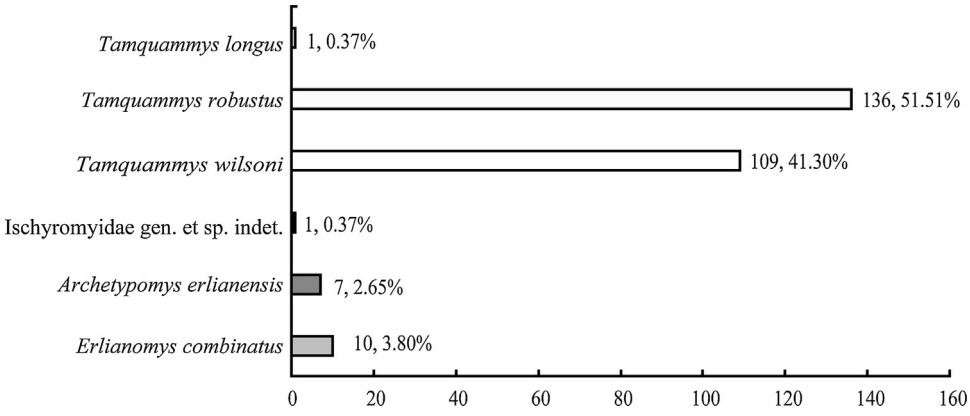

Fig. 3. Diagram of the rodent assemblage compositions from AS-1, by minimum number of individuals.

Archetypomys erlianensis, *Tamquammys longus* and Ischyromyidae gen. et sp. indet. were also found from this horizon.

AS-2: In this horizon only *Tamquammys robustus* and *Tamquammys wilsoni* were found, with more *T. wilsoni* than *T. robustus* (Fig. 4A).

AS-3: This horizon only contains *Tamquammys wilsoni*.

AS-5: The dominant element in this horizon still is *Tamquammys wilsoni*, although *Simplicimys bellus* and *Advenimus ulungurensis* are also present (Fig. 4B).

IM-1: The diversity of taxa and abundance of fossil materials increase significantly in this horizon. *Pappocricetodon neimongolensis*, *Pappocricetodon* cf. *P. zhongtiaensis*, *Pappocricetodon* sp., *Yuomys huheboerhensis*, *Yuomys* sp. A, *Yuomys* sp. B, and *Yuomys* sp. C from this horizon are the earliest record in the Nuhetingboerhe-Huheboerhe area, and these fossils suggest that cricetids and yuomids were already diversified in IM-1 (Fig. 5). The ischyromyid *Asiomys dawsoni* occupys 17.24%. The ctenodactyloids of this horizon include *Tamquammys*, *Simplicimys*, *Yuomys*, and *Yongshengomys*. The specimen numbers of *Tamquammys* decreased significantly, but the diversity of ctenodactyloids from this horizon increased.

Based on the MNI, it is evident that the rodent assemblages of the Nuhetingboerhe-Huheboerhe area from different Formations show transformation. In the upper part of the Nomogen Formation, *Chenomys* is dominant, and *Tamquammys wilsoni* and *Tamquammys robustus* are already present. *Tamquammys* is a dominant genus in the Arshanto Formation, *Tamquammys wilsoni* and *Tamquammys robustus* were present in the basal and lower part of the Arshanto Formation and their percentages are similar to each other. Only *Tamquammys wilsoni* has been discovered from the middle and upper parts of the Arshanto Formation. In the lower part of the Irdin Manha Formation, ischyromyid *Asiomys*, cricetid *Pappocricetodon*, and ctenodactyloid *Yuomys* are the earliest record for their genera in the Nuhetingboerhe-Huheboerhe area, and *Tamquammys* decreased significantly and ctenodactylodis *Simplicimys* and *Yongshengomys* were also found from this formation.

4. Biostratigraphic correlation and discussion

4.1. Upper part of the Nomogen Formation

This rodent assemblage is characterized by dominance of original ctenodactyloids *Chenomys* and a minor occurrence of *Yuanomys*, *Tamquammys wilsoni*, *Tamquammys robustus*, and *Advenimus hupeiensis*.

