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The Tunggurian Stage of the Continental Miocene in China

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Abstract: The Tunggurian Age was nominated in 1984, and the Second National Commission on Stratigraphy of China formally suggested establishing the corresponding chronostratigraphic unit, the Tunggurian Stage, based on the Tunggurian Age in 1999. The name of this stage comes from a lithostratigraphic unit, the Tunggur Formation, and the stratotype section is located at the Tunggur tableland, 15 km southeast of Saihan Gobi Township, Sonid Left Banner, Inner Mongolia. The Tunggurian Age is correlated to the Astaracian of the European land mammal ages, and they share the same definition of the lower boundary at the base of the paleomagnetic Chron C5Bn.1r with an age of 15.0 Ma. In the Tairum Nor section on the southeastern edge of the Tunggur tableland, this boundary is situated within the successive deposits of reddish-brown massive mudstone of the lower part of the Tunggur Formation, with a distance of 7.6 m from the base of the grayish-white sandstones in the middle part of the section. The Tunggurian is approximately correlated to the upper part of the marine Langhian and the marine Serravallian in the International Stratigraphical Chart. The Tunggurian Stage includes two Neogene mammal faunal units, i.e. NMU 6 (MN 6) and NMU 7 (MN 7/8). The Tairum Nor fauna from the Tairum Nor section corresponds to NMU 6, and the Tunggur fauna (senso stricto) from the localities on the northwestern edge of the Tunggur tableland, such as *Platybelodon* Quarry, Wolf Camp and Moergen, corresponds to NMU 7. Among the Middle Miocene mammalian faunas in China, the Laogou fauna from the Linxia Basin, Gansu, the Quantougou fauna from the Lanzhou Basin, Gansu, the Halamagai fauna from the northern Junggar Basin, Xinjiang, and the Dingjiaergou fauna from Tongxin, Ningxia correspond to NMU 6.

Key words: Tunggurian, Miocene, stratotype, biostratigraphic unit, paleomagnetic age, China

1 Introduction

In 1929, Spock, a member of the Central Asiatic Expedition (CAE) organized by the American Museum of Natural History (AMNH), established the Tunggur Formation at the tableland 15 km southeast of the present Saihan Gobi Township, Sonid Left Banner, Inner Mongolia. The formation, composed dominantly of fluvial deposits with a maximum thickness of less than 80 m, can be divided into two sedimentary units. The upper unit, consisting mainly of grayish-white sandstones and variegated mudstones, as well as occasional gray marls, is well exposed along the northern and western edges of the Tunggur tableland. The lower unit is characterized by rather uniform red or lavender mudstones interrupted by a channel sandstone along the southern edge of the tableland named Tairum Nor, and is also exposed at the lower part of the Aletexire section on the northern edge. Both units are fossiliferous (Qiu et al., 2006).

In June 1928, the CAE found a partial proboscidean skeleton near a well named Gur Tung Khara Usu (Andrews, 1932). The bone bed was promptly reported by Spock (1929) as the Tung Gur Formation, a name reversed from the local well Gur Tung Khara Usu. After a year's suspension, the CAE team carried out a more extensive expedition in the Tunggur area in 1930, and found abundant mammalian fossils, including a series of exquisitely preserved *Platybelodon* skeletons from the two localities *Platybelodon* Quarry and Wolf Camp. The fossils, housed in AMNH, were subsequently described by various specialists, including two proboscideans (Osborn,

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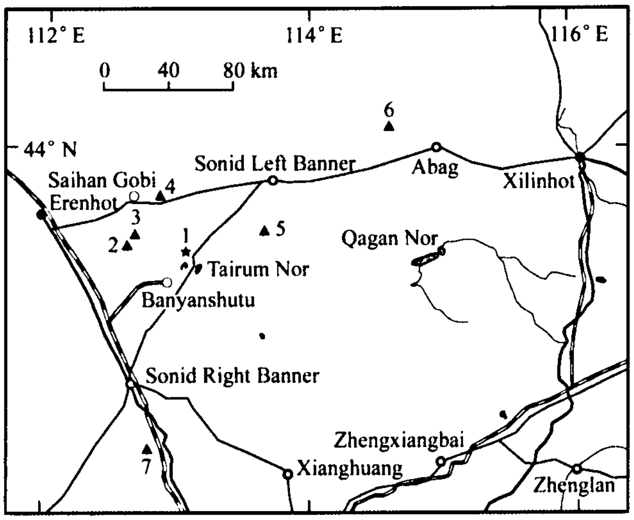

Fig. 1. Location of the Tunggur area in Inner Mongolia.
1. Stratotype section; 2. *Platybelodon* Quarry; 3. Wolf Camp; 4. Moergen; 5. Gashunyin Adege; 6. Baogeda Ula; 7. Amuwusu.

1929; Osborn and Granger, 1931, 1932), one anchitheriine horse (Colbert, 1939b), one chalicothere (Colbert, 1934a), eight carnivores (Colbert, 1939a; Hunt and Solounias, 1991), one suid (Colbert, 1934b), two bovids (Pilgrim, 1934), four cervids (Colbert, 1936a, 1940), one giraffe (Colbert, 1936b), four rodents (Stirton, 1934; Wood, 1936; Wang, 1988), two lagomorphs (Dawson, 1961), and three rhinocerotids (Cerdeño, 1996). The Middle Miocene mammalian fossils found from the Tunggur area are known as the Tunggur fauna.

In 1959, a brief visit to the Tunggur area was organized by a joint Sino-Soviet paleontological expedition (Chow and Rozhdestvensky, 1960), but only two taxa, a beaver and a carnivore, were published (Li, 1963; Zhai, 1964). During 1986–1987, a renewed effort by the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) led to substantial progress in both geology and paleontology (Qiu et al., 1988). In particular, intensive screen-washing at the Moergen locality revealed more than 20 species of small mammals (Qiu, 1996). Subsequently, Qiu and Wang (1999), Dong (1999), and Wang (2004) described some new materials discovered in and around the Tunggur area. Wang et al. (2003a) discussed the litho-, bio-, and magnetostratigraphy and paleoenvironment of the Tunggur Formation. Qiu and Wang (1999) first indicated that the horizon and age of the fossils found from Tairum Nor are lower and earlier than those of the traditional Tunggur fauna, and then these fossils were named the Tairum Nor fauna. Wang et al. (2003a) further restricted the Tunggur fauna to the fossils from the upper part of the Tunggur Formation, and referred the fossils from the lower part of the Tunggur Formation to the Tairum Nor fauna.

Li et al. (1984) nominated the Middle Miocene Tunggurian Age on the basis of the Tunggur fauna as a representative, approximately corresponding to the Astaracian (MN 6–8) of the European land mammal ages. They referred some mammalian fossil localities to this age, such as Tunggur and Jining (Inner Mongolia), Tongxin (Ningxia), Koujiacun (Shaanxi), Xianshuihe, Xishui, Qin'an, and Pingliang (Gansu), Lierpu, Diaogou, Ledu, and Qaidam (Qinghai), Xiaolongtan (Yunnan), Erlanggang, Zhongxiang, and Shennongjia (Hubei). Qiu and Qiu (1990) considered that the Tunggurian Dingjiaergou fauna from Tongxin corresponded to the European MN 6, and its contemporaneous localities included Koujiacun and Jiulongkou in Cixian (Hebei); the Lengshuigou fauna from Lintong (Shaanxi) corresponded to MN 7; the Tunggur fauna corresponded to MN 8, and its contemporaneous localities included Shaping in Fangxian (Hubei), Halamagai in the northern Junggar Basin (Xinjiang), Lingyanshan in Nanjing (Jiangsu), and Xiaolongtan. Tong et al. (1995) reconfirmed the correlation between the Tunggurian and the Astaracian, and estimated the age of the Tunggurian as within 15.5–12 Ma.