Chenomys possesses several primitive ctenodactyloid features, including that the lower cheek teeth increase in size posteriorly and that the lower molars have distinct mesoconids and hypoconulids (Li and Meng, 2015). The lower teeth of *Tsagamys*, *Ulanomys*, *Adalomys*, *Bumbanomys*, *Tsagankhushumys*, and *Sharomys* (Shevyreva, 1989; Dashzeveg, 1990) from the Bumban Member of the Naran-Bulak Formation of the Tsagan Khushu locality in the Nemegt Basin of Mongolia have a short hypolophid, or none at all, and are similar to the lower teeth of *Chenomys*.

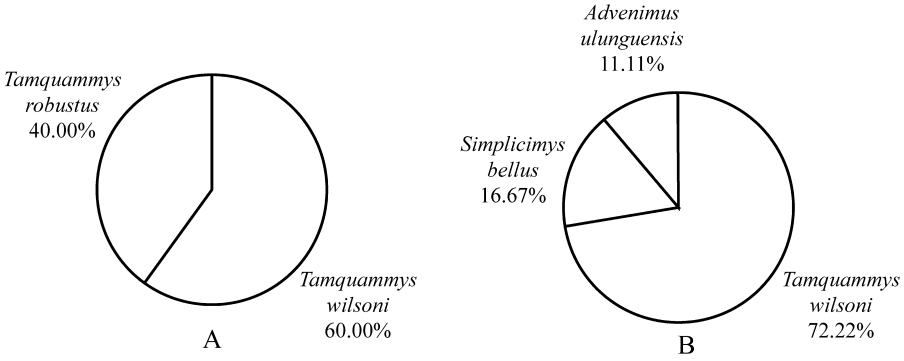

Fig. 4. Diagrams of the rodent assemblage compositions from the Arshanto Formation (A, AS-2; B, AS-5), by minimum number of individuals.

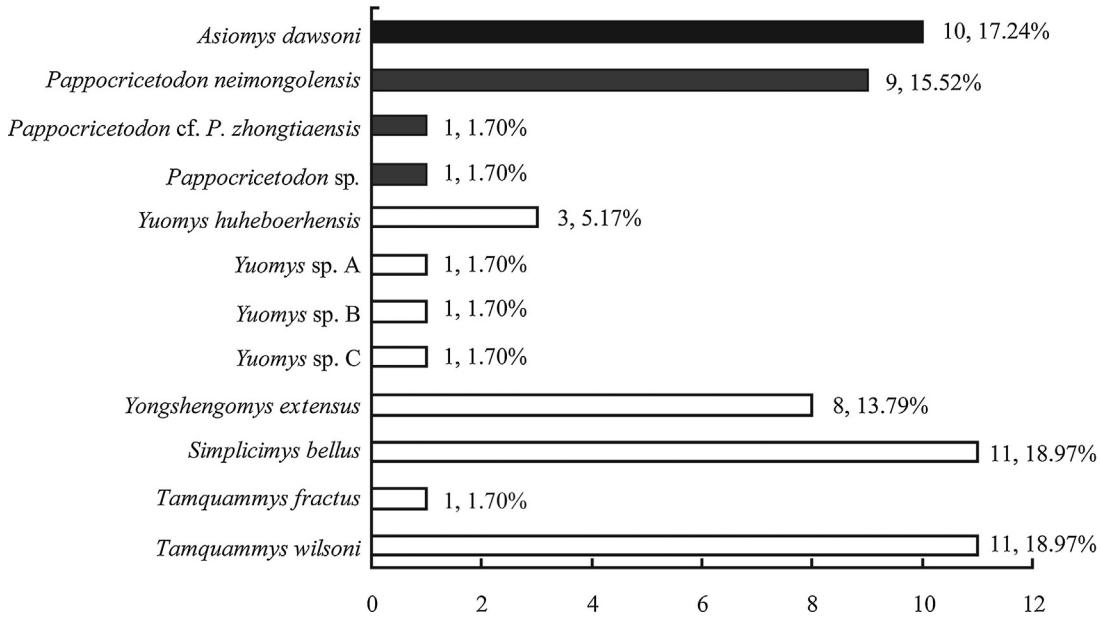

Fig. 5. Diagram of the rodent assemblage compositions from IM-1 (the lower part of the Irdin Manha Formation), by minimum number of individuals.

Yuanomys is similar to *Cocomys* from the Lingcha Formation of Hunan (Li et al., 1989), *Kharomys* and *Sharomys* (Dashzeveg, 1990) from the Bumban Member, and *Alagomys* (Tong and Dawson, 1995) from the Wutu Basin and the Nemegt Basin. In general, the tooth cusps and conules in the aforementioned taxa are pronounced, and crests are weak. The cusps of *Yuanomys* are relatively slimmer and more isolated than those of *Cocomys*. The teeth of *Kharomys* and *Sharomys* have more inflated cusps and conules. Compared to molars of *Alagomys*, the molars of *Yuanomys* are quadrate, with expansion of the hypocone and development of the precingulum. Generally, *Yuanomys* displayed more primitive dental features, and it emerged as the most basal ctenodactyloid in a phylogenetic analysis (Li and Meng, 2015).

Advenimus hupeiensis was found in the upper part of the Nomogen Formation and the Yuhuangding Formation of Hubei. In the phylogenetic analysis, *Bandaomys* from the Wutu Basin, *Exmus* and *Hohomys* from the Yuhuangding Formation, and *Chenomys* and *Tamquammys* from the upper part of the Nomogen Formation are basal ctenodactyloids (Wible et al., 2005; Li and Meng, 2015).

Those fossil assemblages from the Lingcha Formation, the Wutu Basin, the Yuhuangding Formation, and the Bumban Member in the Nemegt Basin can be correlated with that of the upper part of the Nomogen Formation by sharing the similar primitive ctenodactyloids with bunodont cheek teeth having weak lophs connecting the main cusps (Tables 2 and 3).

Bowen et al. (2002) have found the transient carbon isotope excursion that marks the Paleocene–Eocene boundary in the Hengyang basin. Ting et al. (2011) suggest the Lingcha fauna seems to correlate to the earliest Wasatchian (Wa-0). Tong and Wang (2006) suggest the age of the Wutu fauna is most likely to be Early Eocene. Rodent fossils found in the middle part of the Yuhuangding Formation and the assemblages from the lower and middle part of the Yuhuangding Formation can be assigned a Bumbanian age (Lucas, 2004). Based on the rodent assemblages, the age of the upper part of Nomogen Formation belongs to the Bumbanian land mammal age, and is correlative to the early Ypresian age and equivalent to the early Wasatchian of the North American Land Mammal Age.

Gomphos elkema from both the NM-3 and NM-4 horizons is a typical mammal species of the Mongolian Early Eocene Bumbanian (Meng et al., 2004). The euprimates *Baataromomys ulaanus* from the NM-3 is very similar to "*Teilhardina*" *brandti* of the Wasatchian (Wa-0), and they are thought to be congeneric (Ni et al., 2007). Recent magnetostratigraphic work in the Nuhetingboerhe-Huheboerhe area (Sun et al., 2009) shows the *Gomphos*-bed near the Paleocene–Eocene boundary within the long C24r in the Nuhetingboerhe section. The early–middle Eocene boundary is recorded in the Huheboerhe section. The Nomogen Formation consists mainly of late Paleocene deposits, with some earliest Eocene and middle Paleocene strata. The assigned ages based on the rodent assemblages are in agreement with the ages based on other mammals and paleomagnetic result (Sun et al., 2009; Wang et al., 2010).

4.2. Arshanto Formation

Tamquammys is dominant in this formation, *Erlianomys* and *Archetypomys* were found from AS-1, and *Simplicimys* and *Advenimus ulungurensis* were present in AS-5.

Erlianomys from AS-1 is a primitive myodont rodent and it is more primitive than *Palasiomys* and *Pappocricetodon* (Tong, 1992, 1997) from the Middle Eocene Liguanqiao and Yuanqu basins, and *Elymys* (Emry and Korth, 1989; Emry, 2007) from the early Bridgerian (early Middle Eocene) Sheep Pass Formation near Ely, Nevada, North America (Tables 2 and 3).