In 1999, the Second National Commission on Stratigraphy of China formally suggested establishment of the chronostratigraphic unit, the Tunggurian Stage, whose time span corresponds to the Tunggurian of the Chinese land mammal ages (NCSC, 2001).

2 Stratotype Section of the Tunggurian Stage

The Tunggur tableland is situated in Sonid Left Banner, Inner Mongolia, 15 km southeast of Saihan Gobi Township and 80 km east of Erenhot (Fig. 1). Cenozoic deposits east of Erenhot generally lie in the upper part of the fill of a series of NE-SW trending rift subbasins. Collectively, these fault-controlled subbasins form the Eren Basin, initially filled in the Jurassic through Cretaceous by fluviolacustrine deposits and often forming half grabens or asymmetric grabens, up to 3000–5000 m thick (Lin et al., 2001). The Mesozoic deposits are mostly in the subsurface, but they may crop out on basin margins, as near the town Bayanshutu (Fig. 1).

In central Inner Mongolia between the cities of Erenhot and Xilinhot is a large span of rolling plains with few notable landmarks. Besides occasional patches of granites, usually weathered to ground levels, the most conspicuous features are a series of low tablelands, commonly 40–80 m above ground level and forming elevated benches that extend tens of kilometers in a single stretch. Outcrops along their edges often contain fossils. The Tunggur tableland is outlined in a northeast-southwest-oriented tongue-shaped

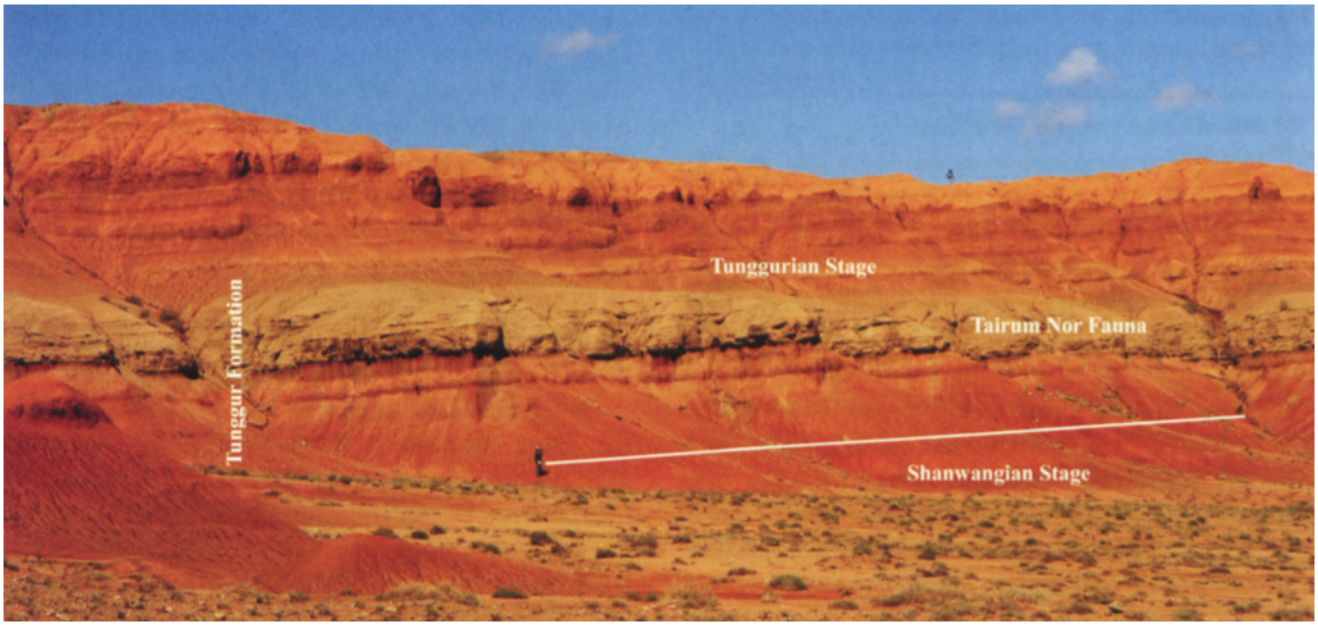

Fig. 2. The Tairum Nor section on the southeastern edge of the Tunggur tableland in Inner Mongolia.

platform, although its northeastern extent becomes gradually less well defined (Wang et al., 2003a, fig. 1).

Neogene deposits in the Tunggur and surrounding areas are often confined to small basins of just a few square kilometers that are less than a few meters in thickness. The Tunggur Formation and the overlying Baogeda Ula Formation, on the other hand, represent much larger depositional basins of several hundred square kilometers in size and up to 100 m in thickness. Over the entire Tunggur tableland, the structural disturbance of the Tunggur Formation is minimal. No direct contact can be observed between the Tunggur Formation and its underlying deposits. To the south of the tableland, Meng et al. (1996) and Qiu and Wang (1999) reported a new fauna of Early Miocene age from Gashunyin Adege (Fig. 1). The Gashunyin Adege deposits, however, are confined to a small basin in an area of granite basement rocks, and they are unlikely to be superposed by the Tunggur Formation. The Baogeda Ula Formation bearing a *Hipparion* fauna, which is the overlying sediments of the Tunggur Formation, is exposed at approximately 20 km northeast of the easternmost Tunggur locality, at Roadmark 482 km, where it is seen to overlie the Tunggur Formation disconformably (Wang et al., 2003a).

The classical section of the Tunggur Formation is located on the northwest edge of the Tunggur tableland, and its strata belong to the upper part of the Tunggurian Stage according to an analysis of its mammalian fossils. The establishment of a stage is determined by the definition of its lower boundary, so that the stratotype section of a stage should include its lower boundary. The Tairum Nor section on the southeast edge of the Tunggur tableland includes the strata of the lower Tunggurian judged from the mammalian fossils, and the Tairum Nor fauna is found from the grayish-white sandstones and red mudstones of the lower part of the Tunggur Formation at this section (Fig. 2). The proposed stratotype of the Tunggurian Stage is where the Hohhot-Xilinhot Highway intercepts the southeastern edge of the Tunggur tableland at Roadmark 346 km, with the geographical coordinate of 43°24′53.4″ N, 113°07′06.1″ E, and the elevation of 1037 m. The southern escarpment has the best exposures in the Tunggur tableland. However, only the Tunggur Formation is exposed, without underlying strata, and it is overlain by Quaternary yellow conglomerates.