Archetypomys is a primitive rodent and occupies an intermediate phylogenetic position between alagomyids and rodents of

Table 2
Comparison of Rodent fossil assemblages of the Nuhetingboerhe-Huheboerhe area with other concerned faunas in China.

Erlian Basin, Inner Mongolia		Lingcha Formation, Hunan	Wutu Formation, Shandong	The lower part of the Hetaoyuan Formation of Xichuan, Henan
Lower part of the Irdin Manha Formation	**Ctenodactyloidea** *Tamquammys* *Simplicimys* *Yongshengomys* *Yuomys* **Cricetidae** *Pappocricetodon* **Ischyromyidae** *Asiomys*			**Ctenodactyloidea** *Tamquammys* *Viriosomys* *Tsinlingomys* *Chuankueimys* *Saykanomys* *Stelomomys* *Boromys* *Zoyphiomys* **Cricetidae** *Palasiomys* (*Raricricetodon*) **Zapodidae** *Primisminthus* **Cylindrodontidae** *Orientocylindrodon* cf. *Pareumys* sp. cf. *Mysops* spp. **?Ischyromyidae indet.** **?Geomyoidae** *Hydentomys*
Arshanto Formation	**Ctenodactyloidea** *Tamquammys* *Simplicimys* *Advenimus* **Ischyromyidae** **Myodonta** *Erlianomys* **Archetypomyidae** *Archetypomys*			
Upper part of the Nomogen Formation	**Ctenodactyloidea** *Yuanomys* *Chenomys* *Tamquammys* *Advenimus*	**Ctenodactyloidea** *Cocomys* cf. *Tsagamys* sp.	**Ctenodactyloidea** *Bandaomys* **Ischromyidae** *Actitoparamys* *Taishanomys* **Alagomyidae** *Alagomys*	**Ctenodactyloidea** *Hohomys* *Exmus* *Advenimus*

modern aspect. In our phylogenetic analysis *Archetypomys* is the sister of *Tribosphenomys* (Li and Meng, 2015).

The ctenodactyloid rodents from locality Andarak 2 in Kyrgyzstan were described as *Alaymys*, ?*Adolomys*, *Advenimus* cf. *A. burkei*, *Advenimus* sp., *Khodzhentia*, *Petrokozlovia* cf. *P. notos*, *Petrokozlovia* sp., *Saykanomys* cf. *S. bohlini*, *Saykanomys* sp., and Ctenodactyloidea indet. (Averianov, 1996). *Alaymys* is similar to *Tamquammys*, and they are sister groups in Averianov's phylogenetic analysis. Averianov and Godinot (1998) suggested that the Andarak fauna is roughly contemporaneous with mammal assemblages from the Arshanto Formation in Inner Mongolia, but the earliest myodont *Erlianomys* and the primitive rodent *Archetypomys* from AS-1 are not present in the Andarak fauna; therefore, we assume that the rodent fauna from Andarak 2 is similar to the upper part of the Arshanto Formation. Data from the shark fauna and sequence stratigraphy suggest a late early Eocene (late Ypresian) age for the Andarak 2 locality (Averianov and Godinot, 1998).

The age of the Arshanto Formation was traditionally considered Middle Eocene (Qi, 1987), but Meng et al. (2007c) suggested that the lower part of the Arshanto Formation is probably late Early Eocene rather than Middle Eocene. According to our analysis of rodent assemblages, the age of the Arshanto Formation is earlier than Middle Eocene, corresponding to the Arshantan land mammal age and correlated to the middle–late Ypresian.

4.3. Lower part of the Irdin Manha Formation

This rodent assemblage is characterized by a wide variety of ctenodactyloids, more diversified than the assemblages from the Nomogen and Arshanto Formations, including the ischyromyid

Table 3
Comparison of Rodent fossil assemblages of the Nuhetingboerhe-Huheboerhe area with selected faunas in Asia.