Besides the wide exposure on the Tunggur tableland, the Tunggur Formation is also distributed southwest of Xinhaote in Abag Banner, south of Beilemiao and north of Qagan Nor in Sonid Left Banner, Aqitula and southeast of Saihan Tal in Sonid Right Banner, and Hahuduge, Yuqigenghua, Manhua, and Mandele in Siziwang Banner, with the largest thickness of about 100 m (Zheng et al., 1999). The sedimentary sequence of the Tairum Nor section is clear, and it consists of a sequence of upper red mudstone, middle channel sandstone, and lower red mudstone. The upper red bed is lighter and more orange, and appears to be more pedogenic in origin with repeated color bands. The lower red bed, on the other hand, is darker red and more uniform (lacking bedding planes) when viewed from the distance. The layers are inclined northwestwards, with a dip angle of 3°–5°. The measured section at Tairum Nor is 35.6 m thick, and the layers from top to bottom are as follows:

Quaternary

4. Yellow conglomerates ~1 m

----------------Disconformity--------------

Middle Miocene Tunggur Formation

3. Lighter and more orange red mudstone that is more pedogenic in origin with repeated color bands 11.0 m

2. Channel sandstones, yielding mammal fossils: *Anchitheriomys tungurensis*, *Leptarctus neimenguensis*, *Aelurocyon*? sp., *Sthenictis* sp., *Tunguricti spocki*, *Platybelodon grangeri*, *Acerorhinus zernowi*, and *Hispanotherium matritense* 3.5 m

1. Darker red and more uniform red mudstone without bedding planes, yielding mammal fossils: *Mioechinus*? *gobiensis*, *Atlantoxerus orientalis*, *Tachyoryctoides* sp., *Distylomys tedfordi**, *Heterosminthus orientalis*, *Gobicricetodon flynni*, *Plesiodipus leei*, *Megacricetodon* sp., *Desmatolagus*? *moergenensis*, *Alloptox gobiensis*, *Bellatona forsythmajori*, and *Dicerocerus* sp. 20.1 m

Not to bottom

* Indicates uncertainty in precise stratigraphic level in historical collections.

3 Features and Correlations of the Tunggurian Biota

When Li et al. (1984) nominated the Tunggurian Age, they analyzed the general features of the mammalian faunas in this age, and suggested that the age is approximately correlated to the European Astaracian Age. In that time, the known Tunggurian mammalian fossils are nearly 70 species, among which many species are more advanced than the Shanwangiàn mammals of the same genera, such as *Gomphotherium*, *Anchitherium*, *Listriodon*, and *Oioceros*. In the micromammals, cricetodonts close to the European ones are rare, and they are replaced by the rodents *Plesiodipus* and *Protalactaga* with the Asian characteristics. The corresponding species of the lagomorph *Alloptox*, *A. anatoliensis* is also found from the late Middle Miocene in Turkey. Qiu and Qiu (1990) further divided the Tunggurian mammalian faunas into three horizons correlated to the European MN 6–8, represented by the Dingjiaergou, Lengshuigou, and Tunggur faunas, respectively. They have clearly indicated that the Tunggur fauna belongs to the late Tunggurian Age, and it is the latest representative of the Eurasian *Anchitherium* fauna.

Tong et al. (1995) considered that the evolutionary features of mammals in the Tunggurian Age are as follows: Proboscideans began a major radiation and ruminants began a diversification. The interval is defined by the first appearance of Dipodidate and Hyaenidae. Quite a number of genera are new, among which *Heterosminthus*, *Protalactaga*, *Plesiodipus*, *Bellatona*, *Gobicyon*, *Platybelodon*, *Kubanochoerus*, and *Turcoceros* are typical for this age; some are common in the late *Hipparion* faunas, also *Chilotherium* and *Ictitherium* for example. The families Ctenodactylidae, Tachyoryctoididae and the genera *Megacricetodon*, *Democricetodon*, *Alloptox*, *Hemicyon*, *Plesiaceratherium* and others made their last occurrence in this interval.

3.1 Mammalian faunas of the lower Tunggurian Stage (NMU 6)

The fossils in the stratotype section (Tairum Nor) for the lower boundary of the Tunggurian Stage are characterized by mammals, especially micromammals. The holotype of *Platybelodon grangeri* was found from Tairum Nor (Spock, 1929). Qiu and Wang (1999) proposed the Tairum Nor fauna, based on collections from the lower red bed, because of its presence of *Tachyoryctoides*, a survivor from Oligocene and Early Miocene, and primitive morphologies in *Atlantoxerus*, *Heterosminthus*, and *Gobicricetodon*. In addition, Wang (1988) described a peculiar ctenodactyloid, *Distylomys tedfordi* from the AMNH Tairum Nor collection, which is not seen elsewhere in the Tunggur Formation. The middle channel sandstone mostly produced large mammals. New materials of the primitive hyaenid *Tungurictis* from calcareous nodules on the top of the channel sandstone indicate an individual somewhat smaller than the type skull from Wolf Camp, and they have more slender upper carnassials and less transversely elongated upper molars. These morphological differences may indicate stratigraphic differences, although they may be accounted for by individual variation (Wang, 2004). The three Tairum Nor carnivores, *Leptarctus neimenguensis*, a new species of *Sthenictis*, and a form related to *Aelurocyon*, are absent in the northern and western escarpments of the Tunggur tableland, which is interpreted to be due to a lower stratigraphic level at Tairum Nor (Wang et al., 2003a). An elasmothere discovered recently from the middle channel sandstone of the Tunggur Formation further demonstrates this feature.

This specimen (IVPP V 15151) is the anterior part of a rhinocerotid mandible with the right cheek tooth row from p3 to m2. The mandibular symphysis is narrow anteriorly, strongly concave lingually, and slightly convex labially, with a posterior border at the anterior part of p2. The alveolus of i2 is large, and the alveolus edge is sharp. The mental foramina are slit-like, two on the right and three on the left. The horizontal ramus is low and thick, with a height of 55 mm and a thickness of 39.5 mm at the p4/m1 boundary. Cement filling is present mainly in the lingual valleys and labial grooves of lower cheek teeth. The labial

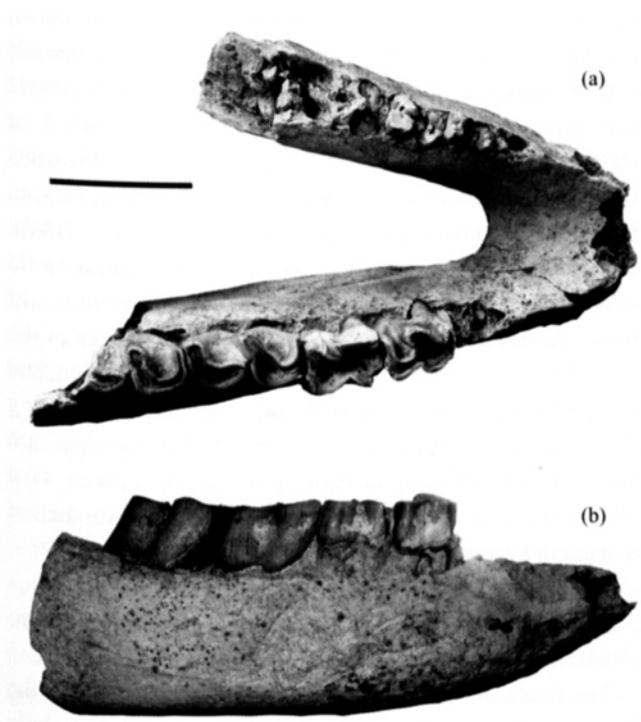

Fig. 3. Lower jaw with cheek teeth of *Hispanotherium matritense* from Tairum Nor.
V 15151: (a) The occlusal view; (b) the lateral view. Scale bar = 5 cm.

groove is deeply V-shaped. The paralophid is short on premolars but long on molars. The constricted metaconid declines backwards. The lingual and labial cingula are absent. The lingual valleys are U-shaped. The crowns of the lower molars are high, and become short towards their bases (Fig. 3).

IVPP V 15151 from Tairum Nor is generally similar to the specimens of *Hispanotherium matritense* from other localities in Eurasia, with minor differences (Cerdeño, 1992; Iñigo and Cerdeño, 1997; Deng, 2003), and it is obviously smaller than *H. tungurense* from the Tunggur fauna (Table 1). The origin of the *Hispanotherium* lineage may be in southwestern Europe. After that it dispersed eastward to Asia. The age of *H. matritense* from the Chinese localities corresponds to MN 6 (Deng, 2003).

The faunal list from Tairum Nor includes *Mioechinus*? *gobiensis* of Insectivora, *Atlantoxerus orientalis*, *Anchitheriomys tungurensis*, *Tachyoryctoides* sp., *Distylomys tedfordi*, *Heterosminthus orientalis*, *Gobicricetodon flynni*, *Plesiodipus leei*, *Megacricetodon* sp., *Desmatolagus*? *moergenensis*, *Alloptox gobiensis*, and *Bellatona forsythmajori* of Rodentia, *Leptarctus neimenguensis*, *Aelurocyon*? sp., *Sthenictis* sp., and *Tungurictis spocki* of Carnivora, *Platybelodon grangeri* of Proboscidea, *Acerorhinus zernowi*, and *Hispanotherium matritense* of Perissodactyla, and *Dicerocerus* sp. of Artiodactyla.

To sum up, the Tairum Nor fauna is characterized by the earliest appearance of *Anchitheriomys*, *Atlantoxerus*, *Gobicricetodon*, *Plesiodipus*, *Leptarctus*, *Tungurictis*, and *Dicroceros*, and the latest occurrence of Ctenodactylidae and Tachyoryctoididae. It is distinguishable from the classic Tunggur fauna from the northwestern edge of the Tunggur tableland (except the lower part of the Aletexire section) in its retention of a few holdover genera from the Oligocene and presence of some new forms that are more primitive in morphology. The Tairum Nor fauna shows close affinities with the Dingjiaergou fauna of Tongxin, Ningxia, and the Halamagai fauna of the Ulungur River area, Xinjiang in sharing quite a number of genera, especially in having the joint occurrence of *Tachyoryctoides*, *Alloptox*, and *Platybelodon* (Qiu et al., 2006). Both the Halamagai and Dingjiaergou faunas are considered to correspond to NMU 6 of China or MN 6 of Europe (Ye et al., 2001; Deng, 2006a), so the Tairum Nor fauna also belongs to NMU 6 or MN 6 (Qiu et al., 2006). Based on mammalian correlations, other Chinese mammalian faunas correlated to Tairum Nor fauna include the Jiulongkou fauna from Cixian, Hebei (Chen and Wu, 1976), the Laogou fauna from the Linxia Basin, Gansu (Deng, 2003, 2004), and the Quantougou fauna from the Lanzhou Basin, Gansu (Qiu, 2000, 2001a, b).

The Dingjiaergou fauna includes *Alloptox gobiensis*, *Atlantoxerus* sp., *Heteroxerus* sp., *Megacricetodon* sp., *Democricetodon* sp., *Cricetodon* sp., *Protalactaga grabaui*, *Heterosminthus orientalis*, *Sayimys* sp., *Tachyoryctoides* sp., *Prodistylomys* sp., *Dryomys* sp., *Steneofiber* sp., *Pliopithecus zhanxiangi*, *Amphicyon* sp., *Gobicyon* sp., *Tongxinictis primordialis*, *Sansanosmilus* sp., *Amebelodon tobieni*, *Serbelodon zhongningensis*, *Platybelodon danovi*, *Gomphotherium yinnanensis*, *Hispanotherium matritense*, *Chalicotherium* sp., *Eurolistriodon intermedius*, and *Kubanochoerus gigas* (Qiu et al., 1999; Deng, 2003).

The Jiulongkou fauna was published by Chen and Wu (1976), including *Percrocuta hebeiensis*, *Sansanosmilus palmidens*, *Macrotherium* sp., *Dicerorhinus* sp., *D. cixianensis*, *Plesiaceratherium gracile*, *Palaeomeryx*? sp., *Dicrocerus*? sp., *Stephanocemas*? sp., *Oioceros*? *jiulongkouensis*, *O.*? *robustus*, and *O.*? *stenocephalus*.

Table 1 Measurements and comparisons of the lower cheek teeth of *Hispanotherium matritense* from Tairum Nor, Inner Mongolia (mm)

Teeth	*H. matritense*		*H. tungurense* (Cerdeño, 1996)
	Tairum Nor (V 15151)	Spain (Iñigo and Cerdeño, 1997)	
p3: length	25	22.3–28.3	27.7–31.9
p3: width	18.2	17.4–20	21.7–23.2
p4: length	27.2	25.6–29.6	29.8–37.6
p4: width	–	21.4–23.3	23.7–33.7
m1: length	39.8	26.6–38.6	41.1–41.9
m1: width	22.5	20.6–27.8	27.5–34.6

In recent years, some new discoveries add the components of the Halamagai fauna, and the new faunal list is as follows: *Schizogalerix duolebulejinensis*, *Mioechinus*? aff. *gobiensis*, *Pliopithecus bii*, *Eutamias* sp., *Atlantoxerus giganteus*, *A. junggarensis*, *Palaeosciurus* sp., *Steneofiber depereti*, *Anchitheriomys tungurensis*, *Tachyoryctoides* sp., *Protalactaga grabaui*, *Miodyromys* sp., *Microdyromys* sp., *Leptodontomys* sp., *Sayimys* sp., *Plicalagus junggarensis*, *Sinolagomys* sp., *Alloptox gobiensis*, *Sinomylagaulus halamagaiensis*, *Nimravus*? sp., *Pseudaelurus cuspidatus*, *Protictitherium* sp., *P. intermedium*, *Thalassictis chinjiensis*, *Simocyon* sp., *Gobicyon* sp., *Oligobunis*? sp., *Zygolophodon*? sp., *Z.*? *junggarensis*, *Gomphotherium* sp., *G.* cf. *shensiensis*, *Platybelodon* sp., *Anchitherium gobiense*, *Acerorhinus* sp., *Lagomeryx* sp., *Stephanocemas* aff. *thomsoni*, *Eotragus halamagaiensis*, *Micromeryx* sp., and *Palaeomeryx* sp. (Ye et al., 2001; Wu et al., 2003).

The Laogou fauna includes *Alloptox* sp., *A. minor*, *Megacricetodon sinensis*, *Protalactaga tunggurensis*, *Sayimys* cf. *obliquidens*, *Pliopithecus* sp., *Hemicyon teilhardi*, *Amphicyon tairumensis*, *Gobicyon* sp., *Percrocuta tungurensis*, *Pseudaelurus guangheensis*, *Choerolophodon* sp., *Gomphotherium* sp., *Platybelodon grangeri*, *Zygolophodon* sp., *Anchitherium gobiense*, *Alicornops laogouense*, *Hispanotherium matritense*, *Chalicotherium* sp., *Kubanochoerus gigas*, *Listriodon mongoliensis*, *Dorcatherium* sp., *Moschus* sp., *Palaeotragus tungurensis*, and *Turcocerus* sp. (Guan, 1988; Deng, 2003, 2004).

The Quantougou fauna includes *Mioechinus gobiensis*?, *Heterosminthus orientalis*, *Protalactaga grabaui*, *P. major*, *Microdyromys wuae*, *Mellalomys gansus*, *Myocricetodon plebius*, *Ganocricetodon cheni*, *Megacricetodon sinensis*, *Paracricetulus schaubi*, and *Plesiodipus leei* (Qiu, 2000, 2001a, b). Qiu and Li (2003) suggested that the Quantougou fauna is slightly older than the Tunggur fauna and simultaneous with the Tairum Nor fauna.