Erlian Basin, Inner Mongolia		Bumban Member of Naran Bulak Formation, Nemegt Basin, Mongolia	Lower Alay beds, Andarak 2, Kyrgyzstan
Arshanto Formation	**Ctenodactyloidea** *Tamquammys* *Simplicimys* *Advenimus* **Ischyromyids** **Myodonta** *Erlianomys* **Archetypomyidae** *Archetypomys*		**Ctenodactyloidea** *Alaymys* ?*Adolomys* *Advenimus* cf. *A. burkei* *Advenimus* sp. *Khodzhentia* *Petrokozlovia* cf. *P. notos* *Petrokozlovia* sp. *Saykanomys* cf. *S. bohlini* *Saykanomys* sp. Ctenodactyloidea indet.
Upper part of the Nomogen Formation	**Ctenodactyloidea** *Yuanomys* *Chenomys* *Tamquammys* *Advenimus*	**Ctenodactyloidea** *Sharomys* *Kharomys* *Tsagamys* *Ulanomys* *Adolomys* *Tsagankhushumys* *Bumbanimys* ?*Esesemomys* **Alagomyidae** *Alagomys* **Ivanantoniidae** *Ivanantonia* **Orogomyidae** *Orogomys*	

Asiomys and primitive cricetids. *Yuomys huheboerhensis* from the lower part of the Irdin Manha Formation is smaller and has morphologically simpler teeth than other known species of the genus. *Pappocricetodon neimongolensis* from the lower part of the Irdin Manha Formation is more primitive than other species of the genus in having a smaller anterocone, a shorter mure and mesoloph, a more prominent hypocone on M3, and a longer posterior arm of the protoconid. Based on the primitive characters of *Yuomys huheboerhensis* and *Pappocricetodon neimongolensis*, the age of the lower part of the Irdin Manha Formation might be earlier than Late Eocene.

The rodent assemblage of the Shipigou fauna from the lower part of the Hetaoyuan Formation of Xichuan, Henan (Table 2), is characterized by the followings: primitive ctenodactyloids (tamquammyids and yuomyids) are major components. They make up one-third of the total species and more than one-half of the total individuals. The primitive cricetids and zapodids account for 15.3% of the total individuals. Cylindrodonts are already diversified. The rodent assemblage from the lower part of the Irdin Manha Formation is similar to that of the Shipigou fauna. *Tamquammys* was found in two localities. *Chuankeimys* and *Tsinlingomys* from the Shipigou fauna together constitute the sister clade of *Yongshengomys* from the Irdin Manha Formation in the phylogenetic analysis (Li and Meng, 2015). *Pappocricetodon neimongolensis* (Li, 2012) from the Irdin Manha Formation and *Palasiomys* from the Shipigou fauna are primitive cricetids. The Shipigou fauna is generally considered the Irdinmanhan in age, equivalent to the early Uintan of North America (Tong, 1997).

Based on these comparisons, the age of the rodent assemblage from the lower part of the Irdin Manha Formation is Irdinmanhan land mammal age and is correlated to the early Lutetian of the Geological Time Scale and to the early Uintan of North America Land Mammal Age.

5. Conclusions

1) Nearly 3300 rodent specimens collected from the Nuhetingboerhe-Huheboerhe area in the Erlian Basin represent at least 388 individuals counted by the minimum number of individuals.
2) Rodent fossil assemblages from the Nuhetingboerhe-Huheboerhe area in the Erlian Basin characterize different strata: primitive ctenodactyloids such as *Chenomys* and *Yuanomys* are dominant in the upper part of the Nomogen Formation; *Tamquammys* is very common in the Arshanto Formation; *Asiomys*, *Pappocricetodon*, and *Yuomys* appear in the lower part of the Irdin Manha Formation, and *Tamquammys* is rarer in this formation than in the Arshanto Formation.
3) On the basis of the comparison of the rodent assemblages, I consider that the upper part of the Nomogen Formation is corresponding to the Bumbanian in age. The Arshanto Formation is mostly early Eocene and correlated to the Arshantan land mammal age. The age of the rodent

assemblage from the lower part of the Irdin Manha Formation is Irdinmanha land mammal age. The Bumbanian, Arshantan, and Irdinmanhan land mammal ages are correlated respectively to the early Ypresian, the middle–late Ypresian, and the early Lutetian of the Geological Time Scale. The Bumbanian and Irdinmanhan land mammal ages are also correlated to the early Wasatchian and the early Uintan of the North American Land Mammal Ages.

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