In Europe, the type locality of MN 6 is Sansan in France. The rodent faunas of MN 6 are characterized in all European localities by the co-occurrence of two species of *Megacricetodon*. Insectivores show the early known record of *Mioechinus*. Among perissodactyls, *Alicornops* occurs. Artiodactyls show the first record of the truly lophodont *Listriodon* at the beginning of MN 6 (Mein, 1999). These biostratigraphic markers of MN 6 are also found in the Chinese NMU 6. In China, *Megacricetodon* has been discovered from Dingjiaergou, Laogou, and Quantougou; *Mioechinus*? from Tairum Nor; *Alicornops* from Laogou; and *Listriodont* from Laogou (Deng, 2006a). Rodents show the first appearances of *Mellalomys*, *Myocricetodon*, *Protalactaga*, *Plesiodipus*, and *Ganocricetodon* at Quantougou. Among insectivores and lagomorphs, we note the presence of *Schizogalerix* and *Sinomylagaulus*, which seem to be restricted at Halamagai (Bi et al., 1999; Ye et al., 2001). Primates show the occurrence of *Pliopithecus* at Dingjiaergou, Laogou and Halamagai (Deng, 2003; Wu et al., 2003). Two new perissodactyls occur: the rhinocerotid *Acerorhinus* at Halamagai, and *Dicerorhinus* at Jiulongkou. Artiodactyls show the first appearances of the suid *Kubanochoerus* and *Listriodon* at Dingjiaergou and Laogou. *Platybelodon* began to develop very well during this period. Abundant fossils of *Platybelodon* are discovered from Dingjiaergou and Laogou. Taken as a whole, the faunas of NMU 6 are very close to that of Sansan in France (Qiu et al., 1999).

3.2 Mammalian faunas of the upper Tunggurian Stage (NMU 7)

The fauna of the upper Tunggurian is represented by the Tunggur fauna, whose components until now include *Mioechinus* sp., *M.*? *gobiensis*, *Proscapanus* sp., *Yanshuella* sp., *Quyania* sp., *Desmanella storchi*, *Mongolosorex qiui*, *Ansomys*? sp., *Eutamias* aff. *ertemtensis*, *Sinotamias primitivus*, *Atlantoxerus orientalis*, *Anchitheriomys tungurensis*, "*Monosaulax*" *tungurensis*, *Hystricops*? sp., *Steneofiber* sp., *Leptodontomys lii*, *L.* aff. *gansus*, *Keramidomys fahlbuschi*, *Microdyromys wuae*, *Heterosminthus orientalis*, *Protalactaga grabaui*, *P. major*, *Gobicricetodon* sp., *G. flynni*, *G. robustus*, *Plesiodipus leei*, *P. progressus*, *Megacricetodon sinensis*, *M. pusillus*, *Democricetodon lindsayi*, *D. tongi*, *Desmatolagus*? *moergenensis*, *Alloptox gobiensis*, *Bellatona forsythmajori*, *Plithocyon teilhardi*, *Pseudarctos* sp., *Amphicyon tairumensis*, *Gobicyon macrognathus*, *Melodon*? sp., *Mionictis* sp., *Martes* sp., *Tungurictis spocki*, *Percrocuta tungurensis*, *Metailurus mongoliensis*, *Sansanosmilus* sp., *Serridentinus gobiensis*, *Platybelodon grangeri*, *Zygolophodon* sp., *Anchitherium gobiense*, *Chalicotherium brevirostris*, *Acerorhinus zernowi*, *Hispanotherium tungurense*, *Listriodon mongoliensis*, *Kubanochoerus* sp., *Palaeotragus tungurensis*, *Stephanocemas thomsoni*, *Lagomeryx triacuminatus*, *Euprox grangeri*, *Dicrocerus* sp., *Micromeryx* sp., *Turcoceros grangeri*, and *T. noverca* (Wang et al., 2003a; Qiu et al., 2006). Recently, Qiu et al. (2006) named the fossils from the top of the Moergen section separately as the Tamuqin fauna. However, this fauna still has the feature of MNU 7, and it can be referred into the Tunggur fauna.

Based on mammalian correlations, the mammalian faunas of NMU 7 in South China are represented by the Xiaolongtan fauna from Kaiyuan, Yunnan (Qiu et al., 1999). The Kekemaideng fauna from the Ulungur River area, Xinjiang is also correlated with MN 7/8 (Ye et al., 2001).

The Xiaolongtan fauna includes *Dryopithecus keiyuanensis*, *Tetralophodon xiaolongtanensis*, *Gomphotherium* cf. *macrognathus*, *Zygolophodon chinjiensis*, *Tapirus* cf. *yunnanensis*, *Propotamochoerus parvulus*, *Dicoryphochoerus* sp., and *Listriodon* sp. (Qiu et al., 1999).

The Kekemaideng fauna includes *Platybelodon* sp., *Brachypotherium* sp., *Chilotherium*? sp., *Kubanochoerus* sp., *Dicrocerus grangeri*, and *Turcocerus kekemaidengensis* (Ye et al., 1999, 2001).

For this period at Tunggur, insectivores show the first appearances of *Yanshuella* and *Quyania*, and many genera show the last appearances, such as rodents *Microdyromys* and *Megacricetodon*, lagomorphs *Alloptox* and *Bellatona*, carnivore *Plithocyon*, proboscidean *Platybelodon*, perissodactyls *Anchitherium* and *Hispanotherium*, and artiodactyl *Kubanochoerus*. The insectivore *Proscapanus* is found only in the Tunggur fauna.

3.3 Other fossils of the Tunggur Formation

The Tunggur Formation also contains abundant charophytes, sporo-pollens, gastropods, bivalves (dominated by *Lamprotula mongolica*), fishes and reptiles (Zheng et al., 1999). The sporo-pollen assemblage of the Tunggur Formation is characterized by the dominant content of *Quercoidites*, *Chenopodipollis*, and *Artemisiaepollenites*, and by the moderate amount of *Salixipollenites*, *Cyrillaceaepollenites*, *Tricolpopollenites*, along with a few of *Betulaceoipollenites*, *Ulmoideipites*, *Labitricolpites*, *Rutaceoipollis*, *Graminidites*, *Pinuspollenites*, *Abietineaepollenites*, *Ephedripites*, *Polypodiisporites* etc. The components of the sporo-pollen flora are mainly some xerophilous herbaceous angiosperms and temperate broad-leaved types, and the tropical and subtropical components that were widely distributed in the Paleogene are rare, which suggests that the climate was dry and cool during that time (Wang, 1990).

4 Lower and Upper Boundaries of the Tunggurian Stage

According to its definition proposed by NCSC (2001), the Middle Miocene Tunggurian of the Chinese continental Neogene should be correlated to the Astaracian of the European land mammal ages. The lower boundary of the Astaracian is at the base of Chron C5Bn.1r, with an age of 15.0 Ma, and the upper boundary (base of Vallesian) is at the base of Chron C5r.1n, with an age of 11.6 Ma (Steininger, 1999; Lourens et al., 2004). As a result, the lower boundary of the Tunggurian should be at the base of Chron C5Bn.1r, with an age of 15.0 Ma. Therefore, the Tunggurian or Astaracian corresponds to the upper part of the marine Langhian and the marine Serravallian in the International Stratigraphical Chart (Deng, 2002). The lower boundary of the Langhian is at top of magnetic polarity chronozone C5Cn.1n, with an age of 15.97 Ma. The lower boundary of the Serravallian is within magnetic polarity chronozone C5Abr, with an age of 13.65 Ma (Wang and Deng, 2005). In other words, the lower boundary of the Tunggurian or Astaracian is not identical with the lower boundary of a certain stage in the International Stratigraphical Chart. This is frequent in the division and correlation between the terrestrial and marine strata, because the biological events as the main divisional markers have different expressions in the sea and land.

Some researchers want to adjust the lower boundary of the Tunggurian so that it will be identical with a certain marine stage. For example, Wang and He (2005) identically correlated the Tunggurian to the Serravallian. The age of the lower boundary of the Serravalian used by them is 14.30 Ma, which seems to be close to the age of 15.0 Ma for the lower boundary of the proposed Tunggurian or Astaracian. On the other hand, the definition of the lower boundary of the Serravallian has been revised as near the lowest occurrence of nannofossil *Sphenolithus heteromorphus*, within magnetic polarity chronozone C5ABr, and the Mi3b isotopic event (global cooling episode), with an age of 13.65 Ma (Wang and Deng, 2005) close to the base of NMU 7 or MN 7/8. As a result, such a correlation will lose the almost whole lower one (NMU 6) between two biostratigraphic units of the proposed Tunggurian stage, which does not agree completely with the definition of this stage, so this correlation is apparently inadvisable.

4.1 Biostratigraphical markers of the lower boundary of the Tunggurian Stage

The Tairum Nor fauna represents the basal fauna of the Tunggurian Stage, and it comes from the stratotype section of this stage. *Atlantoxerus orientalis* of the Tairum Nor fauna is smaller than specimens of the same species in the Tunggur fauna (Qiu and Wang, 1999). This species first appeared at Tairum Nor, where it is the easternmost distribution of this genus, and it is larger and more advanced than a species of *Atlantoxerus* from the Xiejia fauna (NMU 2 or MN2) in Huangzhong, Qinghai (Qiu, 1996). *Anchitheriomys tungurensis* is also found from the Tunggur fauna, the Halamagai fauna (Wu, 1988), and the Middle Miocene strata in the Zaisan Basin, Kazakhstan

(Qiu, 1996). *Gobicricetodon flynni* first appeared at Tairum Nor, and its size is smaller than specimens of the same species in the Tunggur fauna (Qiu et al., 1999). *Gobicricetodon robustus* of the Tunggur fauna from the higher horizon is more advanced than *G. flynni*, and they have a close ancestor-descendant relationship (Qiu, 1996). Besides the Tairum Nor and Tunggur faunas from the Tunggur area, *Plesiodipus leei* is also found from the Xining Basin, Qinghai, and the Lanzhou Basin, Gansu. The age of the last two localities belongs to NMU 6 or MN 6, so the appearance of this species at Tairum Nor represents its lowest horizon. *P. progressus* of the Tunggur fauna from the higher horizon is obviously more advanced than *P. leei* (Qiu, 1996). *Desmatolagus*? *moergenensis* from Tairum Nor represents the lowest horizon of this species, and it is also distributed in the Tunggur fauna. In the Tunggur area, *Desmatolagus*? sp. is also distributed in the Gashunyin Adege fauna of NMU 4 or MN 4. *Alloptox gobiensis* from Tairum Nor represents the lowest horizon of this species, and it is also found from the Tunggur fauna, the Dingjiaergou fauna, and the Middle Miocene strata in Mongolia and Kazakhstan (Wu et al., 1991). In the Tunggur area, *Alloptox* sp. is also found from the Gashunyin Adege fauna. *A. gobiensis* may be derived from the Shanwangian *A. minor* found in Lantian, Shaanxi. *Bellatona forsythmajori* from Tairum Nor represents the lowest horizon of this species, and it is also found from the Tunggur fauna; its ancestor may be *B. yanghuensis* found from the Middle Miocene in Xinzhou, Shanxi (Zhou, 1988), and *Bellatona* may be the ancestor form of *Ochotona* (Dawson, 1961; Qiu, 1996). Among the micromammals from Tairum Nor, to sum up, the first appearances of *Atlantoxerus orientalis*, *Anchitheriomys tungurensis*, *Gobicricetodon flynni*, *Plesiodipus leei*, *Desmatolagus*? *moergenensis*, *Alloptox gobiensis*, and *Bellatona forsythmajori* can be used as the biostratigraphic markers of the lower boundary of the Tunggurian Stage.

Among large mammals from Tairum Nor, *Leptarctus neimenguensis* represents one of the few carnivores that migrated from North America to Asia during the Neogene. In Eurasia, the genus *Leptarctus* has so far been found only at Tairum Nor. On the other hand, this genus is well represented by many species ranging from early Hemingfordian to late Hemphillian in North America (Qiu, 2003). Similar to the case of *Leptarctus*, the relatives of *Sthenictis* are found in North America. *Sthenictis* is widely known in the Hemingfordian through Clarendonian. *Aelurocyon*? sp. from Tairum Nor is under study (Wang et al., 2003a). Colbert (1939a) described a new genus and species, *Tunguricitis spocki*, collected from Wolf Camp in the Tunggur tableland. *T. spocki* from Tairum Nor fauna displays a smaller size and slightly more primitive morphology. *T. spocki* is present in the Halamagai fauna of NMU 6 in the northern Junggar Basin, Xinjiang (Wang et al., 1998; Wang, 2004). *Platybelodon grangeri* first appeared in the NMU 6 faunas of China, including the Tairum Nor and Laogou faunas (Deng, 2003), and it is also distributed in the Tunggur fauna of NMU 7. *Platybelodon* sp. is found from the Halamagai fauna of NMU 6 (Tong et al., 1990), and *Platybelodon danovi* is found from Dingjiaergou (Qiu et al., 1999), which may belong to the different branches from *P. grangeri*. The more primitive species than *P. grangeri* is *P. dangheensi* from the Xishuigou fauna of NMU 4 or MN 4 in the Danghe area, Gansu (Wang and Qiu, 2002). *Acerorhinus zernowi* from Tairum Nor represents the first appearance of this genus and species, and it also appears in the Tunggur fauna. The last appearance of *A. zernowi* in Europe is in the Vallesian Sebastopol fauna (Cerdeño, 1996), and its closest descendant is *A. tsaidamensis* from the Toson Nor fauna of NMU 9 or MN 10 in the Qaidam Basin, Qinghai (Bohlin, 1937; Deng, 2000). *Dicerocerus* sp. from Tairum Nor represents the first appearance of this genus, and it is also distributed in the Tunggur fauna (Wang et al., 2003a). Among the large mammals from Tairum Nor, to sum up, the first appearances of *Leptarctus neimenguensis*, *Sthenictis*, *Tunguricitis spocki*, *Platybelodon grangeri*, *Acerorhinus zernowi*, and *Dicerocerus* can be regarded as the biostratigraphic markers of the lower boundary of the Tunggurian Stage.

Tachyoryctoides sp. from Tairum Nor represents the last appearance of this genus, and it also appears in the Gashunyin Adege fauna (Qiu et al., 2006). *Distylomys tedfordi* is found only from Tairum Nor (Wang, 1988), and *Distylomys* sp. may appear in the Gashunyin Adege fauna (Qiu et al., 2006). *Hispanotherium matritense* from Tairum Nor represents the last appearance of this species. *H. matritense* is distributed widely in Spain, Portugal and southern France. In China, this species appeared first in Wangshijie of the Linxia Basin during NMU 5 or MN 5, and then it was found from Dingjiaergou, Laogou, and Tairum Nor widely during NMU 6 or MN 6. In the Tunggur fauna of NMU 7 or MN 7/8, *H. matritense* is replaced by the larger-sized *H. tungurense* (Cerdeño, 1996). Obviously, the last appearance events of *Tachyoryctoides*, *Distylomys tedfordi*, and *Hispanotherium matritense* are regarded as the biostratigraphic markers of the lower boundary of the Tunggurian.

Mioechinus? *gobiensis* from Tairum Nor is morphologically similar to *M. gobiensis* of the Tunggur fauna (Qiu and Wang, 1999), and it is present in the Gashunyin Adege fauna (Qiu et al., 2006). *Megacricetodon* sp. also appears at Gashunyin Adege, and

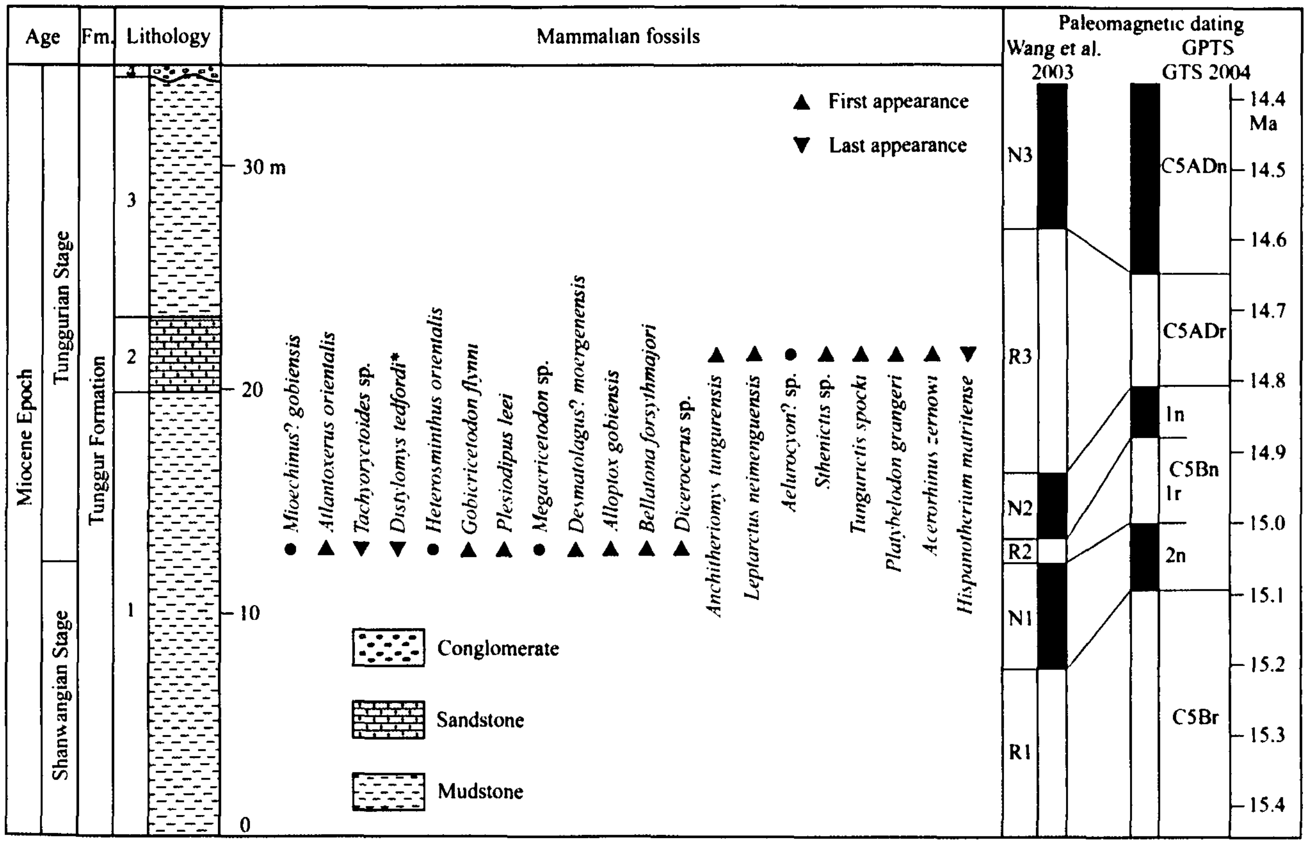

Fig. 4. Comprehensive column section at Tairum Nor of the Tunggur tableland in Sonid Left Banner, Inner Mongolia.
Superscript "*" indicates uncertainty in precise stratigraphic level in historical collections.

two species of this genus, *M. sinensis* and *M. pusillus*, are distributed in the Tunggur fauna (Qiu, 1996). *Heterosminthus orientalis* first appeared in the Shanwangian Chetougou Formation in the Xining Basin, Qinghai (Qiu et al., 1981; Wu et al., 2006), and it is distributed in the Quantougou fauna in the Lanzhou Basin, Gansu (Young, 1927), and the Tunggur fauna (Qiu, 1996).

As mentioned above, there are relatively rich markers for the lower boundary of the Tunggurian. However, it is very difficult to determine the first or last appearance of a species independently. Coexistence of the first and last appeared species is a good method to resolve this issue. For example, they are good biostratigraphic markers of the lower boundary of the Tunggurian that *Hispanotherium matritense* coexists with anyone of *Leptarctus neimenguensis*, *Sthenictis*, *Tungurictis spocki*, *Platybelodon grangeri*, *Acerorhinus zernowi*, and *Dicerocerus* among large mammals, *Distylomys tedfordi* or *Tachyoryctoides* coexists with anyone of *Atlantoxerus orientalis*, *Anchitheriomys tungurensis*, *Gobicricetodon flynni*, *Plesiodipus leei*, *Desmatolagus*? *moergenensis*, *Alloptox gobiensis*, and *Bellatona forsythmajori* among micromammals, and the first appeared species coexist with the last appeared species among both large and small mammals.

4.2 Paleomagnetic marker for the lower boundary of the Tunggurian stage

A paleomagnetic result of the Tairum Nor section shows that this section records three normal and three reversed magnetozones. Wang et al. (2003a, fig. 10) correlated the normal magnetozones to C5Ar.2n, C5Ar.1n, and C5An.2n respectively from bottom to top, and the reversed magnetozones to C5Ar.3r, C5Ar.2r, and C5Ar.1r, with a time span of 13–12.2 Ma. This correlation implies that the Tairum Nor fauna from this section is still within MNU 7 or MN 7/8, slightly earlier than the Tunggur fauna.

According to the analysis to the faunal features, however, the Tairum Nor fauna should belong to NMU 6, corresponding to MN 6 (Deng, 2006a). Paleomagnetically, the lower red bed is of very good homogeneity, so the complex of the relatively long N1 and N2, and the relatively short R2 is not suitable to be correlated to Chron C5Ar.2n-1n. On both the biostratigraphic and paleomagnetic aspects, as a result, the original paleomagnetic correlation is incorrect. Actually, Wang et al. (2003a) also emphasized that their magnetic study was preliminary. Now we correlate N1 and N2 of the Tairum Nor section to Chron C5Bn.2n and 1n, and N3 to the lower part of Chron C5Adn, respectively. In this way, R1 represents the upper part of Chron C5Br, and R2 and R3 represent Chron C5Bn.1r and Chron C5Adr, respectively (Fig. 4). This correlation result is more reasonable both biostratigraphically and paleomagnetically.

The proposed paleomagnetic marker of the lower boundary of the Tunggurian is the base of Chron C5Bn.1r, with an age of 15.0 Ma. This boundary is situated within Layer 1 of the Tairum Nor section, i.e. the successive deposits of the lower red mudstones, 7.6 m apart from the base of the middle sandstones (Fig. 4). The horizon of the Tairum Nor fauna is correlated to Chron C5Bn.2n-C5ADr, corresponding to the lower part of the European MN 6 (Steininger, 1999), with a time span of 15.2–14.6 Ma.

4.3 Upper boundary of the Tunggurian Stage

The upper boundary of the Tunggurian is also the lower boundary of the overlying Baodean, and the proposed lower boundary of the Baodean is determined paleomagnetically by the base of Chron C5r.1n (Deng et al., 2004). In the Tunggur area, however, this boundary is absent in the Tairum Nor section on the southeast edge of the Tunggur tableland and the sections on the northwest edge. In fact, the unique contacting locality of the Baodean Baogeda Ula Formation with the Tunggur Formation in the Tunggur tableland is Roadmark 482 by an unconformable contact. However, there may be the Tunggurian/Baodean boundary at Amuwusu in Jurh, Sonid Right Banner, 106 km south of the Tunggur area (Fig. 1). The small exposures consist of reddish mudstones and grayish-yellow channel sandstones. Fossil remains from this locality are not very diverse, but include both large and small mammals. Most forms of the assemblage can be found in the Tunggur fauna. On the other hand, *Castor*, *Paralactaga*, *Prosiphneus*, and *Ictitherium* of the assemblage frequently occur in the faunas of Late Miocene and Pliocene (Qiu et al., 2006). *Hipparion* has been reported to find in the Amuwusu fauna, so it is a locality with the coexistence of *Hipparion* and *Anchitherium* (Qiu, 1988). As a result, the Amuwusu fauna represents a transitional fauna between the Tunggur fauna of Middle Miocene and the faunas of Late Miocene (Qiu et al., 2006). On the other hand, the fossils at this locality are collected mainly from the weathered section's surface, so that the fossils from the upper red mudstones may have been mixed with those from the lower gray sandstones. A possible explanation is that the upper red mudstones belong to the Baodean with *Hipparion* and other Late Miocene fossils, while the lower gray sandstones belong to the Tunggurian with *Anchitherium* and other Middle Miocene fossils. Between them, there may be the lower boundary of the Baodean stage, i.e. the upper boundary of the Tunggurian.

5 A Correlation of the Tunggurian Strata

The Dalanggou section of the Linxia Basin in Maijiaxiang Township, Guanghe County includes the Shangzhuang, Dongxiang, Hujialiang, and Liushu Formations from bottom to top. The Shangzhuang Formation is composed of brownish-red massive mudstones with banded conglomerate lenses and abundant proboscidean *Gomphotherium* fossils, and other fossils such as perissodactyl *Aprotodon* (Deng, 2006b) and artiodactyl *Turcocerus*. Its fauna is of the late Early Miocene, corresponding to the Chinese late NMU 4 of the Shanwangian or the European MN 4 of the Orleanian. The Wangshijie fauna from the basal sandstones of the Dongxiang Formation is of late Early Miocene to early Middle Miocene, corresponding to NMU 5 of the Shanwangian or MN 5 of the Orleanian (Deng, 2006a). The Laogou fauna from the sandstones and conglomerates of the Hujialiang Formation is of the early Middle Miocene, corresponding to NMU 6 of the Tunggurian or the European MN 6 of the Astaracian. The *Hipparion* fauna from the Liushu Formation is of the Late Miocene, corresponding to NMU 10 of the Baodean or MN 9–11 of the Vallesian and Turolian. Judged from the development of the section, there may be the lower boundary of the Tunggurian Stage in the Linxia Basin, and this boundary should lie in the upper red mudstones of the Dongxiang Formation. The upper Tunggurian fauna, corresponding to NMU 7 or MN 7/8, has not been found in the Linxia Basin, so that there may not be complete Tunggurian strata. However, the paleomagnetic results indicate that the lower boundary of the Baodean stage, i.e. the base of Chron C5r.1n, is situated at the top of the Hujialiang Formation.

In China, there are other sections with a mammalian fauna similar to the Tairum Nor fauna, such as the Tiejianggou section in the Danghe area, Gansu (Wang et al., 2003b), the Dingjiaergou section in Tongxin, Ningxia (Qiu and Qiu, 1995), and the Halamagai section in the Ulungur River area of the northern Junggar Basin, Xinjiang (Ye et al., 2001).

At the Tiejianggou section, the Tunggurian deposits are included in the Tiejianggou Formation (Wang et al., 2003b). The localities of DH9903 and 9905 are within Chron C5ACr with an age of 14.2 Ma (Sun et al., 2005), corresponding to NMU 6 or MN 6. The fossils of DH9903 and 9905 include only *Heterosminthus intermedius* and *Litodonomys xishuiensis* from the middle part of the Tiejianggou Formation. Paleomagnetically, however, the complete Tunggurian deposits between the bases of Chron C5Bn.1r and C5r.1n are well developed at this section (Sun et al., 2005, fig. 4).

At the Dingjiaergou section, the Middle Miocene Zhangenbao Formation overlies the Oligocene Qingshuiying Formation, and underlies the Upper Miocene Ganhegou Formation (Zheng et al., 1999). The section measured by Guan and Zhang (1993, fig. 4) is 197 m thick totally, and it is put together by five parts. *Gomphotherium*, *Kubanochoerus* and *Bunolistriodon* appear first on Layer 5 of this section, and *Platybelodon* appears first on Layer 10. Paleomagnetic analysis has not been made for this section, so it has not been determined that the base of Chron C5Bn.1r is the lower boundary of the Tunggurian Stage.

Three mammalian faunas in the Ulungur River area are considered to be of the Middle Miocene (Ye et al., 2001). The upper Kekemaideng fauna comes from the Kekemaideng Formation, and all of its fossils are members of the Tunggur fauna. *Dicrocerus grangeri* and *Platybelodon* sp. are the most common in the Kekemaideng fauna, and the age of this fauna corresponds to NMU 7 or MN7/8. The middle Halamagai fauna comes from the Halamagai Formation, and it is close to the Dingjiaergou fauna. *Platybelodon* is dominant and *Pliopithecus* is present in both faunas, so the age of the Halamagai fauna corresponds to NMU 6 or MN 6. The lower mammalian fauna comes from the top of the Suosuoquan Formation. Almost all components of the top fauna of the Suosuoquan Formation are member of the Halamagai fauna, but the most common *Platybelodon* and *Stephanocemas* in the base of the Halamagai Formation are absent in this fauna, so its age may be the earliest Middle Miocene or the latest Early Miocene. On the basis of the features of the mammalian faunas, the lower boundary of the Tunggurian Stage should be located in the base of the Halamagai Formation. However, a paleomagnetic analysis (Zhang et al., 2006) indicates that the lower boundary of the Halamagai Formation is within Chron C5En, corresponding to the time span of the early NMU 4 or MN 3, and the lower part of the Kekemaideng Formation is within Chron C5Cn.3n, corresponding to the time span of NMU 5 or MN 5. These results are completely inconsistent with the mammalian ages. Therefore, the lower boundary of the Tunggurian Stage in the Ulungur River area needs further work to determine.

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